Int.J.Curr.Microbiol.App.Sci (2026) *15*(5): 26-31

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 15 Number 5 (2026)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2026.1505.004

Effect of Organic Amendments on Soil Microbial Populations under Protected Cultivation of Cherry Tomato in Cold Arid Soils of Ladakh

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Keywords

Microbial population, Organic amendments, Cold arid soils, Ladakh region, Bacteria, Fungi, Actinomycetes

Article Info

Received: 10 March 2026
Accepted: 24 April 2026
Available Online: 10 May 2026

A B S T R A C T

The present study was undertaken to evaluate the effect of different organic amendments on soil microbial population under cold arid zone of Ladakh region under protected conditions. The experiment was conducted during 2023 and 2024 in a Completely Randomized Design with two factors comprising eight organic treatments and three cherry tomato varieties. Soil samples were analyzed for bacterial, fungal, and actinomycetes population using the serial dilution pour plate method. Results revealed that organic amendments significantly influenced microbial population. The highest bacterial (40.80×10^7 cfu g^{-1}), fungal (28.52×10^5 cfu g^{-1}), and actinomycetes population (1.13×10^3 cfu g^{-1}) were recorded under sea buckthorn pomace along with biofertilizers, followed by poultry manure and vermicompost treatments. The lowest values were observed under control. The study indicated that organic amendments improve soil biological properties by enhancing microbial activity, thereby contributing to sustainable soil health in the cold arid zone of Ladakh region.

Introduction

Soil health is a key determinant of sustainable agricultural productivity, particularly in fragile ecosystems such as cold arid zone of Ladakh region. These environments are characterized by low temperatures, limited organic matter, poor nutrient availability and reduced microbial activity, which collectively restrict crop growth and soil fertility. Improving soil biological properties is therefore essential for sustaining agricultural production under such conditions. Soil microorganisms, including bacteria, fungi and actinomycetes, play vital roles in nutrient cycling, organic matter decomposition and maintenance of soil ecosystem functions. They are involved in processes such as biological nitrogen fixation, phosphorus solubilization and mineralization of organic residues, thereby enhancing nutrient availability to plants. The abundance and activity of soil microbial communities are strongly influenced by soil physicochemical properties such as pH, moisture, temperature, organic carbon and nutrient status Bastida *et al.,* (2021); Jansson and Hof Mockel (2020). Organic amendments are increasingly recognized as sustainable alternatives to chemical fertilizers for improving soil fertility and microbial activity (Shu *et al.,* 2022). Inputs such as farmyard manure, vermicompost, poultry manure, seabuckthorn pomace, apricot oilcake and camel manure supply essential nutrients, increase soil organic carbon and improve soil structure, thereby creating favourable conditions for microbial proliferation. Similar beneficial effects of organic amendments on soil microbial communities and crop performance have been reported by Su *et al.,* (2022) and Wang *et al.,* (2022).

In addition, biofertilizers such as *Azotobacter*, phosphate-solubilizing bacteria (PSB) and potassium-solubilizing bacteria (KSB) further enhance nutrient availability through biological nitrogen fixation, nutrient solubilization and rhizosphere colonization. Cirillo *et al.,* (2023) reported that microbial inoculation improved soil microbial diversity and agronomic performance in tomato. In cold arid regions such as Ladakh, soils are generally low in organic carbon and biological activity due to harsh climatic conditions. Therefore, the utilization of locally available organic resources may provide an effective strategy for improving soil fertility and sustaining crop production. Cherry tomato (*Solanum lycopersicon* var. *cerasiforme*) is an important high-value crop cultivated under protected conditions in the region, where optimized nutrient management is essential for improving productivity and soil health. However, limited information is available on the comparative effects of locally available organic amendments on culturable soil microbial populations under protected cultivation in the cold arid soils of Ladakh. Therefore, the present investigation was undertaken to evaluate the influence of different organic amendments combined with biofertilizers on the abundance of bacteria, fungi and actinomycetes in cherry tomato grown under protected condition.

Materials and Methods

Location of the investigated area

The experimental study was conducted at the PFDC (Precision Farming Development Centre), School of Agricultural Sciences and Technology, University of Ladakh (Leh Campus), erstwhile HMAARI, Stakna, Leh. The experimental site is situated on the left bank of the Indus River at an altitude of 3319 m above mean sea level. Geographically, the location lies between 35°58′55.1″ N latitude and 77°41′99.5″ E longitude. The region is characterized by a cold arid climate with low precipitation, high solar radiation and large diurnal temperature variation.

Soil Sampling and Collection of Samples

The soil samples were collected from the experimental plots laid out under different treatment combinations at the PFDC, School of Agricultural Sciences and Technology, University of Ladakh (Leh Campus), Stakna, Leh. The experiment comprised eight organic amendment treatments along with three cherry tomato varieties arranged in a Completely Randomized Design. Soil samples were collected from each treatment plot after the application of treatments during both years of experimentation. Composite soil samples were obtained by collecting soil from each plot. The soil samples were collected from the rhizosphere zone of cherry tomato plants at a depth of 0–20 cm using standard soil sampling procedures. The collected soil samples were immediately brought to the laboratory and stored under refrigerated conditions at a temperature below 4°C to preserve microbial activity using standard procedures (Sofi *et al.,* 2016).

Estimation of total microbial count

Soil microbial count was determined by serial dilution plate technique (Aneja, 2001) using selective media, viz., Nutrient Agar (NA) for bacteria, Potato Dextrose Agar (PDA) for fungi, and Actinomycetes agar for actinomycetes. In this technique one gram of the rhizosphere soil was placed in 9 ml of sterilized distilled water under aseptic conditions and shaken thoroughly to prepare a soil suspension. Serial dilution 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7} were prepared. Then 1 ml aliquot from specific dilution was added over cooled and solidified nutrient media (NA) in petri plates. The plates were rotated for uniform distribution. The plates were incubated at temperatures specific to particular microbe for 2-3 days. The colonies that developed on media were counted by electronic colony counter. Three replications were taken for each sample. The microbial population was expressed as colony forming unit per gram of soil (cfu/g soil).

Statistical analysis

Statistical analysis was carried out using the standard statistical procedures described by Gomez and Gomez (1984). The significance of treatment effects was tested by the F-test at the 5 per cent level of probability. Whenever the F-test was found significant, the critical difference (CD) at $P \leq 0.05$ was calculated for comparison of treatment means.

Results and Discussion

Total Bacterial Count

The data presented in Table 1 revealed that the total viable bacterial count was significantly influenced by organic nutrient treatments, whereas varietal and interaction effects were non-significant. The bacterial population ranged from 26.60 to 41.73 $\times 10^7$ cfu g^{-1} soil during the study period. Among the treatments, T_1 (Sea buckthorn pomace + biofertilizers) recorded the highest pooled bacterial count (40.80 $\times 10^7$ cfu g^{-1} soil), which was statistically at par with T_5 (Poultry manure + biofertilizers) (39.81 $\times 10^7$ cfu g^{-1} soil) and T_6 (Vermicompost + biofertilizers) (39.16 $\times 10^7$ cfu g^{-1} soil).

The lowest bacterial population was observed under T_8 (control) (27.94 $\times 10^7$ cfu g^{-1} soil). The higher bacterial population under T_1 may be due to enhanced carbon availability and microbial stimulation by sea buckthorn pomace. Similar findings were reported by Yang *et al.,* (2023). Organic manures are known to improve soil organic matter status, aeration and moisture retention, thereby creating a congenial environment for soil microorganisms (Sumbul *et al.,* 2020). The inoculation of biofertilizers such as Azotobacter, phosphate solubilizing bacteria (PSB) and potassium solubilizing bacteria (KSB) might have further enhanced bacterial proliferation through biological nitrogen fixation and nutrient solubilization processes (Chhetri *et al.,* 2025).

Total Fungal Count

The data presented in Table 1 indicated that the total viable fungal count was significantly influenced by organic nutrient treatments, whereas varietal and interaction effects were non-significant. The fungal population ranged from 13.80 to 29.79 $\times 10^5$ cfu g^{-1} soil during the experimental period.

Among the treatments, T_1 (sea buckthorn pomace + biofertilizers) recorded the highest pooled fungal count (28.52 $\times 10^5$ cfu g^{-1} soil), which was statistically at par with T_5 (Poultry manure + biofertilizers) (27.90 $\times 10^5$ cfu g^{-1} soil) and T_6 (Vermicompost + biofertilizers) (27.10 $\times 10^5$ cfu g^{-1} soil).

The lowest fungal population was observed under T_8 (control) (14.81 $\times 10^5$ cfu g^{-1} soil). The higher fungal population under organic amendments may be attributed to the addition of decomposable organic substrates and favourable soil conditions for fungal growth and colonization. Similar findings were reported by Alori *et al.,* (2023). Similar enhancement in fungal population under organic nutrient management was also reported by Oyege and Bhaskar (2023).

Total Actinomycetes Count

The data presented in Table 1 revealed that the total viable actinomycetes count was significantly influenced by organic nutrient treatments, whereas varietal and interaction effects were non-significant. The actinomycetes population ranged from 1.01 to 1.14 $\times 10^3$ cfu g^{-1} soil during the experimental period.

Among the treatments, T_1 (Sea buckthorn pomace + biofertilizers) recorded the highest pooled actinomycetes count (1.13 $\times 10^3$ cfu g^{-1} soil), which was statistically at par with T_5 (Poultry manure + biofertilizers) (1.11 $\times 10^3$ cfu g^{-1} soil) and T_6 (Vermicompost + biofertilizers) (1.10 $\times 10^3$ cfu g^{-1} soil).

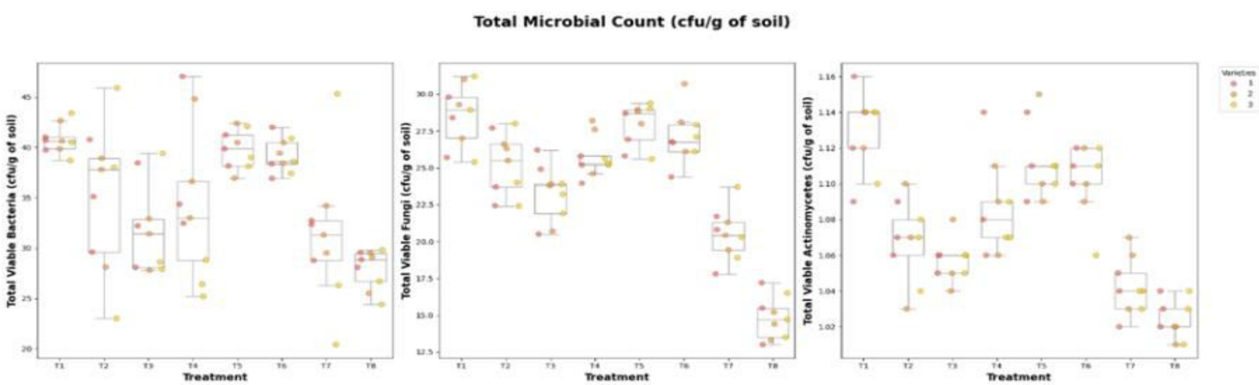
The lowest actinomycetes population was observed under T_8 (control) (1.02 $\times 10^3$ cfu g^{-1} soil). Organic amendments also improve soil aeration and aggregation, creating favourable conditions for proliferation of actinomycetes (Omokore *et al.,* 2024; Wu *et al.,* 2025) Similar increases in actinomycetes population with the application of organic manures and biofertilizers were also reported by Bamboriya *et al.,* (2022) and (Bhatti *et al.,* 2017).

Table.1 Effect of organic nutrient treatments on soil microbial population after harvest of cherry tomato (pooled mean data of 2023 and 2024).

Treatment	Bacteria (cfu g^{-1} soil)	Fungi (cfu g^{-1} soil)	Actinomycetes (cfu g^{-1} soil)
T_1 (Sole Seabuck Thorn pomace + Biofertilizers (Azotobacter + PSB +KSB))	40.80 ×10^7	28.52 ×10^5	1.13 ×10^3
T_2 (Sole Apricot Oilcake + Biofertilizer (Azotobacter + PSB +KSB))	35.24 ×10^7	25.18 ×10^5	1.07 ×10^3
T_3 (Sole Double Hump Camel Manure + Biofertilizer (Azotobacter + PSB +KSB))	31.86 ×10^7	23.22 ×10^5	1.06 ×10^3
T_4 (Sole FYM + Biofertilizer (Azotobacter + PSB +KSB))	37.96 ×10^7	25.72 ×10^5	1.09 ×10^3
T_5 (Sole Poultry Manure + Biofertilizer (Azotobacter + PSB +KSB))	39.81 ×10^7	27.90 ×10^5	1.11 ×10^3
T_6(Sole Vermicompost + Biofertilizer (Azotobacter + PSB +KSB))	39.16 ×10^7	27.10 ×10^5	1.10 ×10^3
T_7 (Sole biofertilizer (Azotobacter + PSB +KSB))	31.20 ×10^7	20.48 ×10^5	1.04 ×10^3
T_0 (Zero Input (control)	27.94 ×10^7	14.81 ×10^5	1.02 ×10^3
CD (P≤0.05)	**5.16**	**1.78**	**0.02**

Note: Variety and Treatment × Variety interaction effects were non-significant (NS).

Figure.1 Effect of microbial treatments on (A) Bacteria, (B) Fungi, and (C) Actinomycetes population. The box plot displays the median, interquartile range (IQR), and outliers. Individual replicates (n=3) are overlaid as points coloured by variety. Significant differences (p < 0.05) between treatments are indicated by different lowercase letters.



In conclusion, Organic nutrient management significantly enhanced soil microbial populations under protected cultivation of cherry tomato in the cold arid conditions of Ladakh. Among the treatments, sea buckthorn pomace combined with biofertilizers recorded the highest bacterial, fungal and actinomycetes populations, followed by poultry manure and vermicompost integrated with biofertilizers, while the control recorded the lowest values. The results indicate that the combined use of locally available organic amendments and microbial inoculants improves soil biological health and microbial activity. Therefore, the integration of such organic resources offers a sustainable and eco-friendly nutrient management strategy for improving soil fertility and cherry tomato production under cold arid conditions.

Author Contributions

Tsering Lanzes: Investigation, formal analysis, writing—original draft. Shahnaz Mufti: Validation, methodology, writing—reviewing. Dorjay Namgyal:—

Formal analysis, writing—review and editing. Ishaq Aabidi: Investigation, writing—reviewing. L. Mashine: Resources, investigation writing—reviewing. Rehana Rasool: Validation, formal analysis, writing—reviewing. Munib-ur-Rehman: Conceptualization, methodology, data curation, supervision, writing—reviewing the final version of the manuscript. F. A. Khan: Investigation, formal analysis, writing—original draft. Neazad Ahmad Wani: Validation, methodology, writing—reviewing.

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:

Tsering Lanzes, Shahnaz Mufti, Dorjay Namgyal, Ishaq Aabidi, Mashine L., Rehana Rasool, Munib-ur-Rehman, Khan F. A. and Neazad Ahmad Wani. 2026. Effect of Organic Amendments on Soil Microbial Populations under Protected Cultivation of Cherry Tomato in Cold Arid Soils of Ladakh. *Int.J.Curr.Microbiol.App.Sci.* 15(5): 26-31.
doi: https://doi.org/10.20546/ijcmas.2026.1505.004