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Role of earthworms in soil health and variables influencing their population dynamic: A review

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Abstract
Earthworms combine the various soil layers and add organic material to the soil. This combination increases the fertility of the soil by allowing organic matter to spread throughout the soil and allowing plants to access the nutrients which are stored. The earthworm works as soil conditioners by enhancing the soil biological, chemical, and physical properties. They accomplish this through a variety of processes, including aeration, soil organic matter breakdown, the release of plant nutrients, and their part in the accelerated uptake of nitrogen as a result of plant growth hormone secretion. The population of the soil is affected by a wide range of soil and environmental conditions. In addition, it is still unknown how soil worms alter the makeup of soil microbial communities and how they affect the microbial activity of the soil. Earthworms lower microbe activity and abundance by consuming microorganisms or by choosing and promoting particular microbial groupings. Although primarily mediated by indirect microbial community change, earthworms have a direct impact on the plant's development and recycling of nutrients. The decrease in soil earthworms is partly a result of agricultural activities, especially the usage of pesticides. There are no established links between the prevalence of earthworms, crop productivity, and opposing effects on yield. Hormone-like compounds found in earthworms support plant development and health. This review discusses how earthworms interact with soil fertility and various agricultural techniques, including variables affecting earthworm population dynamics in all situations that allow the adoption of environmentally friendly and earthworm-friendly farming techniques for an ideal earthworm, productive, and fertile soil behaviour.

Keywords: Earthworms, soil health, variables, population dynamic

1. Introduction
The earthworm is one of the important macrofauna of terrestrial invertebrate that belongs to the phylum Annelida, Class Chaetopoda, and Order Oligochaeta. (A.A. Ansari and S.A. Ismail 2012) [1] Earthworms are hermaphrodites (Munnoli, P. M. *et al.*, 2010) [17], which is generally found in the common root zone of the plant from 10 cm top soil to 2 meter deep in subsoil. Earthworm help to decompose the agricultural residue and make soil for favorable crop growth. More than 4200 species of earthworm (Megadrile and microdrili) have been identified and classified into three groups (plate. 1.1) based on their burrowing and feeding habits (Thomas and Trivedy 2002) [24].

1.1 The types of earthworms
1.1.a Epigeic
The earthworm species Epigeic are surface dwellers, and live at the soil surface where high organic matter content. They feed the leaf litter, decaying plant roots, animal waste, and humus. Compared to other group of Epigeic earthworms have short life, but they have a high cocoon production rate, and efficiency for waste recycling with high consumption rate. Some example belongs to the Epigeic group are Eisenia fetida, Bimastos Parvus, Dendrobaena rubida, Eisenia hortensis etc.

1.1.b Endogeic
These earthworm species are topsoil dwellers found in the topsoil layer where a high amount of organic matter is present. They feed litter, and organic-rich soil, and organize horizontal burrows lined by mucus and excretory product. Comparatively Epigeic, Endogeic species have a long life cycle, recycle efficiency varies from species to species, and is well established in some species. An example of endogenic Species adopted in waste management: eudrilus eugeniae.

1.1.c Anecic

Earthworms belonging to this category are subsoil dwellers who organize vertically borrow by feeding the litter and soil. Have a long life cycle and low cocoon production throughout the year. as compared to other spices. some examples of Anecic Species adopted in waste management are Pheretima elongate, Megascolex megascolex, *Perionyx excavatus*, *Lumbricus terrestris*, Amnthus diffringens, *Lampito mauritii*, Perionyx sanisbaricus, *Lumbricus rubellus*.

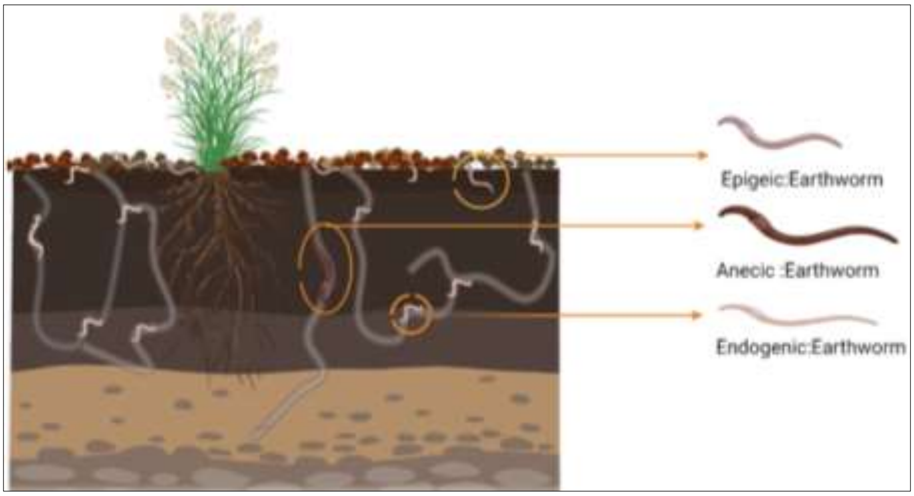

Plate 1: Three groups of earthworms based on their burrowing habits

Vermicompost is one of the major organic manures and has ample demand in agriculture, gardening, and household planting methods. Commercially species like *Eisenia fetida*, *Eudrilus eugenie*, etc. are used for casting of earthworms for vermicomposting. Eisenia fetida which is also called a Red Earthworm has a high rate of multiplication. It converts the organic materials from the top that is a surface feeder, they are well adapted to the very variable moisture and terms conditions. (Bouché, 1977; Lee, 1985) [30, 16].

Plate 2: Red earthworm (*Eisenia fetida*) a surface feeder earthworm

2. Importance of earthworms as agriculture prospectus

Earthworms make the hole into the soil through a burrowing activity which enhances aeration, drainage, decomposition, formation of humus, development of soil structure, and cycling of nutrients through burrowing activity by ingestion of organic matter and making the soil more fertile. The addition of earthworms and vermicompost enhance the physical and chemical processes in soil, and also maintains an optimum level of soil media in terms of metal concentration, soil porosity, aeration, pH, and electrical conductivity. Earthworms are also known as ecological engineers (Hale *et al.*, 2005) [5]. Earthworms can consume a wide range of unstable organic matter such as animal waste, industrial waste, sewage sludge, etc. The earthworm casting maintains and increases the availability of soil major and micronutrients, PGR, enzymatic activity, and a more microbial environment (Krishnamoorthy, R. V and S. N. Vajranabhaiah 1986) [11].

3. Contribution of Earthworms in beneficial farming

Appropriate soil conditions and sufficient nutrients in soil ensure sustainable farming, presence of earthworms leads to improve overall soil health. Organic matter is physically fermented, chemically degraded, transformed, and translocated by the earthworm Nitrogen phosphorus and potassium is the macronutrient that needs the plant in large amounts, the deficient amount leads to improper growth of plants. In vermicompost, the major nutrient (NPK) is low compared to standard fertilizer. The reduced N content in vermicast is due to ingestion of organic matter, but vermicompost soil has high nutrient content compared to non-vermicompost soil this was due to high enzymic activity, PGR, and provides good interaction of soil microflora for luxuriant growth of the plant (Tomlin 1983) [25], Satchell 1967) [21].

3.1 To enhance the availability of soil Nitrogen

The N mineralization is increased by earthworm casting but it also depends upon species to species and their interaction with another soil biota, soil organic matter, climatic conditions, and soil characteristics (Butenschoen *et al.*,2009) [3]; (Lee KE 1985) [16] N mineralization increased by earthworm casting either directly or indirectly. Directly, N mineralization is possible by the metabolic process of ingestion of organic substance into the metabolic product (faeces, urine, mucus) and dead tissues whereas indirectly, the production of vermicompost leads to changes in the overall soil properties which improves the interaction with other elements of soil biota. Nitrogen presence in the litters returned into the soil by ingestion by Earthworms, the Nitrogen fixing bacteria present in the Earthworm gut which leads to improved Nitrogenous activity and Nitrogen fixation in soil. It was observed that 60-70 kg/year of nitrogen was fixed into the soil by death tissue of L. terrestrinin woodland in England (Edwards and Bohlen, 1996) [31].

3.2 To enhance the availability of soil phosphorous

Phosphorus is the 2nd most limiting nutrient after nitrogen for plant growth (Vance *et al*. 2000) [27]. Plant uptake phosphorus mainly in two forms $H_2PO_4^-$ and HPO_4^{2-}, Comparison to other macro nutrient the availability of phosphorus is low due to less water soluble thus less mobile to plant uptake. Earthworm casting may modify the concentration and chemical form of phosphorus in soil by ingestion process, increases of available form soil phosphorus by earthworm casting significantly affected due to the pH level of earthworm gut and intestine track of earthworm, and a large amount of mucus secreted by earthworms and metabolic activities increases during the digestion process. (Kuczack *et al.*, 2006) [13]. In many studies, concluded that earthworm casting increases the phosphorus availability from surrounding soil for plant growth (Shilpa Pangotra *et al.*, (2006), R.C. Le Bayon)

3.3 To enhance the availability of soil Potassium

Potassium is the 3rd macronutrient plays a major role in physiological process that regulates stomata opening and closing in plants. Earthworm casting increases the phosphorus availability in soil dynamic which enhance plant growth (Vos, H. M *et al.*, (2014) [28]. Under experiment, (A. Basker *et al*., 1992) [32] concluded that earthworm casting of common pasture earthworm species *aporrectodea calingionosa* increases the exchangeable potassium by shifting the potassium equilibrium from un-available form of potassium to available form.

4. Earthworm's population depends on

The earthworm population is depending on soil factors and agronomical factors.

4.1 Soil factors

Soil factors are the various soil ecosystem condition that is responsible for the activity, population density, abundance, and distribution of earthworms. Individual physical-chemical properties of soil pH, soil type soil temperature, soil organic matter soil moisture regulate the growth of the earthworm population, (Wood, 1974; Lee, 1985; Werner *et al.*, 2005) [29, 16, 33].

4.1.a Soil Type

A soil with a light, medium-loam texture, well aerated, with high organic matter and low salinity favor the earthworm abundance. A heavy clay, sandy, alluvial soil, and high salinity resist the earthworm population but high calcium concentration with fairy deep soil of medium texture favors the earthworm growth. Soil cover is very important to maintain the earthworm population. Earthworm reduces the toxicity in soil by ingesting organic matter with the help of beneficial bacteria present in their gut but also toxicity showed a negative effect on the earthworm population (Edwards and Bohlen, 1996) [31].

4.1.b Soil moisture

Earthworm body constitutes 75-90% of the body weight (Grant, 1955) [35]. An adequate amount of soil moisture determines the earthworm activity, population, and biomass (Olson, 1928; Wood, 1974) [36, 29]. A different spice of earthworm has a different soil moisture requirement for proper growth and development in a particular region of the world. (Zaller and Arnone, 1999) [37]. The earthworm could survive well in the soil where the optimum moisture ranges between 60-70% which is favorable for proper growth and development, increasing moisture leads to fatal of the earthworm whereas with decreases in moisture earthworm moves to the surface soil and gets contact with ultra-violet ray or by predation. An earthworm can survive in adverse soil moisture conditions in soil either by moving in search of moisture region or by aestivation. (Baker *et al.*, 1998) [2].

4.1.c Soil temperature

Temperature is the factor responsible for earthworm fertility because earthworm is Hermaphroditic. An earthworm can reproduce multiple times throughout the year but the hatching of cocoons is temperature specific and under extreme temperatures cocoons remains in a dormant period until reach favorable temperatures. An adequate range of soil temperature favor earthworm growth and development several deep studies found that different species have different temperature requirement and tolerance capacity in wide soil type and climate condition. On average earthworms require 10-210C temperature for growth and development, it has been observed that earthworms can resist cold and moist conditions as a comparison to hot and dry soil (Edwards and Bohlen (1996) [31], Holmastrup *et al.*, (1991) [8].

4.1.d Soil pH

Soil Ph is an important chemical property of soil health determination. Earthworms are pH sensitive which controls all microbial activity, Nutrient availability to plants through soil and Earthworm survival. optimum pH for earthworm growth and population should be neutral pH but it also found that earthworms can tolerate from pH 5.0 to 8.0 below or above this range the earthworm count decreases. Different species of earthworms have different pH requirements for example L. *rubellus* and A. *caliginosa* are the species of earthworm that can survive from pH 4 to neutral (Stp-Bowitz 1969) [23]; Werner *et al.*, (2005) [33].

4.1.e Soil Organic matter

Organic matter is the main source of the earthworm's food, it can be animal manure, dairy and poultry waste, food industry waste; slaughterhouse waste, or biogas sludge. High organic matter provides favorable conditions for earthworm growth and population. The low amount of organic matter in soil has an adverse effect on in earthworms' weight, population, and survival rate. E. fetida, E. andrei, and P. excavates are earthworm species which has the best result of vermicomposting with paper and food industry waste (Joshi 1997 Schmidt 2004) [34, 22].

Table 4: Growth and population parameter of earthworms

Growth parameter for Earthworm		
Parameter	**Favourable condition**	**Unfavourable condition**
pH	7 neutral	Less than 5.0-greater than 8.0
Land type	Undisturbed soil	Heavy tillage
Rainfall	Medium	High rainfall
Organic matter	High	Low
Temperature	10-20^{0}c	Less than 10- greater than 20^{0}c
Moisture	65-75%	Less than 65- greater than 75%
Soil type	Loam light texture	Sandy
C: N Ratio	Below 25:1	Above 25:1
Soil condition	Aerobic	Anaerobic

4.2 Agronomic factors

Earthworm casting has numerous benefits to soil health and few harmful effects which accelerate agronomic production. The earthworm is a bio indicator and bioengineer for the soil ecosystem which not only increases soil fertility, but also improves the biological physical, and chemical properties of the soil, The presence of a high population of earthworms indicates the soil is fertile, non-toxic soil with neutral pH and good soil health so, we can say that earthworm is an indicator of soil fertility, soil toxicity, and soil health. Nowadays, the population distribution and variations of earthworms from site to site are indications of poor soil management practices, fertilizer use chemical use, and agronomical production techniques. The population of earthworms is affected by the operation of tillage with heavy farm machineries, rotary tillage, sandy, salty, acidic, arid, barren soils, mice, mites, very toxic insecticides, pesticides, and herbicides.

4.2.a Tillage Practices

Tillage is an important cultural practice for agricultural production. Recent agricultural practices, with the help of high-farm machinery in agriculture, improve the efficiency of crop production. Tillage facilitates incorporating crop residue in the soil which increases the food source for earthworms and the earthworm population significantly increases by decomposition of organic matter but also tillage has an adverse effect on an earthworm. A higher number of earthworms was observed in undisturbed soil such as grassland, and forestland due to tillage practices which disturb the soil at regular intervals causing fatal death by reputing earthworms and causing a decline of earthworm community in the soil (Chan 2001; Kladivko, 2003) [40, 12].

4.2.b Cropping Practices

It is important to maintain a low C: N ratio in the soil through various cropping practices such as leguminous crops for the earthworm population. earthworm prefers a low C: N (25:1) ratio of organic matter for decomposition whereas saw dust flax, waste straw, coir waste, etc. including all crop residues with high lignocellulose content, have a high C: N Ratio (27-208:1) are less suitable for earthworm substrates for composting (Thomas and Trivedy 2002) [24].

4.2.c Fertilizers Application

These days, Fertilizer application is very common for agricultural production to supply sufficient nutrients to crops and its effect on earthworms is both beneficial and harmful to earthworms from site to site. The beneficial effect of fertilizer application is directly related to the health of the soil and the soil responsible for the earthworm population. Under organic fertilizer, the earthworm count significantly increases due to organic fertilizer promotes soil health and provides a good source of organic matter for earthworm feed, whereas, the harmful effect of inorganic acidifying fertilizer on soil health changes the soil to acidic and acidic soil the population of earthworms declines easily.

4.2.d Application of plant protection chemical

To cure the Infestation of Insect Pests and Pathogenic causal organisms instantly Insecticide, Pesticides, Fungicides and Herbicide became an integral part of Plant Protection extensive use of that chemicals some toxic residue remains in the soil, Although some toxicity being digested by the earthworm, which cause an adverse effect on earthworm growth and population. Certain organophosphate and carbamate neonicotinoid insecticides, such as bendiocarb, carbaryl, chlorpyrifos, etc., and certain fungicides, such as carbendazim and thiophanate-methyl, have a negative effect on growth, the population, and activity of earthworms Redmond CT (2016) [20]; Baker SW and Binns DJ (1998) [2]; Potter DA (1990) [38]; Larson JL (2012) [39]. The most common earthworm species for casting *Eisenia fetida* are comparatively has more tolerance to chemical whereas, some earthworm spices vary in sensitivity, report have shown a negative impact in earthworm population in response to high dose of organic chemical deposition 141617. To estimate the chemical toxicity in earthworms, 'Mortality' is the mostly used parameter, (Amorium *et al*.,) tested the two spices of earthworm *Enchytraeus albidus* and *Enchytraeus* with *Pendimedipham herbicide* under his test he found that reproduction to be a more sensitive endpoint than mortality rate of both species.

5. Conclusion

Earthworms as farmers' friend, increase soil fertility and maintain soil health in numerous ways, by intermixing soil and decomposition organic matter, and mineralization Improvement in the consistency of soil texture with a concomitant increase in porosity, infiltration, soil-water retention, and reduces soil toxicity are other characteristics of worm worked soils but certain factors threaten to their population density and distribution. Recent agricultural practices such as conventional tillage, and indiscriminate use of inorganic fertilizers and pesticides are also responsible for the decrease in earthworm numbers in soil ecosystems. The decline in soil health is thus a result of a decrease in earthworm numbers due to several factors. In this article, these factors are described systematically. Therefore, this article was made to collect ideas about factors that enhance earthworm activity and soil health. The input of sufficient organic manures instead of chemical fertilizers with minimal disturbances in the soil can be adopted for the optimum activity of earthworms in soil for healthy and fertile soil.

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