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Earthworm-The Soil Architect

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Abstract: *Darwin wrote, 'there may not be any other creature in world that has played so important a role in the history of Life on earth'. The cast of earthworm labeled as biogenic structures consist of assemblies of organo-mineral aggregates. The earthworm influence on soil organic properties, altering soil profile and engineering of soil fertility level varies with the ecological categories .Anecic species construct and excavate small burrows into deeper soil layers, they are larger sized species and drag decayed or putrid organic matter and leaves from soil surface inside their burrows and thus redistribute the organo-mineral layers. Endogeic earthworms exclusively build extensive corridors inside the soil layers, ingest mineral soil matter, and are known as "ecological engineers," or "ecosystem engineers." Through biogenic physical structure assemblage they craft appropriate environment and resources availability for other organisms in the earth . This is done by mixing intestinal mucus and available water to the consumed mineral soil thereby enhancing microbial activity . Epigeic species are surface settlers, feeding on litter and decomposing plant byproducts without mixing organic and inorganic matter. They strongly affect the decomposition processes and have a wider range of enzymatic activities probably due to ingestion of microflora and thereby affected the decomposition . The combined or individual effects of these three functional categories are responsible for maintaining the soils fertility in ecosystems and soil food web .This paper is an attempt to highlight and emphasise on the importance of earthworm on soil profile.*

Keywords: *drilosphere, earthworm, soil fertility.*

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I. Introduction

Soil is any part of the earth where plant roots or in other words that supports vegetation. Soil formation is a long-term process determined partly by climatic conditions and the nature of the parent material (Chesworth, 1992). As such modification of parent mineral matters is a result of interactions between climatic topographic and biological effects which takes a fairly long time. It involves the breakdown of primary minerals and the incorporation of organic matter. Soil formation involves two stages viz.weathering and pedogenesis or soil development.

Soil can be appropriately called soil complex because of the following five components:-Mineral matter, humus (soil organic matter), soil water or solution, soil atmosphere and finally the biological systems which among many other flora and fauna includes oligochaetes. Soil structure is an important component of soil fertility as it affects physical processes (erosion, runoff, infiltration, aeration, drainage, water retention, soil evaporation, thermal and mechanical properties of soil), nutrient cycling (mineralization, immobilization, ion exchange), carbon cycling (respiration, organic inputs, root and microorganism turnover, decomposition,humification and physical protection of organic matter, localization of organic matter) and biological activity (movement of soil fauna, microorganism activity) (Dindal, 1985; Elliott and Coleman, 1988; Jastrow and Miller, 1991;Lee and Foster, 1991; Lavelle *et al*., 1992;Oades, 1993). Earthworms show wide variation in body size. The smallest earthworms may be about 10 mm long e.g. *Bismastos parvus* and *Microscolex phosphoreus*.The largest is about 7000mm (7 meters) found in south Africa,*Microchaetus rappi.*The largest Indian species is *Drawida nilamburensis* which measures about 1000 mm (1 meter). Generally earthworm species can live from 4 to 8 years. Some species under ideal conditions can even live for 10-14 years. In the case of *Eisenia fetida*, it lives for 4 to 5 years.

In natural tropical and temperate ecosystems, earthworms are usually considered to be responsible for a 'good' soil structure and improved soil physical properties (infiltration, water retention, resistance to erosion),although negative effects have also been reported (Rose and Wood, 1980), e.g. coalescence of excrements forming a sticky and compact soil surface, impeding water infiltration.

The relationship between soil and earthworm is as old as the history of mankind. Earthworms have over 600 million years of experience as waste and soil managers. No wonder, Charles Darwin called them 'friends of farmers and unheralded soldiers of mankind working day and night under the soil'. The great Indian scientist Surpala in tenth century A.D. wrote Vrikshayurveda (Science of Tree Growing) where he recommended adding earthworms in pomegranate plants to get good quality fruits. In fact, Darwin (1881) was among the first to include biota, especially earthworms, in the list of factors responsible for soil formation through the accumulation of earthworm casts and mixing processes. Earthworms have been divided into three main ecological categories that may contribute differently to ecosystem processes and thus ecosystem services. Epigeic species live in the litter and produce casts at the soil surface that affect its roughness and the distribution of macrospores. Anecic species live in vertical burrows, used as shelters and connected with the soil surface. Endogeic species make horizontal or randomly oriented burrows in the mineral soil, considered as temporary structures because they are rarely re-used (Bouché, 1977; Lee, 1985).

The importance of earthworms in chemical weathering was first studied by Darwin (1881) in an experiment where the red colour of red-oxide sand disappeared after passing through earthworm intestines, probably because of dissolution of the oxide by acidic enzymes in the earthworm's digestive tract. This paper is just an attempt to see how earthworms effect soil modifications.

Earthworms' relationship with soil

There are about 3920 named species of earthworm so far reported worldwide. In India, so far, 509 species, referable to 67 genera and 10 families, have been reported (Kale, 1991).Certain species of earthworms such as *Eisenia fetida* (tiger worms), *Aporrectodea tuberculata, Lumbricus terrestris, L. rubellus, Dendrobaena rubida, D. veneta, Eiseniella tetraedra, Allobophora chlorotica* have been found to tolerate and remove wide range of chemicals from soil. Among the many earthworms the Tiger Worms (*Eisinea fetida*), the African Night Crawler (*Eudrillus euginae*) and the Indian Blue Worm (*Perionyx excavatus*) are the most versatile waste eaters and biodegraders. Several of them are bio-accumulators and bio-transformers of toxic chemicals. After the Seveso Chemical Disaster in Italy (1976), when a vast area was contaminated with 'dioxin', only the earthworms *Eisinea fetida* survived. This indicated the tolerance level of earthworms in worst case scenarios.

In the majority of terrestrial ecosystems, earthworms are the most abundant animal biomass (Lavelle & Spain, 2001). Earthworms are typical ecosystem engineers as they have a large impact on soil structure, which is not essentially associated with trophic relationships.For example, the tropical earthworm *Reginaldia omodeoi* , Sims, formerly known as *Millsonia anomala*, can ingest up to 30 times its own biomass of soil per day, but very little of the ingested organic matter is then assimilated (8%). Moreover, little of the assimilated carbon is used in biomass production (6%); the remainder is respired (94%) during activity and physical modifications of the soil (Lamotte & Bourli` ere, 1978; Lavelle, 1978). As natural bioreactor they convert organic waste into organic manure. The ingested organic matter is macerated, mixed with ingested inorganic soil material, passed through the gut and excreted as a cast, which are enriched with available plant nutrients and thus enhance soil fertility. But the distribution and abundance of earthworms are governed by a number of ecological factors viz.temperature, moisture, pH, available organic matter. . Edwards and Lofty (1972) have reported that earthworm activity is influenced by soil parameters besides feed.

Earthworm's role in Soil modification

With respect to soil formation, earthworms are a special and one of the most important biotic components of the soil as they maintain the soil structure and improve soil fertility. In general, the effects of earthworms on soil properties are related to their populations and activities, such as feeding, casting, and burrowing. Ismail (2005) showed that earthworms are enormously significant in soil formation , primarily by their consumption and fragmentation of organic matter as well as the thorough integration of the fragments with mineral particles to create water stable aggregates. After the soil has been ingested by earthworms, it undergoes many transformations in the earthworm gut. Soil macrostructure is strongly modified due to intense mixing and water addition which starts in the gizzard.

Earthworms have been used for land recovery, retrieval and rehabilitation of sub-optimal soils such as poor mineral soils, polder soils, open cast mining sites, closed landfill sites and cutover peat (Lowe and But,2003; But *et al*). Within the environment of the soil, an earthworm's sphere of influence is known as the 'drilosphere system'. This includes the burrow systems; surface and belowground earthworm casts, internal earthworm gut and process, the earthworm surface and contact with the soil, and associated biological, chemical and physical interactions, in addition to the soil microorganisms (Brown and Doube, 2004).

In fact it was Aristotle in the 4th century B.C. who first drew attention to their role in turning over the soil and called them intestines of the earth. The earthworm can consume organic matter at the rate equal to their body weight every day. Under favorable condition; they can multiply by 28, i.e. 256 worms, every 6 months from a single individual, doubling their population every 60–70 days. Earthworms are hermaphrodites and they can double their population in one month in ideal conditions of temperature, moisture, and food, which is organic, matter. (Harender and Bhardwaj, 2001). Survival and development of earthworms is highly influenced by environmental factors like temperature, bed moisture, rainfall, relative humidity (Nagavallemma *et al.,* 2004) which determines the population in field.

Visvanathan *et al*. also found that most earthworms consume half their body weight of organics in the waste in a day. These farmer friends have no eyes, legs and anus in the true sense of the term. Slime, which is a secretion of earthworms, contains nitrogen which is an important nutrient for plants. The sticky slime also helps to hold clusters of soil particles together forming aggregates. Earthworms make a large contribution to the total weight or biomass of invertebrates in soil.

The main source of food for earthworms is the organic waste such as agro-horticultural crop waste, weeds, forest leaf litter; agro-industrial wastes etc. and defecates the faucal pellets known as vermicompost.Even the dormant microorganisms in soils are stimulated to live by earthworms which supplies in their gut organic carbon, moisture, optimum temperature and pH for their duplication. Microorganisms are the ultimate decomposers and mineralizers in the waste food-chain and in the degradation of humic fractions.

Earthworms accelerate organic matter degradation by increasing the available surface area of organic matter through comminution (Ingham *et al* ., 1985; Seeber *et al* ., 2008).Given the most favorable conditions of temperature (20–30^{o}C) and moisture (60–70%), about 5 kg of worms (numbering approximately 10,000) can vermiprocess 1 ton of waste into vermicompost in just 30 days. Earthworms' body work as a 'biofilter', and they have been found to remove the biological oxygen demand (BOD5) by over 90%, chemical oxygen demand (COD) by 80–90%, total dissolved solids (TDS) by 90–92% and the total suspended solids (TSS) by 90–95% from wastewater. Most significant is that there is no sludge formation.

The darkening of soil mould is a slow process, which involves mainly chemical reactions and microbial activity. This process, nevertheless, may be accelerated by earthworms that prepare the soil and litter mixtures composed of fragmented and macerated leaves and fine soil particles for microbial attack. It is well known by vermicompost producers that humus can be obtained from organic matter within a few months (Edwards et al., 2011). One of the most important roles of earthworms in soil may be their control of humification rates through feeding, burrowing and casting activities and interactions with microorganisms (Dell'Agnola & Nardi, 1987; Ponge, 1991; Bernier, 1998).

Despite the acute lack of understanding in the relationship between the soil physical structure and their hydraulic properties, it is very well known that earthworms affect soil water regulation because of their modification of soil porosity through the production of macroporosity (burrows or aestivation chambers), mesoporosity and microporosity. (Casts) (Peres *et al*., 1998). In fact,Ehlers (1975) showed that after 10 years of earthworm inoculation, the infiltration rate of water through soil increased from 15 to 27mm hour^{-1}.In the studies conducted by Sharpley *et al* ., (1979) and Shuster *et al* .,(2002), it was shown that the increase in infiltration rate related to earthworm burrows can decrease soil erosion by upto 50%. Clements *et al*., (1991) showed in their experiment that the induced absence of earthworms in a grass sward greatly reduced soil moisture and infiltration rate.

In addition to contributing towards mineral weathering, increasing infiltration rate and the formation of humus, earthworms bury organic matter from the surface, and equally bring soil particles from deep soil horizons to the surface. Recent organic matter is buried in the soil, whereas soil from depth is brought to the soil surface by the deposition of casts above-ground, particularly by the anecic species. Soil pH may also change due to earthworm activities. The effect on pH is mainly due to earthworm casts and their compositions. The cast may be more alkaline than the soil due to the presence of basic cations (Ca^{2+}, Mg^{2+}, K^{+}) in high amounts in the cast.

An earthworm's excrement, also called its cast or casting, can be around 60% of its body weight or even several times higher than that value, depending on the earthworm species. The excrement is similar to the material initially taken in by the earthworm, although this material undergoes a mechanical grinding step and is then digested by the microorganisms that live in the earthworm's intestinal system. This two-step digestion process enables the cast to decompose and also modifies the chemical and biological properties of the original material. For example, the levels of organic C and some other nutrients in earthworm casts have been found to be higher than the original material taken in by the earthworm (Kizilkaya and Hepşen 2004, 2007).

In some tropical situations, long-term field experimentation (Blanchart *et al* .1999) has revealed interacting processes between compacting (*R. omodeoi*) and de-compacting (small eudrilid) species, resulting in the maintenance of soil structure. It is a fact that Earthworms both condense and loosen soil. For example, Lavelle *et al* ., (2004) reported that *Reginaldia omodeoi* augmented bulk density from 1.24 to 1.31 g cm^{-3},and from 1.37 to 1.48 g cm^{-3} in two different studies. Alegre *et al*. (1996) also observed a significant increase in bulk density from 1.12 to 1.23 g cm^{-3} and a decrease in porosity from 58 to 53% in the presence of *Pontoscolex corethrurus* Muller. In another study, Blanchart et al. (1997) demonstrated that *R. omodeoi* , a compacting endogeic earthworm, decreased total soil porosity by 3%,whereas Eudrilidae (species unidentified), small de-compacting endogeic earthworms, increased it by 21%. De-compacting earthworms destroyed macroaggregates formed by compacting ones, whereas the reverse is done by the de-compacting ones. Such variability helps in the regulation of the soil structure in dynamic way (Blanchart et al., 1997) .Such activities of the earthworm greatly modifies the soil and helps in the development of fertile soils.

II. Conclusions

Earthworms ensure sustainable soil fertility by improving the physical, chemical, and biological characteristics of the soil. They play a major role in modifying soil profiles by way of burrowing, moving particles within and between horizons, forming and disintegrating aggregates, and changing porosity, aeration and water infiltration and retention capacity. In the process, the degraded products of their excreta find resolvable route to sustainable agriculture, which in itself is a very relevant solution for developing countries like India to enhance sustainability of soil organic matter for balance of physical-chemical and biological properties. Earthworms has become synonymous to “clean technology” especially in the field of organic waste management and also a handy tool in the sustainable organic agriculture dream that an agro-based economy like India wants to propogate.In more than many ways the replacement of chemical fertilizers by Vermicompost technology using earthworms will ensure production of safe organic foods, which is now the crave of people worldwide.

Dr. Anatoly Igonin of Russia very rightly said, ‘Nobody and nothing can be compared with earthworms and their positive influence on the whole living Nature. They create soil and everything that lives in it. They are the most numerous animals on Earth and the main creatures converting all organic matter into soil humus providing soil’s fertility and biosphere’s functions: disinfecting, neutralizing, protective and productive’. The tag of soil bio-waste manager and soil architect can hence be rightly attributed to earthworms in the true sense of the term.

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