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Review Paper

Earthworms as the modulators of soil properties

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Abstract

The scientific literature dealing with the part of earthworms in modulating the soil properties including the gist of author's study has been reviewed. Earthworms are known to enhance the soil fertility by increasing the levels of nutrients like nitrogen, phosphorus and potassium that makes vermicompost suitable to use as fertilizer. Partly release of carbon as CO_2 *due to respiration and lowering of C/N ratio has been observed during vermicomposting. Earthworms increase the organic matter's mineralization in soil by boosting the bacterial population and reducing soil erosion. This value additive property of earthworm makes them more capable of waste management too. Various types of agricultural and household wastes can be reduced to organic manure by the process of vermicomposting. Thus, the process of vermicomposting not only encourages the sustainable development but also helps in reducing the waste into value added organic fertilizer.*

Keywords: Earthworms, Soil, Nutrients, Nitrogen.

Introduction

Soil being the greatest heritage of mankind is the most valuable natural resource, has laid the foundation of agriculture since ages[1]. Earthworms are the annelids of order oliogochaeta whose evolution dates approximately 6 billion years back[2]. By feeding on debris they play crucial role in putridness of organic matter into nutrient rich manure. Earthworms improve the soil ecology by altering physico-chemical and biological assets of soil. Their potential in enhancing soil physical traits like bulk density, infiltrability, hydraulic conductivity, porosity and aggregate stability has also been previously documented[3]. Earthworms not only influence the structure of soil by ingesting the soil and breaking the organic matter partially, but also help in close fraternization of soil fractions.

Finally the expulsion of partially digested material as surface or sub-surface casts also improves texture, aeration and water holding properties of soil[4]. Earthworms systematically blend the soil, form water-stable aggregates, and aerate the soils leading to the improvised water holding capacity. The soil enrichment process speeds up due to the worm casting which acts as the microsites for the microbes present in soil. Nitrogen fixation in casts is reasonably higher than in soil due to the presence of nitrogen fixing microbes in the earthworm's gut and casts. Nitrogenase activity in casts has also been reported higher as compared to soil, thus stamping the occurrence of higher nitrogen fixation in worm casting[5]. Thus, an earthworm as soil engineer improves the soil physico-chemical and biological properties.

This review thus deals with the portrayal of earthworms in intensifying the fertility and soil productivity.

Ecological classification of earthworms

The major types of earthworms found in the soil ecosystem can be classified on the basis of habitat[6,7].

Epigeic Earthworms: The term epigeic in Greek stands for "upon the earth." These compost worms don't create permanent burrows underground and spend most of the time above at upper soil surface. They are phytophagous worms and are efficient bio degraders. For example: *Eisenia fetida, Lumbricus rubellus, L. castaneus.*

Anecic Earthworms: The term "anecic" means "up from the earth". Worms in this category tend to make vertical tunnels into the ground, but their primary food source is decaying matter on top of the soil and they are considered to be geophytophagous. For example: *Lumbricus terrestris* species has been classified as anecic.

Endogeic Earthworms: They feed on the sub soil surfaces and feed on soil organic matter and dead roots along with large quantities of soil. Hence, they are considered to be geophagus. Examples include *Allolobophora chlorotica, Apporectodea caliginosa*.

Impact of earthworms on soil quality

Earthworms are known to mix the layers of soil and this mixing allows the proper dispersion of organic matter through the soil. This mixing makes available the nutrients held in soil available to plants and thus enhances soil fertility. Earthworm brings about the improvement in the soil physical, chemical and biological properties and acts as soil engineers. The physico-chemical changes so as to convert in vermicompost. The process of break down induced due to the activity of *E. fetida* on the substrate leads to significant reduction in odor and carbon content. It results in increasing the nutrient status of vermicompost *i.e.*, 17.90% in nitrogen, 44.73% in phosphorus and 18.24% in potassium has been recorded, thus it marks the utility of vermicompost as a good fertilizer for agroecosystems[8].

Effects on physical properties of soil: The two major activities of earthworms which results in influencing the soil structure are: eating soil through the mouth and breaking down and mixing the organic matter, then conclusively voiding the gut contents as subsurface casts and burrow inside the sub-layers of soil, thus importing subsoil to the surface. Worms ingest the large amount of soil and grind it in gizzard. Then they are digested chemically and are absorbed in the body. However, the rest of material is excreted out as 'vermicastings' which accredit to the enrichment in soil porosity, aeration and production of soil aggregates[9]. Earthworms' excretion in the form of vermicastings are rich in NPK, micronutrients and valuable soil microbes and consists more water-stable aggregates as compared to the nearby soil. The worm feeding activity also influences the soil's moisture holding capacity and water drainage from soil, both of which add to soil fertility and plant growth[10].

Impact of worm activity on chemical properties of soil: The earthworm's gut is well known for breaking down the organic matter into finer particles, so as to expose the greater surface area of the organic matter to microbial decomposition and is egested in their casts, this result in rapid mineralization of organic matter, resulting in nutrient liberation in feasible forms that can be easily absorbed by the plants. The chemical properties of vermicasts have greater phosphorus, exchangeable potassium, manganese and total exchangeable calcium as compared to those of non-ingested soil. Vermicasting is rich in organic carbon and nitrogen (1-3 times)[11] which clearly indicates the involvement of earthworms in providing shield to soil carbon in microaggregates, ultimately resulting in long-term stabilization of soil[12]. Yadav *et al*.[3] has also reported the decreased carbon levels in the casts of earthworm during the process of vermicomposting. Chaudhuri *et al.*[13] studied the changes in organic carbon, phosphorous and potassium availability due to the feeding activity of five earthworm species viz. *Pontoscolex corethrurus, Drawida assamensis, Drawida papillifer, Eutyphoeus comillahnus and Metaphire houlleti.* As a result of worm's feeding, significant increase in the levels of the organic C (1.63%) and available P (27.60 mg 100 g^{-1}) and K (49.0 mg 100 g^{-1}) content of the soil has been observed. Patil[14] observed the increased levels of recycled nitrogen in soil in short span of time that ranged from 20 to 200 kg N/ha/year. The addition of worms' metabolic and excretory products (vermicast), mucus, body fluid, enzymes and decaying tissues of dead worms may be the most probable reason for the increase in nitrogen contents[3]. Muthunarayana *et al.*[15] has also stamped the increase in levels of nitrogen during vermicomposting of fruit and vegetable wastes. Whalen *et al.*[16] stated nitrogen release from worms' bodies even after their death, is decomposed rapidly that results in nitrogen addition during vermicomposting process. Christensen[17] observed that about 50% of the N in dead worm tissues has been mineralized in 7 days. Earthworm casts contain higher amount of available P than surrounding soil without earthworms. Lee[18] suggested that the route of organic matter via worm's gut leads in the increase on bioavailable phosphorus (P) forms. Easy bioavailability of phosphorus is partially due to the presence of 'phosphatases' enzyme in gut of worm and partly due to release of phosphate solubilizing microbes in the worm castings. Nuutinen *et al.*[19] noticed positive correlation between worms and soil phosphorus content, which may also be attributed to the increased phosphatase activity in worms gut.

Impact of earthworms on microorganisms of soil: Earthworms have a complex inter-relationship with microorganisms. They are the microsites for millions of useful microbes including the nitrogen fixation bacteria in their gut. The symbiotic relationship between bacteria and worms' gut has also been previously documented. The nutrients like nitrogen and phosphorus present in intestinal mucus are excreted by worms which are further acted upon by microbes that results in microbial multiplication and dynamic soil remediation. Utmost micro-organism species found in earthworm's alimentary canal are same as compared to those in the soil. However, in earthworm casts the microbial community is largely amplified as compared to the surrounding soil[20]. Enhanced communities of bacteria, actinomycetes and fungi of higher enzymatic activity have been found in earthworm casts as compared to those present in enclosing soil[21]. Most of the microorganisms in soil remain in quiescent stage with low metabolic activity, anticipating for the optimum conditions and worm gut acts as suitable microsite for them[21]. The degradation of the organic matter has been found to be enhanced by the activities of earthworms due to the overall increase in microbial respiration in soil. Morgan and Burrows[22], advocated the significance increase in count of beneficial bacteria (upto 1000 times) and 'actinomycetes' in the ingested material. Facultative anaerobic bacteria's such as *E.coli*, *Proteus mirabilis*, *Klebsiella* and *Staphylococcus aureus* were identified in the gut of *Eudrilus eugeniae*. Bacterium *Pseudomonas*, *Paenibacillus*, *Azoarcus*, *Burkholderia*, *Spiroplasm*, *Acaligenes*, and *Acidobacterium oxalaticus*, *Clostridium butyricum*, *C. beijerinckii* and *C. paraputrificum* has also been reported to be associated with gut of earthworms[23,24]. The presence of *Ochrobactrum sp*., *Massilia sp*., *Leifsonia sp*. and bacteria belonging to families Aeromonadaceae, Comamonadaceae, Enterobacteriaceae and Flavobacteriaceae has also been previously reported in earthworms' alimentary canal[25].

Impact of earthworms on plant growth: Earthworms are farmer's friend because they mix the upper and lower soil layers and doing so they bring the nutrients from lower soil layer to the layer of root penetration from where plants can easily absorb the nutrients. They improve soil fertility in multiple ways thereby increasing agricultural production. Earthworms liberate profitable substances like cytokinins and auxins to the plants[26]. The valued impact of earthworms on plant growth may be attributed to various reasons along with the occurrence of macro and micronutrients in vermicast and their secretions in significant quantities[27]. Reports also advocate that the metabolites secreted by earthworms may also be responsible for provoking plant growth.

Conclusion

Vermicomposting by the use of earthworms offers a self-sustaining and eco- friendly method for conversion of organic waste into nutrient rich manure. Not only, earthworms enhance the soil fertility by feeding upon it, they also help in increasing the beneficial microbes in soil. They act upon soil to make it nutrition rich and thus make it suitable for proper plant growth and development. Thus earthworms offer a ray of hope for sustainable agriculture in the areas where the problem of soil infertility is increasing.

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