Naveen Shodh Sansar (An International Refereed / Peer Review Multidisciplinary Research Journal)
RNI No.- MPHIN/2013/60638, ISSN 2320-8767, E- ISSN 2394-3793, Scientific Journal Impact Factor (SJIF)- 8.054,
October to December 2024, E-Journal, Vol. I, Issue XLVIII, ISO 9001:2015 - E2024049304 (QMS)

Effect of Soil Biota on Physicochemical Properties of Soil

Harish Raghunath Khairanar* Dr. Pramod Pandit Dr. Dhananjay Dwivedi*****

*Research Scholar, Devi Ahilya Vishwa Vidyalaya, Indore (M.P.) INDIA
** Principal, Govt. New Model College, Barwani, Indore (M.P.) INDIA
*** Professor (Chemistry) P.M.B. Gujarati Science College, Indore (M.P.)INDIA

Abstract : Soil biota plays an important role in soil formation, soil development, organic matter decomposition and in soil structure formation.On decomposition of organic matter they free up nitrogen, potassium and phosphorus which are primarily nutrients for plants in crops field. Biochemical activities of soil organisms help in cycling of various nutrients in soil, improve physicochemical properties of soil, water regime and hummus availability. They are acting as a driving agent within food webs for releasing, transformation, relocation and storage of elements throughout the ecosystem by several biological activities.

Qualitative research approach has applied in study on the effect of soil biota on physicochemical properties of soil.In this research paper primary and secondary data has collected by different sources vizsubjective opinions, real-time field observations, already existing written materials such research articles, literature review , textual data etc. has been collected, analysed and reviewed.

This paper, briefly highlighted some of the biological functions of soil biota, there interaction, effect and importance to improve soil physicochemical properties under sustainable soil management activities in agricultural production. This study would play an important role to establish natural farming, sustainable agriculture practice, food quality and soil environmental health, at global aspects.

Keywords: Soil biota,Soil physicochemical properties, Soil organic matter , Nitrogen fixation, Soil biodiversity.

Introduction - The majority of life on Earth is dependent upon six critical elements: hydrogen, carbon, oxygen, nitrogen, phosphorus and sulfur. These elements are reduce, reuse and recycle by soil biota. Due to invisibility to the naked eye soils are one of the most poorly researched and diverse habitats on earth .The soil is one of nature's most complex ecosystemsthat contains thousands of different organisms, which interact and contribute to the global cycles that make possibleall life support system. Approximately a teaspoon soil in size, containing all the domains (Bacteria, Archaea,Eukarya) and elements of life. This means that one might see the 'biological universe' in a single gram of fertile soil.The species numbers, composition and diversity of a given soil depend on many factors, including aeration, temperature, acidity, moisture, nutrient content and organic substrate.

Soil biota include the bacteria, actinomycetes, ,cyanobacteria,fungi and algae, the protozoa, nematode ,collembolan, mites, termites, ants and other associated micro-organisms.Activities of soil biota in soil environment and soil ecosystem functions have been considered the most important component of soil quality managements and nutrient recycling (Kramer and Gleixner, 2008).

Therefore, the objectives of this paper are to provide a concise elucidation of the roles of soil biota and their biodiversity in the aspect of global soil development, soilquality and naturalfarming.This study establish the necessities ,importance, effect , and biochemical functional processes of biota to improve soil physicochemical properties for agricultural land at global aspects.

Material and methods: Qualitative research approach has applied in study on the effect of soil biota on physicochemical properties of soil.In this research paper primary and secondary data has collected by different sources viz field work, laboratory work and by real-time field observations. Subjective opinion , farmers options, Scholars guidance, their experience, valuable suggestions has examined during the investigation. Already existing written materials such as annual reports, research articles, record, documents, literature review , textual data etc. has been collected, analysed and reviewed.

Not only scientific approach has taken in, collection of data, sampling analysis**,** interpretation of data, conception ,designing and in drafting the of manuscript but involved in revising it critically for important intellectual content for the research paper also.

Soil biota and types of soil biodiversity: Soil biodiversity can be classified into 4 major groups: micro-organisms,

micro-fauna, meso-fauna, macro-fauna. Plants also be considered through their root system.

Microorganisms are members of the soil biota but are not members of the soil fauna. The soil fauna is the collection of all the microscopic and macroscopic animals in a given soil. Soil animals can be conventionally grouped by size classes: micro fauna (µm; protozoa, nematodes), mesofauna (mm; micro arthropods, mites and collembolan, termites, ants), andmacro fauna (cm;, earthworms, spiders, insects macro arthropods),

Soil biota in a general term refers to all soil organisms living and communicating in soil environment. Ritz et al. (2004)considered soil biota as the 'biological engine of the earth',-driving and transforming physical, chemical, biological and ecological processes in global soils.

Their ranges were identified as the smallest in different sizes, extremely diverse ,abundant and able to decompose almost any existing natural material in soil . (Table 1: common population of some soil microorganisms)

Table-1:Common population of some soil microorganisms:

S.	Organism	Number per gram of soil
1.	Bacteria	10^8-10^9
2.	Actinomycetes	10^7-10^8
3.	Fungi	10^5-10^6
4.	Algae	10^4-10^5
5.	Protozoa	10^4-10^5
6.	Nematoda	10-10^2

Role of soil biota to improve soil physicochemical properties: A small fraction of the soil is made up of 0-10% biological organisms, or parts of organisms. The percent present depends on the parent material , period of time and strongly influenced by environmental conditions. Biological content includes both microscopic organisms such as some fungi, bacteria, archaea and macroscopic organisms such as plant roots, rodents, insects, earthworms. This organisms may be alive or dead when dead they become "organic matter".

Thesustainable function of natural and agricultural soil ecosystems is dependent on these active groups of biota and their biodiversity offer.Coleman (2001) noted that the soil biota contribute with a wide range of essential services to the sustainable function of all ecosystems, by acting as the primary driving agents of regulating the dynamics of soil organic matter, nutrient cycling, soil carbon sequestration and greenhouse gas emission, modifying physical structure of soil, enhancing plant health and maintain soil quality (Castro-Huerta et al., 2015).

Bacteria: Soil bacteria are the active organisms fall into four functional groups-decomposers, mutualists (form partnership with plants-nitrogen-fixing bacteria), pathogens and lithotrophs or chemoautotrophs; played a vital role in soil nutrient cycling (Coleman et al., 1983)**.** Bacteria contribute to the carbon cycle by fixation (photosynthesis) and decomposition of organic materials and hence might improve soil colour and soil quality (FAO, 2005).Their activities might also help to improve the strength of soil particles and soil resilience against soil erosion.

Fungi: Fungi also help in binding soil particles and an increase water infiltration and soil water holding capacity(Ritz et al., 2004).

Protozoa: These organisms move soil particles and help in the decomposition processes of soil organic matter (Song et al.,2004).

Nematodes: Nematodes are considered the major consumers classified as fungal feeders, bacteria feeders, plant feeders, predators and omnivores (Usman, 2013). These groups of nematodes were identified to range between 2 to 100 µm wideand 0.15 to 5 mm long (FAO, 2005).Yeates and Coleman (1982)recognized nematodes in soils environment. These flexible organisms play an important role in soil health, soil function, and soil organic matter decomposition processes (Kramer and Gleixner, 2008).

Termites: Termites are divided into three groups according to the structure of their nests (those that build mounds): (a) above ground, (b) on the soil surface, and (c) below ground. Termites are described as surface litter feeders, grass harvester, wood feeders and soil feeders 'humivores' (FAO, 2005). Termites played an important role in modifying the soil particles into fine and stable aggregate, increase soil water infiltration rate and aerates the soil(Allen, 1990).

Table-2: Ecosystem services provided by soil biota (adapted after modifications made by Brussaard, 2012 from the work of Kibblewhite et al., 2008)

S.	Ecosystem services	Ecosystem functions
1.	Water quality and supply	Soil structure maintena -nce, Nutrient cycling
2.	Erosion control	Soil structure maintenance
3.	Atmospheric composition and climate (greenhouse gas) regulation	SOM dynamics
4.	Pollutant attenuation and degradation	Decomposition
5.	Pest and disease control	Nutrient cycling
6.	Biodiversity conservation	Biological population regulation

Earthworms: Earthworms are considered numerous and grouped into 23 families, 700 genera and many species (Usman,2013).Earthworms play a significant role in regulating soil physical and chemical properties and soil processes (Lubbers et al., 2011).They redistributes nutrients, aerates the soil and increases surface water infiltration, decompose of dead organic matter and transformed soil colour and surface soil layers (Edwards, 2000).It noted that earthworms essentially change soil structure by casting and burrowing and as such improve soil aggregate stability, cohesion and adhesion in soil and pore-size division.

Plants (Through extensive root system): Soil biota such as plants as a major producersuse solar energy to fix carbon from carbon dioxide through photosynthesis, and help to produce roots, tubers and other underground organs within soil body. The root plays an important function in binding soil particles and resilienceagainst soil erosion and unacceptable environmental changes. The leaves and litter materials from the trees also add organic matter to the soils.

Table-3: Soil fauna and their eating habits:

Microphytic feeders:	
Organism	**Microflora consumed**
Springtails	Algae, Bacteria, Fungi
Mites	Fungi, Algae, Lichens
Protozoa	Bacteria, other microflora
Nematodes	Bacteria, Fungi
Termites	Fungi
Carnivores secondary consumers :	
Predator	**Prey**
Mites	Springtails, Nematodes, Enchytraeids
Centipedes	Springtails, Nematodes, Snails, Slugs, Aphids, Flies
Moles	Earthworms, Inspects
Carnivores tertiary consumers :	
Predator	**Prey**
Ants	Spiders, Centipedes, Mites, Scorpions
Centipedes	Spiders, Mites, Centipedes
Beetles	Spiders, Mites, Beetles

Effect of soil biota on physicochemical properties of soil : Soil biota directly or indirectly participate in many biochemical functions that affect the physicochemical properties of soil in various ways that are mentioned below:

Soilorganic matter: Organic matter consists of dead plants, animal, microbes and fungi or their parts, as well as animal and microbial waste products in various stages of decomposition. Eventually, all of these break down into humus, which is relatively stable in the soil. Increasing levels of organic matter aid in soil structure, nutrient mineralization, biological activity, cation exchange capacity, water-holding capacity, and water and air infiltration rates.Soil organic matter which is the vital component of soil quality development in soil environment undergoes some important decomposition processes process that are as:

Mineralization: Mineralization is a biochemical breakdown of organic materials by soil biota.

Humification: Humification is the change of simple organic substances into larger molecules, which finallybecome humus (FAO, 2005).

Nitrogen fixation: Biological nitrogen fixation, the process by which some micro-organisms (certain bacteria) are able to transform atmosphere nitrogen gas into nitrate and make it available to the ecosystem. During biological nitrogen fixation, microbes form symbiotic relationships with plants, in which microbes provide nitrogen to the plants and the plants provide sugars from photosynthesis to the microbes. The main nitrogen-fixing bacteria in agricultural systems are from the genus *Rhizobium*, and are associated with plants of the bean family (*Leguminosae*).

Ammonification: Ammonification is the release of ammonium ions from decomposing organic matter. This process is also called nitrogen-mineralization, as it changes the unavailable organic forms of nitrogen into plant-usable forms. The ammonium that is produced is held in the soil solution, adsorbed onto CEC sites, or taken up by plants.

Nitrification: Nitrification is process in which ammonium is transformed into nitrate. In this process Nitrosomas spp. oxidize ammonium to nitrite and Nitrobacter spp. oxidize nitrite to nitrate.

Denitrification: Nitrogen can be lost from wet soils where anaerobic conditions occur. Under these conditions some bacteria get their oxygen from nitrate rather than oxygen gas, releasing nitrogen, gas back into the atmosphere. This process is called denitrification. Though nitrogen can be lost from the soil ecosystem this way, denitrification can be a very useful function where excess concentrations of nitrate occur in the soil.

Immobilization: Nitrogen is unavailable to plants (immobilized) when it is in the organic form. Usually, rates of mineralization in the soil are higher than rates of immobilization. However, if organic matter added to the soil has less than 1.5% nitrogen, soil microbes will rapidly take up the available nitrogen, so that the rate of immobilization will temporarily exceed the rate of mineralization. This temporarily decreases the amount of nitrogen available to plants.

Soil formation: Soil biota played a vital role in soil formation process. Biota (Flora, Fauna, Microorganisms and plants roots) in conjunction with climate, modifies parent material to produce soil.

Soil structure: Biological factors help bind soil particles together like Bacterial exudates, high organic matter content, root activity and exudates (sugars that act as glue),Fungal hyphae, Macro fauna (especially earthworm) activity and waste,

Ritz et al. (2010)noted that soil biota produce soil structure by a number of direct and indirect processes. These processes are:

I. Moving and aligning primary particles alonghyphal surfaces.
II. Adhering particles together by the action of adhesives involved in colony cohesion, and other exudates, such as extra-cellular polysaccharides.
III. Enmeshment and binding of aggregates by fungal hyphae and actinomycete filaments, and associated mycelia.
IV. Coating pore walls with hydrophobic compounds, particularly by fungi which produce such polymers to insulate their mycelia, which have a relatively large surface area: volume ratio.

Soil aggregate formation: Soil biota bind soil particle together, improve the stability and cohesion of aggregate

development and help in nutrients cycling within the pores of different sizes(Six et al., 2004).

FAO (2005) noted that numerous microbes exist in soil particles and or within the surface areas of soil micro-aggregates. Thus, soil micro-aggregates could be considered as zoological houses where millions of bacteria and fungi occupied. Their presence provides many essential ecosystem services to soil aggregates and soil structures .

Soil texture: Soil texture means fineness or coarsenessaffects plant rooting, soil structure and organic matter content, determine the pore-size distribution, soil water holding capacity and air-filled pore space in soil aggregates that provide habitat for soil organisms. One can visualize all the interactions of gases, water, organisms and organic and inorganic constituents at the "micro scale "provide us with a "glimpse of the universe" in a gram of soil.

Soil permeability: Microorganisms (bacteria and fungi) and macroorganisms (insects and earthworms)increase soil permeability and infiltrationby encouraging the formation of soil aggregates and creating macropores.

Soil temperature: Growingplants shade the soil, cool the surrounding air through transpiration which reducing the temperature. Soil temperature influences on soil physicochemical properties and biological activity. Below about 40°F there is little biological activity. At lower temperature organic matter accumulation increase.

Table-4: Size classification of soil organisms according to body width (Adapted and modified after Swift et al., 1979)

Microflora & Microfauna (Less than 100 µm)	Meso fauna (100 µm to 2 mm)	Macro and Mega fauna (2 mm to 20 mm)
Bacteria, Fungi, Nematodes, Protozoa, Rotifera	Acari Collembola Protura, Diplura, Symphyla, Enchytraeide, Chelonethi, Isoptera, Chilopoda, Diplopoda	Opiliones Isopoda Amphipoda Megadrili(Earthworms) Coleoptera Araneida Mollusca

Soil colour: Greenish, bluish, and gray colors in the soil indicate wetness. The colors are caused by the reduction of iron by bacteria in anaerobic conditions, when the bacteria get the electrons they need energy from iron rather than from oxygen.

Result and discussion: Field work, real-time observations and textual data etc. that has been collected, analysed and reviewed , indicated that soil biota directly or indirectly participate in many biochemical functions that affect the physicochemical properties of soil in various ways.

Overall it noted that soil biota and their biodiversity play a role in soil formation ,soil fertility,and nutrient uptake by plants. There biodegradation processes reduce hazardous waste and control of pests through natural biocontrol among the food webs. They improve soil physicochemical properties and enhance crop productivity through recycling the basic nutrients (nitrogen, potassium, phosphorus, and calcium)required for all ecosystems.

They break down organic matter into humus hence enhancing plants nutrients, soil moisture retention and reducing leaching of nutrients. They increases soil porosity through soil aggregate stability and hence water infiltration and thereby reducing surface water runoff and decreasing erosion.

Environmental issues related to agricultural soils and food security are quite very important in determining and understanding the role of soil biota and their biodiversity (Walletal.,2001).Agricultural soil management, environmental pollution, global warming, soil degradation and climate change are directly and indirectly connected with the existence and biodiversity of many soil organisms(de Bello et al., 2010).

Conclusion: The role of soil biota is vital to soil properties and soil components. Soil biota maintain critical processes such as carbon storage, soil carbon sequestration and greenhouse gas emission, nutrient cycling andsoil physicochemical properties. They influence the stabilization and destabilization of soil organic materials for soil quality and soil fertility development.

Properunderstandings of soil biota and their biodiversity in soil environment would provide ways to improve soil health, soil function, soil quality, soil fertility and sustainable soil management activities in agricultural production.Generally, without vital recycling processes of soil organisms, the soil would become a stockpile of dead plant and animal materials with no facilities to reprocess essential nutrients such as carbon, nitrogen and phosphorus in soil ecosystem .

Both the field and laboratory data requirements are quite important, we have shown that assessments and analyses are possible in the aspects of physical, chemical and biological relationships between soil biota and the role they played in soil medium.

This study will emphasize the needs to further expand our understanding into many aspects of soil organisms and their roles in relation to nature farming, sustainable agriculture, environmental pollution, global warming, climate change and food security.

Loss of soil biota leading to the long term deterioration of soil fertility and the loss of agricultural productivity. Implementing sustainable practices in agriculture, natural farming, plantation, reducing deforestation and over grassing , limited use of fertilizer and pesticides can be improve soil biota in agriculture land.

Acknowledgement: I wish to express my profound sense of gratitude and thanks to my esteemed Supervisor Dr.

Pramod Pandit (Principal, Government New Model College Barwani (MP)) and Co- Supervisor Dr. Dhananjay Dwivedi (Professor Department of Chemistry P.M.B.Gujarati Science College, Nasiya Road, Indore,MP.- Research center) for their inspiring guidance, constant encouragement and help extended during the investigation, conception ,design, collection of data, sampling, analysis and preparation of the research paper.

I also express my sincere thanks and gratitude to Dr. Mahesh Baviskar (Profe. Depart. of Chem. Govt. PG. College Sendhwa, Dist. Barwani (MP)),Dr. Dinesh Kanade(HOD&Profe. Depart. of Chem. Govt. PG. College Sendhwa, Dist. Barwani and DrVikas Pandit (Profe. Depart. of Chem. Govt. PG. College Sendhwa, Dist. Barwani)for their valuable suggestions and help during theinvestigation, analysisinterpretation of data, who involved in drafting the manuscript , revising it critically for important intellectual contentand preparation of the research paper.

I also wish to express my sincere thanks to Soil Scientist Dinesh Jain Sir and JitenAlawe sir (Krishi Vigyan Kendra-KVK Barwani) for providing me the necessary laboratory facilities, valuable instructions , devices, instruments,costly chemicals during my investigations.

I also wish to express my sincere thanks to Shree RajendraMotiyaniji(President and Chairman Person of Sendhwa Welfare & Development Trust Sendhwa Dist.Barwani MP)for their direct and indirect support, blessings in my work.

My heartly thanks to my father Shree Raghunath Khairanar, my mother SmtRajani Khairanar My lovely Brother Shivendra Khairanar who were always present in all of my good and the bad times and all my family member for their love blessings, inspiration, financial support and never ending faith in me.

I also want to express feelings of gratitude to my wife Smt.Shivani Khairanar for her love, devotion, trust and care enabled me to achieve this goal. I am thankful to the almighty for his grace and immense blessings, always showered upon me.

I also extend my thanks to all who helped me directly or indirectly during their course of investigation.

References:-

1. Allen, J.J., 1990. Termites, soil fertility and carbon cycling in dry tropical Africa: A hypothesis. Journal of Tropical Ecology ,6 (3): 291-305.
2. Brussaard, L., 2012. Ecosystem services provided by the soil biota. In: Soil ecology and ecosystem services. Wall, D.H., Bardgett, R.D., Behan-Pelletier, V., Herrick, J.E., Jones, T.H., Ritz, K., Six, J., Strong, D.R., van der Putten, W.H. (Eds). Oxford University Press. pp.45-58.
3. Castro-Huerta, R.A., Falco, L.B., Sandler, R.V., Coviella, C.E., 2015. Differential contribution of soil biota groups to plant litter decomposition as mediated by soil use. PeerJ 3:e826.
4. Coleman, D. C., 2001. Soil biota, soil systems, and processes. In: Encyclopaedia of Biodiversity. Levin, S.A. (Ed).Vol. 5, Academic Press. pp.305-214.
5. Coleman, D.C., Reid, C.P.P., Cole, C.V., 1983. Biological strategies of nutrient cycling in soil systems. Advances in Ecological Research 13: 1-55.
6. de Bello, F., Lavorel, S., Díaz, S., Harrington, R., Cornelissen, J.H.C., Bardgett R,D., Berg, M.P., Cipriotti, P., Feld, C.K., Hering, D., da Silva, P.M., Potts, S.G., Sandin, L., Sousa, J.P., Storkey, J., Wardle, D.A., Harrison, P.A., 2010. Towards an assessment of multiple ecosystem processes and services via functional traits. Biodiversity and Conservation 19(10): 2873-2893.
7. Edwards, C. A. Chapter 6: The Living Soil: Earthworm In: Soil Biology Primer. Tungel, A., Lewandowski, A. HappevonArb, D. (Eds.) 2000. Soil and Water Conservation Society & NRCS Soil Quality Institute, Ames, IA., USA.Available at: www.statlab.iastate.edu/survey/SQI/soil_biology_primer.htm [Access date: 05.12.2015].
8. FAO, 2005. The importance of soil organic matter: key to drought-resistant soil and sustained food production. FAO Soils Bulletin, No. 80. Food and Agricultural Organization of United Nation, Rome, Italy. pp.11-47.
9. Kibblewhite, M.G., Ritz, K., Swift, M.J., 2008. Soil health in agricultural systems. Philosophical Transactions of the Royal Society B: Biological Sciences 363: 685–701
10. Kramer, C., Gleixner, G.,2008.Soil organic matter in soil depth profiles: Distinct carbon preferences of microbial groups during carbon transformation. Soil Biology and Biochemistry 40(2): 425-433.
11. Lubbers, I.M., Brussaard, L., Otten, W., Van Groenigen, J.W., 2011. Earthworm-induced N mineralization in fertilized grassland increases both N2O emission and crop-N uptake. European Journal of Soil Science 62(1): 152 – 161.
12. Ritz, K., Harris, J., Murray, P., 2010. The role of soil biota in soil fertility and quality, and approaches to influencing soil communities to enhance delivery of these functions. Defra project code: SP1601: Sub-Project A of Defra Project SP1601: Soil Functions, Quality and Degradation – Studies in Support of the Implementation of Soil Policy. Cranfield University and Rothamsted Research, UK, 34 pp.
13. Ritz, K., McHugh, M., Harris, J.A., 2004. Biological diversity and function in soils: contemporary perspectives and implications in relation to the formulation of effective indicators. In: Agricultural soil erosion and soil biodiversity: Developing ýndicators for policy analyses. Francaviglia, R. (Ed.), OECD, Paris, France. pp. 563-572.
14. Six, J., Bossuyt, H., Degryze, S., Denef, K., 2004. A

history of research on the link between (micro) aggregates, soil biota,and soil organic matter dynamics. Soil and Tillage Research 79(1): 7–31.
15. Song X., Song Y., Sun T., Zhang W., Zhou Q., 2004. Bio-indicating function of soil protozoa to environmental pollution. Chinese Journal of Applied Ecology 15(10): 1979-1982. [in Chinese].
16. Swift, M.J., Heal, O.W., Anderson, J.M., 1979. Decomposition in terrestrial ecosystems. University of California Press, Berkeley & Los Angeles, USA. 372p.
17. Usman, S., 2013. Understanding soils: Environment and properties under agricultural conditions. Publish America, Baltimore, USA. 151p.
18. Wall, D.H., Adams, G., Parsons, A.N., 2001. Soil Biodiversity. In: Global biodiversity in a changing environment: Scenarios for the 21st century. Chapin III, F.S., Sala, O.E., Huber-Sannwald, E. (Eds.), Springer-Verlag, New York, USA. pp. 47–82.
19. Yeates, W.G., Coleman, D.C., 1982. Role of nematodes in decomposition. In: Nematodes in soil ecosystem. Freckman,D.W. (Ed.). University of Texas Press. Austin, USA. pp. 50-80.

****