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Evaluation of Physicochemical and Microbial Parameters to Assess Soil Health in Agricultural and Garden Soils of Nagaland

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ABSTRACT

This study presents a comparative analysis of the chemical composition and microbial population in agricultural and garden soils to evaluate soil fertility, nutrient availability in land use systems. Agricultural soils, managed through regular tillage, synthetic fertilization, and irrigation, were compared with garden soils, which are typically enriched with organic matter and subject to minimal mechanical disturbance. Key chemical parameters analyzed included pH, organic matter, nitrogen (N), phosphorus (P), potassium (K), and essential micronutrients. Agricultural soils showed higher concentrations of nitrogen and phosphorus due to frequent fertilizer applications but exhibited lower organic matter content.

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The pH in agricultural soils tended to be slightly alkaline, influenced by lime amendments, whereas garden soils were more acidic, attributed to organic decomposition and natural nutrient cycling. Microbial analysis revealed differences in total microbial count, encompassing bacteria, fungi, and actinomycetes, as well as key functional groups such as nitrogen-fixers and decomposers. Agricultural soils recorded higher bacterial populations driven by nitrogen input but had reduced microbial diversity due to monoculture and chemical inputs. Conversely, garden soils demonstrated greater microbial diversity and a higher presence of beneficial fungi and actinomycetes, supported by rich organic content and reduced soil disturbance. The results highlight that although agricultural soils provide quick nutrient access, their microbial health and long-term sustainability may be compromised. The garden soils promote healthier, balanced ecosystems through enhanced microbial activity and organic enrichment.

Keywords: Soil fertility, Microbial diversity, Chemical composition, Agricultural vs. garden soils

1. INTRODUCTION

The soil is the foundation of every terrestrial ecosystem, and it plays a crucial role in the major global biogeochemical cycles of carbon, nutrients, and water (Smith et al., 2015). Soil has a wide range of chemical and physical characteristics. Numerous different soil types are created by the interaction of natural processes like leaching, weathering, and microbial activity. In addition to acting as a structural support for the plant, soil provides the vital nutrients, water, oxygen, and root support that plants require to grow and flourish (Powlson et al., 2001). It also serves as a buffer to safeguard delicate plant from drastic temperature changes (Onwuka and Mang, 2018). Healthy soil is a living, dynamic ecosystem that is teeming with small and large organisms that convert dead and decaying matter, among other essential functions. Fertile soil contains primary plant nutrients like nitrogen, phosphorus, and potassium, along with minor nutrients that aid in the growth of agricultural and horticultural crops (Kumar and Singh, 2016). Soil is a ubiquitous medium for growing all types of crops, and as a result, soil is crucial to human societies because we rely on it to produce food and other resources (Tilman et al., 2002). The state of the soil has a significant impact on the environmental sustainability of forestry, horticulture, and agriculture. Additionally, the production of wholesome food, which affects human health, is directly related to soil health (Frac et al., 2018).

Since time immemorial, the Northeastern region of India has fascinated and inspired naturalists and scientists. Its diverse and rich flora and fauna attract biologists from all over the world. It offers numerous diverse microclimates and ecological niches to higher plants as well as to microorganisms. The Northeastern region has been identified as a hotspot for biodiversity, so the scientific community must also pay attention to its microbial diversity. Therefore, given the diverse biodiversity of Northeastern India, including Nagaland state, extensive exploration of the soil fungal and bacterial diversity is essential. Nagaland is a hilly state in the Northeast India. It has a total geographical area of 16,579 sq km. It is bordered by Manipur in the south, Myanmar in the east, Assam in the west, Arunachal Pradesh, and a portion of Assam in the north. It is located between 93° 20′ to 95° 15’ E longitude and 25° 60’ to 27° 40’ N latitude. The climate in the state ranges from subtropical to temperate and experiences summer rain from the South West Monsoon and winter rain from the North East Monsoon, with an average annual rainfall of 2000–2500 mm. The temperature ranges from 16 to 31°C in summer, while in winter it can drop down upto 4°C. Dimapur district, under Nagaland state, has a hilly topography and several mountain ranges, narrow valleys, and a few plains, due to which agriculture can only be practised on manageable slopes (Jamir et al., 2015). Agriculture that uses a monoculture system has the potential to alter certain soil properties, including species richness, microbial activity, and community structure. The dynamics of the microbial community in soil have been shown to be considerably impacted by changes in land use patterns (Gupta et al., 2022).

Nagaland, a state in Northeast India, is characterized by diverse agro-ecological zones, ranging from steep hills to valleys, with varying soil types and land use patterns. Agriculture is the primary occupation of the majority of the population, with rice being the staple crop. Garden soils, typically found in homesteads and urban areas, are often managed more intensively with organic amendments and irrigation. Understanding the differences in chemical composition and microbial population between agricultural and garden soils in Nagaland is essential for developing sustainable soil management practices that enhance agricultural productivity and promote environmental conservation.

The chemical composition of soil includes both organic and inorganic components. Organic matter, derived from decomposed plant and animal residues, is a vital source of nutrients, improves soil structure, and enhances water-holding capacity. Inorganic components, such as minerals and clay particles, provide essential nutrients and influence soil pH, cation exchange capacity (CEC), and other chemical properties. Key chemical parameters commonly analyzed in soil include pH, organic carbon, nitrogen, phosphorus, potassium, and micronutrients. Bardgett, and van der Putten, (2014). The microbial population in soil is incredibly diverse, encompassing bacteria, fungi, archaea, and other microorganisms. These microbes play critical roles in nutrient cycling, organic matter decomposition, disease suppression, and plant growth promotion. Bacteria are the most abundant microorganisms in soil, involved in a wide range of biochemical processes, including nitrogen fixation, nitrification, denitrification, and phosphate solubilization. Fungi are important decomposers of organic matter and form symbiotic associations with plant roots, enhancing nutrient uptake (Torsvik, and Ovreas, 2002).

Comparative analysis of chemical composition and microbial population in agricultural and garden soils can provide valuable insights into the impact of land use and management practices on soil health and fertility. Agricultural soils, often subjected to intensive cultivation, fertilization, and pesticide application, may exhibit altered chemical properties and microbial communities compared to garden soils, which are typically managed with organic amendments and less intensive practices (Chaudhary et al., 2018). However, chemical imbalances in soil, such as high levels of salinity, nutrient deficiencies, or pH extremes, can inhibit microbial activity, reducing microbial diversity and affecting soil fertility. This feedback loop between soil chemistry and microbial populations makes it crucial to manage both aspects for optimal soil health. To compare chemical composition and microbial population in agricultural and garden soils, assessing land use impact on nutrient levels, microbial diversity, and overall soil health and fertility.

2. MATERIALS AND METHODS

Soil Sample Collection

Soil samples were collected from the surface layer (0–15 cm) of agricultural and garden lands in different regions of Nagaland. Samples were air-dried, sieved through a 2 mm sieve, and stored in sterile containers for analysis. The present study was conducted during 2024-25 to assess various soil characteristics and nutrient availability status under cultivated (terrace and valley) and hilltop forest soil (0-15 cm) under Zabo farming system. The villages from the Chenloisho, Mon town, Dimapur district were selected for soil sampling. One composite soil sample from cultivated area and one sample from the hilltop forest soil were collected from each selected village.

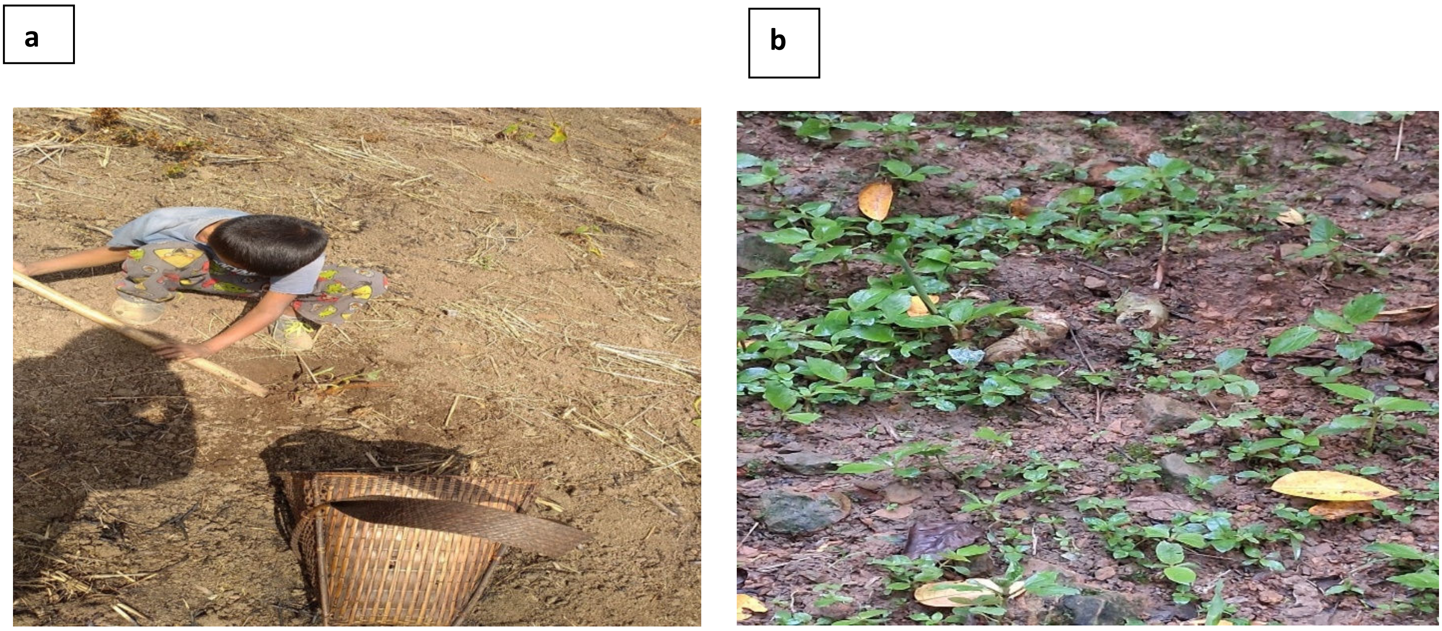


Figure 1. a) Agricultural and **b)** Garden soil lands in Nagaland

Physicochemical Analysis of Soil

Determination of Soil pH:

The pH of the wet soil samples was determined in 1:2.5 soil water suspension, potentiometrically measured using a pH meter (Page et al., 1982).

Estimation of Electrical Conductivity (EC) (ds/m)

EC of the soil was obtained in soil water (1:2) extract using conductivity meter (Richard, 1954). CEC of the soil was determined by leaching of soil with 1N ammonium acetate (NH4OAC) at pH 7.0 (Chapman, 1965).

Estimation of Nitrogen

Nitrogen was estimated by alkaline KMnO4 method. 5 grams of 2 mm sieved soil was distilled with 25 ml of 0.32% alkaline potassium permanganate solution in the presence of 25 ml of 2.5% sodium hydroxide (NaOH) solution in 300 ml distillation tube using N distillation system. The liberated ammonia collected in boric acid mixed indicator solution was titrated against 0.02 N H2SO4 to estimate available N by Subbaih and Asija (1956).

Estimation of Phosphorus

P in soil was determined by following the stannous chloride blue colour method (Bray and Krutz 1945; Page et al., 1982). Finely grinded air dried soil (5 gm) was extracted with 50 ml of 0.03N NH4F in 0.025N HCL for 5 min in a reciprocating shaker. After shaking, the soil suspension was filtered through Whatman No. 42. 5 ml of the supernatant was taken for developing blue colour by adding 5 ml of Dickman Bray's reagent and 1 ml stannous chloride. Finally, intensity of blue colour was measured at 660 nm and concentration of P was obtained from the standard curve. Available phosphorus was expressed as kg ha-1.

Estimation of Potassium

Potassium was analyzed by Hanway and Heidal (1952) method, wherein 5 gram of 2 mm sieved soil was shaken with 25 ml of neutral normal ammonium acetate solution for 5 minutes and filtered through Whatman No. 42 filter paper. The extract was analyzed for sodium and potassium using flame photometer (Hanway and Heidal 1952). Values of soil attributes were analyzed by SPSS (v.01) for group comparison using non-parametric Kruskal-Wallis H test, incorporating Monte-Carlo significant test at 95% confidence limit.

Estimation of Organic Carbon (%)

Method: Walkley-Black titration method (Wet Oxidation).

Procedure:

1. Weigh 1.0 g of finely ground air-dried soil into a 500 mL conical flask.
2. Add 10 mL of 1 N potassium dichromate solution.
3. Add 20 mL of concentrated sulfuric acid carefully and swirl the flask gently to mix.
4. Let the mixture stand for 30 minutes at room temperature.
5. Add 200 mL of distilled water to dilute.
6. Add 10 drops of diphenylamine indicator (the solution turns violet).
7. Titrate the solution with 0.5 N ferrous ammonium sulfate until the color changes from violet to brilliant green.
8. Run a blank (without soil) using the same procedure.

Calculation:

Organic Carbon (%) = (B−T)×N×0.003×100

Weight of soil (g)

Where:

B = Volume (mL) of FAS used in blank

T = Volume (mL) of FAS used in sample

N = Normality of FAS (usually 0.5 N)

0.003 = Equivalent weight of carbon oxidized by 1 mL of 1 N $K_2Cr_2O_7$

100 = For percentage conversion

Enumeration of Nitrogen-fixing Bacteria

Procedure:

Sample Preparation and Serial Dilution:

Weigh 1 g of soil and suspend it in 9 mL of sterile distilled water → 10^{-1} dilution.

Continue serial dilution up to 10^{-6} as needed.

Inoculation on Selective Media:

Transfer 0.1 mL from appropriate dilutions onto selective media plates:

Azotobacter: Spread on Ashby's Mannitol Agar

Azospirillum: Inoculate in semi-solid malate medium (observe pellicle formation)

Rhizobium: Spread on YEMA plates with Congo red

Incubation:

Incubate at 28–30°C for:

Azotobacter: 3–5 days

Azospirillum: 2–3 days

Rhizobium: 3–5 days

Count colonies from plates with 30–300 colonies and calculate CFU/g of soil:

$$\text{CFU/g} = \frac{\text{Number of colonies} \times \text{dilution factors}}{\text{Volume plated (mL)}}$$

Estimation of Actinomycetes Population

Medium: Actinomycetes Isolation Agar.

Procedure:

Plate serial dilutions and incubate for 5–7 days at 28°C.

Identify based on tough, leathery, pigmented colonies with earthy odor.

3. RESULTS

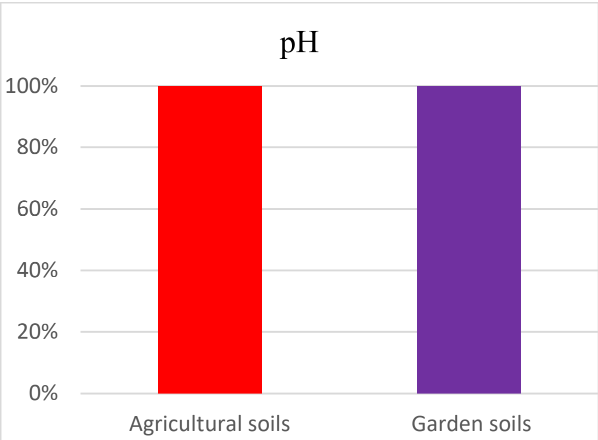
The present study soils in Nagaland play a crucial role in supporting both agricultural and horticultural productivity. Their chemical composition and microbial characteristics significantly impact plant health, crop yield, and the overall ecological balance. A comparative analysis of agricultural and garden soils in Nagaland reveals several notable differences in physicochemical and microbial parameters. Soil pH is one of the primary indicators of soil reaction. Agricultural soils in Nagaland exhibit a more acidic nature with a pH of around 5.8, which is common in upland tropical regions due to leaching and organic acid accumulation. In contrast, garden soils have a near-neutral pH of approximately 6.7, likely a result of frequent additions of compost, kitchen waste, ash, and other organic amendments that buffer acidity. In terms of electrical conductivity (EC), both agricultural and garden soils are non-saline, with low EC values below 0.8 dS/m. Garden soils show a slightly higher EC value (0.29 dS/m) compared to agricultural soils (0.18 dS/m), which could be attributed to the concentrated addition of organic fertilizers and nutrients in small gardening spaces.

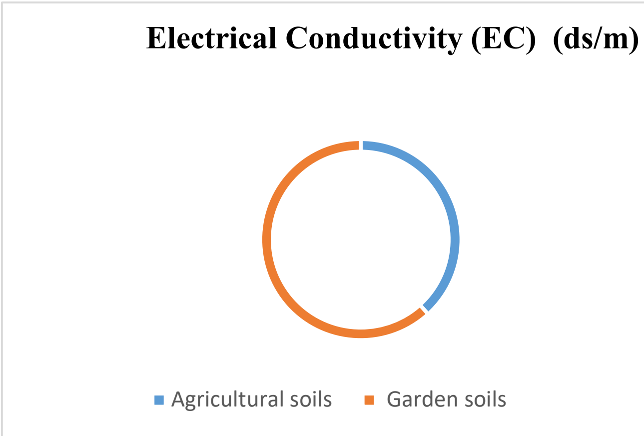
Macronutrient content also varies between the two soil types. Agricultural soils are richer in nitrogen (250 kg/ha), due to the use of nitrogen-based fertilizers, leguminous crop rotations, and nitrogen-fixing microbes such as Azotobacter and Rhizobium. Garden soils, on the other hand, contain about 195 kg/ha of nitrogen, mainly sourced from compost and slow-releasing organic matter. Phosphorus levels are relatively close in both soil types, with agricultural soils having slightly more (93 kg/ha) than garden soils (91 kg/ha), possibly due to the use of phosphorus fertilizers like DAP and livestock manure. Potassium levels are notably higher in agricultural soils (284.7 kg/ha) compared to garden soils (235.8 kg/ha), reflecting the application of potassium-rich fertilizers and crop residues are presented in Table 1 & Fig. 2.

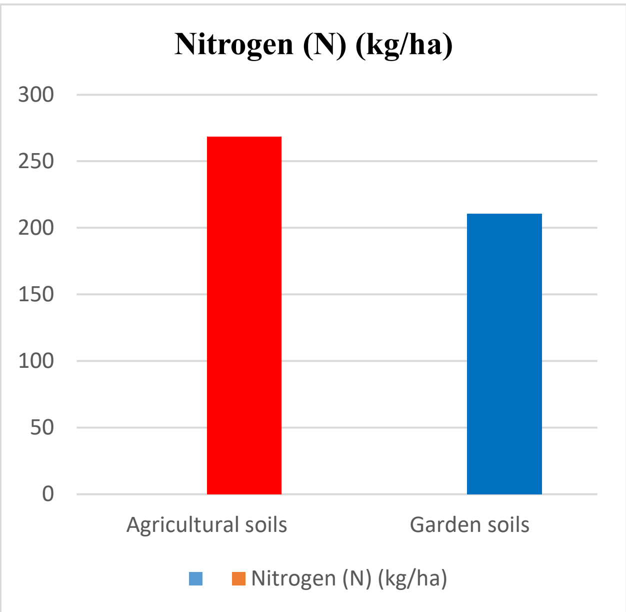
Organic carbon, which is a key indicator of soil fertility and microbial activity, is significantly higher in garden soils (3.2%) due to regular input of organic matter such as compost, leaves, and household waste. Agricultural soils show a healthy but slightly lower value (2.1%), which still supports microbial processes.

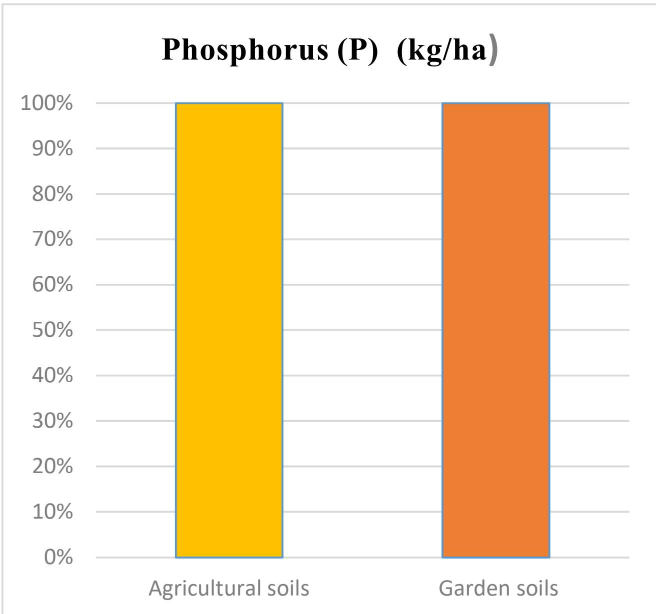
Table 1. Parameters of Agricultural Soils and Garden Soils in Nagaland.

S.no	Parameters	Agricultural soils	Garden soils
1	pH	5.8	6.7
2	Electrical Conductivity (EC) (ds/m)	0.18	0.29
3	Nitrogen (N) (kg/ha)	268.5	210.4
4	Phosphorus (P) (kg/ha)	15.8	13.4
5	Potassium (K) (kg/ha)	284.7	235.8









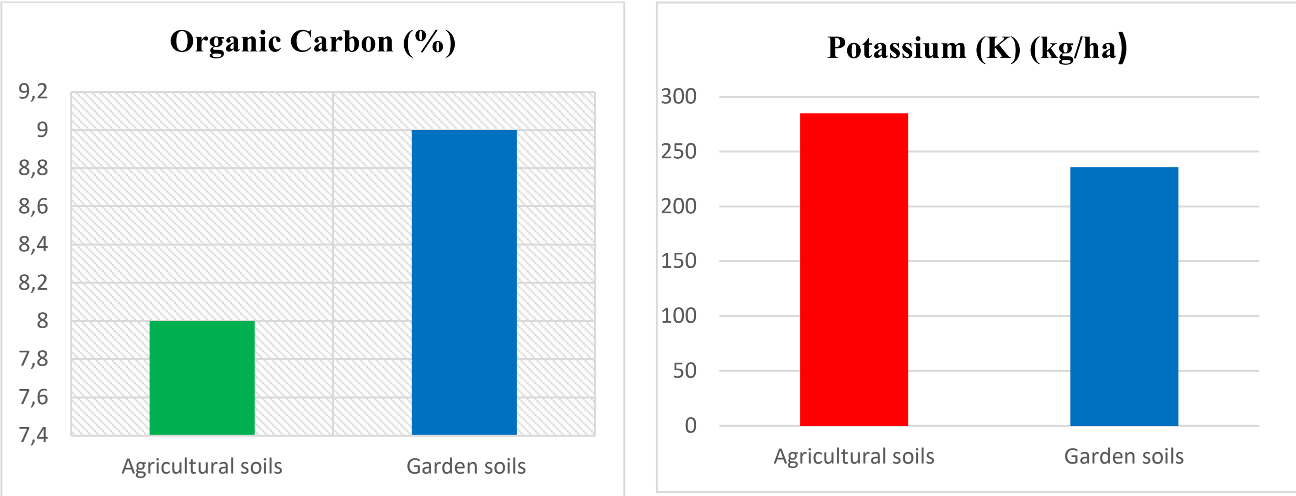


Figure 1. Analysis of agricultural and garden soils in pH, Electrical Conductivity (EC) (ds/m), Nitrogen (N) (kg/ha), Phosphorus (P) (kg/ha) and Potassium (K) (kg/ha)

Microbial analysis highlights the total microbial population in garden soils as higher (10^9 CFU/g) compared to agricultural soils, likely due to diverse plant types, consistent moisture, and abundant organic inputs. Garden soils foster beneficial microbes like Bacillus and Actinobacteria, which have roles in decomposition and antimicrobial activity. Meanwhile, agricultural soils harbor nitrogen-fixing and phosphate-solubilizing bacteria such as *Azotobacter, Rhizobium,* and *Pseudomonas*. In terms of fungal communities, agricultural soils contain beneficial fungi like Trichoderma and mycorrhizae that enhance nutrient uptake and plant resistance to disease. Garden soils, though also containing mycorrhizae, show more saprophytic fungi like *Aspergillus* and *Penicillium* due to the decomposition of organic residues. Regarding pathogen presence, agricultural soils show low pathogenic load owing to biodiversity, crop rotation, and natural antagonism. However, garden soils, particularly when over-watered or poorly drained, may host soil-borne pathogens such as *Fusarium* and *Pythium* are presented in Table 2 and Fig.2.

Table 2. Microbial Analysis Parameters of Agricultural Soils and Garden Soils in Nagaland.

S.NO	Parameters	Agricultural soils	Garden soils
1	Organic Carbon (%)	2.1	3.2
2	Total Microbial Count (CFU/g)	10^8 CFU/g	10^9 CFU/g
3	Bacterial Population	Dominated by *Azotobacter, Rhizobium*, and *Pseudomonas*	*Bacillus, Actinobacteria*
4	Fungal Population	*Trichoderma*, mycorrhizal fungi	*Aspergillus, Penicillium*, and *mycorrhizae*

5	Actinomycetes	Moderate	High
6	Nitrogen-fixing Bacteria	Rhizobium, Azospirillum	Present but lower in diversity

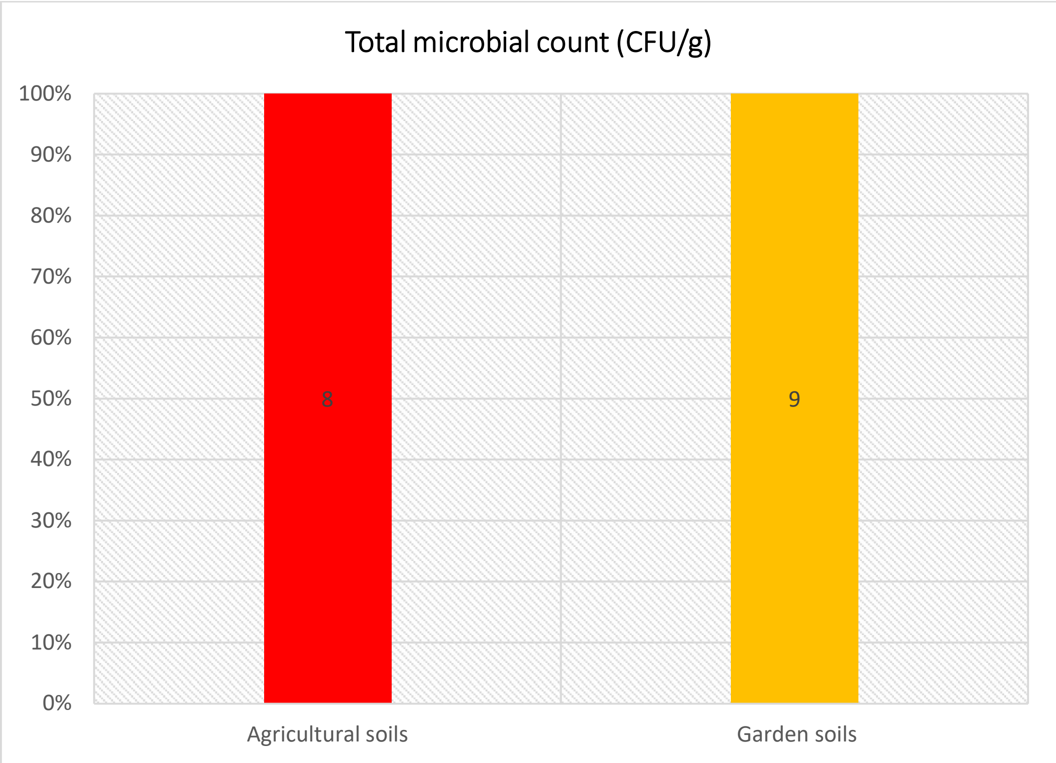


Figure 2. Analysis of agricultural and garden soils in total microbial count (cfu/g).

In summary, agricultural soils in Nagaland are characterized by higher macronutrient availability and slightly acidic pH, making them suitable for nutrient-demanding crops. Garden soils exhibit better balance in pH, higher organic carbon content, and greater microbial diversity, supporting sustainable horticultural practices. These findings underscore the importance of tailored soil management strategies to maintain soil health, enhance productivity, and ensure sustainable land use across different environments in Nagaland.

4. DISCUSSION

The present study comparative analysis of the chemical compositions and microbial populations in agricultural and garden soils provides valuable insights into how different land use practices and management approaches influence soil health, fertility, and biological activity. Through this study, it has become evident that soil quality is not only determined by its chemical makeup, such as pH, nutrient availability, and organic matter content, but also significantly affected by the diversity and abundance of microbial populations that inhabit the soil ecosystem. Agricultural soils, which are often subjected to intensive cultivation, synthetic fertilizers, herbicides, and pesticides, displayed marked differences in both chemical and biological characteristics compared to garden soils (Brady and Weil, 2016).

While these soils may initially show higher levels of certain nutrients due to fertilizer inputs, they frequently suffer from imbalanced nutrient ratios, reduced organic matter, and diminished microbial diversity. Prolonged chemical use can lead to soil acidification, loss of beneficial microorganisms, and the disruption of natural nutrient cycling processes. This microbial depletion can negatively impact plant health, yield sustainability, and the long-term viability of the soil (Paul, 2014).

In contrast, garden soils, particularly those managed with organic practices such as composting, mulching, and minimal chemical input, tend to exhibit a more balanced nutrient profile and a richer, more diverse microbial community. The increased organic matter in garden soils provides essential substrates for microbial growth and supports a wide variety of bacteria, fungi, actinomycetes, and other soil organisms that contribute to improved soil structure, nutrient mobilization, and plant resilience against diseases. The presence of such microbial richness not only promotes healthier plant growth but also enhances the soil's ability to recover from environmental stressors and human interventions (Hartmann et al., 2015).

The differences observed in this comparative study underscore the critical role of soil management practices in shaping both chemical and biological soil properties. Garden soils, due to their more sustainable management, serve as a model for regenerative practices that can be adopted in agricultural systems to improve soil health. Techniques such as crop rotation, cover cropping, reduced tillage, incorporation of organic amendments, and reduction of synthetic inputs should be considered essential strategies to rehabilitate agricultural soils and restore microbial balance (Lal, 2015).

Moreover, the study highlights the interdependence between chemical and microbial aspects of soil. A fertile and productive soil must not only provide sufficient nutrients but also sustain a living, dynamic microbial community capable of supporting ecosystem functions (Torsvik et al., 2002). Therefore, soil conservation and enhancement should be approached holistically, considering both abiotic and biotic components to ensure long-term sustainability in agricultural productivity and environmental quality.

5. CONCLUSION

The comparative analysis of chemical composition and microbial population between agricultural and garden soils reveals distinct differences primarily influenced by land use practices and input types. Garden soil generally exhibits higher organic matter content, better nutrient balance, and greater microbial diversity due to the frequent addition of organic materials and minimal disturbance. In contrast, agricultural soil tends to show signs of nutrient depletion, reduced organic matter, and lower microbial activity as a result of intensive farming practices, chemical inputs, and repeated tillage. These findings highlight the importance of sustainable soil management in agricultural systems. Incorporating organic amendments, reducing chemical usage, practicing crop rotation, and minimizing soil disturbance can help restore soil fertility and microbial health, aligning agricultural soil quality more closely with the richer and more balanced profile seen in garden soils.

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