



Chapter

[15]

Role of earthworm biodiversity in soil fertility and crop productivity improvement

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Abstract

The earthworms are the biological indicator of the soil ecosystem as they indicate the health and fertility of the soil for proper cropping. In the soil for proper aeration, rich nutrient contents earthworms are very essential organisms. They enhance the nutrients contents, increase water holding capacity, and improve microbial activity in the soil. All over the world approximately 3627 species of earthworms are there. Earthworms are of two type's microdrilli and megadrilli, in microdrilli group about 280 species, and the rest all are under megadrilli. Megadrilli group earthworms are soil living earthworms, they are grouped under three subgroups epigeic, endogeic, and anecic. Earthworms work for formers day- night without any labor charge and make the soil more nutritious and more aerated that helps in crop production. The major problem nowadays is to be recycled the organic waste into humus like products. For crop production enhancement organic manure is a better option instead of chemical fertilizer. Earthworms decompose the organic waste into organic manure. By the use of vermi techniques (use of earthworms and organic waste) in the presence of oxygen organic waste turns into manure. The diversity and number of the earthworms in the soil change the soil texture and improve nutrient contents.

Keywords

Biodiversity, Earthworms, Soil, Vermicompost, Waste recycling

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Introduction

The burrowing habit of earthworms makes the soil more porous and creates a new way to proper aeration in the soil. Earthworms feed decaying organic waste and soil and excrete approximately 60 to 80% of their feed (Sinha *et al.*, 2002). Their role in soil fertility is very crucial as they make soil more air convener and discharge nutrients into the soil present in their feces. Earthworms are the “intestine of the earth” said by Aristotle they decompose the organic matter like plants leaves decaying fruits and soil also (Bhadauria and Sexana, 2010). The soil fertility increases with an increase in the nutrients, proper aeration, and water holding capacity, along with these factors microbial activities also have a huge impact on the soil. The fertility of the soil is directly proportional to the crop improvement (Rochester *et al.*, 2001). Earthworms are delivering natural services to human beings from ancient times to nowadays by providing worm manure (vermicast) and vermiwash which positively affects soil fertility and crop improvement. Earthworms are the friends of the farmer they plough the field without any cost. Earthworms work for farmer's day-night and improve crop productivity by making their field more nutritive by converting the decaying organic matter into humus-like products. Earthworms are soil ecosystem modifiers as they are improving the soil nutrient profiles (Jones *et al.*, 1994).

General description and origin of earthworms

Earthworms are soil worms that live in organic matter-rich soil. Earthworm feeds on surface decaying organic matter like plant leaf, fruit wastes, and other biodegradable wastes. They consume waste and convert it into humus-like products like vermicompost (manure). The ancestor of today's earthworms was originated approximately 600 million years ago and from the days of origin, they enhance the soil profile by making the soil more porous and secreting their mucus into the soil (Sinha, 2009). The first earthworm named by Linnaeus in 1758 that was *Lumbricus terrestris*. The next species of earthworm discovered was *Eisenia fetida* described by Savigny (1826) and Cuvier (1824). Earthworms are found over the globe except in snowy and very hot regions because earthworms are very temperature sensitive however they have diverse habitats where nutrient-rich organic matter easily available like the garden, paddy fields, and places rich in moisture contents nearly 55 to 60% (Gupta *et al.*, 2016). The earthworms is long, with cylindrical elongated body, compressed at both the ends, the body of earthworms is covered with a soft thin pellicle. The pellicles of earthworms are transparent and temperature-sensitive.

Body divided metamericly into 80 to 100 segments. Earthworms are hermaphrodite mean male and female reproductive organs found in single organisms. Sexual maturity attains at the age of 6 weeks. When environmental conditions favorable a pair of earthworms can produce more than 100 cocoons in 6 weeks to 6 months (Ismail, 1997).

Systematics: Earthworms come under the phylum Annelida and belong to the group Oligochaeta. The

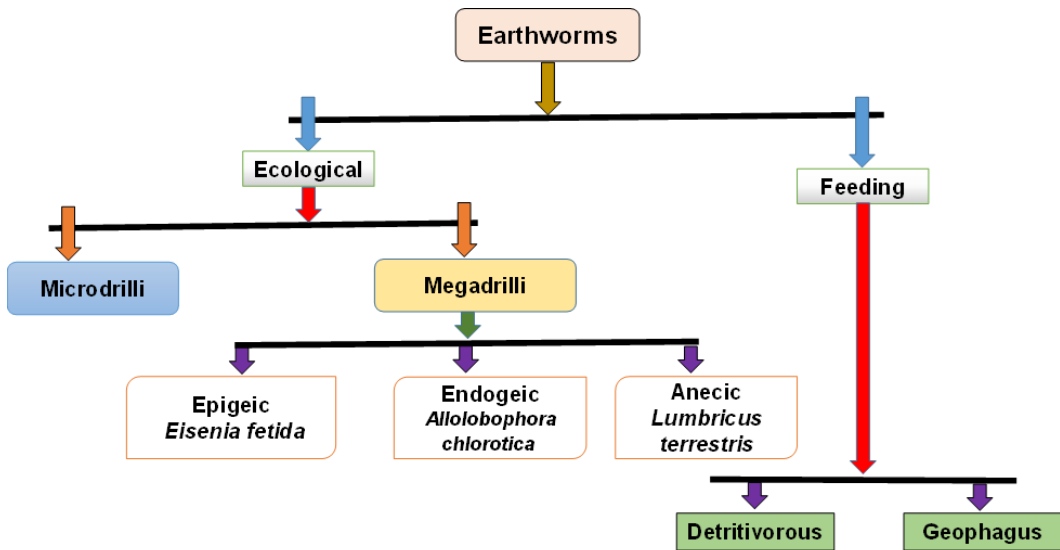


Figure 1. Systematic of earthworm distribution based on the ecological and feeding niche.

name earthworm is derived from the burrowing habit in the soil. In the world 3627 species of earthworm are present (Figure 1). Out of 3627 species, in India, 509 species are present which come under the 67 genera (Sinha *et al.*, 2002).

Classification of earthworms based on their ecological adaptations

Based on the ecological adaptations firstly divided into two categories microdrilli and megadrilli. Out of total 3627 earthworm species, 280 are microdrilli, these are the aquatic species and the rest comes under species megadrilli. Further megadrilli can be classified into three subgroups depending on the inhabiting layer of the soil (Bouche, 1977) (Figure 2).

Epigeic earthworms (e.g. *Eisenia fetida*, *Eudrilus eugeniae*, *Perionyx excavatus* etc.): Epigeic earthworms are surface feeder detritivorous worms that feed on surface debris, decaying organic wastes like crop residues, decaying organic wastes, leaf litters, plant roots, and animal dung and convert them into vermicast. Due to the short lifespan fecundity rate is high and epigeic earthworms are reproduced in diverse habitat and harsh environments (Kozenko *et al.*, 2020). *E. fetida* is the most suitable species for vermiculture over the globe. Epigeic earthworms are small in size, they are 1 to 18 cm in length (Xiao *et al.*, 2011). Epigeic earthworms live in the upper soil layer and do not build burrows and as well as epigeic species of earthworms are not involved in organic and inorganic matter mixing. Feed decaying organic wastes.

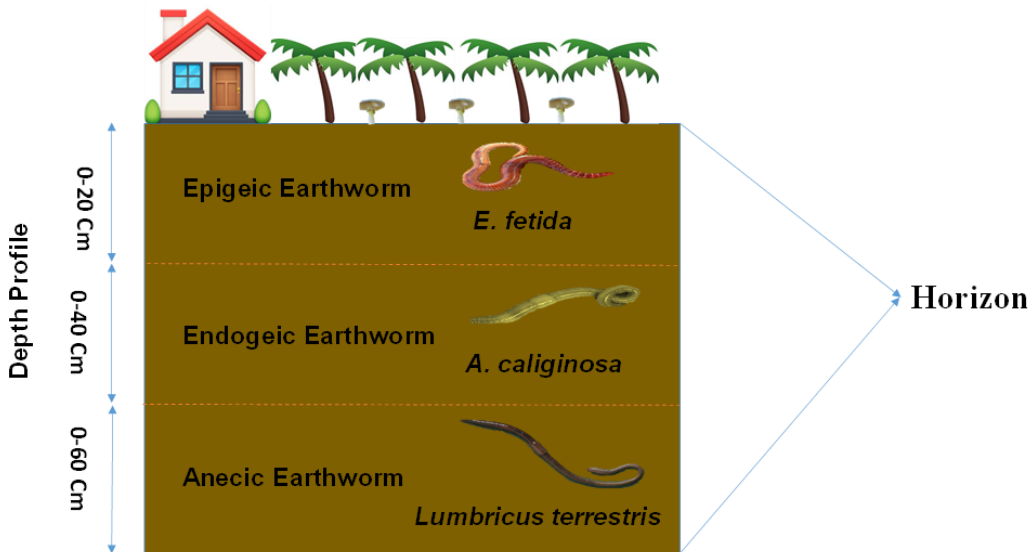


Figure 2. Habitat niche of the earthworms in the different layers of soil.

Endogeic species (e.g. *Allolobophora chlorotica*, *Aporrectodea icterica*, *Murchieona muldali*, *Octolasion cyaneum* and *Octolasion lacteum*): Endogeic species of Earthworms are soil-inhabiting organisms they are not surface dwellers, live beneath the topsoil. The body size of the endogeic species is 2.5 to 30 cm in length. Endogeic species built horizontal burrow in the soil (Capoweiz *et al.*, 2001; Perreault and Whalen, 2009). Endogeic species are the native species of Australian continents and are commonly found in New Zealand (Baker *et al.*, 1999; Murchie and Gordon, 2013). The feeding matter of this species is soil which contains less organic matter as compared to surface layer feeding material. The soil texture is mainly changed by these species because endogeic earthworms feed more soil and less organic matter. These earthworms are not much suitable for vermicomposting but good for improving soil structure. The fecundity rate is low as compared to epigeic. Life span is relatively longer as compared to epigeic earthworms.

Anecic (e.g. *Aporrectodea longa*, *Aporrectodea nocturna*, *Lumbricus friendi* and *Lumbricus terrestris*): Anecic earthworms live in the deeper part of the soil in vertical burrows. They live in the soil at the depth of 3 meter. Anecic earthworms make vertical burrows and about 2 cm in diameter. They are the longest species category because anecic earthworm is about 3cm up to 20 cm long. Anecic earthworms help in the mixing of the organic nutrients in the soil and enhance the soil texture (paedogenesis). Anecic earthworms come out from their burrows at night and move to soil surface and where they eat decaying organic organic matter with some part of soil. This species of earthworm is not suitable for vermiculture because of the low decomposition efficacy of organic matter, low fecundity but anecic earthworm have a longer life span as compared to epigeic and endogeic earthworms (Bhadauria and Sexana, 2010).

Classification of earthworms' based on the feeding behavior

Based on the feeding habit earthworms can be classified as geophagous and detritivorous (Lee, 1985). Detritivorous feed on decaying organic waste like plant litters, decaying vegetables, fruits, and plant roots, cattle dung at the soil surface and near the soil surface. They are humus former, convert the organic matter into the vermicompost. Epigeic is the detritivorous surface feeder of earthworms. Geophagous earthworm eat soil because they live beneath the soil in the horizontal burrow. Endogeic species are geophagous also called humus consumers because they eat soil with some part of organic waste.

Earthworms as bioindicator of soil fertility and health

The earthworms are the biological indicator of the soil ecosystem as they indicate the health and fertility of the soil for proper cropping (Pulleman *et al.*, 2012). The number of earthworms in the soil determines the health of the soil and indicate the microorganisms like bacteria, fungi, viruses and other organisms in the soil, the high number of earthworm indicates the high biodiversity of the microorganisms in the soil (Lakzayi *et al.*, 2015). A prominent microbial community is present in a rich organic matter area as many organisms like bacteria, fungi are present there for decomposition vermicompost is high in organic nutrients (Hedlund, 2002). Bacterial community and fungal hyphae in association with plant, enhance the soil productivity (Artursson *et al.*, 2006; Nuccio *et al.*, 2013). The high microbial population of bacteria, fungi, actinomycetes, and the higher enzymatic activity seen in the soil where the population of earthworm is high an area having higher earthworm diversity also have a higher microbial diversity that helps in the crop yield production without the use of chemical fertilizers (Haynes *et al.*, 1999).

Role of earthworms in crop improvement

For a better and high yield of crop production and nutrients, rich organic production sustainable soil environment is necessary. Earthworms excrete various plant growth regulators in their mucus-like auxin and cytokinin (Krishnamoorthy and Vajranabhaiah, 1986). Earthworms play a key role in maintaining soil texture and balance soil ecosystem (Shuster *et al.*, 2000). The major macrofauna of soil is earthworms they enhance the soil texture and nutrient content by secreting mucus in the soil, convert the organic biodegradable matter into nutrient-rich humus like manure (vermicast) (Sharma and Garg, 2018). Earthworms improve soil fertility by changing the biochemical and physical properties of soil. Earthworm excretion by-product vermicast is rich sources of various inorganic and organic nutrients (Edward *et al.*, 1995; Kale, 1998; Lalitha *et al.*, 2000). Vermicast increases the inorganic salt concentration which is used by the plant root system. Soyabean and wheat production increase 51% and 47% respectively by the use of earthworms and their vermicast (Palanisamy, 1996). Vermicomposting positively modulates the functioning of organic nutrients in the soil, mucus present in the vermicast

speed up the primary breakdown of organic residue into the simpler compound which easily absorb by plants (Lavelle, 1988; Six *et al.*, 1998; Kumar *et al.* 2019). Organic matter ingestion by earthworm from the soil, mixing them with gut mucus and convert them into humus (Jairajpuri, 1993). The feeding mechanism of earthworm function as a soil fertility enhancer because earthworms improve soil aeration, nutrient content and increase microbial activity (Hickman and Reid, 2008; Lemitiri *et al.*, 2014; Medina *et al.*, 2019). Earthworms burrowing and nutrient-rich mucus-secreting habit increase the soil profile by enhancing the physical, chemical, and microbial activity (Lin *et al.*, 2016; Le Bayon *et al.*, 2021). Organic matter in the gut contains a high level of nutrients and water as compared to nutrients and water present in the soil and these organic matters after digestion excrete out from the anus in the form of vermicast which is enriched with a high nutrient content that improves the soil ecosystem (Buck *et al.*, 2000; Singh *et al.*, 2016). In vermicast high nutrient content of N, P, K, and Ca is available which is easily absorbed by the plant root system and enhance the crop productivity (Bhadauria and Ramakrishnan, 1989).

Technologies of vermicompost production

Vermitechnology is a scientific method in which we use epigeic (surface feeder) and endogeic (subsurface feeder) species of earthworm for the conversion of biowaste into the vermicast with the help of soil microorganisms. Vermicomposting is the process of the decomposing of the biodegradable organic waste with the use of worms and microorganisms into the vermicast which is nutrient-rich organic manure. By the use of earthworms, we decompose organic biodegradable waste into the manure (Gunadi *et al.*, 1997) and minimize the waste impact on mankind. In 21st century rapid civilization, industrialization, and urbanization generate enormous waste from various sectors. In vermicomposting kitchen waste, institutional waste, paper waste, industrial waste, agricultural waste, and cow dung are used for earthworm feeding and earthworm convert these organic waste into manure. The role of earthworm in the formation of vermicompost from the biodegradable organic waste and improve fecundity of soil since 1881 by Darwin. The process of decomposition of waste into nutrient-rich manure was established by Kale *et al.* (1982) and Ismail (1993). Epigeic species of earthworms are extensively used in the vermicomposting like *Eisenia fetida*, *Eudrilus eugeniae*, *Eisenia andrei*, *Perionyx excavatus*, and *Lumbricus rubellus* are the most commonly used species in vermicomposting. Endogeic and anecic species of earthworms are not good for vermicomposting because both the species are not surface decaying material feeders, they live inside the soil by making horizontal and vertical burrow respectively but both the species are very useful in nutrient recycling and nutrient mixing in the soil. For this reason, endogeic and anecic species of earthworms are used for the modification of soil texture. Application of vermicompost on the agricultural practices we can minimize the negative impact of chemical fertilizers on the crops (Figure 3) . So by the use of vermicomposting we can easily decompose organic waste into nutrient rich organic manure. This technique convert the biodegradable waste into the humus like product without harming the environment (Tables 1 and 2). Compost obtain from the vermicomposting process is odorless, nutrient-

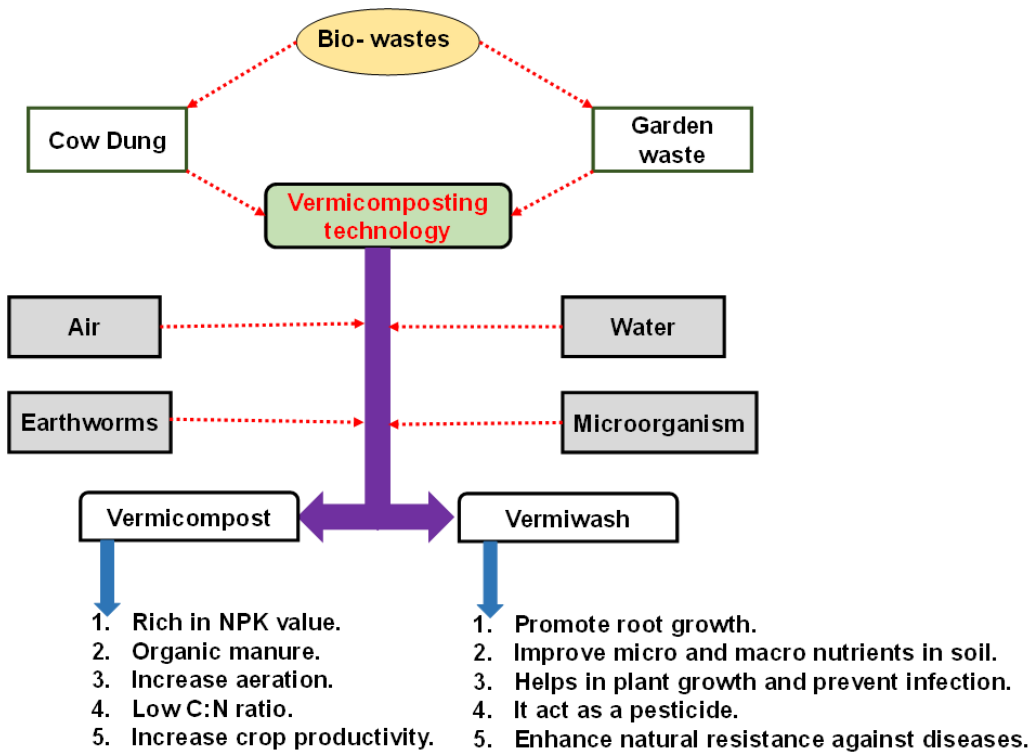


Figure 3. Vermicomposting process and use of vermicompost and vermish.

rich, and has many insecticidal properties (Rajiv *et al.*, 2010; Sinha *et al.*, 2011; 2013).

Future scope and recommendation

The future of vermiculture in the field of agriculture is very bright as excessive use of pesticides and chemical soil productivity enhancer affect human health and soil health very badly. To overcome this problem whole world move toward organic farming. Vermicomposting is a very cheap and easier method to minimize this problem. By the use of earthworm minimize pesticide use in the crop field. To better understanding, the earthworm's role in agro ecosystems stabilization, improving soil texture, improve the microbial community in soil which helps in nitrogen fixation, and determine the factor that influences or inhibit the earthworm activity need more research. Earthworms are found all over the world except desert and snowy climate. Which species best suitable for organic waste decomposition and environment friendly and best adapted for their geographical climate. To understanding this problem needs more research in the field of earthworm biology.

Table 1. Approximate physiochemical properties of vermicast (Perera and Nanthakumaran; 2015).

Properties	Vermicompost	Compost	Soil
Organic matter	17.77%	76.90%	20.72%
Nitrogen	0.91%	1.15%	0.48%
Phosphorous	0.14%	0.17%	0.11%
Potassium	0.2%	0.6%	0.5%
Carbon	9.90%	44.35%	11.95%
C/N ratio	10.87%	38.56	24.85
pH	6.98	7.21	7.25
Electrical conductivity	1.1	0.2	0.4
Moisture contents	15.58%	12.20%	11.64%
Bulk density	0.5 g cm ⁻³	1.3 g cm ⁻³	1.6 g cm ⁻³
Particle density	2.49 g cm ⁻³	2.50 g cm ⁻³	2.68 g cm ⁻³
porosity	0.76	0.48	0.40

Table 2. Studies on utilization of industrial wastes and organic amendments for vermicomposting.

Industrial waste	Organic amendments	Earthworm species	References
Paper mill waste	Primary sewage sludge	<i>Eisenia andrei</i>	Elvira <i>et al.</i> (1996)
Paper mill waste	Cattle manure	<i>Eisenia andrei</i>	Elvira <i>et al.</i> (1998)
Paper mill sludge	Cow dung	<i>Eisenia fetida</i>	Kaur <i>et al.</i> (2010)
Food industry sludge	Cow dung and Poultry droppings.	<i>Eisenia fetida</i>	Banu <i>et al.</i> (2005)
Solid textile mill sludge	Cow dung	<i>Eisenia fetida</i>	Kaushik and Garg (2003)
Textile industry waste	Cow dung and soil	<i>Eisenia fetida</i>	Garg <i>et al.</i> (2006a, b)
Sugar mill filter cake	Horse dung	<i>Eisenia fetida</i>	Sangwan <i>et al.</i> (2008)
Olive oil industry waste	Municipal biosolids	<i>Eisenia andrei</i>	Benitez <i>et al.</i> (2005)
Coffee pulp Pressmud	Cow dung	<i>Perionyx ceqlanensis</i>	Prakash and Karmegam (2010)
Sugar industry sludge	Cow dung, biogas slurry and wheat straw	<i>Eisenia fetida</i>	Suthar (2010)
Sago industry solid waste	Cow dung and poultry manure	<i>Eisenia fetida</i>	Subramanian <i>et al.</i> (2010)
Distillery sludge	Cow dung	<i>Eisenia fetida</i>	Suthar (2008)
Dairy industries sludge	Sewage sludge	<i>Eisenia fetida</i>	Gratelly <i>et al.</i> (1996)
Solid paper mill waste	Brewery yeast	<i>Lumbricus terrestris</i>	Butt (1993)

Conclusion

Several studies conclude that the role of earthworm diversity to improve soil fertility and enhance crop productivity. Earthworms digest organic matter and convert them into the humus. Humus has a high value of inorganic salts like N, P, K, and Ca these are the main integrant that enhances the crop productivity. The earthworm found in the different layer of the soil like epigeic earthworm found in the upper layer of the soil and not built the permanent burrow so this species is not involved in the mixing nutrients and aeration in the soil but the composting process is very fast as it decomposes biodegradable organic matter into the nutrient-rich manure. Vermicast or earthworm manure changes the soil profile, texture, and stabilization of the microbial community in the soil. Endogeic earthworms live in the horizontal burrow and feed on soil and some plant litter and help in the mixing of nutrients in the soil and change the texture of the soil. Anecic earthworms live in the deeper parts of the soil by making a vertical burrow. The decomposition efficiency of organic waste of anecic earthworms is very low but this species eat organic wastes like plants litters, leaves, decaying organic wastes on the soil surface. For feeding they come out their burrows at night and feed then returns to their burrows. They excrete their droppings in their burrows and changes texture, aeration, nutrient content in the soil. So the impact of the earthworm biodiversity on soil fertility and crop improvement is very important.

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