

Comparative study of soil biological properties under organic and conventional farming systems in acidic soils of Meghalaya, India

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Abstract

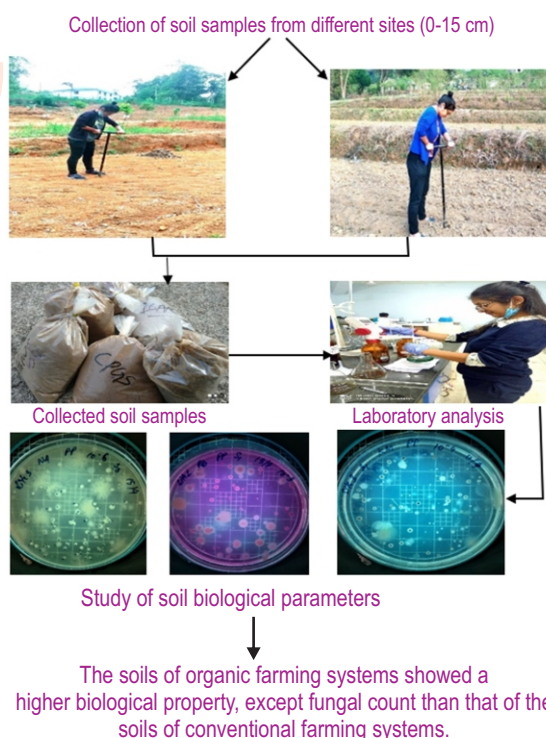
Aim: To compare the soil biological properties under organic and conventional farming systems. The lack of information on these properties results in an unbalanced use of nutrient sources in crop production. Therefore, proper research in this area is important to harness the benefits of soil biological properties into the desired crop yield and productivity.

Methodology: Five different sites consisting two conventionally managed sites, *i.e.*, CPGS-AS Farm, Umiam and Palwi Village, Bhoirybong Block, and three organically managed, *i.e.*, ICAR Farm, Umiam; Kyrdem Village, Bhoirybong Block and virgin soil of CPGS-AS Farm, Krydemkulai were selected for study. A total of 40 random soil samples were collected in a zig-zag manner from the plough layer (0-15 cm depth) from each site. The soil samples were well composited and six composite samples of 1 kg each were derived from each of the sites and stored in the freezer at 4°C for microbial studies. The collected soil samples were studied for various biological properties using standard protocols and the properties were compared. A completely randomized design (CRD) was used for analysis and the means were compared by Duncan's Multiple Range Test ($p < 0.01$).

Results: Biological properties viz. soil organic carbon, bacterial count, actinomycetes count, acid phosphatase activity, soil microbial biomass carbon and soil microbial biomass phosphorus, except fungal count resulted in higher amounts in soils collected from organic farming systems than that of the conventional systems.

Interpretation: Organic farming systems have better soil biological properties compared to the conventional farming systems indicating superior soil health and soil fertility status under organic farming systems.

Key words: Acidic soil, Conventional farming, Soil biological properties



Introduction

Soil has a reserve complex network of organisms which influences various soil physical and chemical properties such as soil structure, colour, consistency, porosity, density, aggregate stability, aeration, pH, soil nutrient content, cation exchange capacity, soil organic matter, etc., as well as the biological parameters of soil such as microbial biomass, microbial enzyme activity, soil respiration, etc. These altered physical, chemical and biological parameters ultimately affect crop growth and production (Sanjay-Swami *et al.*, 2017; Sanjay-Swami and Singh, 2020). More than 95% of the soils of North-Eastern Region (NER) of India are of acidic nature, out of which approximately 65% fall under strongly acidic to very strongly acidic range having pH less than pH 5.5 (Thakuria *et al.*, 2016). Out of the total of 21 Mha of acidic soil of NER, India, 2.24 Mha soil covers the Meghalaya state (Singh and Sanjay-Swami, 2020). NER of India is a hotspot for organic farming due to the presence of rich biomass and organic and livestock manures with limited usage of chemical fertilizer ($<12 \text{ kg ha}^{-1}$) (Singh *et al.*, 2021). Meghalaya is an organic state by default as farmers here are dedicated to organic farming and do not use any chemical fertilizers (Darjee, 2023).

Due to the influence of soil microorganisms, the organic farming systems enjoy a unique nature of nutrient class compared to the conventional farming systems (Saha and Mandal, 2011). The microorganisms present in an organic farm influence the soil health and soil quality (Samaei *et al.*, 2022) through secretion of various organic acids and enzymes which, in turn, contribute to organic matter decomposition and soil nutrients availability (Cooper *et al.*, 2018). Almost every enzyme and organic acid released by soil microorganisms has exclusive power to chelate various soil cations such as Fe, Al, Mn, Zn, Mg, Ca, etc., which has abundant potential for solubilization of unavailable nutrients bound with them (Adeleke *et al.*, 2017) making them available for plant uptake and nutrition.

Krause *et al.* (2023) studied soil bacterial community composition in tropical arable organic and conventional farming systems and found that distinct bacterial community structures with enhanced bacterial richness was observed in organic farming systems compared to conventional farming system. Wang *et al.* (2023) reported that organic fertilizer had a greater effect on soil microbial community structure and carbon and nitrogen mineralization. Compared to conventional NP fertilizer, applying organic fertilizer significantly increased the soil respiration and mineralized nitrogen content. Lori *et al.* (2023) reported that the nutritional status (C and N) of the soil, microorganism count, microbial biomass and respiration of soil was higher in organic soils than conventional soils. In a recent study, Yağanoğlu and Aydin (2024) studied the effect of organic and chemical fertilizers on the activity of soil enzymes in soils of different compositions. They reported that the acid phosphatase was found to be at par in sandy loam soils under both organic fertilizers (10.0) and chemical fertilizers (10.1). However, in case of silty loam soils and clay soils, it was found to be higher in case of

organic fertilization compared to chemical fertilization. In silty loam soils, the acid phosphatase activity under organic fertilization was $9.91 (\mu\text{g p-np g}^{-1} \text{ soil h}^{-1})$ and under chemical fertilization was $9.56 (\mu\text{g p-np g}^{-1} \text{ soil h}^{-1})$. In clay soils, the values were 8.09 and 7.60 ($\mu\text{g p-np g}^{-1} \text{ soil h}^{-1}$), respectively. The other enzymes viz. urease, alkaline phosphatase and dehydrogenase were reported to be higher under organic fertilization compared to chemical fertilization in all the three textural classes. Diepeningen *et al.* (2006) collected soils from 13 organic sites and nearby 13 conventional sites. Soil analysis reported that the soils of organic clay sites had bacterial diversity of 47.50 S° and the corresponding conventional clay sites had bacterial diversity of 41.00 S° . They also reported that the soils of organic sandy sites had bacterial diversity of 52.00 S° and the corresponding conventional sandy sites had bacterial diversity of 45.86 S° . However, such reports and comparison of soil biological properties are lacking in Ri-Bhoi district, Meghalaya. Hence, the current research aims to compare the soil biological properties under organic and conventional farming systems of Ri-Bhoi district, Meghalaya.

Materials and Methods

Five distinct sites in Ri-Bhoi district, Meghalaya were selected for study. Two sites were conventionally managed (A farm at CPGS-AS, Umiam and a Farm at Palwi village, Bhoiymbong), while three sites were controlled organically (A farm at ICAR, Umiam; a farm of Kyrдем village, Bhoiymbong and a virgin forest soil farm at CPGS-AS, Kryдемkulai). Forty soil samples were collected randomly (0 to 15 cm depth) from each site, processed and well composited. Six composite sub-samples were derived from each site and the composited soil samples were stored in the refrigerator at 4°C for the analysis of microbial parameters. Analyses of soil organic carbon, bacterial count, fungal count, actinomycetes count, acid phosphatase activity, soil microbial biomass carbon and soil microbial biomass phosphorus were carried out as per the standard protocols. Soil organic carbon (SOC) was estimated based on rapid dichromate wet digestion method by Walkley and Black (1934). Serial dilution technique of Wollum (1982) was followed for bacterial, fungal and actinomycetes count. Acid phosphatase activity was analyzed by Tabatabai and Bremner (1969) method. Soil microbial biomass carbon (SMBC) and soil microbial biomass phosphorus (SMBP) were analysed using Brookes and Joergenson (2006) method. The culture plates of bacteria, fungi and actinomycetes are shown in Fig. 1.

Basic characteristics of soil sampling sites: The CPGS-AS Farm at Umiam, one-year-old, was conventionally managed with general chemical inputs having Inceptisol soil order. The total area coverage of the field was 2.5 acres. The pH of the soil was found to be 4.70. Cropping sequence followed was Maize-Fababean-Maize. The Palwi Village of Bhoiymbong Block, more than 5 year old, was conventionally managed with general chemical inputs having Alfisol soil order. The total area coverage of the field was 2.5 acres. The pH of the soil was 4.58. Crops cultivated in this field were pineapple, turmeric and vegetables. The ICAR Farm at Umiam, 15 year old, was organically managed

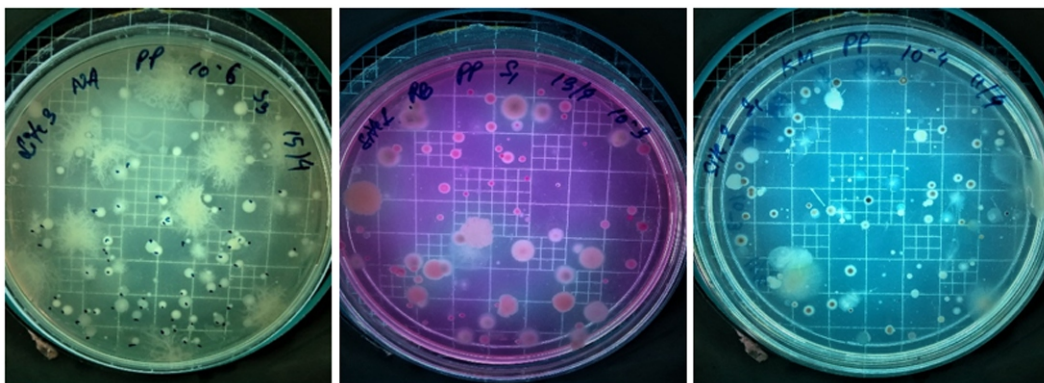


Fig. 1: Colonies of bacteria, fungi and actinomycetes from left to right.

with FYM, vermicompost and manures having Inceptisol soil order. The total area coverage of the field was 2.5 acres. The pH of the soil was 4.91. Crops cultivated in this field were Maize, French bean, pea and potato. Kyrdem Village in Bhoirymbong Block, 20 year old, was organically managed with occasional FYM and manures having Alfisol soil order. The total area coverage of the field was 2 acres. The pH of the soil was 4.94. Crops cultivated in this field were turmeric, maize and vegetables. The CPGS-AS Farm at Krydemkulai, virgin forest soil, and hence, naturally organic, having Inceptisol soil order. The total area coverage of the field was 2.5 acres. The pH of the soil was 5.15.

The data obtained from laboratory analysis were statistically analysed and means of each of parameters were compared using Duncan's Multiple Range Test and significance of differences between the parameters' means was tested with critical difference value at 1% level of probability ($p < 0.01$, 99%) as described by Gomez and Gomez (1984).

Results and Discussion

Organic soils possess higher soil organic carbon (SOC) as compared to conventional soils. The highest SOC was found in the virgin forest soils of CPGS-AS Farm, Krydemkulai (2.53%) while a SOC value of 1.13% was recorded in the conventionally managed CPGS-AS farm, Umiyam (Table 1). The higher SOC in the organic farm soils was due to continuous addition of organic amendments in the soils of organic farm along with practicing conservation tillage and cover cropping. Continuous cultivation of crops with chemical fertilizers without addition of organic matter depleted the soil organic carbon in conventional soils (Crystal-Ornelas et al., 2021; Nandhini et al., 2021; Maucieri et al., 2022).

Organically managed soils harbored significantly higher microbial population as compared to the conventionally managed soils (Table 1). A peak value of $25.55 \text{ cfu} \cdot 10^7 \text{ g}^{-1}$ soil of bacterial population was obtained in the virgin forest soil of the farm of CPGS-AS, Krydemkulai which declined to $10.78 \text{ cfu} \cdot 10^7 \text{ g}^{-1}$ soil

and $9.38 \text{ cfu} \cdot 10^7 \text{ g}^{-1}$ soil in the conventional farm of CPGS-AS, Umiyam and conventional farm of Palwi village, respectively. No significant difference in bacterial population was noted in the organic soils of the farm of ICAR, Umiyam and farm of Kyrdem village with the respective values of $19.90 \text{ cfu} \cdot 10^7 \text{ g}^{-1}$ soil and $20.85 \text{ cfu} \cdot 10^7 \text{ g}^{-1}$ soil. The reason behind the fact that the bacterial population was more in organic soils than conventional soils might be due to more amount of energy provided to the microbial community by decomposing soil organic matter and plant residues which helped the bacteria to proliferate (Gupta et al., 2019; Laldintha and Dkhar, 2015). Also, soil salinity effects caused due to fertilizer application in the conventional soils affected the bacterial population negatively and hence, the population might be more in organic soils (Ghorbani-Nasrabadi et al., 2013). Higher bacterial population in organic soils might also be due to increased moisture conservation phenomenon in organic soils which is in conformity with the work of Mishra (2010). Zhang et al. (2020) confirmed that the bacterial population was higher in higher soil pH (6.32) and lower in the lower soil pH (4.63), which is in consonance with the results of the present investigation. Similar dependence of bacterial population on soil pH was confirmed by Shen et al. (2019).

The fungal population was found to be significantly higher in conventional sites compared to the organic sites with the highest value of $11.43 \text{ cfu} \cdot 10^4 \text{ g}^{-1}$ soil in the farm of Palwi village followed by a value of $9.80 \text{ cfu} \cdot 10^4 \text{ g}^{-1}$ soil in the farm of CPGS-AS, Umiyam (Table 1). The fungal populations of the soils of all the organic sites were observed to be statistically insignificant with the lowest value of $7.93 \text{ cfu} \cdot 10^4 \text{ g}^{-1}$ soil in the farm of CPGS-AS, Krydemkulai followed by $8.45 \text{ cfu} \cdot 10^4 \text{ g}^{-1}$ soil and $8.58 \text{ cfu} \cdot 10^4 \text{ g}^{-1}$ soil in the farm of Kyrdem village of Bhoirymbong and the farm of ICAR, Umiyam, respectively. Devi et al. (2012) elaborated in their experiment on diversity of culturable soil micro-fungi that there was a negative correlation of fungal population distribution and soil moisture content. This might be the reason of relatively lower population in organic soils as the moisture content was relatively higher in these soils due to higher organic materials. Also, fungal

Table 1: Status of microbial parameters of selected sites under conventional and organic production system

Sites	Status	SOC (%)	Bacterial count (cfu*10 ⁷ g ⁻¹ soil)	Fungal count (cfu*10 ⁴ g ⁻¹ soil)	Actinomycetes count (cfu*10 ⁵ g ⁻¹ soil)	Acid phosphatase activity (µg p-np g ⁻¹ soil h ⁻¹)	SMBC (mg kg ⁻¹ soil)	SMBP (mg kg ⁻¹ soil)
CPGS-AS farm, Umiam	Conventional	1.13±0.06 ^e	10.78±0.38 ^c	9.80±0.25 ^b	2.80±0.09 ^c	213.13±3.16 ^d	246.02±2.88 ^c	8.43±1.26 ^c
Palwi village, Bhoirybong	Conventional	1.20±0.07 ^e	9.38±0.22 ^d	11.43±0.15 ^a	2.33±0.09 ^d	209.11±3.74 ^d	229.61±3.38 ^d	8.09±0.60 ^c
ICAR farm, Umiam	Organic	1.81±0.14 ^b	19.90±0.22 ^b	8.58±0.11 ^c	3.03±0.14 ^b	352.81±3.30 ^e	403.53±3.26 ^b	16.18±0.44 ^b
Kyrdem village, Bhoirybong	Organic	1.65±0.10 ^b	20.85±0.14 ^b	8.45±0.12 ^c	3.40±0.09 ^b	365.91±2.90 ^b	416.16±4.10 ^b	16.96±0.29 ^{ab}
CPGS-AS farm, Krydemkulai	Organic	2.53±0.13 ^a	25.55±0.20 ^a	7.93±0.19 ^c	3.83±0.09 ^a	395.49±2.93 ^a	452.99±3.27 ^a	19.08±0.28 ^a

*Means not sharing the same letters in the same column differ significantly (at p<0.01) by DMRT

population has a greater affinity to flourish in acidic conditions, i.e., lower pH, which might be another reason for their higher growth in the conventional soils (Wang *et al.*, 2022).

The actinomycetes population almost followed a similar trend as that of the bacterial population and significantly higher values of actinomycetes count were observed in the organically managed soils with values of 3.83 cfu*10⁵ g⁻¹ soil, 3.40 cfu*10⁵ g⁻¹ soil and 3.03 cfu*10⁵ g⁻¹ soil in the farm of CPGS-AS, Krydemkulai, farm of Kyrdem village and the farm of ICAR, Umiam, respectively. The lowest value of actinomycetes population was found to be 2.33 cfu*10⁵ g⁻¹ soil in the conventional soil of Palwi village which differed significantly to that of the conventional farm of CPGS-AS, Umiam with a value of 2.80 cfu*10⁵ g⁻¹ soil (Table 1). The higher actinomycetes population in organic soils as compared to the conventional soils might be due to application of higher amounts of organic manure for quite a longer period of time under organically managed systems (Nath *et al.*, 2012).

Acid phosphatase activity significantly showed an increasing trend in the organic soils with values 352.81 µg p-np g⁻¹ soil h⁻¹, 365.91 µg p-np g⁻¹ soil h⁻¹ and 395.49 µg p-np g⁻¹ soil h⁻¹ in the farm of ICAR, Umiam, farm of Kyrdem village and the virgin forest soil of the farm of CPGS-AS, Krydemkulai, respectively (Table 1). Significant difference was seen in the values of acid phosphatase activity between the organic soils and the conventional soils. However, the values were observed to be statistically at par in both the conventionally managed soils, i.e., 213.13 µg p-np g⁻¹ soil h⁻¹ in the farm of CPGS-AS, Umiam and 209.11 µg p-np g⁻¹ soil h⁻¹ in the Palwi village. The major contributor of acid phosphatase enzymes activities in the soils is the soil microorganisms which are efficient enough in hydrolysis of organic P compounds in significant amounts (Dhuldhaj and Malik, 2022; Ghorbani-Nasrabadi *et al.*, 2013).

Hence, higher amounts of acid phosphatase activity in organic soils might be due to higher abundance of biological

activities and increased microbial biomass in organic soils. Margalef *et al.* (2017) suggested that the phosphatase activity declined in highly weathered soils, and, on the other hand, forest soil exhibited higher phosphatase activity due to higher amount of organic carbon content. Probably, this also contributed to the reason behind the lowest acid phosphatase activity in the highly weathered Alfisols of the Palwi village and the highest value in the virgin forest soil of the farm of CPGS-AS, Krydemkulai in the present investigation. The higher acid phosphatase activities in organic soils might also be due to the presence of higher organic materials, higher substrate availability and increased soil organic carbon concentrations since they play a key role as precursor for enzyme synthesis as elaborated by Omenda *et al.* (2019); Piotrowska-Dlugosz and Wilczewski (2014) and Wang *et al.* (2013) in their experiments.

The soil microbial biomass carbon (SMBC) was found to be significantly affected by two different farming systems (Table 1). The SMBC content was found to be significantly higher in the organic soils with highest value of 452.99 mg kg⁻¹ soil followed by 416.16 mg kg⁻¹ soil and 403.53 mg kg⁻¹ soil in the virgin forest soil of the farm of CPGS-AS, Krydemkulai, farm of Kyrdem village and farm of ICAR, Umiam, respectively. Quite a low content of SMBC was observed in both the conventional soils and the values differed significantly in both. A value of 246.02 mg kg⁻¹ soil was recorded in the farm of CPGS-AS, Umiam and a value of 229.61 mg/kg soil was recorded in the farm of Palwi village. High amounts of SMBC in organic soils as compared to the conventional soils might be due to the abundant microbial community present in the organic nutrient sources in organic soils along with the availability of diverse substrate carbon and moisture content which revived the indigenous soil microbiota, conforming with the findings of Gupta *et al.* (2019); Kumar *et al.* (2017) and Kumari *et al.* (2013).

The data presented in Table 1 revealed that significantly higher values of SMBP were observed in the organically managed soils when compared to the conventionally managed

soils. Similar to SMBC, the SMBP of virgin forest soil in the farm of CPGS-AS, Krydemkulai was reported to be highest among all the studied sites (19.08 mg kg⁻¹), soil which was significantly different to the values reported in the farm of ICAR, Umiam (16.18 mg kg⁻¹ soil). However, the SMBP of the farm of Kyrdem village was found statistically at par with both the two organic soils mentioned above with a value of 16.96 mg kg⁻¹ soil. The values in both the conventional soils did not differ significantly and the lowest value (8.09 mg kg⁻¹ soil) was reported in the farm of Palwi village, followed by a value of 8.43 mg kg⁻¹ soil in the farm of CPGS-AS, Umiam. The increase in SMBP in organic soils might be due to the increase in microbial communities and their influence which was in line with the findings of Malik *et al.* (2013) who elaborated that the incorporation of organic amendments like FYM and poultry litter resulted in a significant increase in microbial biomass concentrations as compared to the unamended soil. Singh *et al.* (2022) also reported higher amount of SMBP in organic soils in a long-term field experiment with the application of 20 t ha⁻¹ FYM compared to conventional inorganic fertilizers.

The current study revealed significant differences in microbial activities between organic and conventional farming systems. Organic farming systems showed higher levels of soil organic carbon, bacterial count, actinomycetes count, acid phosphatase activity, soil microbial biomass carbon, and soil microbial biomass phosphorus, except for fungal count, which was higher in conventional soils. These findings highlight the benefits of organic farming for soil health, suggesting that organic practices can improve crop yield and sustainability, thus enhancing food security and farmers' livelihood.

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