Earthworm in Agricultural Production and Environmental Management

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ABSTRACT

In Nigeria favourable climatic and ecological features exist at the same time potentially resourceful efficient and versatile earthworm species are much present in soil environment. These earthworms are capable to address the food security, soil and environmental bioremediation and sustainable soil productivity. Often time these organisms are being destroyed by deleterious cultural practices, use of chemical fertilizers and pesticides leading to their going extinct faster than desired. Through their burrowing activities in conjunction with vermicompost production, soil material mixing, and distribution activities contribute immensely to enhance soil biological and physiochemical properties. Earthworms being omnivorous decomposes organic wastes faster than merely microbial decomposers and turn the wastes into excellent vermicompost product that is marketable. Vermicompost contains plant nutrients and beneficial microbes that can promote plant growth, reduce the incidence of pathogens, nematodes and other pests as it promotes the synthesis of anthocyanin and flavonoids that act as deterrent to diseases and pests. Thereby increase the growth of healthy plants and yield. The recovery of plant nutrients by modification of wastes that are bound in Nigeria in their different kinds and quantity and threat to soil-air-water quality is very much important for their management and environmental health. There is need to evolve adequate and appropriate research strategies to develop useful biotechnology to harness these renewable agricultural resources using earthworm potentials to address Nigerian food security and environmental degradation. This paper therefore highlights some resourceful features and practical utilization of earthworms in agricultural productions and environmental management.

Keywords: Biodiversity, Bioremediation, Bio-reclamation, Earthworm, Mycoremediation, Organic wastes

INTRODUCTION

Environmental degradation as witness today is a monumental threat to human existence, sustainable development, ecosystem sustainability, agricultural production etc. Increase in population and man's activities that include but not limited to mining, technology, construction, deforestation etc. contributes immensely to the environmental deterioration through the depletion of fossil fuels, contamination of water resources and carbon iv oxide (CO_2) generation. The traditional way of rejuvenating the degraded soil especially with regard to crop production, which is fallowing with vegetation have practically disappeared (except for academic purposes) due to population increase whereby most of the arable lands are used for residential buildings and establishment of desired project for the community and government. Vegetation rejuvenate the fertility of the degraded soil, because plant nutrients depleted during cropping and harvest season are replenished with those from fallow plants as well as increase the organic matter (OM) content of the soil. Intensive agricultural production in an effort to checkmate population increase through food security has led to the rampant use of chemicals (inorganic fertilizers, pesticides, herbicides etc.).The chemicals though increased the yield of crops (Nweke et al., 2013; Okoli and Nweke, 2015; Nweke and Nsoanya, 2015) but to the expense of environmental degradation and ecosystem imbalance. Their use in agricultural soils have led to decline in soil productivity due to imbalanced use of the chemicals which adversely affected crop productivity and cause environmental degradation. Long term and high dose application of some of these agrochemicals cause soil acidification and salinity. And these are one of the major abiotic stresses that limit agricultural production. Agrochemicals pollute underground water, decrease the aggregate sizes of the soil and their stability, dispersion ratio, soil respiration, earthworm population and other soil inhabitants etc. (Obi and Ebo, 1995; Haynes and Naidu (1998); Okigbo, 2000; Whalen and Chang, 2002; Sridhar and Adeoye, 2003). Therefore, overcoming the stress problems would have a positive impact in crop production. Environmental degradation due to the use of these chemicals in crop production activities has created greater interest in the search for alternative that will reverse the decreasing trend in the productivity and environmental harmony. This however, can only be achieved through the adoption of sound ecological and sustainable crop production practices. Nigerian soils and southeastern soils in particular are deficient practically in all necessary plant nutrients, but large quantities of these nutrients are contained in agricultural wastes, domestic wastes, industrial wastes and their byproducts that are wasted virtually on daily basis. In rural areas and urban cities millions of organic wastes are generated which either burnt or land filled. And when these wastes are dumped in large heaps air penetration to enable degradation becomes impossible leading to the production of methane gas and greenhouse gas of which are harmful to the environment. These harmful gases are noted in the studies of Zirbes et al. (2011) to have devastating effect on earth's atmosphere. The waste generation in Nigeria has increased with increase in population and urbanization. In some cases, these wastes are indiscriminately disposed and this worsen the serenity of the cities in Nigeria. The generated wastes in some cases are beyond the capacity of the city authorities to handle in order to maintain a clean and sustainable environment. This constitute environmental hazards, lost in economic value and increase in amount needed in disposing off the wastes.

In nature soil organism like earthworm have been found creditable to have the ability to convert the organic wastes into safe, useful and valuable product containing plant nutrients and very rich organic matter (OM) necessary for soil fertility and productivity. Earthworms are important soil organism in nature that help to maintain the flow of soil nutrients from one system to another. Hence their use in waste management can be an established procedure for the collection, transportation and disposal of waste products which is economically feasible, environmentally viable as it will reduce environmental degradation. The fact that earthworm population in uncultivated soil is higher about 8-10 times relative to the cultivated soil (Navellema et al., 2004), plenty in grassland than arable land, indicates that earthworm population decreases with soil degradation. Hence the organism can be used as a sensitive indicator of soil degradation. However, the population of earthworm do not decrease by the impact of tillage operations but rather decreased from the organic matter reduction in the soil. Studies have shown that row cropping reduce the number of earthworms but inclusion of field crops or grass in rotation and intercropping tend to increase earthworm population (Ramsay and Hills, 2000; Tian et al., 2000). Earthworms are however, sensitive to a lot of factors such as feed composition, soil characteristics, climatic conditions, cultural practices, cropping pattern, chemicals etc. These factors modify their activities, multiplication, number in soil, feeding etc. Therefore, a simple biotechnological process which could provide adequate safe disposal of waste and needed plant nutrients for sustainable soil productivity and environmental harmony is described (Mba, 1983, 1996, Nweke, 2013, Nweke, et al., 2020ab). Food security and civilization ultimately depends on the adequate maintenance of a fertile top soil. Therefore, it is in our best interest to encourage earthworms in their organic waste management and soil building activities.

MATERIALS AND METHODS

The present work employed a comprehensive literature review methodology to achieve its aim and objectives. According to Cronin et al. (2008) literature review is a systematic and critical analysis of existing scholarly publications, reports, and data relevant to a specific topic. It serves to synthesize existing knowledge, identify research gaps, and provide a foundation for further investigation. A narrative literature review approach was adopted, allowing for a broad and in-depth exploration of the earthworm ecology. This approach according to Paré and Kitsiou, (2017) is suitable when the aim is to provide a comprehensive overview and critical analysis of a complex topic, drawing on diverse sources of information. The narrative approach facilitated a holistic understanding of the issue, encompassing underlying, challenges, causes, and potential interventions. Thus, the review relied mainly on peer-reviewed journal articles published in reputable academic databases, Wikipedia, national research reports, science direct, research gate and google scholar, earthworm encyclopedia, earthworm information (UC Davis). Peer-reviewed articles were however, prioritized as they represent rigorous research that has undergone scrutiny by experts in the field, ensuring the quality and reliability of the information as noted by Smith, (2017). Other sources include student dissertations, seminars and personal experience in teaching and research in the area that span over 15 years and still counting. The inclusion of diverse sources is aimed to create a balanced and comprehensive picture, avoiding over-reliance on any single type of source. All were reviewed, discussed and conclusion drawn from the results.

Earthworms: Biology, Ecology, classification and community

Earthworms are invertebrates and the most important soil organisms with regards to their influence in organic matter degradation, nutrient recycling and soil development. They are like nature tiller or soil mixer as they incorporate plant litters into the soil, ingest it and excrete the nutrient rich cast on the soil. Aristotle the 4th century BC recognize their activities in soil and called them intestine of earth probable due to their appearance and burrowing nature. Charles Darwin, the 19th century biologist also studied their influence on the ability to degrade wide variety of plant litter. Earthworm is the largest member of *Oligochaete* in the phylum *Annalide* of class clitella and order of *Haplotaxida* and sub-order of *Lumbricina*. Over 4200 species of *Oligochaete* are known in the world. *Oligochaete* meaning the worms has hooks like chetae for gaining hold on to the substrate hence called *Oiligochetae*, Oligo means few and chetae mean hair. Of these number about 3600 belong to megadrilis (earthworm or big worm) though, it is estimated that the global total may be twice that number while about 280 are Microdrilis (small worms). Though most commonly seen earthworms are *lumbricids*. There are several other families such as *Haplotaxidae, Sparganophilidae, Megascolecidae, Glossoscolecidae, Monilgastridae, Octochaetidae, Ocenerodrilidae* and others. About 2/5 of oligochaete families comprise aquatic or semi-aquatic worms and the remaining families comprise mostly or exclusively terrestrial earthworms. These families are often very much different from the *lumbricids* in physiology, habitat and behavioral activities (Edwards and Lofty, 1972; Martin, 1976; Darwin and Seward, 1903; Reynold, 1994; Bohlen, 2002; Ratty, 2004; Ratty and Hutha, 2004; Munnoli et al., 2010).

The known and seen earthworms across the globe are grouped into two, burrow and non-burrow types. The burrowing type live deep in the soil, they are pale, about 20-30cm long and live less than 15years. They can only come to the soil surface at night, make 3.5m depth tunnel in the soil and ingest about 90% soil and 10% litter waste and produce about 5.6kg cast. Examples include, *pheretima elongata, pheretima asiatica, pontoscolex corathrurus* etc. The non-burrowing types such as *Eudrilus eugenae, Eisenia fetida* live in the A-horizon upper layer of the soil surface. They are red or purple (color found in Nigeria) in color, 10-15cm long and 28 months life span. The non-burrowing earthworms eat mostly litter materials and about 10 % soil. Hence, they convert organic waste into valuable product-vermicompost faster than the burrowing earthworms. They can tolerate temperature ranging from 0-40^{o}C, but the regeneration capacity is more at 25-30^{o}C and moisture level of 40-45% in the pile. Generally, regardless of type and size earthworm can survive temperatures as low as at 50^{o}F (10^{o}C) but feed most rapidly and efficiently at temperatures 15 – 25^{o}C (59 -77^{o}F). The scenario simply suggests that adaptability to temperature varies with earthworm species especially with regards to their vermicomposting activities. *Perionyx excavatus* (blue worm) are found adaptable and suitable to warmer climates while the red worms are suitable in all but tropical climates. Hence it is necessary to monitor the temperature of earthworm decomposing compost in the worm bin to avoid killing the earthworms. Thus, weekly turning of the compost is important to checkmate the exorbitant rise in the temperature. Earthworms vary greatly in size, but not in shape some are less than 20mm long, while some endemic geophagous like *Drawida nilamburensis and D. grandis* may reach up to 1m in length. *Megascolides australis* species in Australia attain a length of over 4m, while species like *Microchaetus microchaetus* can reach up to 7m in length. In pedo-ecosystem, earthworm show species-specific distribution, hence its presence in a particular habitat and its absence in another habitat. The source applies to its composition in variety of soils that range from grassland, plantation, forest, uncultivated to cultivated soils. Thus, species that are good for one location may not be good for another location, because species are only reliable when they are compatible with the species food. This is however true for burrowing earthworms as they require much time to acclimatize with their new environment (Raw, 1962; Appelhof, 1997; Loren and Taylor, 1998; Bohlen, 2002; Nagavellema et al., 2004; Wikipedia; earthworm on encyclopedia.com).

On the basis of physiological, morphological and behavioral adaptation to enable them partition available materials in the soil, earthworm can be grouped or classified into epigeic, aneceic and endogeic earthworms. Epigeic earthworms are small to medium size, uniformly and heavily pigmented, short life cycle, high reproduction rate and regeneration. They thrive on the upper soil surface within the litter layer, feeds on the surface layer and mineralize them. They are phytophagous and not often ingest soil. They contain gizzard that is very active in litter degradation, which aids in rapid conversion of the litter into vermicompost. Epigeic earthworms are efficient bio-degraders and nutrient releaser, tolerant to soil disturbances, helps in OM comminution and litter decompositions. Thus, they can be efficiently used for vermicomposting. Epigeic earthworms includes, *Eisenia fetida, Eudrilus eugenae* (indigenous to Nigerian soils), *lumbricus rubellus, lumbricus, festivus, Eisenilla tetraedra, Binastus minusulus, Dendro drilus* rubidus etc. Aneceic earthworms are dorsally pigmented and larger with low reproductive rate and very sensitive to soil disturbance. They are nocturnal organism, phytogeophagous, feed on upper layer surface plant litter and soil, forms muck hill and live in extensive deep vertical permanent burrows. The formation of vertical burrows influence air- water relationship and their movement from deep soil layers to surface layer aid in efficient mixing of nutrients. Examples includes; *Lumbricus terrestris, Lumbricus polyphemis, Aporrectodea longa, Lampito mauritii* etc. (Edward and Loft, 1972; Bouche, 1977; Lee 1985; Edwards and Bohlen, 1996; Edwards, 2014; Wikipedia).

The aneceic and epigeic earthworms are mostly harnessed for converting organic waste into vermicompost. These organisms being surface dwellers are of no significant value in modifying the soil structure even though they are capable of working on litter layer converting them into valuable product. However, there are some species within the aneceic group (*Lampito mauritii*) that are capable of creating an effective drilosphere that is soil volume of microflora and fauna influenced by earthworm and at the same time excellent compost producer. Endogeic species earthworms are soil feeders, small to large size worms. They are less pigmented; life cycle is of medium duration and form extensive horizontal burrows. They are moderately tolerant to soil disturbance, geophagous feeding on a particular plant litter and soil. Because they feed mainly on soil, they bring about remarkable changes in soil characteristic especially physical structure. Thus, endogeic earthworms can effectively utilize energy from poor soil for soil improvement. Examples include; *Pontoscolox corethrurus*, (some of the species are indigenous to Nigeria soil) *Alltobophora chlorotica, Millosnia anomalia, Octolasia cyaneums* etc. Endogeic earthworms are further classified into polyhumic, which are medium size earthworms that are rich soil feeding, dwelling on the top soil. Mesohumic type are medium size earthworms that dwell in A and B horizon of soil. They feed on bulk soil. Oligohumic are those earthworms that dwell in B and C horizon feeding on poor deep soil. They are very large worms. In summary the endogeic worms are respectively separated by descending importance of litter rich mineral soil in their diet and increasing body size. Earthworm species however, do not always fall clearly into these three main categories (Epigeic, Aneceic and Endogeic) and may even exhibit traits of different group at different life stages or under different ecological conditions (Edwards and Lofty, 1972; Hartenstein et al., 1979; Brown, 1995; Bhatnayar and Palta, 1996; Kooch and Jalilvand, 2008; Suther and Singh, 2008; Pathma and Sakthivel, 2012).

Table 1. Ecological categories and characteristic features of earthworms

Ecological category	Habitat	Characteristic features	Diet (food)	Rate of reproduction /cocoon production	Efficiency in bio-degradation	Species	Attribute in waste management	Ecological adaptation/ management
Epigeic	Leaf litter; compost ; A-horizon upper soil layer dwellers	Very active in litter layers; non-burrowing, small -large size; short life cycle; body uniformly pigmented	Mainly Litter and very small amount of soil	High reproductive rate and cocoon production	Very active due to active gizzard	*Eisenia fetida, Eudrilus eugenae; Lumbricus rubellus; Eisenilla tetraedra; Binastus minusculus; Dendrodrilus; rubidus, D. veneta; B. eiseni* etc.	Efficient bio-degraders and nutrient releaser; OM communion; litter decomposition; Very effective for vermicomposting /compost production	Phytophagous, High regeneration rate, tolerance to soil disturbance
Endogeic (groups; polyhumic;	A-B-C horizon soil layer	Small -large size; medium life cycle; less	majorly soil feeder	Moderately high reproductive rate and	Not active	*Aporrectodea calignosa*; *A. rosea*; *Octolasion*	Efficient in some species that are A-horizon upper soil	Geophagous; moderately tolerance to soil disturbance;

mesohumic; oligohumic)	dwellers (base on group)	pigmented; construct extensive horizontal burrows lined with mucus and excretory materials		cocoon production		*cyaneum*; *Allolobophora chlorotica*; *Pontoscolex corethrurus*; *Millsonia anomala*; etc.	dwellers but not effective in B-C horizon soil layer dwellers this group cannot be used for waste management but efficient in mixing of soil nutrient being deep soil layer feeder; bring in positive changes in soil physical structure, and can be used in soil management program	nocturnal; low regeneration rate in some species (deep soil dwellers)
Aneceic	Surface and deeper soil dwellers	Dorsally pigmented; Large size worm; construct extensive vertical and permanent deep burrows lined with mucus and excretory materials	majorly soil feeder and less litter material	Low reproductive rate/cocoon production	good in wastes recycling	*Lumbricus terrestris; L. Polyphemus; Aporrectodea longa; Lampito mauritii*; *Perionyx excavates*; *Pheretima elongate*; *Megascolex megascolex* etc.	good in waste management (soil surface dwellers); form muck hill; efficient mixing of soil nutrient and can be used in soil management program	Phytogeophagous (A-horizon dwellers) and geophagous (deep soil dwellers) nocturnal; very sensitive to soil disturbance, high regeneration rate in some species

Naturally, earthworms act like bio reactors, altering the nature of the organic waste by fragmenting them. Soil type, topography and vegetation however, determine the relative abundance and species composition of earthworm communities. It is equally influenced by land use history and earthworm biogeography. The majority of animal biomass in soil in any productive system are accounted by earthworm ranging from tropical pastures, savanna, rain forest to temperate, grassland, pastures and forest and many tropical and temperate agroecosystems. Earthworms generally do not thrive in deserts, arid grassland or in extreme alpine or boreal habitat. They are often not present in strongly acidic forest soils with poor litter quality. A worldwide survey of earthworms in tropical regions reported that a total of 51 exotics and 151 native species commonly occur in tropical agroecosystem while *lumbricid* earthworms of European origin dominate many North American agroecosystems of which approximately 100 nature earthworm species have been described and at least 45 exotic species have been introduced (Muys, and Lust,1992; Rahmani,1998; Fragoso, et al., 1999, Schell, et al., 2002; Scheu, et al., 2003; Six, et al., 2004). Earthworms are commonly seen in large numbers on soil surface after heavy down pour (rainfall) which flood soil, despite needing a moist environment to allow the diffusion of gases across their skin membrane. The soil become saturated (water logged) leading to insufficient oxygen for the worms. Hence the earthworms come to the surface to get the O_2 required and breathe more easily. Some species of earthworm (*Lumbricus terrestris*) come to the surface during rainfall to mate. This however is limited to few species. To protect themselves from drowning, they escape to the surface, but if the soil is unnaturally hard (impermeable surface) they may later become stranded and die from exposure. This is why they are seen in places like foot parts, drive ways, un-cemented residential compounds etc. after rain storms. However, certain species of earthworm can thrive and survive immersion for several days in oxygenated water. Another reason is that the earthworms may be using the moist condition on the surface to travel more quickly than they could do underground hence colonizing new areas quickly. Since the relatively humidity is higher during and after rain storm, they do not become dehydrated. Nevertheless, this activity may be dangerous in the day time since earthworms die quickly when exposed to direct sunlight with its strong ultra-violet and content. They can also be vulnerable to fowl and birds. Another hypothesis is that there are many other soil inhabitants and their respiration increases CO_2 content, this gas dissolve in the rain water to form carbonic acid. As the soil becomes too acid for the earthworms, they seek a more natural environment on the soil surface. Earthworms move beneath the soil by means of waves of muscular contractions which alternately shorten and lengthen the body. The shortened part is anchored to the surrounding soil by tiny setae (claw like bristle) set along its segmented length. In all the body segments except the first, last and clitellum, there is a ring of S-shaped embedded in the epidermal pit of each segment (perichaetine). The whole burrowing process is aided by the secretion of lubricating mucus. Earthworms can make gangling noises underground when disturbed as a result of the earthworm moving through its lubricated channels. They also work as biological pistons forcing air through the tunnel as they move. Through this activity, earthworm aerates and mixes the soil and is constructive to mineralization and nutrient up take by plants. Further certain species of earthworm come to the soil surface to feed on the higher concentration of plant litter present there, mixing it with mineral soil. Because a high level of OM mixing is associated with soil fertility, an abundance of earthworm is beneficial to the organic farmer. In fact, it may be doubted whether there are many other animals which have played so much important a part in the history of the world as have these lowly organized creatures and about 10.6 tons/acre of materials are brought to the soil surface (Charles Darwin,1881; Ramsay and Hills, 1978; Ammer et al., 2005; Hale et al., 2005; Saulter et al., 2006; Jimens et al., 2006; Wikipedia).

Anatomy/Reproduction/Regeneration

Earthworms are long, narrow, cylindrical, bilateral symmetrical segmented soil dwelling invertebrates with a glistening dark brown body covered with delicate cuticle. They are terrestrial annelids, members of the class oligochaete because they crawl using longitudinal mucus which are located under the epidermis. Earthworm have bilateral symmetry and corresponding external and internal segmentation. This simply means that if you cut an earthworm you would find that one half is the mirror image of the other half. The first segment is specifically named the peritonium contain the mouth. There is a small tongue-like lobe just above called the prostonium. The prostoniun is for the earthworm to ‘see’ its surrounding. The prostonium and the skin aid the earthworm to move through the soil. As it tunnels through the soil the mucus from the body react with the soil of the tunnel and form a type of cement which makes the tunnel wall stable and the tunnel can be reused. They have a thinly pigmented cuticle bearing setae (small bristle of the earthworm skin), on all segments except the first two. The very last segment is called the periproct and anus. Except for the first and last segment all the other segment has been located around each segment. Earthworms have a simple and closed circulatory system, muscular, slimy moist outer body. The body plan is a tube and digestive system within a tube. Earthworms have two main blood vessels that extend through the length of their body, a ventral blood vessel which leads the blood to the posterior end and a dorsal blood vessel which lead to the anterior end. The dorsal vessel contractile and pump blood forward, where it is pumped into the vessel by a series of heart (aortic arches) which vary in number in different taxa. The blood distributes from the ventral vessel into the capillary on the body wall and other organ and into a vascular sinus in the gut wall where gases and nutrients are exchanged. This arrangement may be complicated in the various groups by sub oesophagal, supraoesophagus, parietal and neural vessels, but the basic arrangement holds in all earthworms (Tian et al., 2000; Pathma and Sakthivel, 2012; Munnoli, 2010; Wikipedia)

All earthworms are hermaphrodite (contain both male and female organs), but cannot fertilize their own egg. Their sex cell (gonads) are situated in specific segments which vary from among different taxa. They weigh over1,400-1,500mg after 8-10weeks. Their body contain 65% protein, 70-80% high quality lysine rich protein on a dry weight basis, 14% fats, 14% carbohydrate, and 3% ash. Depending on the species and ecological situation, life span of earthworms can vary between 3-15years. The gut of earthworm is a straight tube starting from mouth followed by a muscular pharynx, oesophagus, thin wall crop, muscular gizzard, fore gut, mid-gut, hindgut, associated digestive glands and ending with anus. The gut consists of mucus containing protein and polysaccharide, organic and mineral matter, amino acid, and microbial symbionts like bacteria, protozoa, and micro-fungi. An increase in moisture, nitrogen and OC content in the earthworm gut provide the organism with an optimum environment for the germination of endospores and activation of dominant and docile microbes. Many digestive enzymes are noted from earthworm alimentary canal ranging from cellulase, amylase, lipase, to protease, urase and chitinase. Some of these enzymes are made to be active by the domiciled in the worm gut. Earthworms have two pairs of testes, surrounded by 2 pairs of testes sacs, there are 2 or 4 pairs of seminal vesicles and male pores which produce, store and release the sperm and ovaries and ovipores in about segment 13 that release egg via female pores on segment 14. They also have one or more pairs of spermathecae (depending on the species) that are internal sacs which receive and store sperm from the other earthworm in copulation. Again, some species however, use external spermatophores for transfer instead (Hartenstein et al., 1979; Munnoli et al., 2010; Pathma and Sakthivel, 2012; Wikipedia).

Copulation and reproduction are separate processes in earthworms. The mating pair overlap front ends ventrally and each exchanges sperm with the other. At the sexually matured stage they develop a swollen area of the epidermis called a clitellum. Thus, the clitellum is only seen in earthworms that are ready to reproduce. The number of the segment clitellum begins and the number of segments that make up the earthworm is important for identifying earthworms. The clitellum may be red, reddish-brown or pinkish in colour. However, earthworms are ready to mate if the clitellum is orange colour. Most of the materials secreted to form earthworm is produce within the clitellum glandular bond which is near the front of the earthworm, but behind the spermathecae. For example, this region produces or secrets cocoon or egg sac in which one or more eggs are deposited and then the cocoon is passed over the anterior segment and deposited in or on the soil. The young develop within the cocoon and newly hatched earthworms resemble adults. The time of hatching and reproductive maturity varies widely among different earthworm species and is influenced by diets and environmental factors. Some indefinite time after copulation, long after the worms have separated, the clitellum secretes the cocoon which form a ring around the worm. The earthworm then backs out of the ring and as it does so inject its own egg and the other worm sperm into it. As the worm slips out, the end of the cocoon seal to form a vaguely lemon-shaped incubator (cocoon) in which the embryonic worms develop. They emerge as small, but fully formed earthworms, except for lacking the sexual structures, which develop later in about 8-12 weeks (about 2-3months) or more. They attain full size in about one year, sometimes sooner. Several earthworm species are mostly parthenogenetic in which case the male structures and spermathecae may become abnormal or missing (sexual reproduction resulting in clones).

Earthworms have the ability to regenerate lost segments though this capacity varies between species and is dependent on the extent of the damage. The regeneration ability of earthworms makes it possible that two whole earthworms can be grown from bisected specimen in certain species. Temperature, moisture and food supply helps in earthworm regeneration as they are major components of the earthworm habitats. Land under vegetation improve earthworm habitat leading to potential increase in earthworm population because of high soil moisture content, increase food supply and lower temperature. Vegetation have a different canopy structure, litter fall, biomass partitioning and ground cover, thus they create different earthworm habitat that aid to different restoration about the earthworm population. Materials with high decomposition rates are more palatable food for earthworm that increase their regeneration rate and population growth. The high-quality organic residue improves the earthworm population and invariably increase the degradation rate of the OM. Thus, there is interactive effect of organic residue, decomposition rate and earthworm regeneration ability (Wikipedia; earthworm on encyclopedia.com).

Uses of Earthworm

Earthworm apart from their use in producing bio-humus, bait, live food for rearing frog and fish, fish hatcheries, zoos and biology class teachers, earthworm can be dried and grind into powder and use as food additive to provide nutritional balance in animal and poultry feed production as well as in rabbitry feed production. The powdery food additive some times are equally used in hamburger and other minced meat products. For the pharmaceuticals, collagen can be extracted from the worm, antibiotics can also be produced from earthworm body fluid made up of different nutrients and respiratory gases. For the medicinal purposes though in this area their efficacy requires proper scientific study, they are used in the treatment of many illnesses like jaundice, fever, rheumatism, bladder stones and impotency since ancient times in Asia, Latin and north America (Waldon 1978, Ramsay and Hills, 1978).

Earthworm multiplication and cast production

Earthworms are the most numerous and major inhabitant of soil in productive ecosystem. Though they do not live in isolation with other soil organisms but their influence in organic matter degradation, nutrient recycling, water holding capacity and infiltration, modification of the soil structure and bio-physicochemical properties are of paramount importance to soil dwellers and agriculture. They survive on a wide variety of temperature 13-25^{o}C and moist environment which should be as damp as a wrung-out sponge. While moisture is vital, so is oxygen. earthworm body is photosensitive and therefore they require a dark environment. They prefer a slightly acidic to neutral pH level for maximum activity. Earthworms are voracious feeder of different organic residues that influence greatly their multiplication, population and growth. They feed on materials such as kitchen and compound wastes, fruits wastes, crop wastes, vegetable wastes, urban wastes, animal wastes, industrial wastes, grasses etc. They consume limited amount of citrus wastes due to limonene, a chemical compound found in citrus toxic to the worms, hence it is best to avoid feeding them with the material. Earthworms have no teeth, so any food they eat must be small enough to swallow or soft enough for them to bite, so in the case of grass diet, it need to be chopped into pieces and fermented for some weeks before using it to feed the worms. Some foods which may not soft enough initially for them to consume are quickly degrade so that the worm can consume them. Oily food is not palatable to worm nor advisable to feed them with such, due to their potential odour on degradation and pests problem attraction to the worms. In most sterile soil to avoid introduction of foreign organism a grit in their bedding are required for them to pick up and use in gizzard to grind food. The most used in earthworm bins is rock dust, oyster flour that is ground oyster shell. Not with standing their voracious feed on wide variety of organic materials, earthworms utilize only a small portion of these organic waste for their multiplication and growth and excrete a large portion of the waste consumed in a half-digested worm-casts. Worm casts contain about 40% more humus than the top 6 inches of soil in which the worms live. An investigation in USA showed that fresh earthworm cast is 5,7, and 11 times richer in N, PO4, and available K respectively than the surrounding upper 6 inches of soil (Mollison (1988). And that by sliding in their tunnel's earthworms act as an innumerable army of pistons pumping air in and out of the soil on a 24 hours cycle, but more rapidly at night. Thus, the earthworm not only create passages for air and water to traverse, but is itself a vital component in the living biosystem that is healthy soil. Numerous organic residues have been evaluated for reproduction and growth of earthworms these materials directly affect their efficiency in casts, multiplication and vermicompost production. Zagore and Sidor (1999) evaluated and compared various non-standard feed materials for the preparation of vermicompost. Their studies found out that the mixture of cotton waste with cattle manure in the ratio of 1:5 was the best for earthworm growth and vermicompost production. The use of grape cake alone increased earthworm weight slightly. Tobacco (*Nicotiana tobacum*) waste, used as feed increased earthworm, but failed to reproduce, while a mixture of tobacco waste with rabbit manure in the ratio of 1:5 was observed to be lethal to the worm. The suitability of olive cake, municipal bio-solid and cattle dung as substrate were evaluated by Nogales et al. (1999). They reported in their study large weights of newly hatched earthworms in substrate containing dry olive cake. In another study conducted by Manna et al. (1997), maize straw was found to be the most suitable feed material for tropical epigeic earthworm multiplication and vermicompost production relative to soybean (Glycine max) straw, wheat straw, chicken pea (*Cicer arientinum*) straw and city refuse. In a multiplication trial conducted at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) with three different earthworm cultures (*Eudrilus eugenae*, *Esenia fetida* and *Perionyx excavatus*) using wheat straw, chickpea straw, tree leaves, *peltophorum spp* and parthanium mixed with cow dung as feed material showed desirable results. The study showed increased earthworm population and size during incubation for 90days. In the same station the three types of earthworm multiplied 12-18 times relative to initial population when grown individually using legume tree leaves and cow dung moistures as raw materials. Further studies on earthworm multiplication conducted at ICRISAT using tree leaves and *Glinicidia* stem mixed with cow dung as feed material showed that earthworm population decreased when grown in mixtures of *Glinicidia* and cow dung (Nagavallemma et al., 2004). The result of their studies simple suggest that *Glinicidia* is not a good feed material to use for multiplication of earthworms. The bark of *Glinicidia* is noted to possess toxic properties as it is used as rat poisoning bait. In another study at ICRISAT, there was maximum increase in earthworm population (570%) and weight (109%) when grown on a feed material containing tree leaves (3kg) and cow dung (6kg), while mortality rate of earthworms (about 7-22%) was recorded by growing them in a feed material containing soil (Nagavellemma, 2006). The summary of their studies is that *Glinicidia* and tobacco leaves are not suitable for multiplication of earthworms. The alkaloids and other principal compounds present in these leaves, perhaps may have affected the survival of the earthworms. Thus, indicating that leaves or plant parts containing alkaloids may not be suitable feed materials for earthworm multiplication and reproduction.

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Findings from their studies equally indicated that mixing earthworm feed with rabbit manure and soil may not be ideal.

Table 2. Consumptive rate of earthworm on substrate (food) devoid of soil

Earthworm specie	Diet	Consumptive rate mgg^{-1}	Reference
Octolasion tyrtaecum	Maize	8.8	Pandey et al. 2006
	Grass	11.7	
	wheat	15.9	
Eudrilus eugenae	Onion waste	30-35	Mishra et al. 2009
Eisenia fetida	Garlic waste	30-35	
Pheretima elongata	Potato peel	375-700	Munnoli, 1998
Eudrilus eugenae	Potato peel	300-600	
Eisenia fetida	Potato peel	300-600	
Eudrilus eugenae	Cow dung	1000-2000	Munnoli, 2007
Eisenia fetida	Cow dung	800-1650	
Megascolex megascolex	Cow dung	650-1300	
Eudrilus eugenae	Activated sludge with dead leaves	2000-5000	Jayshanka, 1994
Eisenia fetida	Activated sludge	10-5000	Mitchell, 1978
		2000-20,000	Hartenstein et al. 1979

In Peradeniya in Srilanka, Samaranyake and Wijekoon (2010) studied the multiplication of 3 epigeic earthworms, *Eudrilus eugenae, Eisenia fetida* and *Perionyx excavatus* in 7 different media which are; cow dung, vegetable refuse, straw, cow dung + vegetable refuse (1:1), cow dung + straw (1:1); vegetable refuse + straw (1:1) and cow dung + vegetable refuse + straw (1:1:1 ratio). The result of their study showed significant different in the multiplication rate of the earthworms, cocoon production and vermicompost. Though these parameters were observed to be high only when cow dung was a component of culture medium inferring the important role of cow dung in the diet of earthworms. Cow dung contain digestive cellulose and other organic matter and also provide optimum pH conditions for earthworm activity. Epigeic earthworms generally feed on organic residue that is nutritionally low, however, Arenda, et al. (1999), noted that partially activated cow dung contains high nutrients and an optimum C/N ration of 30/1 conducive for earthworm growth. Pandey et al. (2006) studied earthworm multiplication and cast on litter diet that consist of grass (*Cynodon dactylon L*), maize leaves (*Zea maize*) and wheat (*Triticum aestivum spear*) leaves. These leaves when chopped into pieces about 1-2cm long moistened and stored at room temperature in loosely sealed nylon bags and allow to decompose slightly till they become visible brown with fungal colorization. Decomposition improve feed acceptability of earthworms. The 3 different media were used as substrate to *Octonochaeta Tyrtaeum* earthworm. Their result findings showed significant increase in earthworm growth and cast production of which varies with the media. High food consumption with wheat leaves than grass and maize leaves were observed. This translate to high cast production, but not in growth and weight of earthworms, as maize which lower amount was ingested by the worms showed a better growth rate in comparison to the other diets. In studies conducted in Nigeria by different

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researchers using different kinds of diets showed remarkable increase in earthworm production and vermicompost. Mba, (1981,1996), studied cassava peel and guava leaves culture with or without animal manure (cow dung) as feed diet for *Eudrilus eugenae*. The study showed increased earthworm population and humus production (vermicompost). Nweke, (2013, 2017), Nweke and Nnabuife (2020) and Nweke, et al. (2016, 2020ab), found from their studies significant increase in earthworm multiplication, survival rate, growth length and vermicompost production in the various kind of diet used in their studies. These evaluated diets range from grasses such as *Bracheria, Andrapogon* and *Paspalum* to *Ageratium* with or without pig manure, cassava peels with or without poultry and pig manure, vegetable wastes and fruit wastes respectively. Land use system also influence earthworm population, growth and cast production. In International Institute of Tropical Agriculture (IITA), Ibadan, south west, Nigeria, Tian et al. (2000) studied 15 herbaceous shrub and woody species along with the natural regrowth vegetation (fallow) dominated by *chromolaena* and continuous maize-cassava intercropping. Population and biomass of earthworm predominantly *Hyperiodrilus africanus* and *Eudrilus eugenae* show higher number in fallow treatment than in maize-cassava for 65% of the sampling dates. Their results equally showed positive correlation between soil moisture in the fallow treatments and earthworm numbers. All fallow treatment supported higher earthworm biomass compare with maize-cassava treatment and seasonal changes influenced earthworm biomass.

Table 3. Earthworm species used in vermicomposting devoid of soil

Earthworm specie	Substrate	Reference
Octolasion tyrtaecum	Maize	Pandey et al., 2006
	Grass	
	wheat	
Eudrilus eugenae	Cassava peels	Mba, 1996; Nweke, 2017
	Guava leaves	Mba, 1996
	Paspalum grass	Nweke et al., 2016
	Andropogon grass	Nweke, 2013
	Bracharia grass	Nweke et al., 2016; Nweke, 2013
	Fruit wastes	Nweke et al., 2020
	Vegetable wastes	Nweke et al., 2020
	Onion wastes	Mishra et al., 2009
	Agricultural wastes	Kale, 1994; Suthar, 2006, 2007
Eisenia fetida	Garlic wastes	Mishra et al., 2009
	Canteen waste	Kale, 1994; Narayan, 2000
	Paper mill waste	Kaur et al., 2010
Pheretima elongata	Potato peel	Munnoli et al., 2000
	Sugar cane waste	Bhawalker, 1995

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	Tomato waste	Singh, 1997
Perionyx excavates	Sericulture waste	Gunthilingaraj and Ravignanam, 1996
	Tannery waste	Shahul et al., 2002
Megascolex mauritii	Municipal waste	Ravichandran et al., 2003
Eudrilus eugenae and Irridorilus	Ageratum species	Nweke and Nnabuife, 2020
Eudrilus eugenae/ Perionyx sasibaricus/ Perionyx excavatus	Municipal solid waste	Ranganath Ready et al., 2002
Eisenia fetida	Distillery industrial waste	Munnoli, 1998
Pheretima elongata		Munnoli, 1998
Eudrilus eugenae/Eisenia fetida/Perionyx excavatus	Tree leaves Cow dung Glincidia stem	Nagavellemma et al., 2006
Eudrilus eugenae/Eisenia fetida/Perionyx excavatus	Vegetable refuse Straw Cow dung	Samaranyake and Wijekoon, 2010

Earthworm vermicomposting

Vermicomposting is a biotechnological process of using live earthworm to compost or degrade organic material into useful product called vermicompost, also known as bio humus, worm cast, vermicast or worm manure. Certain species of earthworm such as epigeic and endogenic are used in this process of waste conversion to a better product. Earthworm vermicomposting is a non-thermophilic, but mesophilic (characterize by bacteria and fungi) bio-oxidation of organic waste into vermicompost through the interaction of micro-organisms. Although micro-organism is mainly responsible for biochemical decomposition of OM, earthworm play an important role in the process by fragmenting and conditioning the substrate, increasing the surface area for growth of micro-organism and altering its biological activities. The process is very much active at about 10-35^oC and faster than other compositing techniques. As the materials passes through the earthworm gut a significant transformation takes place to the extent that the resulting vermicompost or earthworm cast are very rich in plant nutrients and microbial activities. Several enzymes, intestinal mucus and antibiotics in earthworm intestinal tract play an important role in the breakdown of organic macromolecules. Vermicomposting quickens the OM decomposition process and conversion of the waste into valuable bio fertilizer (vermicompost) of which is more homogenous material compare to thermophilic composting. Vermicomposting increase the ash concentration, thus accelerating rate of mineralization which is oxidation of chemical compounds in the OM into forms that could be easily available and assimilated by crops. Earthworms are voracious feeders and consume various kinds of organic wastes and reduce their volume by 40-60%. Each mature worm weigh about 0.5- 1.05g, eat waste equivalent to its body weight and produces cast equivalent to about 50% of the waste it consumes in a day. Vermicomposting is a very useful method of converting solid organic wastes into vermicompost. The vermicomposting is an efficient nutrient recycling process that provide for the use of earthworm as versatile material bioreactor for cost-effective and eco-friendly waste management. Earthworms has the efficiency to consume all types of organic rich waste material that include but not limited to fruit wastes, vegetable wastes, crop wastes, fermented grasses, tea wastes, industrial wastes, leaf litter wastes, dairy farm wastes, garden wastes, paper mill wastes, sugar mill wastes, slaughter house wastes, hatchery wastes, urban or municipal wastes, deep litter wastes etc. (Nagavallema et al., 2004; Ghosh, 2004; Zambare et al., 2008; Asha Aalok et al., 2008; Karim et al., 2011; Jayakuma et al., 2012; Nweke, 2013; Pigares and Lakshmi Prabha, 2014, Nweke, et al., 2020ab).

Vermiculture

The art of producing, rearing and raising earthworms of which requires large amount of organic material with which to feed the worms is termed vermiculture. Industries where large quantities of organic wastes are generated such as sewage sludge companies, paper mill companies, slaughter houses, sugar industries, canneries and breweries vermiculture could easily be integrated for easy management of the wastes, earthworm and vermicompost production. Through vermiculture many of these organic wastes including urban waste could be recycled thus solving many of our present problems in respect to solid waste disposal and water pollution management. For example, some of the rabbit farmers have found out that earthworms placed under hutches are very effective in controlling odour from rabbit droppings and provide extra income if the worms are sold. This can as well be incorporated by livestock farmers to manage the wastes and odour generated from animal droppings/dung. It will also make the droppings/dung richer in plant nutrients, increase the surface area and weight reduction for easy evacuation. These worms can be sold to fish hatcheries, zoos, fishermen, poultry farmers and biology classroom teachers. The earthworm mostly used for breeding are *Eisenia Fetida*, and *Eudrilus eugenae* they can effectively thrive in culture devoid of soil. They are adapted to the special condition in rotting vegetal manure piles. In addition, vermiculture host many other organisms such as molds, insects etc. and these organisms play role in the composting processes, where earthworm is the major catalyst for the composting process.

Vermicompost/vermiwash/vermiTea/Leachate

Vermicompost is the product made by earthworms. The term vermi is from Latin word that means a worm. Vermicompost is fully stabilized organic material with low carbon-nitrogen ratio. It has high microbial capacity and activities and enzymatic diversity and content. Vermicompost contain mucus that helps prevent nutrients from washing away. A very fine particulate structure, good moisture-holding capacity and contain all substances or nutrient in forms readily available to plants. Also rich in plant growth factors such as indole acetic acid (IAAS), kinetin or gibberellins associated with humic and fulvic acids acting as plant growth regulators. The plant hormone produced become adsorbed on to the vermicompost are released gradually into soil when used as soil amendment to promote plant growth over several growing season. A very excellent soil conditioner, nutrient rich bio-fertilizer and contain water-soluble nutrients. Vermicompost contain reduced level of contaminants and a higher saturation of nutrients. For vermicompost liquids, there are few terms that can be found in describing vermicomposting derived liquids. They are vermiwash, vermicompost tea, vermicompost leachate/vermileachate, worm bed leachate and vermicompost extract. All these are essentially bio liquid extract of vermicompost consisting mainly of colloidal materials or particles of vermicompost in suspension. This makes them easy to be applied as foliar spray in fertilization. These aqueous vermicompost extract, tea, or leachates are much easier to transport and apply to plants than the solid vermicompost materials. They can replicate most of the benefits of vermicompost when applied to the same plants. These aqueous extracts are produced using a wide array of production methods. It is assumed that microbial biomass activity and plants nutrients can be transferred from vermicompost into the leachate or tea. While the variety of methods are used to make the leachate or tea all start by mixing solid vermicompost with water. The ratio of solid vermicompost to water can range from 1:3 to 1:200. Some processes are aerated and others are not, sometimes supplementary nutrient sources including molasses, algal powders or yeast extracts are added to the teas in expectation that they will increase their microbial activity and effects. The aqueous extracts of vermicompost can as well be extracted by employing non-aerated or aerated techniques. Non-aerated (passive) extraction extract was by placing vermicompost into a fix amount of volume of water with occasional stirring and allowed to sit for 3 days. For aerated extraction air will be pumped and O_2 level need to be maintained 4-5mgl^{-1} or above. Often products such as sugar, grain, fish emulsion, humid acid and other products are added during the process to further enhance the microbial activity of the end product. The chemical free method preparation of these liquids is in favour as an approach of producing environmentally friendly bio-fertilizer. One of the advantages of vermicomposting derived liquids is that nutrients present are completely soluble in water due to its preparation method. Thus, potential to be used as foliar fertilizer. To be used as foliar, the nutrients should be water soluble and salt concentration in it should not be too high to cause scorching on leaves when sprayed.

Studies carried out with this vermicomposting derived liquid (Tea, extract, vermiwash etc.) showed that these bio-fertilizers have profound results in various dilutions indicating potential use of vermicomposting derived liquids as foliar fertilizer. On the other hand, foliar fertilizing compensates the loss of fertilizing effect of conventional soil applied fertilizer through the prevention of leaching. Rate of leaching is different with different composition of soil. For example, higher composition of clay in the soil will have lower leaching rate. Certain nutrients such as Na and Mg are more prone to leaching losses in soil with high clay concentration. Though water holding capacity will also determine the significance of leaching losses. Soil composition and texture play vital role in rate of leaching. Leaching cause ground water pollution, nutrient such as NO_3 and PO_4 cause eutrophication to water body. Vermicompost derived liquids may be added to irrigation water system to provide extra nutrients to plant through fertigation which is a method of combining fertilizer and irrigation water. Nutrients that are completely soluble in water will have no risk of clogging up the sprayer. Available plant nutrients that are present in these liquids are variable and have the potential to be used as nutrients solution in hydroponics culture. Hydroponics culture has the advantage of being carried out in a space limited area (Urban centres). Hydroponics culture is a soilless cultivation method which is a contribution for crop production in area where lands are not available (like in cities) or inadequate for crop production. Also, very good for green house production. Hydroponics is a good media for mushroom and vegetable production. By using these plant nutrients rich vermicomposting derived liquids in hydroponics culture, soil borne diseases and pests can easily be controlled. However, the downside of these liquids is that the nutrient contents of end product strongly depends on the substrate that were used. Thus, substrate high in heavy metal content may produce liquids that contain high value of heavy metals. So, one of the concerns of these bio-fertilizers is the type of substrate the liquid extract is derived from as it directly affects the nutrient nature and content of the products. The nutrient content present in these liquids may be high but may not be completely enough to effect increased crop yield, hence chemical fertilizer sometimes may have to be added for better yield. In all, vermicomposting derived liquids contain valuable nutrients that promote crop growth and yield (Ramsay and Hills, 1978; Waldon, 1978; Bhatnagar and Palta, 1996; Ismail, 1997; Edwards, 1998; Beetz, 1999; Nagavallema et al., 2004; Dominquez, 2004; Dominquez and Edwards, 2004; Aranco et al., 2006, 2007; Edwards et al., 2007; Lesinsky and Veverka, 2008; Roberto Carlos et al., 2008; Asha Aalok et al., 2008; Pant et al., 2009; Theunissen et al., 2010; Gutierrez-Miceli et al., 2011; Quaik and Ibrahim, 2013; Pigares and Lakshmi Prabha, 2014; homelycappers.com; vermontworms.com).

Vermitechnology Methods

Vermicomposting technology is one of the environmentally friendly techniques of using earthworm for waste management, that wastes from agricultural activities, industries and wastes from other sources can effectively be managed and transferred into a wonderful product. Vermitechnology comprises three main processes;

- Vermiculture -- breeding and rearing of earthworms
- Vermicomposting – decomposition of waste materials using earthworms
- Vermi-reclamation – using vermicompost and/or earthworms to reclaim, sustain, and manage marginal degraded, and wastes lands

The benefit of vermitechnology, therefore range from waste biomass management, waste land conversion and reclamation, abatement of organic pollution, animal protein production, earthworm worked manure to improves soil fertility and crop production. There are several methods that can be employed in vermicomposting technology to produce vermicompost (worm manure cast), raising and rearing of earthworm that can be sold out to fish or poultry farmers and their likes. In chosen any method, the type and quality of feed materials need to be taken in to account as the nutrient content of the vermicompost is dependent on the material fed to the earthworms. So, earthworms should be fed with materials high in nutrient content to have very good quality vermicompost. It is also preferable to select a vermicomposting site in the upland and on elevated land to enhance reaction, maintain moisture content and prevent water stagnation during rains especially with regards to pit method in much humid areas. Water management is very important in vermiculture and vermicompost production. Less water kills the earthworm, while too much water chases the earthworm away from the culture. Watering of the culture continued till the compost or earthworm is ready to harvest. The appearance of the cocoon (earthworm egg) and juvenile earthworms in the culture signifies healthy of the culture. Vermitechnology eliminates pathogens, does not produce odour and heavy machinery is not required or needed. The various

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methods and designs that can be used for earthworm and vermicompost production based on the topography, type of soil and amount of water are discussed below

Pit method

The pit method depends much on the type of soil as sandy and silt soils are not advisable especially in humid areas like Nigeria and regions with rain fall intensity of about 2500 - 4000mmy^{-1}. The pit is dug below ground in region with moderate rains. Many pits under a common roof to prevent rain and water stagnation in pit can be built with different dimensions for the individual requirements. The pits made for vermiculture and composting are 1m deep and 1.5m wide, though this varies with the individual peculiarities' in terms of cost, land available, feed materials and quantity of worms at one's disposal. The drawback to the pit method varies from rats, soldier ants, centipedes and indeed other predators that prey on the earthworms to the moving out of the earthworm from the pit if they obtain favourable moisture outside the pit. It is always difficult to take any measure to tackle such predators. Thus, pit method is not suitable for period harvesting, more so there is no guarantee that pit and culture will stand till maturity as the pit may close by itself with soil or ground water. More so biodegradation of wastes is not fast enough as compared to methods like heap method, probably due to limitation in space for turning of the wastes in the pit. Navellema et al., (2004) studied the efficacy of pit and heap methods of preparing vermicompost under field study and they found out that heap method was better than the pit method, earthworm population was high with 20 fold increase in *Eudrilus eugenae* for heap as against 17 fold increase in the pit method, biomass production was 46 fold increase in heap as against 31 fold in pit, while vermicompost produced was 51 kg in heap compared to 40 kg obtained from the pit method.

Heap Method

In this method polythene sheet or jut sheet is spread on the ground and then waste materials are spread on them. This is specifically suitable for vermicomposting to produce vermicompost (casts or worm manure) and can be done indoor or outdoor. Many heap rows are possible in this method depending on the space available. The method is good for large scale vermicomposting production under greenhouse reserved specially for the purpose only. Field farm house or shed can equally be used for the production. This method increases waste degradation high earthworm production, biomass production and consequent vermicompost production. If the method is carried outdoors, constant inspection is necessary to prevent predators and much heat development that might kill the worms.

Tank method above the ground

Tanks of various sizes and shape can be made with different materials such as blocks, hollow blocks or asbestos sheets. It can be constructed with dimensions suitable for operators. Tanks method can only be adopted for internal (indoor) vermicomposting with full roofing material cover. Note blocks used in setting up the tank may wear out, collapse, absorb moisture from compost and become weak. This structure may not be suitable and efficient, wet materials exert horizontal pressure on walls. Holes can serve as an entry to predators and earthworm move out of the system. Hence thick concrete wall with plaster with many units under common roof for protection against rain is ideal as this prevent the above shortcomings. The thick wall with plaster has long lasting life and permanent in nature, safe guards the worms against predators. The structure is completely sustainable and continuous economic resources for the users or operators. It is very good for research work using surface dwellers and deep burrower earthworm species on various type of wastes with period harvesting. Note that vermicomposting can equally be carried out inside old poultry house, old fish pond or cow/sheep and goat sheds protected with a thatch roof, bamboo roof (where obtainable) or zinc roof (where affordable) for protection from adverse weather and predators.

Old tyre method

Used vehicle tyres are cheap, litter the streets and can constitute environmental problem. The used vehicle tyre can be useful when converted to vermicomposting material (as introduced and proved in Nweke, 2013) to enhance its environmental management. Tyre containers are made from old vehicle tyre, one side of the tyre should be covered and sewed with fibre sack so that it can have bottom. The tyres depending on the number used (about four is okay to make the four tyres wormer) should be stacked together that is place the tyres on top of each other in one frame and the foot of the frame stand inside a container or cup containing condemned engine oil. The culture should be covered with polythene sheet to prevent light from getting into the culture and to prevent the culture from drying out. The essence of the oil will be to protect the vermiculture and earthworm from predators and parasites like ants, beetles, centipedes etc. Adequate moisture is maintained and uncovering (removal of the polythene sheet) the culture every day to ensure fresh air circulation in the culture and minimize CO_2 build up and at the same time monitor the earthworm activities. After about 7- 8 hours, the culture is later covered. The activity continued until the culture is matured and ready for harvest and sale.

Mosquito net method

Vermicomposting and earthworm rearing can be achieved using old mosquito net (introduced and proved in Nweke et at., 2020). The mosquito net needs to be soaked in water for 24hours and washed properly before been used. Sacks are made from the mosquito net of which the size and dimension depends on the production capacity needed or desired. Net sacks work well and can be watered directly without untying the sacks. The net is airing and convenient for small scale farmers or gardeners especially if the gardener lives in an apartment in cities where space is very limited. It can be placed in open space or indoors, hence ideal for both indoor and outdoor vermicomposting and can easily be monitored against predators. The holes in the net are so tiny thus the exit of worms is restricted.

Other Methods

There are many other methods that can be employed in vermicomposting. They include air tight container of which the cover will be removed 9-12 hours every day till maturity to allow for fresh air circulation and reduction of CO_2 build up that will be detrimental to the worms. Also ideal since light limit earthworm activities and air tight container protect the worms against the known predators. Plastic buckets or boater, wooden box or worm bin, metal containers, Styrofoam etc. can also be used for vermicomposting. Though wood may eventually be eaten or decay and need to be replaced and plastics crack easily, some people prefer wooden compost worm bins because worms may breathe better and absorb excess moisture which can be hazardous to the worms. However chemically treated woods should be avoided as it can be dangerous to the worms and leach harmful chemicals into the vermicompost. Styrofoam have been found to release toxins in to the earthworm environment, while metal containers often conduct heat too readily, are prone to rusting and may release heavy metals into the vermicompost. Also, some woods like red wood and cedar sp. contain resinous oils that may harm worms in culture. Plastics and metal containers need holes in the bottom for excess liquid to drain into tray or cups provided for collection. In vermicomposting the liquids collected from the holes are vermiwash or leachate which are water percolated through the column of earthworm action will collect excretory products and mucus secretions of worms and nutrients from soil organic molecules. The liquid wash away the valuable plant nutrients and microorganisms present in drilosphere. Drilosphere as explained by Brown et al. (2000), is the environment made up of microenvironment in earthworm gut, surface that earthworm is in contact with soil surface and below ground of the vermicompost, middens, burrows and diapause chambers. The liquid can be used again to water the culture or used as liquid fertilizer or foliar spray for gardeners. The earthworm should be well ventilated and protected for maximum production. As in any livestock enterprise it is critical to maintain optimal conditions. Moisture and aerobic condition in the growing medium must be maintained to ensure healthy growing worm populations. Profitable production depends on both growth and reproduction rates of worms and choice of a suitable species for the food stuff available. Different species have preferred ranges of temperature and moisture conditions. African species of earthworm like *Eudrilus eugenae* indigenous to Nigeria and *Eisenia fetida* are ideal for the preparation of vermicompost and after completion of the vermicomposting process, the vermicompost should be removed and replaced by fresh waste material (Earthworm-Wikipedia).

Substrate or materials for vermicomposting

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Substrates for vermicomposting are bound (many) and can be rated based on physical and chemical characteristics. The various substrates use for vermiculture are livestock wastes (dairy, poultry, pig, sheep and goat etc.), agricultural wastes, industrial wastes, leaves of crops and trees, vegetable wastes, grasses, weed plants before flowering, municipal solid wastes, food industry wastes, biogas sludge, sewage sludge, sugar cane factory wastes, paper mill wastes, fibre from coconut etc. Agricultural wastes have been tested extensively in combination with an easily biodegradable substrate such as cow dung, pig and poultry manure respectively. Addition of neem cake/leaves if available in vermiculture can boost earthworm biomass production and very significant in the establishment of the microflora and deterrent to disease causing organism like fungus. However, not all earthworms' species are tolerant to the additive material but *Eudrilus eugenae* tolerates 1.6 - 6.4% concentration of neem cake in the culture medium. The addition has positive effect on the worm activity and production. Also, rock phosphate powder if available can be sprinkled on waste materials to be used for vermicomposting. This will help to improve the nutritional quality of the vermicompost (Kale et al., 1986; Sailaja et al., 2002; Nweke and Chukwuma, 2023).

Factors governing vermiculture/vermicomposting Technology

Climate and Temperature

The most commonly used earthworm in vermicomposting process feed rapidly at temperature of 15-35^{o}C or 59-77^{o}F. They can as well survive at temperature 50^{o}F or 10^{o}C, however, temperature above 87^{o}F or 35^{o}C may hamper the worms' activity and limit biomass production. This temperature ranges simply means that indoor vermicomposting with *Eudrilus eugenae* and *Eisenia fetida* in all is suitable especially in tropical climates like Nigeria, while worms like *Perionyx excavatus* are suitable and adapted for warmer climates. Thus, if the worm culture is kept outside it should be placed in shelter position to keep it away from direct sunlight and insulated against frost in winter for temperate climates. It is necessary to monitor the temperature of the worm culture as the feed stocks used can decompose, heating up the worm bin or structure as they decay and kill the worms. Temperature effectively control the activity, metabolism, growth, respiration and reproduction, fecundity and growth period from hatching to sexual maturity of earthworm. Cocoons hatch sooner at high temperatures. Improper temperature can increase pests and predators though this depends on the type of feed stuff used

Soil Type

Light and medium loam soils are the most ideal soil for earthworm production as compared to the use of heavy clay, gravely sand and alluvial soils. Silt and clayey sand, clay loam and sandy loam may be suitable for vermicomposting process. Soil type influence the impact of earthworm on microbial respiration of which its increase varies with soil type. It may be higher in clay loam and silt clay loam soils but decreased in sandy loam. Naik et al. (2007) recorded high population of earthworm in light and medium loams soils relative to heavier clays, gravelly sands and alluvial soils, while microbial respiration of *L. terresteris* decreased in sandy loam soil but increased in clay and silt clay loam soil (Shaw and Pawluk, 1986)

Feed materials

Earthworm feed on a wide variety of organic feed stocks and extract sufficient nourishment from them to survive. The type and amount of feed available to the worms influence the size, population of the worms, species present, rate of growth and fecundity. Feed quality and type also influence soil microbial activity and biomass and yield of earthworm species. It is the rich microbial life that converts nutrients already present in the soil into plant available form. While worm mucus produces in cause of vermicomposting help to prevent nutrients from washing away with the first watering and held moisture better than plain soil. The microbial activity of compost may be greater if it is aerated. The dark brown waste liquid or leachate that drains into the bottom of some vermicomposting systems as water rich food break down is best applied back to the system when added moisture is needed due to the possibility of phytotoxic content and organic acid that may be toxic to plants. A varied mixture of feed stocks influences as well the N, K and P content of the resulting vermicompost. Having worms escape from the feed culture medium is most observable in vermicomposting process. Generally, they stay in the system, but may try to leave the vermicomposting when first introduce to the feed culture or often after a rain storm when outside humidity is high. Maintaining adequate conditions in the vermicomposting system and putting light over the system when first introducing earthworms will eliminate or minimize the problem. Predators, flies and odour are attracted by certain feed materials such as meat or dairy products and kitchen wastes. So, avoiding the use of these kind of feed materials in vermicomposting will decrease the possibility of odour and pests.

Moisture Content

Earthworm body weight constitute about 70-90% water. Therefore, prevention of water loss in vermicomposting process is a major factor in successful vermi reactors, especially when the system is outdoor. In a natural soil earthworm interaction, the worms tend to move to a safer area with moisture, when there is a less soil moisture in particular area of habitat. In extreme condition when the whole area is dry worms adjust themselves and survive by losing large water about 70-75 from their body to the surrounding. However, they become active when favourable soil moisture conditions are regained. Moisture conditions influence all earthworm activities, biomass production, growth, cocoon production and juveniles. Juveniles sometimes tolerate low moisture especially when transferred to new environment with favourable moisture, adjust faster than adult worms. Moisture level is a significant factor in the setup of a vermiculture/vermicomposting system. Therefore, vermicomposting system need to be carefully designed to hold water without causing water logging. Note that the use of food with high moisture content and inadequate watering can make the culture to become anaerobic and kill the worms or make them to escape from the culture. To restore healthy conditions and prevent the worms from dying the excess water should be removed and the system returned to the normal moisture level.

pH

The pH of the vermiculture varies with the input fed to the worms. The pH of the waste or soil can be a factor that limit the distribution, population and species of earthworm. Earthworms thrive most on pH level of 6.0-7.0 for maximizing the productivity in organic waste management. Earthworms can equally thrive in soils of pH 5.40, because there are some species of earthworm that are acid tolerant (*Dendrobaena rubida, D. octaedra*) while some were acid-intolerant (*Allolobophora calignose, A. nocturna, A. longa*). Species like *lumbricus terretris* are not sensitive to pH levels while *Perionyx excavates* can effectively perform well in a wide range of food waste pH levels (Guild, 1951; Satchell, 1955; Singh et al., 2005).

Benefits of earthworm activities and vermicompost for agricultural sustainability and environmental management

Soil

Earthworm through their burrowing activities mix different layers of soil, facilitate flow of water through the soil profile and aerate the soil. They break down and mineralize and incorporate OM deeper into the soil profile. Earthworm by burrowing bring soil from deep layer on to the surface layer which after long period of time, change the mineralogy of the surface soil. They feed on the surface layer litter and mix them thoroughly through the surface mineral soil. Increase rates of nutrient transformation and uptake by crops, improves soil aggregation and porosity and enhances water infiltrations and solute transport. Increase mineralization of soil carbon, but can as well decrease the mineralization of carbon by contributing to the formation of stable soil aggregates in which carbon is protected from further breakdown. Increased rates of water infiltration into the soil, thus reduce the amount of nutrients lost in the surface runoff. Earthworm enhances N content of soil through their cast production. Earthworm modify the character, productivity and structural properties of soil. Studies on vermicompost showed that it increases macro pore space ranging from 50-500µm resulting in improved air water relationship in the soil which favourably affect plant growth (Marinari, et al., 2000). Vermicompost favourably affects soil pH, microbial population and soil enzyme activities (Maheswarappa et al. 1999, Nweke, 2017). Vermicompost enrich the soil with microorganism and enzymes such as cellulose, phosphatase etc. as well as vitamins and hormones macro and micro elements. The findings of Orozo et al. (1996), Edwards, (1999) and Nweke, (2013) showed that vermicompost contain nutrients such as nitrates, exchangeable phosphorous, soluble K, Ca and Mg in plant available form. Vermicompost increase soil microbial biomass activity and thus strong retention of nutrients (Nweke, 2016). Vermicompost contribute to the biological fertility of the soil by adding beneficial microbes to the soil. The mucus excreted through the earthworm digestive canal, stimulates antagonism and competition between diverse microbial populations. Thus, resulting in the production of some antibiotics and hormones, auxins, gibberellic acid like biochemicals that can boost plant growth. It enriches the soil with favourable pH, a soil conditioner and slow release biofertilizer. Vermicompost contains in plant available form macro and secondary elements and nutrients such as Ca, K, S, Mg, NO_3, PO_4 etc. and sufficient microelements. Vermicompost contains a high proportion of humic substances such as fulvic acid and humic acids etc. which provides site for chemical reactions and biological activities. Nitrogen is a significant factor in photosynthesis, cell division and differentiation, chlorophyll content, growth and somatic embryogenesis, electron transport, anthocyanin production and an important component of protein required for the metabolic process that take place during plant growth. Phosphorous plays a role in increasing water use efficiency, an important factor in crop production in arid climates, improves leaf expansion, axillary bud growth and shoot canopy, improved photosynthetic surface area and carbohydrate utilization. Potassium play a role in the maintenance of plan water balance and protein synthesis (Vance, 2001; Ahloowalia et al. 2004; Witennayer and Merbach, 2005; Theunissen et al., 2010). Liming the soil especially with limestone and some nitrogenous fertilizer in marginal or nutrient deficient soils or poor soils may increase earthworm population. While chemical fertilizers kill worms and, in some cases, depending on the concentrations have little or no effect on populations. Synthetic chemicals though not all are toxic to earthworms affect their productive activities as well as their influence in the use for natural biological control of pests. According to studies Raw (1962) showed that earthworms play useful role in the control of apple scab caused by fungus *venturia inequalis* which overwinters on fallen leaves and twigs. The disease fungus can be controlled by burning the disease materials in the fall by use of $CuSO_4$ but dangerous to earthworm so the cheap and less expensive is to introduce earthworm especially *L. terrresteris* into the orchard soils. They take the fallen leaves and twig into their burrows where they decompose them and increase the OM content of the soil. Hence the leaves and twig cease to be the source of the disease but rather source of mineral elements to the orchard (Raw, 1962).

Plant

Earthworm increase the growth and yield of crops through increase nutrients and water availability and stimulation of microbes that enhance mineralization of plant nutrients. Earthworms through direct production of plant growth promoting hormones enhance plant growth and yield. They also increase the phosphorous availability in the soil in the soluble form so that plants can pick up the available nutrient. Vermicompost play an important role in improving growth and yield of different field crops, vegetable and fruit crops. Vermicompost provide important macro-elements such as N, P, K, Ca, Mg etc. and micronutrients like Fe, Cu, Zn, Mn, Mo, B that enhance crop growth and production in different capacities. Priya and Santha (2014) in comparison of two composts made by two different earthworms observed increased growth of Amaranthus plant in *Lampito mauritii* compost while increased macro nutrient N, P, K and micronutrients Fe, Mn, Zn and Cu were recorded in *Eudrilus eugenae* compost. Calcium play an important role in ethylene adjustment in plants (Zang et al., 2002), while Mg activates more enzymes than any other mineral nutrient and thus important and significant element in plant growth and development (Epstein and Bloom, 2004). The micronutrients are very much involving in photosynthesis and chlorophyll production, cell division and growth, carbohydrate formation and enzyme system maintenance. Photosynthesis though a complex process sensitive to macro and micro element is a process that provides energy necessary for plant growth and reproduction while chlorophyll is principal class of pigment responsible for light absorption and photosynthesis. Thus, when vermicompost is used as soil conditioner or foliar application has the capacity to supply both macro and micro nutrients for optimum plant growth. Vermicompost through the humic acid content increase the accumulation and assimilation of the plant nutrient elements. The higher content of oxygen containing functional groups (OH, COOH) in the humic acids create an important avenue for the interaction with both macro and micro elements (Senesi, et al., 1992). The plant nutrients in vermicompost are in readily available forms for plant uptake. Plants fertilized with vermicompost show higher ability to assimilate plant nutrients that will enhance plant roots development and proliferation (Aranco, et al., 2006) and increase phenolic substances of plant. These phenolic substances such as flavonoids and anthocyanins compounds in many fruits and vegetable provide natural pigmentation (colour), taste, aroma and possess a wide range of antioxidant and therapeutic properties benefit to human health, such as anticarcinogenic, anti-inflammatory, cardio protective, neuroprotective (Heber, 2004, Hu, 2003, Dathie et al., 2003). Phenolic properties are very much important in consumer acceptability and marketability of the crop. Clearly there is a huge potential in the use of vermicompost as it can play major roles not only in soil or plants

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but also for the benefit of human health. Iron (Fe) play an important role in chlorophyll biosynthesis by influencing chlorophyll precursor S-aminolevulinic acid, while copper is part of plastocyanin protein responsible for electron transmission during photosynthesis process (Pustinik and Miller, 1989, Ayala and Sandmann, 1989). Phosphorous and K are essential in several biochemical activities in plants and nitrogenous compound that provide the basis for the reaction in the chloroplast that include enzymes, proteins and chlorophyll required for the photosynthesis. Soil application of vermicompost has potential for improving optimum plant growth and development which is important for greater dry matter and yield. Vermicompost make soil more productive over a long period of time, thus improving their potential to support plant growth development, root initiation and biomass, crop yields and microorganisms essentially for vigorous plant growth.

Vermicompost as bio-fertilizer enhance microbial and antagonistic activity and due to its extraordinary nutrient status, when used as a media supplement enhance seedling growth and development and increased productivity of wide variety of crops. The presence of microbial metabolites in vermicompost cause stimulation of root, internode elongation and precociousness of flowering, this enhance plant metabolism growth and development. Soil application of vermicompost and its use as alternative media in crop production can drastically reduce phonological disorders such as albinism, fruit malformation and occurrence of grey mold in some agricultural crops. Thus, reducing nutrient related disorders thereby increasing the marketability of crops. Earthworm processed waste called vermicompost is of high-quality bio-fertilizer in the sense that it is completely harmless in any concentration or quantity and on any soil type or class, strengthen immunity in plants, does not contain salts of heavy metals nor contain any pathogenic microflora and eggs of helminth.

Disease and pest management

The content of phenolic compounds in vermicompost makes plant that grow under vermicompost have better resistance to diseases and limited attacks by anthropoid pests. Phytochemicals form part of the natural plant defense mechanism against infections and microbial invasions (Edward et al., 2009; Makoi and Ndakideni, 2007). There is greater potential in the use of vermicompost in crop production as it can play good roles on the natural plant defense system. Soil with low organic matter attract low microbial activity and have good environment for crop disease development. But the application of vermicompost can effectively increase the OM and microbial activity of the soil and effectively suppress soil and foliar transmitted plant diseases (*verticillum, plectosporium, phythium, rhizoctonia*) development. Non- thermophilic compost such as vermicompost are source of microbial diversity and activity as such it contains a wide variety of antagonistic microbes that can efficiently act as biocontrol agents in suppressing soil-borne diseases such disease caused by phytopathogenic fungi. Earthworm feeding activities can reduce the survival of plant pathogens and root diseases in crops. Vermicompost can suppress or reduce the incidence of sucking pests under field and green house conditions, damage cause by spider mite (*Tetranychus spp*), aphid, mealy bug (*Pseudococcus spp*), beetles (*Acalynna vittatum*), white caterpillars (*Pieris braesicae L.*) etc. These pests attack wide range of agricultural crops. And suppression of these pests' gains importance because some of them like aphid are key vectors in transmission of plant viruses. Thrips (*Scintothrips dorsalos*), larva horn worms (*Manduca quinque maculata*) and mites (*Polyphago tarsonenus latus*) activities and effect can be suppressed with vermicompost. The uptake of phenolic compounds in plant system by these pests affect their rate of reproduction and survival. The application of vermicompost also can decrease the population of plant parasitic organisms like nematodes, their gall and egg sacs under field and green house conditions through the stimulation of bacterial and fungal antagonists of nematode such as *Trichoderma spp*, *Chitinolytic* bacteria and *Pasteunia penetrans*, *Pseudomonas spp* etc. Vermicompost can increase fungi population capable of trapping nematode and destroying their cysts, increase plant growth promoting rhizobacteria which produce enzymes toxic to plant parasitic nematode (Siddiqui and Mahmood, 1999). Thus, increase the population of fungivorous and bacterivorous nematodes. Disease suppression of vermicompost has been due to activities of competitive or antagonistic microorganisms including actinomycetes that reduce the loses from phytonematode infestation in crop plants. Vermicompost induce reduction in the number and aggressiveness of pathogenic microbes that affect plants and animal diseases (Ramesh, 2000; Aranco et al., 2007; Edwards et al., 2007; Edwards et al., 2009; Pandey and Kalra, 2010; Pathma and Sakthivel, 2012; Chime et al., 2019)

Seed Dispersal

Earthworm burrowing activity may store seeds underground in caches aerates and mix the soil as well as degrade OM content. In the process of these activities' earthworms help to disperse weed seeds. Aneceic earthworms have been recognized as important plant seed dispersers. Through their ingestion and digestion of litter and plant seeds and passage through their gut, their cast modify plant seed germination. Thus, they impact much on the soil seed bank and plant community through direct and indirect on the plant seeds. The dispersal of seeds in earthworm burrows may increase seed survival and contribute to the success of the seed. Earthworm equally facilitates the dispersal of soil microbes through their burrowing, feeding and casting activity. Earthworm have been reported to have buried over 90% *Ambrosia trifida* seeds at a rate 8-fold faster than abiotic seed burial when place on the soil surface and capable of storing seeds underground to the tune of 127 seeds/burrow. Thus indicating that earthworm burrows can increase secondary dispersal and survival of seed dispersed (Grant, 1983; Willems and Huijsmans, 1994; Jimenez and Decaens, 2004; Zailer and Saxler, 2007; FSD, 2010; www.cbd.int/2010).

Bioremediation and Pollution management

Bioremediation is waste management technique that involve the use of organisms to neutralize or remove pollutants from contaminated field rendering the pollutants harmless and ensure environmental health. Earthworm can be used to remove or neutralize pollutants from a contaminated field. So, bioremediation is simply the use of a naturally occurring organism in this case earthworm to break down hazardous substances into less toxic or non-toxic substances or compounds free from harm to the environment. This technology can be employed or applied in situ or ex situ. In the in situ, bioremediation involves the use of earthworm directly to treat contaminated field, while ex situ deals with removal of the contaminated material and treat with earthworm elsewhere. Earthworms are bioremediators, they can efficiently store toxic materials and heavy metals in their tissue including those heavy metals like lead and cadmium that cannot readily be absorbed by microorganisms. Hence, they can be regarded as bio-concentrators of heavy metals and toxic materials. Through this way, earthworm help to detoxify polluted soil and environment. The resinous substances excreted by earthworm and vermicompost production encourage growth of conglomerates of enzymes and microbes that are pollution eating microorganism within the medium (polluted field or material). The addition of vermicompost on the contaminated field can as well encourage and enhance the resident microorganism populations ability to break down contaminants. These autochthonous microbial communities' resident in the contaminated field are capable when stimulated through vermicompost addition to degrade aromatic hydrocarbon common in petroleum contaminated field, like oil spillage commonly found in oil drilling areas. Vermicompost addition favourably affect soil microbial population and enzyme activities and decrease the production of water-soluble chemicals that may cause possible environmental hazard contamination. Vermicompost has the potential to ameliorate damage caused by excess nutrients by its efficient buffering capability. In such manner nutrients which may otherwise cause phytotoxic and environmental problem are removed. During vermicomposting the heavy metals form complex, aggregates with humic acids and other polymerized organic fractions. Hence it reduces the availability of the phytotoxic ions like heavy metal ions to the plants and indirectly to animals and man. Earthworms accumulate and influence the solubility of heavy metals and other toxic substances rendering them ineffective or non-existence in the soil environment. Earthworms are not affected by Sulphur oxidation of which its reduced compounds are toxic to plants and animals. This indicates that earthworm can mobilize microelement in the extraction of toxic elements from polluted substrates and in the control of contamination of soils. The increased ash content during vermicomposting increased mineralization and O_2 content and removal of H_2S, this makes the vermicompost odourless. Thus, the released S-compounds which would have been toxic and dangerous to the environment are removed in the process.

Earthworms feed on partially fermented or decomposed organic materials an indication that there is a synergy between earthworm, fungi and bacteria in organic waste decomposition. Fungi major role in ecosystem is decomposition performed by the fungi mycelium. Mycelium secretes acids and extracellular enzymes that breaks down complex polysaccharides like cellulose and lignin which are compounds composed of long chains of carbon and hydrogen that are structurally similar to many organic pollutants. The synergy between these organisms makes the use of earthworm and its vermicompost (rich in bacteria and fungi) to be more effective in bioremediation and pollution management compared to any other method. Because mycoremediation is equally incorporated in the process. Meaning that any pollutant that cannot be neutralized by bacteria can be removed by fungi and vice versa. Mycoremediation is the use of fungal mycelia in bioremediation to remove organic pollution or decontaminate affected site or land area. It is important to give serious thought to utilize this organism for man's benefit.

High infiltration rates and water holding capacity enhanced by earthworm burrowing activity, shredding of litter, mixing of soil and casting both on soil surface and in tunnel help to prevent NO_3 and pesticides pollution by minimizing runoff erosion and chemical transport to surface waters. The earthworm burrows are also lined with OM that can adsorb many potential pollutants from the infiltrating water. Through this manner, earthworm help to minimize pollution of surface water by improving infiltration rates and decreasing runoff. The use of vermicompost in agriculture will ensure and enhance productivity and sustainability by keeping the soil fertile, reduce pollution and preserve ecological balance. Earthworms are capable of detoxifying cyanide content in crop waste like cassava peel (rind), lethal to soil invertebrates and can inhibit root growth, but rich in plant nutrients. Earthworm proliferates on these wastes and transform them into valuable harmless and odourless vermicompost. Odourless do not attract flies, pests and rodents. Vermicompost addition also proves positive impacts in the remediation of hydrocarbon contaminated soil and improve microbial activity in such soil. There is successful improvement in the structural development and nutrient recycling and productivity in a reclaimed peat and mining sites when earthworms were introduced to the sites (Krivolusky et al., 1980; Waugh and Mitchell, 1981; Ma, 1982; Martirucci, et al., 1983; Garrec and Plebin, 1984; Mba, 1996; Mann et al., 1996; Edwards and Bohlen, 1996; O'Loughlin, et al., 2000; Meagher, 2000; Lovley, 2003; Rattty and Hutha, 2004; Sins, 2006; Lesinsky and Veverka, 2008; Nweke, 2016, 2017; Wikipedia)

Ecological Management

Earthworm cast become dry minutes after release and through this can initiate stable soil aggregates in degraded lands. Cast production together with their burrowing activity promote water infiltration, hence reduce surface erosion. The enhancement of beneficial microflora by earthworm activity and the enrichment of the vermicompost (worm cast) with microbial enzymes can speed up soil reclamation process in degraded land and make it more productive. Earthworms having the ability to feed on various types of organic rich materials transforming them into vermicompost provides the use of them as natural bioreactors and eco-friendly and cost-effective waste management. Introducing earthworm or vermicompost addition in reclaimed degraded land like mining land or oil drilling land can increase the rate of soil improvement and the genesis of the soil structure of the reclaimed land. The reclamation process in degraded land can be quickened by increasing the earthworm population and activity by liming especially with limestone and lesser percentage of urea fertilizer. Earthworms influenced ecosystem, having the ability to moderate the availability of resources directly or indirectly to other organisms in the ecosystem. This they do by causing physical changes on the resource material in abiotic or biotic. Earthworm burrow through the soil taken along its feed of which some of them are lined up or adhere to the wall of tunnel or channel enable the organism to build through residue decomposition organic-mineral structures with specific physical, chemical and biological properties. The structures are usually called bioorganic structures otherwise known as casts. Thus, earthworms are ecosystem engineers. In tropical environment earthworms can be describe as the strongest ecosystem managers as they are capable of influencing organic residues breakdown, soil microbes, plant growth, nutrient recycling and change in the soil structure characteristics in productive ecosystems. Earthworms alters soil properties in ways that are beneficial to plant nutrition and water transmission and enhance favourable microenvironment for microorganism activity. They help to close the metabolic gab when used to recycle waste on site. Their use in bio-waste conversion can reduce waste flow and contamination of other recyclable wastes. When efficiently managed help to create a clean and odourless environment free of pollution. Hence healthy and harmonious ecosystem or environment. On the economic aspect, this can create low skill job when employed at the local or urban centres in the transformation of organic wastes into valuable product like vermicompost. The technology is simple and does not require huge amount to set up. The technology can make vermicomposting and rearing of earthworm practical for crop, fish and poultry farmers (Edwards and Bohlen, 1996; Gonzalez et al., 2003; Ratty and Hutha, 2004; Amner et al., 2005; Amador et al., 2006; Kooch and Javlilvand, 2008)

Threats to Earthworms

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Some agricultural activities are harmful to earthworms and reduce their populations in an agricultural field. Application of chemicals in the form of mineral fertilizers, pesticides, herbicides, dust and sprays have disastrous effect on earthworm populations. Chemical fertilizer kills worms but may not have deleterious effect on the productivity if the concentration is mild or low, while herbicides, insecticides, pesticides, nematicides, fungicides etc. influence much of their productivity cycle and their use in natural control of pest. For example, nitrogenous fertilizers tend to create acid conditions in soils which are fatal to the worms. Often dead worms are found on the surface of the soil following the application of substances like DDT, lime Sulphur, herbicides, lead arsenate and superphosphate. On the other hand, even if they are not totally killed, they can accumulate the pollutants such as lead, cadmium, DDT and dioxins at levels up to about 10-20 times higher than the soil, of which in turn are passed on at lethal dosage to organisms which feed on them such as moles, birds and foxes. Therefore, the most reliable way to maintain or increase the levels of earthworm population in the soil is to avoid the application of artificial chemicals as well as adding organic matter as surface mulch on a regular basis. This will provide them with their food and nutrient requirements and create the optimum conditions of heat and moisture to stimulate their activity.

Earthworm vermicompost, traditional compost and chemical (inorganic) fertilizer compared

The essence of comparison of the three different manures that farmers use in their soil is for the farmers and the users alike to know the impact each create in the soil’s life especially when continuously used. This is itemized using bullet point for easy understanding and digest.

Earthworm vermicompost

- Product of earthworm activity and organic fertilizer.
- It can bring life back to the degraded and marginal land and increase its fertility.
- It contains humic acids, humin, fulvo acids, amino acids, enzymes, vitamins and other active substances.
- Its positive effect in soil can last up to 3–5 years depending on the dosage applied
- It does not contain pathogenic microflora, egg of helminth and salts of heavy metals. Hence cannot cause soil pollution nor ill health to plants and animals.
- It is completely harmless on any soil applied and, in any quantity, or concentration.
- It strengthens immunity of a plant against disease causing organisms.
- It can be used as soil on its own for greenhouse crops and farmers.
- It is about 10–15 times more effective than any known organic fertilizers.
- It can be used in natural soil mixers.
- It is a non-polluting organic fertilizer.
- It suppresses pathogenic microflora and their likes.
- It surpasses compost and other manure types in about 4 –10 times in terms of humus content and on efficiency of action. This is practically the main advantage against all manures.
- There are no seeds of weed plants in its structure.
- It enhances seed germination, accelerates plant growth and increase crop yield.
- The decomposition is faster than any other methods of composting.

- It can be done at smaller or large scales.
- Any organic waste can be used as feed mixture.
- It contains macro and micro elements in their sufficient quantities.
- Improves soil texture, structure and water holding capacity of soil.
- It controls soil acidity, salinity and alkalinity.
- The humus contains high OC content. Thus, ensure high nutrients storage and release.
- There is sufficient quantity of plant growth hormones.
- It can sustain crop production on sustainable basis, thus ensure food security.
- The microbial activity is 15–20 times higher than in the soil.
- It contains about 50 – 60% more humus than the soil.
- The production reduces greenhouse gas emission e.g. CH_4, NO, NO_2.

Traditional Compost

- Organic fertilizer and product of active thermophilic microbes.
- Improve soil structure, soften hard soil and give the soil black to dark brown color
- Enriched the soil with C compounds and this will increase the activities of microorganisms and other soil organisms.
- Release plant nutrients slowly and its effect can last in soil 2–3 years.
- Better utilization of refuse/wastes to enhance the serenity of the environment.
- It can limit the disease and pest attack on plants
- Increase the growth of healthier plant and crop yield.
- Improves nutrient and water holding capacity, infiltration capacity and aeration of the soil and reduce surface run –off erosion.
- It regulates soil temperature and buffers soil chemical reaction (pH)
- It contains many macro and micro elements for plant development.
- It may increase the heavy metal content of the soil to the tune that might be detrimental to plant, soil organisms' and animals alike. Thus, it pollutes the soil environment and therefore care should be taken while using compost whether from agricultural, animal, sewage or industrial wastes compost.
- Through composting some soil pathogens and even some beneficial microbes are destroyed.
- In many of the drier savannas materials to be composted are not always available.
- Labour intensive and time-consuming process and equipment for large scale composting is not present in tropical country like Nigeria.

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- Total amount of nutrients in compost is lower compared to its equivalent in weight in earthworm vermicompost or chemical fertilizer, meaning that large volume is required and that can be a problem and hence not easily adaptable for use on a large area of land.
- Increase the soil OM content, thus conserve plant nutrients
- Its low analysis reduces its competitive economic value
- Its decomposition produces organic acids and CO_2.
- It helps to dissolve minerals like K making it more available to growing plant.
- Provide energy for heterotrophic organisms that decompose OM as their source of carbon.
- Reduce evaporation of water when used as mulch.
- Reduce alkalinity and acidity in soils
- Supply food for all microbes and earthworm and their likes in soil.
- No worm mucus to prevent the washing away of nutrients from the first rain.

Chemical (inorganic) fertilizer

- It contains 1- 3 nutrients in any one type chemical fertilizer e.g. Urea, NPK etc.
- It does not contain secondary macro nutrient elements (e.g. S, Ca, Mg).
- Its addition in soils creates acidity, salinity and alkalinity conditions.
- It contains no OC content and with this limitation the productivity of the soil is challenged and moisture retention capacity of the soil is reduced.
- It cannot bring back to life the degraded land rather it increases further the degradation of the land.
- It creates imbalance in the soil electrical conductivity (EC). This affects greatly microbial activity, plant nutrients transmission and assimilation.
- The activities of some beneficial soil organisms are reduced; such as N-fixing and phosphate (PO_4) solubilizing bacteria thus, the fertility of the soil is impaired.
- It does not contain plant growth hormones.
- It reduces aeration and damage soil aggregation and structural stability properties of the soil.
- Crop production on sustainable basis cannot be achieved.
- It causes soil degradation, distort soil biodiversity and create imbalance in ecological system.

Types of chemical fertilizers include;

Calcium cyanide: $CaCN_2$

Basic slag.

Nitrogenous fertilizer:

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Urea

Ammonium sulphate $(NH_4)_2SO_4$.

Ammonium nitrate: NH_4NO_3

Nitrate of potash: KNO_3

Nitrate soda or sodium nitrate: $NaNO_3$

Phosphate fertilizer:

single super phosphate $CaHPO_4$; $Ca_2(PO_4)_2$.

Ammoniated super phosphate: $NH_4H_2PO_4$; $(NH_4)_2PO_4$

Triple super phosphate: $CaCH_2PO_4$; $CaHPO_4$

Calcium meta phosphate: $Ca\ (PO_2)^n$

Mono ammonium phosphate: $NH_4H_2PO_4$

Rock phosphate: $(CaO)_5P_2O_5$

Potassium fertilizer:

Muriate of potash: KCl.

Sulphate of potash: K_2SO_4

CONCLUSION

The production of degradable organic wastes increases in all the cities across Nigeria and their safe disposal becomes major problem. Meanwhile the rejuvenation of degraded soils by protecting top soil and sustainability of productive soils should be a major concern to the policy makers. Provision of a sustainable environment of the soil by ameliorating with good quality organic material like vermicompost enhances nutrient supply and water holding capacity of soil as well as development of resistance in plant diseases and pests. The utilization of earthworm and vermicompost is of immense benefit to farmers, industries, environment and national economy. Vermicompost is an excellent bio-fertilizer that its addition to soil improves soil physicochemical and microbiological properties of agricultural soil, amplifies the population and diversity of microbial communities. The ecological characteristics and beneficial effect of earthworms have been clearly demonstrated. Their activities influence the rate of soil turn over, mineralization and humification of organic matter. Because earthworms gut provides a conducive environment for the development of bacteria colonies and their cast contain higher number of bacteria than the surrounding soil. They improve soil productivity, remediate contaminated soils among others. Vermicomposting is not a popular technology in Nigeria, in fact the technology does not exist in Nigeria to the best of our knowledge. Hence in Nigeria, the agriculture-based industries and farmers are yet to know and embrace the potential application of vermitechnology and vermicomposting. Thus, this is our little contribution in educating and convincing people to adopt this technology.

REFERENCE

1. Aalok, A., Tripathi, A. R., Soni, P. (2008). Vermicomposting a better option for organic solid waste management. J. Human Ecology, 24: 59-64
2. Ahloowalia, B. S., Malusznyski, M., Nichterlin, K. (2004). Global impact of mutation derived varieties. Euphytica, 135: 187 – 204

3. Amador, J., Gorres, J., Savin, C. (2006). Effect of lumbricus terrestris L. on nitrogen dynamics beyond the burrows. Applied Soil Ecol. 33(1): 61 – 66
4. Ammer, S., Webber, K., Abs, C., Ammer, C., Prietzel, J. (2005). Factors influencing the distribution and abundance of earthworm communities in pure and converted scots pine stands. Applied Soil Ecol. 35(1): 52 – 64
5. Appelhof, M. (1997). Worms eat my garbage 2nd edition Kalamazo, MI flower Pp 3-113
6. Aranco, N. Q., Edward, C. A., Bierman, P. (2006). Influence of vermicompost on field strawberries: Effect on soil microbiological and chemical properties. Bioresources Technological 92: 833-840
7. Aranco, N. Q., Edwards, C. A., Dick, R., Dick, L. (2007). Vermicompost tea production and plant growth impacts. BioCycle Part 1 Pp 51-53.
8. Aranco, N. Q., Edwards, C. A., Yardin, E. N., Oliver, T. J., Byrne, R. J., Keeney, G. (2007). Suppression of two spotted spider mite (Tetranychus urticae), mealy bug (Pseudococcus sp) and aphid (Mycus persicae) population and change by vermicomposts. Crop Prot. 26: 29 – 39
9. Ayala, M. B., Sandmann, G. (1989). Activate of Cu containing protein in Cu depleted plant leaves. Physiol. Plantar. 72: 801 – 806
10. Babayemi, O. J., Hamzat, R. A., Bankole, M. A., Anumudu, N. F., Olomola, O. O. (2006). Preliminary studies on spent tea leaf: In vitro gas production as affected by chemical composition and secondary metabolites. Pakistan J. Nutrition 5(5): 497-500
11. Beetz, A. (1999). Worms for composting. Vermicomposting Natural Sustainable Agriculture Information Science, ATTRA Publication IP 110 Slot 28.
12. Bhatnagar, R. K., Palta, R. K. (1996). Earthworm vermiculture and vermicompositing. Kalyani Publishers, New Delhi
13. Bhawalkar V. S. (1995). Vermiculture bioconversion of organic residues PhD thesis IT Mumbai India Pp 15-45
14. Bohlen, P. J. (2002). Earthworms. Encyclopedia of Soil Science Pp 370 – 373 Marcel Dekker Inc.
15. Bohlen, P. J., Parmelee, R. W., McCartney, D. A., Edward, C. A. (1997). Effect of earthworms (lumbricus terrestri) on the carbon and nitrogen dynamics of decomposing surface litter corn. Agroecosystem, Ecological Applications 7:1341-1349
16. Bouche, M. B. (1977). Strategies Lumbricsennes. In: Soil organisms as component of ecosystems. Ecological Bulletin Stockholm 25: 1 – 122
17. Brown, G. G. (1995). How does earthworm affect microbial and faunal community diversity? Plant Soil 170: 209-231
18. Brown, G. G., Barois, J., Lavelle, P. (2000). Rejuvenation of soil organic matter dynamics and microbial activity in the drilosphere and the role of interactions with other edaphic functional domains. Eur. J. Soil Biol. 36: 177-198
19. Chime, E. U., Ibeh, C.U., Nweke, I. A., Nsoanya, L.N. (2019). Bioefficacy of some biopesticides agents and treated pennisetum biofertilizer against root knot nematode (meloidogyne incognita) on Indian spinach (basella alba) and soil chemical properties. Journal of Information Research and Review 10 (2): 6047-6050
20. Compost worms http://www.homelycappers.com/compost-worms" Retrieved 2008-02-12
21. Cronin, P., Ryan, F., Coughlan, M. (2008). Undertaking a literature review: a step-by-step approach. British Journal of Nursing, 17(1), 38-43.
22. Darwin, C. (1881) reprint (1945). Darwin on humus and earthworms: The formation of vegetable mould through the action of worms with observation on their habits. Pp 153, Faber and Faber, London.
23. Darwin, C. (1881). The formation of vegetable mould through the action of worms with observation on their habits. John Murray, London 1881
24. Darwin, F., Seward, A. C. (1903). More letter of Charles Darwin. In: John, M. (ed.) A record of his work in series of hitherto unpublished letter. Vol. 2, London Pp 508
25. Dathie, G. G., Peter J., Gardner, P. T., Kyle, J. A. M. (2003). Plant polyphenols are they the new magic bullet? Proc. Nut. Soc. 62: 599 – 603
26. Dominquez, J. (2004). State of the art and new perspective on vermicompoting research. In: Edward, C. A. (ed.) Earthworm Ecology second edition CRC Press LLC, Boca Raton, FI USA, Pp 401-424

27. Dominquez, J., Edward, C. A. (2004). Vermicomposting organic wastes a review. In: Hanna, S. H. S., Mikhail, W. Z. A. (eds.) Soil zoology for sustainable development in the 21st century Cairo pp 369-395 Earthworm are the seed dispersers of the month www.cbd.int/2010
28. Earthworm. www.wikipedia.com Retrieved 3rd March, 2016
29. Earthworms: Earthworm on encyclopedia.com assessed 2nd November, 2016
30. Edward, C. A. (2014). Earthworms: The soil biology primer. Natural Resources Conservation Services USDA
31. Edward, C. A., Lofty, J. R. (1972). Biology of earthworms, Pp 283 Chapman and Hall Ltd, London
32. Edward, C. A., Aranco, N. Q., Emerson, E., Pullian, R. (2007). Suppressing plant parasitic nematodes and arthropod pests with vermicompost teas. BioCycle, 38 – 39
33. Edwards, C. A. (1995). Earthworm. McGraw Hill Encyclopedia, Pp 81-83
34. Edwards, C. A. (1998). The use of earthworm in the breakdown and management of organic wastes. In: Edwards, C. A. (ed.) Earthworm Ecology CRC Press Boca Raton Pp 327-354
35. Edwards, C. A., Bohlen, P. J. (1996). Biology and ecology of earthworm 3rd ed. Chapman and Hall, London
36. Edwards, C. A., Aranco, N. Q., Bennett, M. W., Aska, A., Keeney, G. (2010). Effect of aqueous extracts from vermicompost on attack by cucumber beetles (Acalymna vittatum) (fabr) on cucumber and tobacco horn worm (Manduca sexta) (L) on tomatoes. Pedobiologia, 53: 141 - 148
37. Edwards, C. A., Aranco, N. Q., Vasko-Bennet, M., Askar, A., Keene, G., Little, B. (2009). Suppression of green perch aphid (Myzus persicac (sulz) citrus mealy bug (Planococus citri (Risso) and two spotted spider mites (Tetranychus urticae (Koch) attacks on tomatoes and cucumbers by aqueous extracts from vermicompost. Crop Prot. 30: 1-14
38. Epstein, E., Bloom, A. J. (2004). Mineral nutrition of plants: Principles and perspective 2nd ed. Sinauer Associates Sunderland MA ISBN 0-87893-1724
39. Fragoso, B. I., Gonzales, C., Arteaga, C., Patron, J. C. (1999). Relationship between earthworms and soil organic matter levels in natural and managed ecosystems in the Mexico tropics. In: Mulongoy K., Mecch R. (eds.) Soil organic matter dynamics and sustainability of tropical agriculture. John Wiley and Sons Chi Chester UK, Pp 231 – 239
40. FSD, (2010). Earthworm. 5th International Symposium-workshop on frugivorous and seed dispersal (1985-2010).
41. Garrec, J. P., Plebin, R. (1984). Accumulation of fluorine in earthworms living in contaminated soils. Environ. Pollut. 7: 97 – 105
42. Ghosh, C. (2004). Integrated vermi-pisciculture-an alternative option for recycling of solid municipal waste in rural India. Bioresource Technology 93: 71-75
43. Gonzales, G., Seastedt, T. R., Donato, Z. (2003). Earthworm, arthropod and plant litter decomposition in aspen and lodge pole pine forest in Colorado, USA. Pedobiologia, 47(2): 863 – 869
44. Grant, J. D. (1983). The activities of earthworms and the fates of seeds. In: Satchell, J. F. (ed.) Earthworm ecology from Darwin to vermiculture. Chapman and Hall, 107 – 122
45. Guild, W. F. M. (1951). Earthworm in agriculture. Scottish Agric. 30: 220 – 230
46. Gunthilingaraj K., Ravignanam T. (1996). Vermicomposting of sericultural wastes. Madras Agricultural Journal 83(7): 455-457
47. Gutierrez – Miceli, F. A., Oliva-Liaven, M. A., Nazar, P. M., Ruiz-Sesma, B., Alvarez-Soli, J. D., Dendooven, L. (2011). Optimization of vermicompost and worm bed leachate for the organic cultivation of Radish. J. Plant Nutrition 34 (11): 1642 – 1653
48. Gutierrez-Miceli, F. A., Garcia-Gomez, R. C., Riacon-Rosales, R., Abud-Archila, M., Maria Angel, O. L., Cruz, M. J. G., Dendooven, L. (2008). Formation of a liquid fertilizer for sorghum (Sorghum bicolor (L) moench) using vermicompost leachate. Bioresource Technology 99 (14): 6174-6180
49. Hale, C. M., Frelich, L. E., Reich, P. B., Pastor, J. (2005). Effect of European earthworm inversion on soil characteristics in northern hardwood forest of Minnesota, USA. Ecosyst. 8(2): 911 – 927
50. Hartenstein, R., Neuhauser, E. F., Kaplan, D. L. (1979). Reproductive potential of the earthworm Eisenia fetida. Oecologia 43: 329-340
51. Haynes, R. J., Naidu R. (1998). Influence of Lime, Fertilizer and Manure Applications on Soil Organic Matter Content and Soil Physical Conditions: A Review. Nutrient Cycling in Agroecosystems, 51: 123-137. https://doi.org/10.1023/A:1009738307837

52. Heber, D. (2004). Phytochemical beyond anti-oxidation. J. Nut. 134: 33755- 33765
53. Hu, T. B. (2003). Plant based foods and prevention cardiovascular diseases a review. Am. J. Clin. Nut. 78: 5445-5515
54. Ismail, S. A. (1997). Vermicompost: The biology of earthworms. Orient Longman Ltd Chennai India, pp 92.
55. Jayakumar, Pathma, Natarajan. (2012). Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. Springer Plus Open Access 2012: 1-26
56. Jayashankar S. (1994). Studies of vermicomposting as a method as sewage sludge disposal M. Sc. Thesis Anna University, Madras India, Pp 1-30
57. Jensen, M. H. (2002). Controlled environment agriculture in desert tropics and temperate regions-a world review. Acta Hort. 578: 19-25
58. Jimenez, J. J., Decaens, T. (2004). The impact of soil organisms on soil functioning under neotropical pastures: case study of a tropical anecic earthworm species. Agriculture, Ecosystems and Environment 103: 329 - 342
59. Jimens, J., Lavelle, P., Decaens, T. (2006). The efficiency of soil hand sorting in assessing the abundance and biomass of earthworm communities. Its usefulness in population dynamics and cohort analysis studies. Eur. J. Soil Bio. 139 (1): 265 – 271.
60. Kale R. D. (1994). Vermicomposting of waste materials. Earthworm Cinderela of organic farming Prism Book Pvt ltd New Delhi India, 47Pp
61. Kale, R. D., Bano, K. Vinyak., Bhagyaraj, D. J. (1986). Suitability of neem cake as additive in earthworm feed and its influence in the establishment of microflora. J. Soil Biol. Ecology 6: 93 – 103
62. Karim, R. A., Ghani, N. M. A., Nasari, N. N. (2011). Natural Discovery: Electricity potential from vermicompost (waste to energy). World Academy of Science Engineering and Technology, 58, 2011
63. Kaur A., Singh J., Vig A. P., Dhalwai S. S., Rup P. J. (2010). Co-composting with and without Eisenia fetida for conversion of toxic paper mill sludge to a soil conditioner. Bioresource Technology, 101(21): 8192-8198
64. Kooch, Y., Jalilvand, H. (2008). Earthworm as ecosystem engineers and the most important detritivors in forest soil. Pakistan J. Biol. Sci. 11(6): 819-825
65. Krivolutsky, D. A., Semyashkina, T. E., Mikhal Tsova, Z. A., Turcha Ninova, V. A. (1980). Earthworms as bioindicator of radioactive contamination of soil. Soviet J. Geol. 11: 379 – 383
66. Lee, K. (1985). Earthworm. Their ecology and relationship with soils and land use, Academic Press New York.
67. Lesinky, D., Veverka, M. (2008). Ecotoxicology of hydrocarbon – contaminated soil remediated by vermicompost tea. CODI, 2008 Compost and digestate: Sustainable benefit and impact for the environment and plant production, International Congress, CH-Solothum, 27th - 29th February, 2008
68. Loren, N., Taylor, J. H. (1998). The worm book Tea Speed Press Pp7
69. Lovley, D. R. (2003). Cleaning up with genomics applying molecular biology to bioremediation. Nature Reveals Microbiology, 1(1): 35 - 44
70. Ma, W. (1982). The influence of soil properties and worm related factors on the concentration of heavy metals in earthworm. Pedobiologia, 24: 109 – 119
71. Maheswarappa, H. P., Nanjappa, H. V., Hegde, M. R. (1999). Influence of organic manure on yield of arrow root, soil physicochemical and biological properties when grown as intercrop in coconut garden. Ann. Agric. Res. 20: 318 – 323
72. Makoi, J. H. J. R., Ndakideni, P. A. (2007). Biological, ecological and agronomic significance of plant phenolic compounds in rhizophere of the symbiotic legumes. Afr. J. Biotechnology, 6(12): 1358-1368
73. Mann, D. K., Hunt, T. M., Malkos, E., Sims, J., Twait, S., Wachter, G. (1996). Onsite treatment of petroleum, oil and lubricant (POL) contaminated soils at Illinois Corps of Engineers lake sites. US Army Corps of engineers Technical Report No. A62603 71Pp
74. Manna, M. C., Singh, M., Kundu, S., Tripathi, A. K., Takkar, P. N. (1997). Growth and reproduction of the vermicomposting earthworm Perionyx excavates as influenced by food materials. Biology and Fertility of Soils 24(1): 129-132
75. Marinari, S. Masciandaro, C., Ceccanti, B., Grepo, S. (2000). Influence of organic and mineral fertilizers on soil biology and physical properties. Bioresource Technology 72(1):9-17

76. Martin, J. P. (1976). Darwin on earthworms the information of vegetable moulids. Bookworm Publishing Ontario, Canada
77. Martinucci, G. B., Grespi P., Omodeo P., Osella, G., Traldi, G. (1983). Earthworm and ICDD (2,3,7,8 tetrachlorodibenzo-p-dioxin) in Seveso. In: Satchell, J. E. (ed.) Earthworm ecology from Darwin to vermiculture Chapman and Hall, 273 – 283
78. Mba, C. C. (1981). Humus production from cassava (Manihot esculenta) peel by Eudrilus eugenae (terrestrial oligochetae). Der Tropenland wirt 82; 145-148
79. Mba, C. C. (1983). Utilization of Eudrilus eugenae for disposal of cassava peel. In: J. E. Satchell (ed). Earthworm ecology, From Darwin to vermiculture Chapman and Hall London Pp 315-321
80. Mba, C. C. (1996). Treated cassava peel vermicompost enhance earthworm activities and cowpea growth in field plots. Resource, Conservation and Recycling, 17: 219-226
81. Mbah, C. N., Nweke, I. A. (2009). Vermicomposts from bracharia grass, Andropogon gayanus and pig manure and their effect on some soil properties. Journal of Agriculture and Rural Development (IJARD), 11(2): 1-4
82. Meagher, R. B. (2000). Phytoremediation of toxic elemental and organic pollutants. Current Opinion in Plant Biology 3(2): 153 – 162 https://doi.org/10.1016/S1369-5266(99)00054-0 PMID10712958
83. Mitchell M. J. (1978). Role of invertebrates and microorganisms in soil sludge decomposition National Technical Information Service Springfield Virginia, Pp 35-38
84. Mollison B. (1988). Permaculture. A designer's Manual Tagari Press, 1988.
85. Munnoli, P. M., Da Silva, J. A. T., Saroj, B. (2010). Dynamics of the soil earthworm plant relationship-A review. Dynamic Soil Dynamic Plant (Global Science Books) Pp 1-20
86. Munnoli, P. M. (1998). A study on the management of organic solid waste of agro-based industries through vermiculture biotechnology ME thesis Patiala TET India, Pp 11-30
87. Munnoli, P. M. (2007). Management of industrial organic solid wastes through vermiculture biotechnology with special reference to microorganisms. PhD Thesis Goa University, India 1-334pp
88. Munnoli. P. M., Bhosle, S. (2009). Effect of soil cow dung proportion of vermicomposting. J. Scientific and Industrial Research, 68:57-60
89. Muys, B., Lust, N. (1992). Inventory of the earthworm communities and the state of little decomposition in the forest of Flanders, Belgium and its implication for Forest Management. Soil Biol. Biochem. 24(1): 1677 – 1681
90. Nagavallemma, K. P., Wani, S. P., Stephane, L., Padmaja, V. V., Vineela, C., Babu, R. M., Sahrawat, K. L. (2004). Vermicompost: Recycling wastes into valuable organic fertilizer. Open Access Journal Published by India International Crop Research Institute Semi-Arid Tropics (ICRISAT), 2(1): 1-15
91. Naik, R., Halepyat, A. S., Pajan, B. T. (2007). Effect of organic manure and fertilizer levels on growth yield components and yield safflower (Carthamas tincthorus L.). Kamatava Journal of Agriculture Science 20(4): 834-836.
92. Nayaran J. (2000). Vermicompositing of biodegradable wastes collected from Kuvenpu University campus using local and exotic species of earthworm. In: Proceedings of a National Conference on Industry and Environment 28th 30th December,1999 Karad India Pp 417-419
93. Nogales, R., Melgar, R., Guerrero, A., Lozada, G., Beniteze, E., Thompson, R., Gomez, M., Garvia, M. H. (1999). Growth and reproduction of Eisenia andrei in dry olive cake mixed with other organic wastes. Pedobiologia, 43(6): 744-752
94. Nweke I. A., Ogugua, U. V. (2015). Assessment of soil physicochemical properties under contrasting earthworm (keffia Nigeria) Management practices. British J Res. 2(1): 077-085
95. Nweke, I. A., Nsoanya, L. N. (2015). Effect of Cow Dung and Urea Fertilization on Soil Properties, Growth and Yield of Cucumber (Cucumis Sativus L). Journal of Agriculture and Ecology Research International, 3(2): 81-88. http://doi.org/10.9734/JAERI/2015/14084
96. Nweke, I. A. (2013). Plant nutrient release composition in vermicompost as influenced by Eudrilus eugenae using different organic diets. J. Ecol. Nat. Environ. 5(11): 346-351
97. Nweke, I. A., Nsoanya, L. N., Okoli, E. C. (2013). Effect of organo- mineral fertilizer on growth and yield of maize (zea mays. L) at Igbariam southeastern, Nigeria. Journal of Agriculture and Rural Development 16(1): 1404-1408

98. Nweke, I. A. (2016). Effect of cassava peel compost and earthworm (Eudrilus eugenae) activities on the rheological, physical and biological properties of oil polluted soil. Int'l Journal of Agriculture and Environmental Sciences 1(3): 26-32
99. Nweke, I. A. (2017). Effect of compost and earthworm production on soil properties, growth and dry matter yield of maize in crude oil degraded soil. J. Soil Sci. Environ. Manage. 8(1): 1-10
100. Nweke, I. A., Chukwuma, T. R. (2023). Effect of castor capsules (Ricinus communis) and neem leaves (Azadiracta indica) on soil properties and fungi infection on tomato (Lycopersicum esculentum). Global Scientific Journal, 11(2): 1999 - 2010
101. Nweke, I. A., Nnabuife, P. I. (2020). Interaction between two types of earthworm and ageratum on soil physicochemical properties. Agric. Sci. 2(2): 1-6.
102. Nweke, I. A. Nkwonta, I., Igwe, A. C., Okenmuo, F. (2020a). Nutrient potential from vermicompost of two contrasting organic wastes using tropical earthworm and mosquito net as culture material. Int'l J. Biol. Studies 1(1): 1-7
103. Nweke, I. A., Chime, E. U., Ibeh, C. U. (2016). Influence of different grass diets on cast production efficiency and growth rate of earthworm. Int'l J. Agric. Forestry and Fisheries 4(5): 56-60
104. Nweke, I. A., Chime, E. U., Ogugua, U. O. (2020b). Evaluation of vegetable vermicompost on the chemical properties of two different soils. Journal of Agricultural Policy 3(2): 1-6
105. Nweke, I. A., Ejinkonye, C., Ogugua U. V. (2019). Impact of two contrasting vermicomposts on the fertility status of a sandy soil. Int'l Journal Biology, Physic and Mathematics (Zambrut Publication). 4(1): 34-38
106. Obi M. E., Ebo P. O. (1995). Effect of different management practices in the soil physical properties and maize production in severely degraded soil in south eastern, Nigeria. Res. Technol. 51: 117 – 123
107. Okigbo B.N. (2000). Enhancing the depth of research in agricultural root crops and natural science. Paper presented at the National workshop a sustainable agriculture, food self-sufficiency, poverty alleviation and rural development held from 22-26 May, 2000 National Root Crop Research Institute (NRCRI), Umudike, Nigeria
108. Okoli, P. S. O., Nweke, I. A. (2015). Effect of poultry manure and mineral fertilizer on the growth performance and quality of cucumber fruits, Journal of Experimental Biology and Agricultural Sciences 3(4): 362-367. http://dx.doi,org/10.18006/2015
109. O'Loughlin, E. J., Traina, S. J., Sims G. K. (2000). Effects of sorption on the biodegradation of 2-methylpyridine in aqueous suspensions of reference clay minerals. Environ. Toxicol. Chem. 19: 2168 – 2174
110. Orozo, F. H., Cegare, J., Trujilo, L. M., Roig, A. (1996). Vermicomposting of coffee pulp using the earthworm Eisenia fetida effects on C and N contents and the availability of nutrients, Biology and Fertility of Soils, 22: 162-166
111. Pagarina, P., Totwat, K. L. (2007). Effect of press mud and spent wash in integration with phosphogypsum on metallic cation build up in the calcareous sodic soils. Journal of the Indian Society of Soil Science 55 (1) 52-57
112. Pandey, R., Kalra, A. (2010). Inhibitory effects of vermicompost produced from agrowaste of medicinal and aromatic plants on egg hatching in Meloidogyne incognita (Kofoid and white) chit wood. Current Science, 98(6): 833 – 835
113. Pandey, R. B. H., Bisht, S. P. S., Kandpal, B., Kaushal, B. R. (2006). Feeding and casting activities of the earthworm (Octalion tytaecum) and their effects on crop growth under laboratory conditions. Tropical Ecology 47(2): 291-294.
114. Pandey, S. N., Yadav, K. I. (2009). Effect of vermicompost amended alluvial soil on growth and metabolic responses of rice (Oryza sativa) plants. Journal of Ecofriendly Agriculture, 4(1): 35-37
115. Pant, A. P., Radovich, T. J. K., Hue, N. V., Talcott, S. T., Krenek, K. A. (2009). Vermicompost extract growth, mineral nutrients, phytonutrients and antioxidant activity in Pak Choi (Brassicarapa cv, Bonsai, Chinasis group) grown under vermicompost and chemical fertilizer. J. Sci. Food Agric., 89 (14): 2383-2392
116. Paré, G., & Kitsiou, S. (2017). Chapter 9: Methods for Literature Reviews. In F. Lau & C. Kuziemsky (Eds.), Handbook of eHealth Evaluation: An Evidence-based Approach. University of Victoria.
117. Pathma J., Sakthivel, N. (2012). Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. Springer Plus 2012(1): 26 1(26): 1 – 19

118. Pigares, E., Lakshmi Prabha M. (2014). Electric potential from vermicomposting of spent tea waste by employing exotic earthworm Eudrilus eugenae. Int'l. J. Chem. Tech. Res. (CODEN-USA) 6(2):1022-1027
119. Priya, S., Santhi, S. (2014). Influence of vermicomposts on soil fertility and growth of Amaranthus plants. Int'l. J. Plant, Animal and Environ. Sci. 4(2): 379 – 385
120. Pustinik, J. C., Miller, E. W. (1989). Iron regulation of chloroplast photosynthetic function mediation of PSI development. J. Plant Nut. 12: 407 – 421
121. Quaik, S., Ibrahim, M. H. (2013). A Review on potential of vermicomposting derived liquid in agriculture use. Int'l J. Sci. Res. Publ. 3(3): 1-6
122. Rahmani, R. (1998). Investigation of population and biodiversity of invertebrates in forest types of Neka. PhD Thesis, Tarbiat Modarres University. Raising earthworm successful http//www.p2pays.org/ref/35/34577pdf Retrieved 2009-03-04
123. Ramesh P. (2000). Effect of vermicompost and vermicomposting on damage by sucking pests to groundnut (Arachis hypogea). Indian J. Agric. Sci. 20:334
124. Ramsay, J. A., Hill, S. (1978) (2000 reprint). Earthworms: The agriculturalists friends, Macdonald J. 39(10): 1-7 Ecological Agricultural Project (EAP) Publications, Mc Gill University
125. Ranganath Reddy R. L., Ramakrishhnan Parama V. R., Bhargana M. M. V., Kale R. D. (2002). Vermicomposting a method of urban solid wastes management In: Proceedings of National Seminar on Solid Waste Management 12th – 14th December, 2002 Bangalore India Pp 98-99
126. Ratty, M. (2004). Growth of Lumbericus terristris and Aporrectodea caliginosa in acid forest soil and their effects on enchytraeid populations and soil properties. Pedobiologia 48(2): 321 – 328.
127. Ratty, M., Hutha, V. (2004). Earthworm communities in birch stand with different origin in central Finland. Pedobiologia, 48(1):283 – 291
128. Ravichandran C., Yeshoniketan S., Nagarajan G., Shaikh Kadhan J. (2003). Vermicomposting municipal solid wastes in Tiruchirappalli City, In: Proceedings of National Seminar on Solid Waste Management, 12th -14th December, 2002, Bangalore India Pp 100-103
129. Raw, F. (1962). Studies earthworm populations in Orchards, 1. Leaf burial in apple orchards. Am. App. Biol. 50: 389 – 404.
130. Reynolds J. (1994). Earthworms of the world. Global Biodiversity 4: 11-16
131. Roberto Carlos, G. G., Dendooven, L., Federico Antonio (2008). Vermicomposting leachate forage production. Asian J. Plant Sci. 7: 360 – 367 https://doi.org/10.3923/ajps.2008.360.367
132. Sailajakuman, M. S., Ushakuman, K. (2002). Effect of vermicompost enriched with rock phosphate on the yield and uptake of nutrients in cowpea (Vigna unquiculata L. walp). J. Tropical Agric. 40(2002): 27 – 30
133. Samaranayeke, J. W. K., Wijekoon, S. (2010). Effect of selected earthworms on soil fertility, plant growth and vermicompost. Tropical Agricultural Research and Extension 13(2): 33-40
134. Satchell, J. E. (1955). Some aspects of earthworm ecology. In: Keven D. K., Mc E. (eds.) Soil zoology. Butterworts, London, Pp 180 -201
135. Sauter, K. D., Brown, C. G., James, S. W., Pasini, D. H., Nunesand, N., Benito, P. (2006). Present knowledge on earthworm biodiversity in the state of Parana Brazil. Eur. J. Soil Biol. 42 (1): 321 – 332
136. Scheu, S., Albers, D., Alphei, J., Buryn, R., Klages, U., Migge, S., Platner, C., Salmon, J. (2003). The soil fauna community in pure and mixed stands of beech and spine of different age. Tropic Structure and Strutting Forces Oikes, 110: 163 – 169
137. Senesi, N., Sniz-Jumenez, C., Miano, T. M. (1992). Spectroscopic characteristic of metal humic acid like complexes of earthworm composted organic wastes. Science Total Environment 117-118: 111-120
138. Shahul Hameed P., Gokulakrishman K., Rajaekaran M., Thangavel K., Raja P. (2002). Vermicomposting of solid waste from tanning industry, In: Proceedings of National Seminar on solid waste management 12th – 14th December, 2002 Bangalore, India, Pp 104-106
139. Shaw, C., Pawluk, S. (1986). The development of soil structure by Octolasion tyrtacum, Aporectodea turgida and Lumbricus terrestris in parent materials belonging to difficult textural class. Pedobiologia, 29: 372 – 389
140. Singh N. B. (1997). Development of process package for organic solid waste management through vermiculture technology in organic waste generating industries in Punjab ME thesis TET Patiala, Punjab India Pp 41-95

141. Siddiqui, Z. A., Mahmood, I. (1999). Roles of bacteria in the management of parasitic nematodes a review. Bioresource Technology 69: 167-179
142. Sims, G. K. (2006). Nitrogen starvation promotes biodegradation of N-heterocyclic compounds in soil. Soil Biol. Biochem. 38: 2478 -2480
143. Singh, N. B., Khare, A. K., Bhargaya, D. S., Bhattacharya, S. (2005). Effect of animal substrate, pH on vermicomposting using perionyx escavatus (Perrier 1812). Applied Ecology and Environmental Research 4(1): 85 – 97
144. Six, J. H., Bossuyt, S., Degryze, K., Denef, R. (2004). A history of research on the link between micro aggregates soil biota and soil organic matter dynamics. Pedobiologia, 41 (2): 212 – 235
145. Smith, V. (2017). Evaluating the quality of research: peer review and its alternatives. Journal of Research Practice, 13(1), Article P1.
146. Sridhar M.K.C., Adeoye G.O. (2003). Organo-mineral fertilizer from urban wastes. The Field, 68: 91-111.
147. Suthar, S., Singh, S. (2008). Vermicompost of domestic waste by using two epigeic earthworms Perionyx excavates and Perionyx sansidancus. Int'l. J. Environ. Sci. Technol. 5: 99-106
148. Theunissen, J., Ndakidemi, P. A., Laubscher, C. P. (2010). Potentials of vermicompost produced from plant wastes on the growth and nutrient status in vegetable production. Int'l. J. Physical Sciences 5(13): 1964 – 1973
149. Tian, G., Olimah, J. A., Adeoye, G. O., Kang, B. T. (2000). Regeneration of earthworm populations in a degraded soil by natural and planted fallows under humid tropical conditions. SSSA 64: 222-228
150. Vance, C. P. (2001). Symbiotic nitrogen fixation and phosphate acquisition: Plant nutrition in a world of declining renewable resources. Plant Physiol. 127: 390 – 397 Vermicompost. www.wikipedia.org
151. Waldon B. (1978). Vermiculture is good for you Harrow smith 3(1): 47 - 50
152. Waugh, J. H., Mitchell, M. J. (1981). Effect of the earthworm, Eisenia foetida on sulphur speciation and decomposition in sewage sludge. Pedobiologia, 22:268 – 275
153. Whalen J. K., Chang C. (2002). Macroaggregate characteristics in cultivated soils after 25 annual manure applications. Soil Sci. Soc. Am. J. 66:1637 – 1647
154. Willens J. H., Huijsmans, K. G. A. (1994). Vertical seed dispersal by earthworms. A quantitative approach. Ecography 17: 124 – 130
155. Witennaye, I. L., Merbach, W. (2005). Plant response to draught and phosphorus deficiency contribution of phytohormones root related processes. J. Plant Nut. Soil Sci. 168(4): 531 – 540
156. Zaller, J. G., Saxler, N. (2007). Selective vertical seed transport by earthworms. Implication for the diversity of grassland ecosystems. Eur. J. Soil Biol. 43 Supplement 1: 586 – 591
157. Zambare, V. P., Padul, M. V., Yadav, R. R., Shete, T. B. (2008). Biochemical and microbiological approach as ecofriendly soil conditioner. J. Agricultural and Biological Sciences 3:1-4
158. Zang, F. S., Simasaki, S., Nanzyo, M. (2002). Waste ashes for use in agricultural production II liming effect contents of plant nutrients and chemical characteristics of some metals. Science Total Environment 284: 215-225
159. Zirbes, L., Renard, Q., Dufey, J., Tu, K. P., Duyet, H. N., Lebailly, P., Francis, F., Hanbruge, E. (2011). Valorization of water hyacinth in vermicomposting using epigeic earthworm Perionyx excavatus in central Vietnam. Biotechnology Agronomy Society and Environment, 15: 85 – 93