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Impact of Natural Farming Practices on Soil Health and Microbial Communities

Aradhana Dohroo

School of Agricultural Sciences, Baddi University of Emerging Sciences & Technology, Makhnumajra, Baddi, Distt. Solan (HP), India (dohrooaradhana@gmail.com)

ABSTRACT :

Natural farming practices have been found to effect several changes in the soil that collectively contributed to replenish soil health. The adoption of natural farming practices encountered a variety of practical, economic, and ecological challenges that hindered its widespread implementation. Transitioning from conventional to natural farming required overcoming the knowledge gap associated with alternative techniques such as multi-cropping, cover cropping, and biomass mulching. Long-term natural farming practices have also been investigated to alter soil bacterial, fungal and virus population in the soil microbiome without necessarily affecting beneficial microbial diversity. The microbial community exhibited robust populations of nitrogen-fixers and phosphorus-solubilizers, along with a variety of Archaea implicated in sulphur cycling. Soil microbial community composition, diversity, and richness were found to influence crop yield and food nutrition. Natural farming practices encouraged microbes such as bacteria, fungi, protozoa, and algae and ultimately had a positive effect on soil microbial communities. Incorporation of natural farming practices into arable systems also enhanced bacterial and fungal biomass which maintained microbial diversity, stimulated species richness and supported microorganisms central to soil microbiomic system essential for ecosystem functions as reviewed hereunder.

Keywords: Natural farming practices, soil health, soil microbial population

Introduction

Natural farming practices aim at a sustainable agriculture that avoids synthetic agrochemicals and promote biodiversity conservation and soil health through beneficial microbial communities. These approaches adopt crop diversification, cover cropping, organic amendments, reduced tillage, and integrated livestock management, beside other techniques. Consequently, natural farming plays a pivotal role in enhancing soil quality as reflected in the restoration of physicochemical and biological properties. This review provides a comprehensive status of contemporary evidence on the effects of natural farming practices on soil health and microbial communities.

Soil health broadly includes the soil function through a vital living system that sustains plants, animals, and humans besides soil microbial communities. This concept encompasses physical soil properties, chemical characteristics, and biological traits that influence the sustaining capability. Microbial communities are integral to soil health, carrying out essential functions such as nutrient cycling, carbon decomposition, and pollutant remediation Chen et al., (2018) reported that natural farming practices promote soil health by minimizing soil disturbances often incorporating diverse crop species in rotation or multi-crop system along with livestock integration.

Among the methods that foster soil quality under natural farming, compost application function at its best to promote microbial communities. Incorporating compost supplements help to provide essential nutrients while augmenting the carbon supply, thereby assisting microbial populations in establishing and functioning effectively. Besides, increased microbial diversity support vegetation growth thus emphasizing their vital role in soil health recovery.

Overview of Natural Farming Practices

Natural farming depends primarily on foliar delivery of plant nutrients and the addition of biologically produced nutrient amendments. These elements shape plant nutrition, permit higher carbon inputs in certain soil compartments stimulate microbial-derived mineralization activity, enhance the presence of plant-growth-promoting bacteria, and redirect microbial nitrogen use towards assimilation. Increased soil nutrient availability, together with modifications in nutrient cycling dynamics and microbial activity support and sustain greater crop productivity (Singh et al., 2023).

Soil Health

Soil health refers to the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans and soil **microbiome**. A multitude of physical, chemical, and biological properties contribute to soil health, including nutrient availability, pH, texture, structure, infiltration rate and organic matter content (Singh et al., 2023). Enhanced soil health is critical for sustainable agriculture and natural farming system. Soil provides essential support, nutrients, and water for crop growth and plays a major role in the global carbon cycle. It is a crucial natural element that determines the quality and quantity of crop production. Therefore, natural farming affects soil properties and microbial communities and thus has overall impact on crop growth. Organic matter plays an essential role in soil health by enhancing physical, chemical and biological properties (Zarraonaindia et al., 2020). It improves soil structure, stabilizes soil aggregates and increases water-holding capacity to reduce erosion and runoff, while providing a carbon source for diverse microbial communities that drive nutrient transformations. Natural farming practices depend heavily on organic matter generation and incorporation through residue retention, compost applications and cover cropping which maintain or increase soil organic matter levels. For example, aerobic rice systems continuously supply organic C either by decomposing rice straw or surface mulching of leguminous leaf material achieve near-zero tillage and reduce chemical inputs. Organic matter enhances nutrient availability by increasing cation exchange capacity, pH buffering and retention of macro- and micronutrients to reduce leaching losses. It elevates levels of key nutrients such as nitrogen, phosphorus, potassium, sulphur, calcium and magnesium, while reducing aluminum toxicity. Organic farming systems typically contain greater accumulation of these nutrients relative to conventional practices. The presence of organic matter also supports diverse and active microbial populations. Increased substrate availability, less disturbance, lower chemical inputs and greater plant diversity combine to stimulate microbial growth, enzymatic activity and a wider range of soil processes. Microbial biomass, respiration rates and extracellular enzyme activities commonly increase. Communities shift in response to altered organic inputs, nutrient concentrations and crop choices, frequently coupling with enhanced diversity and higher concentrations of beneficial rhizobacteria such as *Pseudomonas* species and rhizobia capable of nitrogen fixation. Beneficial rhizobactera especially plant growth promoting rhizobacteria (PGPR) that induce systemic resistance (ISR) against pathogen infection.

Soil Microbial Communities

Soil microbial communities provide critical ecosystem functions to the crop plants and are relevant to soil health (Chen et al., 2018). Their role includes degradation of organic matter and residues, formation of soil organic matter, nutrient mobilization, nutrient uptake by vegetation and cycling of nitrogen, sulphur and phosphorous (Lahlali et al., 2021). Change in soil management system may influence these functional roles due to alteration of the soil microbial ecosystem.

Natural Farming and Soil Properties

Adoption of natural farming practices influence various soil attributes by improving soil physical, chemical, and biological properties. Natural farming represents a method to restore soil health unlike environmental concerns associated with conventional farming. The practice of natural farming appears to offer beneficial effects on soil health lending support for its broader adoption (Zarraonaindia et al., 2020).

The soil's physical properties including texture, structure and bulk density, substantially respond to natural farming practices. Insect-pest management system involving synthetic fertilizers and pesticides lead to increased bulk density and reduced aggregate stability, whereas natural farming practices lead to decreased bulk density and enhance aggregate stability. Physical forms and structural arrangements develop during soil formation are influenced by soil treatments. Aggregate stability, frequently measured as mean weight diameter is a vital indicator related to texture and organic matter content. Higher aggregate stability preserves porosity, promoting water infiltration and root growth while reducing surface run-off and erosion. Organic matter is essential to improve structural stability whereas the incorporation of large quantities through compost enhances aggregate stability. Crop rotations that include extensive root and biomass production also contribute significantly. These additions also contribute to insect-pest and disease management. It has been seen that diseases like root rot of apple, stalk rot of cauliflower and rhizome rot of ginger are well managed by these practices which are caused by various species of *Dematophora (Rosellinia), Sclerotinia,* and *Pythium-Fusarium-Meloidogyne* interactions, respectively. Dry soil conditions reduce biological activity, limiting organic matter additions and aggregate formation. Soil structure influences root penetration, seedling emergence, moisture and nutrient availability and air movement. Good structure enables deep drainage and efficient aeration, while poor structure causes problems from inadequate aeration or water saturation. Hence, the physical properties directly bear upon moisture availability, root development, and gaseous exchanges (Singh et al., 2023).

The chemical properties of soils under natural farming are characterized by increases in soil organic C, total N, available P, and exchangeable K and Ca. Numerous long-term experimental results showed that continuous chemical fertilization and pesticide use negatively affect the physico-chemical properties of soil. When natural farming practices i.e., soil health practices through use of manure and no chemical fertilization are followed, then soil fertility was maintained at a level comparable to or even higher than that of natural-farming plots.

Chemical fertilizers influence soil microbial communities, with chemical fertilization able to negatively affect these communities by decreasing diversity, richness, and evenness (Zarraonaindia et al., 2020) when compared with manure treatment or manure substitution. In a long-term experiment, Luan et al. (2020) reported dramatic changes in soil microbial communities in response to chemical fertilization in greenhouse soils. Therefore, the use of chemical fertilizers has a large negative impact on soil microbial communities by reducing community diversity and heterogeneity.

Earth's surface water is largely anomalous based on the planet's overall elemental characteristics and Phanerozoic sea water is related to the production and destruction of continental crust on the basis of granitic rocks that dominate the continental crust. Therefore, trace elements and water interact with the characteristics of the planetary surface. The origin of life on earth is believed to coincide with one or more missing events distributed over the earth and the first life-forms emerge in a nearly waterless environment. Plants and microbes have close associations based on mineral nutrition. Although plants are specialized for phosphate acquisition from mineral nutrition, microbes enhance plant acquisition and play significant roles in soil ecosystems. Control of microbial populations by insects is one of the main drivers of natural farming in the system while indigenous microbes that are maintained by the system are linked to the creation of soil. Maintaining indigenous microbes in the environment, therefore, helps to maintain ecosystem function. The biological properties of natural farming are based on indigenous microbes and insects; these properties are linked to nutrients and mineral nutrition. Modelling natural farming systems aids characterizing soil ecosystems and predicting the behaviour of microbial communities in the natural farming system. The elasticity of microbial communities is a direct consequence of the interactions between insects and indigenous microbes. The use of Exopolysaccharide (EPS) virulence factors to alter the characteristics of physical properties is also important for natural farming.

Impact on Soil Microbial Diversity

Agricultural practices can profoundly influence soil microbial communities, which are central to ecosystem functioning and crop health (Chen et al., 2018). Natural farming which is a set of low-intervention methods designed to maintain and restore fertile soils may differentially impact these communities relative to conventional methods. Techniques commonly used under a natural farming approach include crop rotations with legumes, reduced or no tillage, two-step mulching with organic materials, use of indigenous micro-organisms on plant foliage, and application of fermented mixed vegetable and animal extracts. This review illustrates the relationships among such soil-conserving practices, soil microbial diversity and soil health.

Microbial communities are crucial to soil health (Zarraonaindia et al., 2020). Long-term natural farming practices alter soil bacterial and fungal population without necessarily affecting microbial diversity. Organic systems tend to enrich bacteria from the Acidobacteria, Actinobacteria, Bacteroidetes, Chloroflexi, and Gemmatimonadetes phyla, while certain fungal classes such as Lecanoromycetes account for about 10% of total fungi under organic management are almost absent elsewhere. Variability remains across studies because differences in climate, soil type, and management method influence the number and nature of operational taxonomic units (OTUs) sensitive to farming practices.

Crop Rotation

Crop rotation is regarded as one of the key components of sustainable farming systems. It refers to a planned sequence of different crops grown on the same land in successive seasons over time. Crop rotation is used to avoid nutrient losses, enhance crop yield, and mitigate soil-borne pathogens (Kracmarova et al., 2022). It significantly affects microbial diversity and structures in soil, with diversity increasing in soil of rotation systems with multiple crops. In studies from the Czech Republic, soil microbial communities after 20 years of fertilization and crop rotation were examined to assess long-term effects on bacterial and fungal diversity, community structure, and soil chemistry across Chernozem, Luvisol, and Cambisol soil types. Twelve phyla/classes were present in rotational corn compared to 17 in continuous corn, with Betaproteobacteria, Acidobacteria, Actinobacteria, and Alphaproteobacteria identified as the most important taxa contributing to variations between the two cropping systems in bulk and rhizosphere soils Joseph Jr. Muratore, (2019). These taxa exhibited successional patterns over the growing season that may differ depending on cropping sequence, indicating that overall microbial biomass may not be a sufficient indicator for soil health and crop yields; instead, analyzing the composition and temporal dynamics of microbial groups which could be more useful. Soil communities likely undergo changes during plant growth stages, as total PLFA (Phospholipid Fatty Acid) increased by approximately 50% from winter to summer across various systems. PLFA is a technique used to assess soil microbial communities. It analyzes the fatty acids found in the phospholipids of microbial cell membranes. Information on long-term studies tracking microbial community changes across years and climates remain lacking. The assessment of soil health from a biological perspective increasingly focuses on understanding how microbial community structure and function influence ecosystem services such as crop yield and soil health system.

Cover Cropping

Cover cropping serves as a powerful natural farming strategy to reduce soil degradation and enhance soil health. By maintaining soil cover at all times, cover crops mitigate soil erosion caused by water and wind during fallow periods. This practice safeguards soil structure and preserves organic carbon reserves. Furthermore, cover cropping diminishes soil water loss by modulating evapotranspiration, acting in synergy with conservation tillage to improve overall soil physical properties. Soil microbial communities play vital roles in sustaining ecosystem functioning, facilitating matter and energy turnover, and contributing to other key processes such as organic matter decomposition, re-aggregation of soil particles, and the provision of essential ecosystem services. These microbial communities are pivotal for soil functioning and ecophysiology but are highly susceptible to disturbances induced by agricultural management (Kim et al., 2020). In addition to mediating interaction networks among different soil microorganisms, bacteria also support the activities of soil microfauna and develop symbiotic associations with certain faunal groups to form rhizospheres and promote plant growth. Consequently, the application of cover cropping is of societal importance because it offers considerable benefits to soil health stability and sustains a highly diverse and complex soil microbial community that enhances agricultural productivity (A. Seitz et al., 2024).

Composting

Natural farming offers systems wherein chemical and synthetic inputs are minimized or eliminated and methods synergistically harmonize with biodiversity. Composting, in particular, influences the soil microbiome by building and sustaining soil organic matter, thereby positively affecting microbial populations and ultimately plant growth (Kraut-Cohen et al., 2023).

Continuous compost amendment alters the soil microbial community structure, diversity, and function thereby shifting its activities. The extent of such shifts depends on both the amendment rate and the character of the microbial community introduced through the compost. Agricultural composts also impact the soil microbial community in crop rhizospheres with respect to both the plant's response and the particular properties of the compost applied (Zhen et al., 2014)

Reduced Tillage

Tillage practices also influence the rate of soil degradation and carbon sequestration through their impacts on soil microbial biomass. Microorganisms play an essential role in organic matter dynamics as they produce a variety of extracellular enzymes with the ability to break down organic polymers into smaller molecules. M Zuber, (2017) found that no-tillage and cover crop approaches provided benefits to microbial biomass and enzyme activities that probably add up to long-term system benefits in terms of carbon and nitrogen cycling, highlighting the potential for these approaches to improve soil health. The management of tillage over long periods has a significant impact on related soil quality traits.

Case Studies on Natural Farming

The microbial community exhibited robust populations of nitrogen-fixers and phosphorus-solubilizers, alongside a variety of Archaea implicated in sulphur cycling. Even with reduced tillage focused on deep soil penetration, crop yield and quality are comparable to other approaches, underscoring the efficacy of integrated natural farming practices for maintaining soil function and crop performance. These examples confirm that natural farming can preserve or enhance soil quality through management that supports microbial diversity and biological function.

In other study during 2009, seven farms and an experimental station regionally representative of natural farming systems were selected for detailed study. All were located at elevations between 700 and 1000 meters. Topsoil samples taken from the 0–20 cm layer during the 2010 harvest revealed a pH range between 5.0 and 6.4 (Singh et al., 2023). The local agriculture uses slightly acid reaction water for irrigation. In the farms, soil pH tended toward the upper end of this range, whereas at the experimental station, it was nearly neutral. Soils derived from ancient calcareous mudstone and younger granite debris consisted of silt clay to sandy loam textures.

In a third study, situated in an arid belt characterized by low average annual rainfall, experiences a hot and dry tropical climate that fluctuates between arid and semiarid conditions due to seasonality. Average temperatures ranged from 26 to 35°C throughout much of the year, and the region is predominantly occupied by medium black soils.

Natural farming has emerged as a solution to address low soil fertility and concerns related to long-term sustainability detected at two other study locations demonstrated spatial and temporal adaptability which were similar to those applied in Region A under analogous conditions. No short- or long-term fertilizer treatments have been applied during the adoption period. Sampling was conducted after harvest in the main crop seasons during 2012 and 2013. Soil suspensions were separated via a series of two 1,000-µm sieves; the material retained on the sieves was utilized for microbial community determination. Although the overexpression of photosynthetic-related pathways is consistent with the observed higher diversity of active plants under NPKF, sites within Region C, where natural farming has been practiced for over ten years, exhibited a reversed trend (Chen et al., 2018).

The bacterial community was found to be approximately tenfold greater in soil samples from Region C than from the other two sites. The taxa families differ as well; Alphaproteobacteria dominate in Regions A and B low soil, whereas Acidobacteria prevailed in Region C, and taxonomic composition varies across Regions A, B, and C, irrespective of site. Understanding architectural traits for PHA accumulation is of interest for biomaterial applications (Singh et al., 2023).

Natural farming systems tend to restore the natural soil environment. Consequently, integrated practices comprising natural farming may be an attractive tool for meeting local economic constraints through improved economic efficiency, fertility restoration, and environmental interactions, and creating conditions favorable for application in Region C.

Comparative Analysis with Conventional Farming

Natural farming practices positively influence soil quality and enhance beneficial microorganisms compared to conventional agriculture (Zarraonaindia et al., 2020). While nitrogen fertilization alters soil properties, organic amendments exert a more profound impact on microbial populations and soil functions (Chen et al., 2018).

Conventional row crop agriculture intensively employs synthetic chemicals, causing soil degradation, emphasizing the need for sustainable alternatives such as organic and mixed farming systems that reduce reliance on inputs and recycled nutrients. Organic farming incorporates animal waste, green manure, cover crops, and integrated pest management strategies, mitigating the adverse effects associated with conventional practices. Mixed farming, combining crop and livestock production, improves resource use efficiency and manages risk thereby better emulating natural ecosystems.

Diverse ecosystems typically exhibit greater stability and productivity; accordingly, biodiversity promotes ecosystem resilience to environmental change and specific species fulfill critical structural and functional roles. High-throughput DNA sequencing has unraveled responses of microbial taxa to agricultural management, revealing marker microbial groups characteristic of conventional and organic regimes. Numerous soil bacterial and fungal taxa show management-type specificity. Certain microbial taxa such as Actinobacteria, Acidobacteria, and Proteobacteria are particularly sensitive to intensive agricultural practices. Understanding of soil microbial communities is crucial for bridging the knowledge gap between community composition and ecosystem functioning. Ultimately, elucidating mechanisms by which soil microbes mediate agricultural sustainability and productivity enables design of land use strategies that concurrently optimize yields and conserve soil resources.

Soil Health Metrics

Soil health considers the capacity of a soil to function as a vital living system for sustaining biological productivity, maintaining environmental quality, and promoting plant, animal, and human health. Soil physical parameters such as bulk density, penetration resistance, porosity, nutrient availability, and water retention characterize soils with a good level of health and are typically associated with higher microbial activity and crop productivity (Singh et al., 2023). Natural farming may maintain or enhance soil health across diverse systems and regions. This observation aligns with reports indicating that organic systems generally exhibit higher microbial diversity and abundance than conventional, particularly under stable environmental conditions (Zarraonaindiaet al., 2020).

Microbial Community Composition

Natural farming significantly alters soil microbial communities, reducing diversity yet enhancing beneficial taxa that improve nutrient cycling and crop productivity. An 18-year experiment observed consistent reductions in bacterial, archaeal, and fungal diversity under natural farming, while organic management increased fungal richness and maintained diversity comparable to natural ecosystems. Natural farming also enriched groups such as Proteobacteria, Firmicutes, Bacillus, and Arthrobacter recognized for roles in phosphorus solubilization, nitrogen fixation, and stress suppression. Multiple beneficial taxa—Rhizobiales, Azospirillum, Acidobacteria, candidate phyla AD3 and WS3, and Planctomyces—demonstrated strong positive correlations with plant productivity. These alterations indicate a shift towards microbial assemblages that enhance nutrient availability and plant growth in nutrient-limited environments (Chen et al., 2018). Investigations into horticultural systems with sustained organic fertilizer inputs and inter-annual crop rotations reveal that such practices reinforce the modification of soil microbial communities, favoring various plant-growth-promoting bacteria that potentially contribute to long-term crop yield stability and efficiency (Zarraonaindia et al., 2020). These findings highlight natural farming's impact on microbial dynamics, suggesting pathways through which farm management shapes microbial ecology to support agricultural sustainability.

Challenges in Implementing Natural Farming

The adoption of natural farming practices encounters a variety of practical, economic, and ecological challenges that can hinder widespread implementation. Transitioning from conventional to natural farming requires overcoming the knowledge gap associated with alternative techniques such as multi-cropping, cover cropping, and biomass mulching. Farmers accustomed to synthetic inputs may lack the expertise to effectively manage the timing and quantities of organic amendments necessary to maintain soil fertility. Economic considerations also play a critical role; initial yield reductions during the conversion phase may threaten the financial viability of farming operations. Limited access to sufficient quantities of organic materials for composting can further restrict adoption, particularly in resource-constrained regions. Ecologically, the reliance on natural amendments raises concerns about the potential accumulation of harmful substances and the consistent suppression of specific pest populations. Additionally, the absence of synthetic pesticides and fertilizers demands robust plant health monitoring and alternative pest management strategies to maintain crop productivity. Addressing these challenges is pivotal to enabling the broader application of natural farming, thereby realizing its benefits for soil health and microbial communities (Chen et al., 2018 and Gupta et al., 2022).

Future Thrust

Natural farming has garnered considerable momentum across all regions of the world over the last few decades. Although its origin can be traced to the traditional farming practices, it went mainstream only when Masanobu Fukuoka undertook a campaign, soon after the Second World War, with the goal of reviving the Japanese agriculture and countering the dwindling transformation of the farming practices by chemical fertilizers and pesticides.

Natural farming is a method of agriculture that favors as little outside intervention as possible and instead draws upon the benefits that come from what is already available, e.g., rainfall, sunlight, nutrients from plants and leaves to retain the fertility of the land. While ensuring high crop production, this method is sustainable and environmentally friendly, posing no toxic risks to the health of the community at large.

The soil is a complex living matrix composed of mineral particles interspersed with organic matter and countless microbes. Together, they provide a platform that promotes seed germination and sustains growth. Given the diversity of the species of plants that can be grown at a farm or the scale at which the farm is operated, ensuring the health of the soil can be complicated. For example, without the proper balance between drainage and water retention, the soil becomes either waterlogged or cracked, both of which results in poor crop growth. Consequently, the fertility, as a measure of its ability to grow healthy plants, is often used as the yardstick for soil health.

There are four elements that compose the soil: liquid, atmosphere, mineral particles, organic matter. The ensemble of the liquid and atmosphere forms the soil pore space, a crucial factor in the support of life, particularly for root exchange of oxygen and carbon dioxide. Devoid of pores, the water will be stagnant and devoid of oxygen, a situation which is detrimental to the health of the plants and microbes. The mineral particles, which are the result of decomposition of rock over time, contributes chiefly to the physical structures of the soil. Soil texture, which is determined mainly by the relative composition between sandy soil, clayey soil and silt, provides an indication of the ability to retain nutrients and water.

Natural farming practices lead to several changes in the soil that collectively contribute to replenishing soil health. The soil shows a general increase in moisture due largely to rainfall and irrigation. Although a complete coverage is not observed, roughly 20 %–30 % of the moisture is retained compared to that in the mineral soil. The surface environment at the very least provides an effective mechanism to reduce evaporation of moisture, a critical feature for drought resistance.

Though nitrogen, phosphorous, and potassium show no major change, many of the minor and micronutrients such as silicon, sulfate, iron, manganese, calcium, and magnesium exhibit modest increase, fortifying the chemical composition of the soil. Over longer periods, the accumulation of organic matter and nutrients should be able to sustain plant growth Chen et al.,(2018).

Policy Implications

Policy should encourage farmers to adopt natural farming to curb degradation of ecosystem and socio-ecological systems (Gupta et al., 2022). Soil microbial community composition, diversity, and richness influence crop yield and food nutrition (Chen et al., 2018). Natural farming practices encourage microbes such as bacteria, fungi, protozoa, and algae, and ultimately have a positive effect on soil microbial communities.

Conclusion

Soil health represents the capacity of soil to function as a living ecosystem, supporting plant and animal productivity, regulating water flow, filtering and buffering potential pollutants, sustaining biological activity, maintaining environmental resilience, and promoting plant and animal health. Microbial communities underpin key soil ecosystem functions such as nutrient cycling, organic matter decomposition, and biomass production. In agro-ecosystems, these communities influence nutrient availability, support plant health, and regulate the fate of pesticides and pollutants. While microbes do not mediate all aspects of soil health, they are fundamental to nutrient cycling and plant–soil feedbacks.

Incorporation of natural farming practices into arable systems enhances bacterial and fungal biomass, maintains microbial diversity, stimulation of species richness and support for microorganisms central to below-ground processes essential for ecosystem functions (Zarraonaindia et al., 2020). Lately, a study published in Science (August14, 2025) demonstrated that maize plants grown in high density plots communicated with neighboring plants that triggered a swift immune response which induced production of jasmonic acid in adjacent plants and resulted in reshaping microbiome population.

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