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ECOLOGY AND DISTRIBUTION OF EARTHWORMS IN INDIA: A SYSTEMATIC REVIEW

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Abstract: One of the most significant biotic fauna, an ecological engineer, and a biological indicator of the soil are earthworms, also known as farmer's friends. They play an important role in the mineralization and decomposition of organic matter, and recycling of organic wastes, leading to improvement in soil structure and fertility. They facilitate the increase of microbial biomass and activity, as well as the mobilization of nutrients, by broadening the surface area of organic compounds. The diversity, population size, and spatial arrangement of earthworm species may be used as indicators of the soil and weather conditions within a given geographical region. They function as bioindicators, aiding in the comprehension of the physico-chemical characteristics of their environment. The density and stratification in both horizontal and vertical directions contribute to the process of pedogenesis and formation of soil profiles. These organisms exhibit lower occurrence rates in soils that have undergone disturbance and tend to manifest activity solely under conditions of adequate moisture. The present article provides a comprehensive overview of the ecological characteristics and geographical distribution of earthworms across various habitats in diverse regions of India.

Keywords: Bioindicator, Diversity, Earthworms, Ecological category, Soil fertility.

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INTRODUCTION

Earthworm is an Oligochaete, belongs to the phylum Annelida, a true coelomate phylum of metamerically segmented animals having closed circulatory system (Verma and Prakash, 2020a). Currently 5,738 species/subspecies (5,406 species and 332 unique subspecies) have been described across the world (Mete Misirlioglu *et al.,* 2023). India is the home of its 453 species and subspecies (Hasan *et al.,* 2023). These are underground, nocturnal animals with antioxidant and biomarker qualities (Deswal *et al.,* 2020; Singh and Fatima, 2022). Earthworms are significant soil-sustaining creatures that depend on biological variety and soil faunal biomass to maintain the soil's structure and fertility. They live in damp soil and account for a sizable portion of the biomass of invertebrates in soil.

Earthworms play a crucial role in soil processes as they function as aerators, crushers, grinders, chemical degraders, and biological stimulators, as observed by Edward and Bohlen (1996). Additionally, they are responsible for regulating soil processes. According to Tondoh *et al.* (2007), earthworms serve as a distinctive indicator of soil health, as a high abundance of diverse earthworms is indicative of soil that is in good condition. In addition to serving as a protein-rich source of animal feed, they have been found to be beneficial in land reclamation, soil improvement, and organic waste management.

The earthworm population's density is a crucial factor in regulating the physico-chemical texture of soil and its water-holding capacity across various habitats, as pointed out by Ghafoor *et al.* (2008). The significance of earthworm diversity in maintaining ecosystem stability and providing various ecosystem services has been highlighted in previous studies (Eisenhauser and Schadler, 2011; Blouin *et al.,* 2013).

The existence of earthworm communities in a specific region is influenced by crucial factors such as temperature, moisture, and food, as well as pH and soil disturbance degree (Edward and Lofty, 1977). These factors play a significant role in regulating the density of the earthworm population (Garcia and Fragaso, 2002). In addition to their impact on soil's physical, chemical, and biological characteristics, earthworms contribute to its structural and fertility enhancements through their tilling and mixing activities. Furthermore, they serve a significant function in the formation of humus (Doan *et al.,* 2013; Singh *et al.,* 2016).

Moreover, they are classified as soil macrofauna, exerting significant impact on the ecosystem. According to Jansirani *et al.* (2012), earthworms have the ability to transform biodegradable materials and organic wastes into vermicast, a substance that is abundant in nutrients.

Earthworms have been observed to consume a diverse array of unstable organic matter, including animal waste, industrial waste, and sewage sludge, as reported by Wu *et al.* (2014) and Lim *et al.* (2016). The organic waste modulation that occurs within the gut of earthworms results in the production of distinct products that differ from their parent waste material. These products are commonly referred to as vermicast or black gold, as observed by Patangray (2014) and Lim and Wu (2015). The expulsion of ingested material as casts by earthworms serves as a reliable indicator of soil burrowing and turnover, as evidenced by a study conducted by Chaudhuri *et al.* (2009), which found that 99.9% of the material ingested by earthworms was ejected in that manner.

The primary ecological characteristic of the earthworms is their eating behavior. They obtain nutrition from the soil as leaf litter debris and grinding it in their gizzard. Their feeding and cast-forming characteristics significantly affect the soil structure. The destruction and disturbance of natural forests have an impact on the distribution of earthworms (Chandran *et al.,* 2012).

A variety of biotic and abiotic factors like soil properties, surface litter, vegetation type, and its dynamics, land use pattern local and regional climate, and pressure of human activities generally governed earthworm diversity and distribution pattern (Suthar, 2011; Tondoh *et al.,* 2011). The biodiversity of earthworms has been researched by a number of researchers in various parts of the world (Sautter *et al.,* 2006; Blakemore *et al.,* 2006).

Geographical Distribution and Earthworm Biography

The primary soil invertebrate, earthworms are classified into two groups: megadriles, which live in both terrestrial and aquatic environments, and microdriles, which prefer only aquatic environments. Earthworms are found all across the world, except in deserts, regions with permanent snow and ice, and areas devoid of soil and plants. These characteristics, like the oceans, are natural barriers to the spread or migration of earthworm species because most earthworm species cannot withstand saltwater even for short periods. Nonetheless, some species of earthworm are widespread, and Michaelsen (1903) has used the term migratory worm to describe such species, while the other species, which do not seem able to spread successfully to other areas, have been termed endemic species.

In the soil, earthworms are not dispersed at random. Similar to other subterranean organisms, the species composition and population density of soil-dwelling organisms' exhibit variations based on the landscape and soil depth, and they display distinct demographic patterns over time (Barot *et al.,* 2007).

Earthworm Ecology and Diversity

In soils that have sufficient moisture, earthworm populations are highly variable, so assessing the size distribution and structure of earthworm populations and communities can be difficult. A particular complication is the seasonal changes in the numbers, demographics, and vertical distribution of populations, particularly in temperate regions and some other parts of the tropics, allowing comparison of the earthworm communities.

Soil degradation and habitat loss caused by agricultural activities and unsustainable forest management have represented more pressure on the diversity of earthworms. Anthropogenic activities influence the distribution of animals and cause biodiversity threats (Prakash and Verma, 2022). Earthworm diversity is also affected by environmental variability like the amount and quality of nutrients, energy sources, seasonal change, special differences in soil and climate variability, biotic interaction within the community. Around the world, soil degradation is the most dangerous threat to the diversity of earthworms in this century and should receive more attention (Skubala, 2013). The diversity of earthworms is still limited in many countries, especially in the tropics (Suthar, 2011; Chandran *et al.,* 2012).

EFFECTS OF DIFFERENT FACTORS ON DIVERSITY OF EARTHWORMS

Chemical fertilizers and pesticides

The proper management of soil health is very important for ensuring the sustainable agriculture development and maintenance of biodiversity. Chemical fertilizers, plastics (Verma and Prakash, 2022), e-wastes (Verma and Prakash, 2020b) and pesticides harm the environment, aquatic biota and human health (Prakash and Verma, 2014). They are also influencing the microbial properties of soil.

Soil microflora is a crucial element of the agricultural ecosystem as it contributes significantly to fundamental soil processes and is also actively engaged in enhancing soil fertility and crop productivity. Fertilizers and pesticides strongly influence soil properties and soil functions like rhizodeposition, a nutrient component of bulk and rhizospheric soil, organic carbon of soil, pH, moisture, soil enzyme activities, and many more.

On agricultural land, the effect of chemical fertilizer is not seen in terms of soil quality but also the survival of soil organisms. Earthworms are less able to perform a valuable and crucial function on the exposure of pesticides in the soil ecosystem. Due to the surface application of pesticides epigeic and anecic species are more affected while endogeic species are less affected (Singh *et al.,* 2016).

Due to fertilizer applications on cultivated land, the number and total biomass of earthworms are less than those of non-cultivated land. The observed increase in both the population and biomass of earthworms during the month of August could potentially be attributed to factors such as food availability and climatic conditions as reported by Rathinamala *et al.* (2011). Agricultural land and their communities' composition affect the size and diversity of earthworms in the soil. Inorganic mineral fertilizer superphosphate can be toxic when it contacts directly with earthworms (Abbiramy *et al.*, 2013).

The application of fertilizers and pesticides has been found to enhance crop productivity, albeit at the expense of soil health. According to Pelosi *et al.* (2014), earthworms are susceptible to toxicity from fungicides and insecticides upon direct exposure. The application of pesticides in agricultural settings has a consequential impact on non-target organisms, including earthworms, and can result in ecological harm. The earthworm's biomass and cholinesterase activity are affected by the adverse effect of pesticides like chlorpyrifos and azinphosmethyl (Reinecke and

Reinecke, 2007). The highest mortality of *Eudrilus eugeniae* (100%) was noticed in the treated mixture with urea @10g/kg vermifeed followed by murate of potash MOP @10g/kg vermifeed (95%) (Shruthi *et al.,* 2017). The utilization of chemical fertilizers, specifically phosphorus and potassium, has been found to have a detrimental effect on the biological activity of the earthworm species *Eudrilus eugeniae*. This is evidenced by a decrease in the number of cocoons/earthworms observed in the guava ecosystem.

The neonicotinoid class of insecticides, namely imidacloprid, acetamiprid, nitenpyram clothianidin, and thiacloprid, have been found to exhibit high toxicity towards earthworms. These insecticides have been observed to cause a significant reduction in fecundity and cellulase activity in *Eisenia fetida*, and cause damage to the epidermal and midgut cells of earthworms (Wang *et al.,* 2015). Butachlor consumes the reserve energy from the chloragogen tissue leading to reduce the production of biomass and cocoon of *Eisenia fetida* (Gobi and Gunasekaran, 2010). In a study conducted by Ahmad (2013), the impact of pesticides, specifically cyren, ridomil, triplen, and mamba, on *Lumbricus terrestris* earthworms were examined. He found that the earthworms experienced weight loss, bodily swelling, reduced mobility, and discharge of coelomic fluid. Additionally, there was a decrease in the total number of sperms observed. According to the finding of Suthar (2014), the worms that were exposed to pesticides exhibited a reduced production of cocoons in comparison to the control group. However, an atypical reproductive pattern was observed in *Lampito mauritii*. Hence, to mitigate the adverse impact on soil fauna, it is imperative to gain further insights into the chemical composition, mode of operation, and degradation of pesticides in soil.

Physico-chemical properties of soil

Earthworms have an impact on the soil's physical and chemical characteristics, including pH, organic matter, nitrogen, and phosphorus, through their involvement in the transfer of organic matter and association of soil particles. Ecological studies have shown a strong correlation between the presence of different earthworm species and different types of land usage (Tao *et al.,* 2013). The various soil environments significantly alter the parameters that affect the distribution of earthworms (Rajkhowa *et al*., 2014).

Earthworms are thin-skinned invertebrates that are most vulnerable to changes in soil moisture and temperature or against physical and chemical characteristics of the soils they dwell in, such as soil type, pH, porosity, and organic matter content. Earthworms are sensitive to a number of environmental stresses and have demonstrated specific relationships with them in addition to biodiversity and soil function (Lévêque *et al*., 2015; Rutgers *et al.,* 2016).

Temperature

Like other poikilothermic animals, earthworm's activity, metabolism, growth, respiration, and reproduction are all significantly influenced by temperature (Edwards and Arancon, 2022). Temperature and humidity are often negatively correlated, and earthworms are significantly more constrained by high surface temperatures and dry soil than by low temperatures and wet soil.

The earthworms can modulate the effects of climate warming with declining populations and in turn can interactively affect soil biota (Siebert *et al*., 2019). They also concluded that with increased temperatures, earthworm structures become particularly important for species to find shelter and avoid adverse soil conditions such as water shortages.

Moisture

Moisture is the most important property of soil. The earthworm diversity is affected by temperature and moisture (Blackmore *et al.,* 2006). Soil moisture content plays an important role in the distribution and occurrence of earthworm species (Bhadauriya and Ramkrisnan, 1989). Total earthworm density and biomass were strongly correlated to each other and also positively associated with the moisture of soil (Crusmey *et al.,* 2014).

Earthworms restore their population in the rainy season due to their high reproduction rate and sufficient amount of food present. Soil moisture may be the most important physico-chemical factor affecting local earthworm population densities (Curry, 2004). Earthworms have a considerable ability to survive adverse moisture conditions, either by relocating or aestivating to an area with more moisture. If they cannot avoid dry soil, they can still survive the loss of much of their body's total water content. The activity of earthworms is dependent upon the presence of soil moisture. Nevertheless, the moisture needs of different earthworm species are not uniform, and the moisture prerequisites of earthworm populations across different regions of the world have significant variations even within the same species.

Soil pH

The pH level is the most significant property of soil, which affects nutrient availability in soil and also all other parameters of the soil. It is a limiting factor of earthworm species, diversity, and distribution. According to Goswami and Mondal (2015), high levels of nitrogen, organic carbon, consistent moisture, and soils with a pH range that is somewhat neutral may be responsible for the high population of earthworm variety, but very few are found in soils that are extremely acidic (Edward and Lofty, 1977). The pH of the soil maintains by the vermicompost which acts as a buffer (Singh and Kaur, 2014). Kaviraj and Sharma (2003) observed a decrease in pH in the earthworm cast, due to the mineralization of nitrogen and phosphorus into nitrite or nitrate and orthophosphate.

Earthworms are highly sensitive to the concentration of hydrogen ions (pH) in aqueous solutions. Some species cannot tolerate acidic soil conditions, while others thrive in acidic conditions, and many species can tolerate a wide pH range. Several researchers have found that most species of earthworms prefer soils with a neutral pH (pH = 7.0) (Kumar and Singh, 2013).

Soil type

Soil types have an impact on soil biota. The diversity and abundance of earthworms are not only affected by management practices but also influenced by biotic and abiotic factors. Different types of soil like sandy clay and loamy have been significant with high earthworm density and biomass in the soil. Soil type has a greater effect on cast properties than earthworms. Almost in every type of soil habitat earthworms are present. A greater number of earthworms will be found in healthier soil (Kumar and Singh, 2013).

Organic matter

Organic matter present in the soil affects the diversity of earthworms. The presence of organic matter and the climatic conditions of a particular area determine the diversity of that area (Hackenberger and Hackenberger, 2014). Earthworms are very important to the overall ecosystem as they perform numerous functions such as breaking down organic matter and releasing plant nutrients into the adjacent soil. Soil organic carbon favors the spread and abundance of earthworms. Organic matter content is an indicator of soil fertility and productivity.

Good soil has more than 3% organic matter. Earthworms are the most important soil organisms affecting organic matter degradation, structural development, and soil nutrient cycling, particularly in productive ecosystems (Singh *et al.,* 2022). It shows that earthworms prefer to live in rich organic matter and nitrogen in the soil ecosystem. The distribution of organic matter in the soil strongly influences the distribution of earthworms. High-quality organic matter favorably supports the earthworm population (Cesarz *et al.*, 2013). Soils that are poor in the organic matter do not typically support large numbers of earthworms. Several researchers have reported strong positive correlations between earthworm counts and biomass and soil organic matter content.

Role of earthworms in soil fertility

The earthworms are the biological indicator of the soil ecosystem as they indicate the health and fertility of the soil for proper harvesting. Earthworms break down organic waste into organic fertilizer. Earthworms feed on decaying organic wastes and soil and excrete about 60-80% of their food (Siddiqui and Singh, 2023). Their role in soil fertility is very crucial as they make the soil more air permeable and release nutrients present in their faeces into the soil. From ancient times to the present day, earthworms render natural services to people by providing worm fertilizer (vermicast) and vermiwash, which has a beneficial effect on soil fertility and improving crops. Earthworms are considered beneficial to farmers as they perform the task of ploughing the field without any cost. Earthworms work day and night for farmers, improving crop yields by making their fields more nutritious and by converting the decaying organic matter into humus-like products.

CONCLUSIONS

The earthworm is a crucial component of soil fauna, contributing significantly to the recycling of agrowastes, mineralization, stabilisation, and solubilisation of organic substances. Its presence is instrumental in enhancing soil fertility and crop productivity. The extensive utilization of chemical fertilizers, insecticides, and pesticides resulted in the degradation and complications of soil health, as well as the reduction of soil fauna diversity, human health implications, and environmental impacts. It is imperative for individuals to possess knowledge regarding the utilization of biofertilizers and biopesticides in organic farming due to its environmentally sustainable nature, cost-effectiveness, and non-toxicity towards soil fauna and human well-being. Therefore, it can be inferred that earthworms play a significant role in augmenting soil fertility through the process of biological waste recycling and by serving as a habitat for other beneficial microorganisms.

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