

Original Research Article

<https://doi.org/10.20546/ijcmas.2026.sp13.005>

Comparative Assessment of Physicochemical Characteristics, Bacterial Population and Beneficial Bacteria in Organic and Conventional Farming Field Soils

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ABSTRACT

Soil microbial communities are essential for nutrient cycling, maintaining soil fertility, and supporting plant growth. Their numbers can be affected by farming practices and the effects of plant roots on the surrounding soil. This study compared various physical and chemical properties, total bacterial counts, and specific types of bacteria in soils near plant roots (rhizosphere) and in the surrounding soil (non-rhizosphere) from both organic and conventional farms. Soil samples were taken from an organic farm in Thozhpedu, Madurantakam Taluk, Kanchipuram district, Tamil Nadu, which includes fields growing paddy and brinjal. Additionally, samples were collected from conventional paddy fields in Ongur, Tindivanam Taluk, Viluppuram district, Tamil Nadu. The study measured soil pH, electrical conductivity, organic carbon, and the levels of available nitrogen, phosphorus, and potassium. Total bacterial numbers were determined using a method that involves diluting soil samples and counting colonies on plates, with three repeated tests for accuracy. Specific bacterial groups were isolated using suitable culture media. The findings showed that the total number of bacteria was consistently higher in rhizosphere soils compared to non-rhizosphere soils. The highest bacterial count was found in the rhizosphere soil of the organic paddy field, with $227.33 \pm 35.23 \times 10^4$ CFU g⁻¹, whereas the lowest was recorded in the non-rhizosphere soil of the organic brinjal field, at $37.33 \pm 4.51 \times 10^4$ CFU g⁻¹. A statistical test revealed a significant difference in bacterial populations between rhizosphere and non-rhizosphere soils when all four fields were considered together (Welch's t-test, $p < 0.001$). These results highlight the importance of the rhizosphere in supporting a greater diversity and abundance of cultivable bacteria in both organic and conventional farming environments.

Keywords

Organic farming, conventional farming, rhizosphere, non-rhizosphere, total viable count, soil bacteria, soil fertility

Article Info

Received:

20 August 2026

Accepted:

28 September 2026

Available Online:

10 October 2026

Introduction

Soil is a living system that supports a wide range of microorganisms, which play key roles in breaking down organic material, cycling nutrients, interacting with plants, and maintaining soil fertility. The types and numbers of bacteria in soil can be affected by several factors, such as the physical and chemical properties of the soil, the type of vegetation, root activity, the availability of organic matter, and how the land is managed (Fierer and Jackson, 2006; Garbeva *et al.*, 2004). Therefore, assessment of soil bacterial populations can provide useful information about the biological characteristics and functional potential of agricultural soils.

Agricultural practices can considerably influence soil microbial communities. The repeated application of inorganic fertilizers, synthetic pesticides, intensive tillage and other conventional practices can modify soil chemical properties and microbial habitats. In contrast, organic farming generally emphasizes the use of organic manures, crop residues, biological inputs and reduced dependence on synthetic agricultural chemicals. Differences in organic matter inputs, nutrient availability and soil disturbance between these management systems may consequently influence microbial abundance, activity and community structure (Mäder *et al.*, 2002; Birkhofer *et al.*, 2008; Lori *et al.*, 2017).

Soil microbial diversity is closely associated with soil quality and ecosystem functioning. Microorganisms contribute to nutrient cycling and are involved in processes that determine the availability of essential nutrients to plants. Changes in microbial communities may therefore influence nutrient-use efficiency, decomposition processes and plant productivity. Long-term comparisons of organic and conventional agricultural systems have demonstrated differences in microbial biomass, community structure and microbial activity, although the magnitude and direction of these differences can depend on soil type, crop, climate and management history (Esperschütz *et al.*, 2007; Hartmann *et al.*, 2015; Li *et al.*, 2012).

The rhizosphere refers to the area of soil directly affected by root activity, and it usually has more microbial life compared to surrounding soil. Roots release certain substances into the soil that serve as food for microorganisms, which can influence the types and amounts of microbes that live around plant roots (Badri

and Vivanco, 2009; Dennis *et al.*, 2010). As a result, differences in microbial communities between rhizosphere and non-rhizosphere soils can show how much the presence of plants influences microbial life.

The way land is managed in agriculture can also change the number and activity of microbes in the soil. Studies show that long-term use of organic farming methods is linked to differences in microbial abundance, activity, and community structure compared to conventional farming (Mäder *et al.*, 2002; Hartmann *et al.*, 2015; Lori *et al.*, 2017). Practices such as adding organic materials and reducing chemical use can affect soil organic matter and nutrient levels, which in turn impact microbial communities.

Some beneficial soil bacteria, like those that fix nitrogen or dissolve phosphate, help make nutrients available for plants and support their growth. The presence of these groups can depend on soil conditions, the type of crop, and farming practices. Soil physicochemical properties also play an important role in determining microbial abundance and activity. Soil pH affects nutrient availability and the growth of microorganisms, while electrical conductivity provides an indication of the concentration of soluble salts in soil. Organic carbon represents an important source of energy for heterotrophic microorganisms, whereas available nitrogen, phosphorus and potassium are major nutrients associated with plant growth and soil fertility. Differences in these properties between rhizosphere and non-rhizosphere soils may consequently be associated with differences in bacterial populations.

This study was conducted to compare certain physical and chemical soil properties, total bacterial populations, and specific functional bacterial groups in rhizosphere and non-rhizosphere soils from both organic and conventional farms.

Materials and Methods

Study Area and Field Selection

The organic agricultural fields were located at Thozhpedu, Madurantakam Taluk, Kanchipuram district, Tamil Nadu, India (12.5102266° N, 79.8849254° E). Two agricultural fields, namely a paddy field and a brinjal field, were selected. One organic field was under mixed organic management, whereas the other had been managed organically for more than ten years.

The conventional agricultural fields were located at Ongur, Tindivanam Taluk, Viluppuram district, Tamil Nadu, India (12.230735° N, 79.655624° E). Two conventional paddy fields, designated Paddy field-A and Paddy field-B, were selected. Conventional farming involved the application of inorganic fertilizers and synthetic pesticides together with deep-ploughing operations.

Soil Sample Collection

Soil samples were collected separately from rhizosphere and non-rhizosphere regions of the selected agricultural fields. Rhizosphere soil was collected from soil closely associated with plant roots, whereas non-rhizosphere soil was collected away from the immediate root zone. Samples were collected aseptically and transported to the laboratory for physicochemical and microbiological analyses.

Determination of Soil Physicochemical Characteristics

The selected physicochemical characteristics included soil pH, electrical conductivity (EC), organic carbon and available nitrogen, phosphorus and potassium.

Soil pH was determined using a calibrated digital pH meter following preparation of a soil-water suspension. Electrical conductivity was determined from the soil extract using a calibrated conductivity meter. Soil organic carbon was estimated by the Walkley–Black wet oxidation method using potassium dichromate and concentrated sulphuric acid (Walkley and Black, 1934). Available nitrogen was estimated by the alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus was estimated by the sodium bicarbonate extraction method (Olsen *et al.*, 1954). Available potassium was extracted using neutral ammonium acetate and estimated using a flame photometer (Jackson, 1973).

Enumeration of Total Viable Bacterial Population

The total viable bacterial population was determined by the serial dilution and plate-count method. One gram of each soil sample was suspended in sterile diluent and serially diluted. Appropriate dilutions were inoculated onto suitable bacteriological medium and incubated

under appropriate conditions. Plates containing countable colonies were selected for enumeration (Pershina E *et al.*, 2015).

The total viable bacterial count was determined from three replicate plate counts for each soil sample and expressed as CFU g⁻¹ soil. The results were calculated as mean ± standard deviation (SD).

The bacterial population was calculated according to:

$$\text{CFU g}^{-1} \text{ soil} = \frac{\text{Number of colonies} \times \text{Dilution factor}}{\text{Volume plated (mL)}}$$

Isolation of Selected Beneficial Bacterial Groups

Selected beneficial bacterial groups were isolated from rhizosphere and non-rhizosphere soil samples using appropriate culture media. Presumptive nitrogen-fixing bacterial groups were recovered using Jensen's medium. Characteristic fluorescent bacterial colonies were examined on King's B medium, while phosphate-solubilizing bacteria were screened using Pikovskaya's medium (Rahman MM *et al.*, 2020).

Characteristic colonies showing differences in morphology were selected and subcultured for further examination.

Determination of Frequency of Beneficial Bacterial Groups

The frequency of selected bacterial groups was calculated based on the number of characteristic colonies obtained at the corresponding dilution relative to the total number of bacterial colonies.

$$\text{Frequency (\%)} = \frac{\text{Number of characteristic colonies}}{\text{Total number of bacterial colonies at the corresponding dilution}} \times 100$$

Statistical Analysis

The triplicate total viable bacterial counts were expressed as mean ± standard deviation (SD). The difference between rhizosphere and non-rhizosphere bacterial populations was evaluated using Welch's independent-samples t-test, considering the observations from all four fields together. A p-value of <0.05 was considered statistically significant.

Because the three plates represented replicate determinations within each soil sample rather than three independent field replicates, the statistical analysis was interpreted as a comparison of the observed cultivable bacterial counts and not as a population-level test of farming-system effects.

Results and Discussion

Physicochemical Characteristics of Soil

The selected physicochemical characteristics of the rhizosphere and non-rhizosphere soils are presented in Table 1. Variation was observed in pH, electrical conductivity, organic carbon and available N, P and K among the agricultural fields.

The physicochemical characteristics showed differences between rhizosphere and non-rhizosphere soils. Organic carbon and available N, P and K were generally higher in rhizosphere soils. The organic paddy rhizosphere recorded the highest organic carbon content (0.86%) and available nitrogen (156 mg/kg).

The higher organic carbon and nutrient concentrations in rhizosphere soils may be associated with root-derived organic compounds, plant residues and microbial activity. Root exudates can provide readily available substrates that influence microbial activity and nutrient transformations in the rhizosphere (Badri and Vivanco, 2009; Dennis *et al.*, 2010).

Total Viable Bacterial Population

The total viable bacterial counts obtained from the three replicate determinations are presented in Table 2. The results are expressed as mean $\pm$ SD.

The results clearly demonstrated that the total viable bacterial population was higher in rhizosphere soil than in corresponding non-rhizosphere soil in all four agricultural fields. The highest mean bacterial population was observed in the rhizosphere soil of the organic paddy field ($227.33 \pm 35.23 \times 10^4$ CFU g⁻¹), followed by the rhizosphere soil of conventional paddy field-B ($201.00 \pm 19.00 \times 10^4$ CFU g⁻¹). The lowest bacterial population was recorded in the non-rhizosphere soil of the organic brinjal field ($37.33 \pm 4.51 \times 10^4$ CFU g⁻¹). Among the rhizosphere soils, organic paddy soil showed the highest bacterial population, while organic brinjal soil showed a lower population.

The rhizosphere-to-non-rhizosphere differences were substantial. Based on the mean values, bacterial abundance was approximately 5.09-fold higher in the organic paddy rhizosphere, 3.26-fold higher in the organic brinjal rhizosphere, 2.18-fold higher in conventional paddy-A rhizosphere and 4.94-fold higher in conventional paddy-B rhizosphere.

When all four fields were considered together, the overall mean bacterial population was $178.00 \pm 46.28 \times 10^4$ CFU g⁻¹ in rhizosphere soils compared with $49.25 \pm 16.75 \times 10^4$ CFU g⁻¹ in non-rhizosphere soils. Welch's t-test indicated a statistically significant difference between the two groups ($t = 9.06$, $p < 0.001$).

The significant difference supports the observed rhizosphere enrichment of cultivable bacteria. Plant roots release a variety of organic compounds, including sugars, amino acids and organic acids, which can provide substrates for microbial growth and influence the structure and activity of rhizosphere microbial communities (Badri and Vivanco, 2009; Philippot *et al.*, 2013).

Similar differences in microbial abundance and community characteristics between rhizosphere and non-rhizosphere soils have been reported in previous studies.

The comparison should nevertheless be interpreted cautiously because the three observations for each soil sample are replicate measurements rather than independent field replicates. Therefore, the statistical test demonstrates the consistency of the observed rhizosphere/non-rhizosphere difference within this dataset but does not independently establish a general effect of organic or conventional farming across agricultural regions.

Frequency of Selected Beneficial Bacterial Groups

The frequencies of selected beneficial bacterial groups isolated from the different agricultural soils are shown in Table 3.

The frequencies of selected functional bacterial groups were generally higher in rhizosphere soils than in corresponding non-rhizosphere soils. The highest frequency on Jensen's medium was recorded in the organic paddy rhizosphere (29%), whereas the corresponding non-rhizosphere soil showed 3%.

Figure.1 Total viable bacterial growth from organic rhizosphere soil on nutrient agar following serial dilution and plating.



Figure.2 Total viable bacterial growth from conventional rhizosphere soil on nutrient agar following serial dilution and plating.

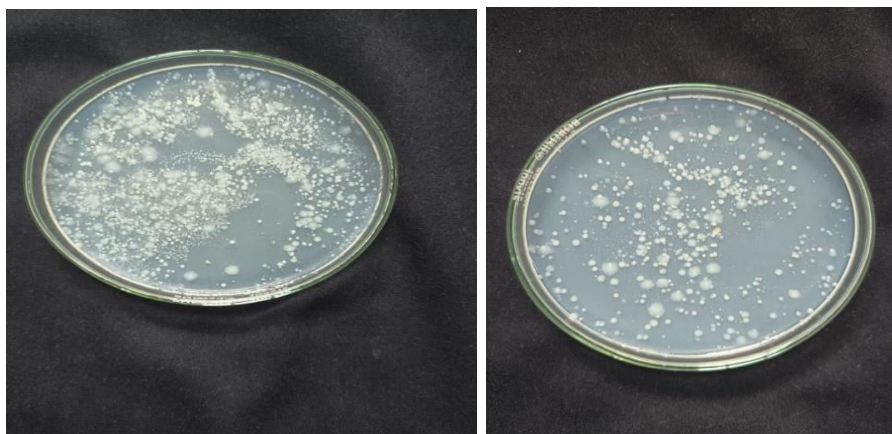


Table.1 Physicochemical Characteristics of Rhizosphere and Non-Rhizosphere soils

Farming system	Field	Soil type	pH	EC (dS m ⁻¹)	Organic C (%)	Available Soil Nutrients (mg/kg)		
						N	P	K
Organic	Paddy	Rhizosphere	7.12	0.42	0.86	156	12.4	143
		Non-rhizosphere	7.28	0.36	0.62	123	9.1	115
	Brinjal	Rhizosphere	6.84	0.48	0.78	142	11.3	132
		Non-rhizosphere	6.97	0.41	0.59	115	8.7	109
Conventional	Paddy-A	Rhizosphere	7.46	0.61	0.54	127	10	124
		Non-rhizosphere	7.58	0.57	0.43	109	7.85	113
	Paddy-B	Rhizosphere	7.32	0.55	0.63	138	9.7	135
		Non-rhizosphere	7.44	0.49	0.45	112	6.55	119

Table.2 Total viable bacterial population of rhizosphere and non-rhizosphere soils

S. No.	Agricultural field	Type of soil collected	Replicate 1 (×10 ⁴ CFU g ⁻¹)	Replicate 2 (×10 ⁴ CFU g ⁻¹)	Replicate 3 (×10 ⁴ CFU g ⁻¹)	Mean ± SD (×10 ⁴ CFU g ⁻¹)
1	Organic Farm – Paddy field	Rhizosphere soil	260	232	190	227.33 ± 35.23
		Non-rhizosphere soil	55	35	44	44.67 ± 10.02
2	Organic Farm – Brinjal field	Rhizosphere soil	143	121	101	121.67 ± 21.01
		Non-rhizosphere soil	33	37	42	37.33 ± 4.51
3	Conventional Farm – Paddy field-A	Rhizosphere soil	168	170	148	162.00 ± 12.17
		Non-rhizosphere soil	77	81	65	74.33 ± 8.33
4	Conventional Farm – Paddy field-B	Rhizosphere soil	201	182	220	201.00 ± 19.00
		Non-rhizosphere soil	35	38	49	40.67 ± 7.37

Table.3 Frequency of Selected Beneficial Bacterial Groups in Rhizosphere and Non-Rhizosphere Soils

S. No.	Agricultural field	Soil type	Jensen's medium	King's B medium	Pikovskaya's medium
1	Organic Farm – Paddy field	Rhizosphere	29%	33%	21%
		Non-rhizosphere	3%	9%	5%
2	Organic Farm – Brinjal field	Rhizosphere	17%	29%	14%
		Non-rhizosphere	9%	13%	11%
3	Conventional Farm – Paddy field-A	Rhizosphere	15%	29%	20%
		Non-rhizosphere	7%	4%	3%
4	Conventional Farm – Paddy field-B	Rhizosphere	11%	23%	7%
		Non-rhizosphere	7%	8%	1%

King's B medium showed the highest frequency in the organic paddy rhizosphere (33%), while Pikovskaya's medium showed the highest frequency in the organic paddy rhizosphere (21%). The higher occurrence of selected functional bacterial groups in rhizosphere soils may be related to the greater availability of root-derived substrates and nutrient-rich microsites.

These observations are consistent with the recognized role of rhizosphere processes in shaping microbial abundance and functional activity (Garbeva *et al.*, 2004; Philippot *et al.*, 2013).

However, because these results are based on culture-dependent screening, the frequencies should be interpreted as the proportion of cultivable colonies displaying the selected characteristics rather than the abundance of the corresponding functional genes in the soil.

In conclusion, the present study demonstrated clear differences in soil bacterial populations between rhizosphere and non-rhizosphere environments under both organic and conventional agricultural management. The total viable bacterial population was consistently higher in rhizosphere soils, with the highest population recorded in the organic paddy rhizosphere.

Analysis of triplicate bacterial counts showed that rhizosphere soils had a significantly higher overall cultivable bacterial population than non-rhizosphere soils ($p < 0.001$). Selected functional bacterial groups were also detected at higher frequencies in several rhizosphere samples.

The physicochemical characteristics indicated variation in soil pH, electrical conductivity, organic carbon and available N, P and K between sampling sites. Higher organic carbon and available nutrients observed in several rhizosphere soils may contribute to the greater microbial abundance, although the present study does not establish causal relationships.

Overall, the findings emphasize the importance of the rhizosphere as a biologically active soil environment. Further studies using independent field replicates, molecular identification and functional assays would provide a more comprehensive assessment of microbial diversity and functional potential under organic and conventional farming systems.

Author Contributions

N. Shyamala: Conceived the original idea and designed the model and wrote the manuscript. M. Prabhakaran: Designed the model and the computational framework and analysed the data. S. Kanimozhi: Writing - Review & Editing, Visualization, Supervision.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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How to cite this article:

Narayanan Shyamala , Mariyappan Prabhakaran and Shanmugam. Kanimozhi. 2026. Comparative Assessment of Physicochemical Characteristics, Bacterial Population and Beneficial Bacteria in Organic and Conventional Farming Field Soils. *Int.J.Curr.Microbiol.App.Sci*. Special Issue-13: 35-42. doi: <https://doi.org/10.20546/ijcmas.2026.sp13.005>