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Soil microbial diversity in conventional and organic agricultural farming systems

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Abstract
Microbes are the most varied category of soil creatures, although little is recognized about them. Until recently, research focused on culturable organisms; however, a lot of information is now being acquired from both culturable and, as of yet, unculturable organisms. The functions of the soil microbial community have an impact on various soil processes and, as a result, productivity. There would be no other life forms without microorganisms and their roles. A better understanding of soil microbial ecology can only improve land management decisions. Low-input agriculture systems seek to reduce the usage of synthetic fertilizers and pesticides in order to promote long-term productivity and ecosystem health. Despite the soil microbiome's critical role in agricultural output, we still have a limited grasp of microbial diversity's complex response to organic and conventional farming. The application of high input conventional farming practices, such as synthetic insecticides, herbicides, chemical fertilizers, genetically modified microorganisms, growth regulators, and other chemicals, has adversely impacted not only soil fertility but also poses serious risks to human health and the environment. Nowadays, organic farming is a viable substitute for traditional farming methods. Using sustainable agricultural practices, organic farming attempts to preserve and improve the health of the land, biodiversity, and natural resources. It plays a vital part in lowering soil erosion, nutrient leaching (especially nitrate and phosphorus), improving soil's ability to retain water, and reducing greenhouse gas emissions. One of the soil functions that agricultural land offers to civilization is the supply of habitat variety.

Keywords: Soil microbial community, sustainable agricultural practices, organic farming, biodiversity, conventional farming

1. Introduction

Plants and related microbes interact in a variety of ways during agriculture. In modern agriculture, focus is placed on ecologically friendly methods, particularly in developing nations, to improve system sustainability with the least detrimental consequences to produce quality and quantity. The configuration of the soil microbial community and the sustainability of the soil have been discovered to be affected by contemporary agricultural methods including heavy tillage, the use of hazardous agrochemicals, monoculture, etc. [2]. In order to raise a healthy and profitable crop, it is anticipated that agriculturally significant microorganisms will play a significant role in numerous strategies, in particular integrated nutrient management and disease and pest management to reduce the use of agrochemicals without compromising agricultural output [3]. These advantageous microorganisms appear to have the capacity to offer an alternate way to counteract the negative impacts of certain elements of the widely used traditional agricultural practices [4]. Diverse environmental activities, such as the reduction of debris, stimulation of nutrient cycling, plant growth, and degradation of toxins, pesticides, are supported by soil microbes. Finding out if any of these soil ecosystem services are impeded by the addition of pesticides is crucial because all of these roles are essential to both farmers and society [5]. Since industrialization, urbanization, and agriculture began to take off, soils have seen a wide range of environmental changes that have altered the taxonomic diversity and operation of the local microbial communities [6]. For thousands of years, farming has allowed human populations to control the planet's landscapes. In order to support the expanding human population, agriculture science has been improved over time.

2. Emergence of microbial diversity

Soil is the one amongst the key components for supporting life on Earth. Indeed, almost ½ of the Sustainable Development Goals (SDGs) are linked to soil [7];

The majority of them can be achieved by utilizing land sustainably and improving soil quality, which is defined as "soil's ability to function as a vital biological system to sustain biological productivity, enhance environmental quality, and maintain plant and animal health," where "animal health" also includes "human health" [8]. More specifically, the ability of soil to supply the several ecosystem services, which are given by soil processes and soil functions, should be used to define soil quality [9]. The more comprehensive idea of soil health now includes the idea of soil quality [10]. An integral component of agro ecosystem management is soil health [11]. And is frequently evaluated by combining a group of physical, chemical, and biological markers that are reflective of the fundamental ecosystem services provided by soil [9, 12-14]. To support the food production for the expansion of human population, healthy soils are crucial. Given the effects of future climate change, soils with active microorganisms and intimate interactions between plants and animals promote effective nutrient cycling, disease resistance, and general crop health as well as long-term ecosystem stability [15]. The primary organisms that maintain plant biomass production and plant health are specifically soil microorganisms [16]. Numerous researches have demonstrated that both direct and indirect modification of plant root and soil microbial populations appears to be a favorable technique to improve food crop productivity, nutritional quality, and safety with positive implications on human and environmental health [17, 18]. Evidence suggests that soils with higher biodiversity levels are generally more resilient than those with lower biodiversity levels because they are more resilient to environmental perturbations [19]. Actively involved in biological functioning and the provision of ecosystem services, and highly sensitive to environmental changes in terms of modifications to biomass, structure/diversity, and activity, microbial communities present a great potential to assess the functional biodiversity in soils [20-22].

Ecologically based pest management and biological fertilizers are used in organic farming as a low-input agricultural approach to maintain crop output. Along the entire supply chain, international and national institutional entities regulate and certify this method and the generated products [23, 24]. It is well recognized that using organic farming methods has many positive ecological effects. However, some research has shown that organic farming typically results in lower agricultural yields than conventional farming [25]. In order to produce the same quantity of product as with conventional systems, more cultivable land must be used, which has an adverse effect on forests and other natural habitats. Nonetheless, organic farming appears to be more competitive under stress conditions and exhibits higher spatial and temporal stability [26]. For instance, crops cultivated organically yield more when stressed by drought and up to 70 % more when stressed severely. This results from enhanced soil properties such greater soil aggregation and water retention, higher SOM concentrations, highest nutrient availability, and increased biomass of the soil food web. There are conflicting data on the variety of soil microbes in organic and conventional farming. Recent meta-analyses have demonstrated that soil microorganisms typically respond well to organic farming by increasing their global microbial biomass, species richness, enzyme activity, and heterogeneity [27]. When compared to conventional farming, organic farming modifies the structure of the soil's microbial population, increases richness, decreases evenness, and disperses less [28].

3. Significant factors that influence microbial diversity

Many recent researches have focused on collecting the variety of soil bacteria and documenting how certain environmental changes or disturbances affect soil bacterial communities. At the local scale, vegetation type, carbon and nitrogen availability, and crop rotation may influence microbial community composition; at the continental scale, soil pH was a greater predictor of community structure. All living organisms are maintained through oxidation-reduction reactions; however, redox potential (Eh) has been given relatively little attention in agriculture, in way of comparison to pH, which is considered the master variable, and it was discovered that bacterial diversity was most dependent on soil factors rather than land-use mode. However, it was discovered that the organization of microbial communities is significantly related to the kind of soil vegetation.

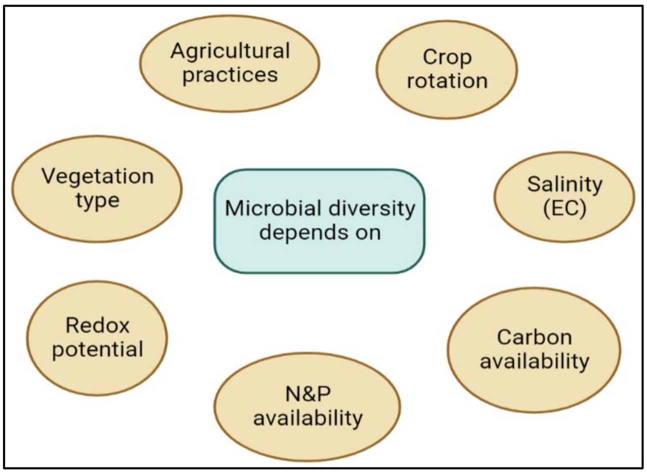

Fig 1: Factors on microbial diversity depends (Image created using Bio-Render)

4. Soil diversity associated with earthworms

Earthworms are frequently referred to as "nature's ploughman" or "the farmer's friend." The physical, chemical, and microbiological communities of the soil are affected by earthworms. Large soil particles and leaf litter are broken down, increasing the amount of organic matter available for microbial degradation. Organic wastes are ground and digested with the aid of aerobic and anaerobic bacteria to produce valuable Vermicompost. It has been discovered that earthworm activity increases the good micro flora and suppresses the bad pathogenic microorganisms. A substantial source of micro- and macronutrients as well as microbial enzymes is found in soil wormcasts. It is anticipated that the activity of earthworm gut bacteria will affect their capacity to boost plant nutrient availability. Earthworms break down the litter and have an impact on the activity of the soil's micro flora, which has an indirect impact on the dynamics of soil's chemical processes. It seems complicated how earthworms and microbes interact. Along with rhizospheric soil, earthworms consume plant growth-promoting rhizospheric bacteria like Pseudomonas, Rhizobium, Bacillus, Azosprillium, and Azotobacter. Due to the favorable microenvironment of the stomach, these bacteria may become activated or increase in number. Thus, the population of rhizobacteria that promote plant growth grows as a result of earthworm activity (PGPR). Earthworms improve soil aeration through their burrowing activities, which in turn stimulates and speeds up microbial activity by increasing the population of soil microorganisms, microbial populations, and biomass [29].

5. Earthworms influence soil microbial communities:
Depending on the species of earthworm and the microhabitat that are taken into account, whether the study is focused on intestinal earthworms, plasters, or soil, earthworms can have a neutral, negative, or favorable impact on the microbial richness and variety of ecosystems. The impact of earthworms on the diversity of soil microbes during the vermicomposting process has also been studied. Equine sp. specifically epigeic earthworms. EPIGEIC earthworms Uh, or E. Uh, or Fetidas boosted the variety of the substrate throughout its initial vermicomposting phases, at the very least, demonstrating that different time scales were taken into consideration in the evaluation of bacterial diversity. Agriculture activities such as crop rotation, fertilization, pesticide use, lime application, drainage, tillage, and irrigation can have a significant impact on earthworm biomass and behavior. Numerous research examining the effects of tillage on earthworm populations came to the conclusion that deep ploughing and intensive tilling reduced earthworm populations in clay loam soils. The effects of tillage in sandy loams were complicated and dependent on a variety of factors, including the types of earthworms present in the soil. The quantity of earthworms was promoted by no-tillage farming practices. However, providing that the disruption is not repeated, populations seem to recover from less intense agricultural forms within a year.

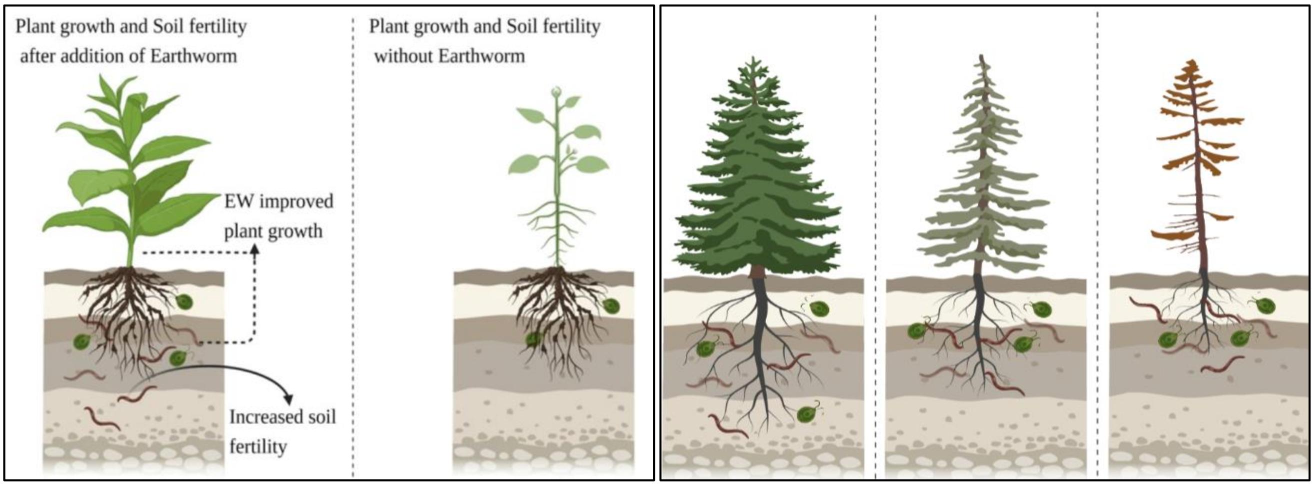

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Fig 2: Influence of earthworms on microbial diversity and plant growth

6. Effect of climate change on microbial diversity
Climate refers to a region's average weather over a long period of time, including factors like temperature, humidity, air pressure, wind, precipitation, etc. A location's climate is influenced by its latitude, height, geography, the presence of adjacent bodies of water, and those bodies of water's currents. Global biodiversity is being impacted by climatic change. It causes the Earth's environment to deteriorate and the loss of biodiversity in plants, animals, and microorganisms [30, 31]. A loss of biodiversity results from the disruption of the host-microorganism connection brought on by climate change. According to reports, changed patterns of microbial interactions also affect the activity of terrestrial ecosystems and bacterial diversity [32, 33]. Additionally, it has an impact on how organisms interact and how species are distributed. A loss of biodiversity results from the disruption of the host-microorganism connection brought on by climate change. According to reports, changed patterns of microbial interactions also affect the activity of terrestrial ecosystems and bacterial diversity [34].

7. Organic Farming: Concept and Components
In Central Europe and India, organic agriculture essentially started at the same time. In Pusa, Bengal (now in Bihar), where he works as an agricultural advisor, the British botanist Sir Albert Howard, who is frequently credited as the founder of modern organic agriculture, documents traditional Indian farming practices and eventually came to value them above his theory of conventional agriculture. JI Rodale starts to popularize the phrase and practices of organic agriculture in the US, especially among consumers through promoting organic gardening [35].
Introduction to the term Organic Farming" – 1939 Lord North-bourne coined the phrase "organic farming" in the beginning. The phrase is derived from his explanation of "the farm as organism" in his book "Look to the Land" (1940). Lady Eve Balfour conducted the first thorough scientific side-by-side comparison of organic and conventional farming under the influence of Sir Albert Howard's research [36]. A production method known as organic farming preserves the health of the soil and people while maintaining a sustainable relationship with the environment. It depends on biodiversity, different ecological processes, and natural cycles to replace the usage of chemical inputs that have negative environmental impacts.
One of the many production techniques that are friendly to the environment is organic agriculture. For most emerging nations, agriculture continues to be the main driver of economic growth. It is crucial for guaranteeing food security, reducing poverty, and preserving the essential natural resources that current and future generations throughout the world will be completely dependent upon for their life and well-being. We are about to enter the twenty-first century, and within just two generations the population of the entire planet will unavoidably quadruple. In metropolitan regions that implement the green revolution approach, more than 90 % of

emerging countries, particularly in Asia, will live [37]. The USDA study team on organic farming defines it as "a system which avoids or largely excludes the use of synthetic inputs (such as fertilizers, pesticides, hormones, feed additives, etc.) and to the maximum extent feasible relies upon crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives, and biological system of nutrient mobilization and plant protection." Fundamental ecosystem services that the soil provides include the cycling of nutrients, management of pests and diseases, transformation of organic materials and hazardous chemicals, and regulation of water [38]. The majority of the time, the use of green revolution technologies, such as increased use of synthetic agricultural chemicals like fertilizers and pesticides, adoption of nutrient-responsive, high-yielding crop varieties, increased exploitation of irrigation potentials, etc., has increased production output. The usage of these large energy inputs without making the right decisions is causing a decline in crop output and productivity as well as a decline in the health of the soil and the environment. The following are the effects of Green Revaluation Technology (GRT) that have been the most regrettable for Indian agriculture and the rest of the world:

1. Altered soil reactivity
2. Emergence of an unbalanced nutritional intake
3. Damage to the soil's vegetation
4. Reduction of earth worm activity
5. Decrease in organic matter or soil humus
6. Altered atmospheric chemistry
7. Decreased productivity
8. A decline in quality produce
9. Degradation of soil aeration, structure, and water-holding ability

It focuses on enhancing the biological fertility of the soil so that crops can absorb the nutrients they require through consistent soil turnover and release of nutrients in response to plant needs. The development of an ecological balance within the system, the application of bio-pesticides, and a variety of cultural approaches, such as crop rotation, mixed cropping, and cultivation, all contribute to the control of pests, diseases, and weeds. All wastes and manures are recycled on an organic farm, however exporting the goods causes a constant loss of nutrients. Increasing the number of crops and animals in systems like polycultures, agroforestry, integrated crop/livestock systems, etc. to reduce risk.

8. Conventional Farming: Concept and Components

Conventional farming consistently handles resource inputs (such as fertilizer, irrigation water, additives, and pesticides), ignoring the naturally inherent spatial heterogeneity of soil and crop conditions within and within fields. The homogeneous application of inputs leads in resource over and under application. Most growers’ overapply inputs in an attempt to optimize crop output across the entire field [39]. Overuse of inputs reduces profitability and has a negative environmental impact on soil, surface water, groundwater, and drainage water. Site-specific crop management ensures that inputs are applied when, where, and in the quantities required. Site-specific crop management takes into account local variability by managing at a spatial scale relatively small than the entire field with the goal of cost-effectively optimizing crop profitability and production while making productive use of finite resource inputs to lessen negative environmental impacts.

Although the word "conventional agriculture" is broad and has several connotations, a crop can be categorized as conventional if synthetic chemicals are employed to keep the plants healthy. In conventional agriculture, a substantial quantity of energy and chemicals are needed to obtain the best crop production feasible. "This practice typically degrades soil quality, destroys biodiversity, and changes the natural environment." (USDA.gov). Conventional agriculture was created to increase farming productivity, but it does so at a significant environmental cost.

Farmers find it simple to maintain conventional farming because it often uses monocropping but is also quite expensive. Farmers will assign entire fields to just one crop in a conventional system, which promotes uniformity. Conventional systems' success or failure can be determined by uniformity. The benefits of a uniform crop include lower labor costs and simpler harvesting, but they can also have an adverse effect on biodiversity and render crops more prone to infections [40]. Farmers can relatively easily maintain conventional systems due to chemicals and genetically modified organisms, but doing so requires ongoing energy and financial investment. In a normal system, farmers may use pesticides and herbicides on crops considerably more effectively if they are made up of just one variety of plant, but this has a number of unforeseen consequences. In conventional agriculture, the preservation of environmental quality and biodiversity is typically not a priority because the main purpose is to enhance yields.

9. Conventional farming vs Organic farming

Conventional farming	Organic farming
It is built on the principles of economic orientation, heavy mechanization, specialization, and misappropriates the growth of businesses with a fragile market-oriented agenda.	Its foundations include an emphasis on the environment, effective input usage, diversification, and stable, balanced enterprise combinations.
Using chemicals to preserve plants, add fertilizer to the soil to supplement nutrients, manage weeds with herbicides, and, rarely, combine with livestock	Cycle of nutrients on the farm, weed control through crop rotation and cultural techniques, plant protection through non-polluting agents, and improved livestock combinations
Conventional farming is based on the belief that crops and plants should be fed	The guiding principle of organic farming is "feed the soil, not the plant."
Production is not environment-integrated, but instead extracts more by technical manipulation, excessive fertilization, and a failure to address nutrient imbalance.	Production is integrated into the environment, plant and animal conditions are balanced, and deficiencies must be remedied.
Low input-to-output ratio and significant pollution	High input -to- output ratio and no pollution
Natural resource economics without taking into account the principles of natural improvement	Adopting comprehensive techniques ensures maximum consideration of all-natural resources.

10. Conventional versus organic farming based on soil microbial diversity

The following areas should be compared between conventional and Organic agriculture: biodiversity, production, soil composition and erosion, water consumption, energy use, and greenhouse gas emissions. Each strategy's overall feasibility as a countermeasure to escalating tendencies will be determined by the environmental impact and production levels of that method. These comparisons are required to determine the optimal agricultural practice that can sustainably meet the demands of the present population. Despite the fact that these comparisons are based on scientific evidence, much more study is required before a final conclusion can be reached.

There are not enough resources to meet the needs of the current population. Conventional agriculture is a practical approach to feed more people without considering the environmental harm caused by intensive production; "population growth and growing consumption of calorie- and meat-heavy diets are predicted to roughly treble human food demand by 2050" [41]. Production levels become a significant point of reference when tackling this rapid expansion. According to a recent meta-analysis, "Organic yields are generally 25 % lower than conventional yields, albeit this varies with crop kinds and species and depends on the comparability of farming systems" [42]. Most studies show that sustainable crops yield significantly less than conventional farming.

This variation in production is the result of numerous causes, because conventional crops are created particularly to give high yields, the divergence should be anticipated. Usually, conventional crops are genetically altered to bring out better than sustainable crops in particular situations. To compensate for their homogeneity, these crops are also sprayed with hazardous pesticides and herbicides. The question of whether greater biodiversity is associated with higher yields has given rise to some research, which found that "farmland biodiversity is typically negatively related to crop yield; generally, organic farming per se does not have an effect other than via reducing yields and thereby increasing biodiversity" [43]. (Sustainable agriculture reduces productivity levels, yet studies suggest that more biodiversity is associated with higher levels of healthier crops.

Due to its influence on the health and productivity of agricultural systems, biodiversity is a key factor in this comparison. Plants are more resistant to pests and disease as biodiversity increases [44]. This needs to be stressed because traditional farming suppresses biodiversity & instead relies on synthetic pesticides to maintain the crop health. Only 10 % of the pesticides applied each year—over 940 million pounds—reach their intended targets; this figure might be drastically lowered if conventional agriculture adopted sustainable alternatives. The use of methods like intercropping and integrated pest management to traditional systems might help to advance biodiversity's.

High biodiversity supports organic farming because it improves the effectiveness of the natural cycles on which crops rely. Because of its flexible crop rotations, lower nutrient inputs, and pesticide restriction, organic farming is often associated with a much higher degree of biological activity, as reflected by bacterium, fungus, springtails, mites, and earthworms. Organic farming methods are often significantly richer in micronutrients and more diverse in species than conventional farming systems. In order to maintain the health of the crops and the environment, it is crucial to promote high nutrient levels and biodiversity. Although crop productivity is not directly influenced by biodiversity, the health and sustainability of sustainable agriculture are greatly impacted by it [45].

11. Conclusion

Soil is one of the most important ingredients for supporting the life on Earth. Indeed, soil is linked to nearly a dozen of the Sustainable Development Goals (SDGs). The majority of them can be achieved by using land sustainably and improving soil quality, which is defined as "soil's ability to function as a vital biological system to sustain biological productivity, enhance environmental quality, and maintain plant and animal health," where "animal health" includes "human health" [8]. Soil quality should be defined precisely by the soil's ability to deliver the numerous ecosystem services which is provided by soil functions and processes. Soil quality is increasingly included in the broader concept of soil health. Soil health is the important aspect of agro ecosystem management.

The technology of agriculture has made it possible for human populations to increase exponentially and take over the landscapes of the globe. Humans may now manage entire ecosystems to support their existence due to advances in this science. But when populations rise, there are fewer resources available. Three key resources—soil, fuel, and water—determine the survival of the world's population, hence it is imperative that they be used as effectively as possible. It is demonstrated that organic farming practices outperform conventional farming practices for a variety of metrics in a comparison of sustainable and conventional agriculture. It is well accepted that biodiversity is critical to preserving soil health. However, microbial diversity loss as a result of anthropogenic activity remains a global issue. Until recently, our understanding of soil biodiversity was constrained by laboratory methods focused on microbial cultivability.

There are not enough resources to meet the demands of the current population. Conventional agriculture is a practical approach to feed more people without considering the environmental harm caused by intensive production. Studies suggest that organic farming reduces productivity levels, yet studies suggest that more biodiversity is associated with healthier crops. Only 10 % of the pesticides applied each year reach their intended targets. The use of methods like intercropping and integrated pest management to traditional systems might help to advance soil bio-diversity's endangered life cycle.

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