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Influence of Organic and Natural Farming Nutrient Management Practices on Soil Microbial Biomass Carbon and Enzymatic Activity in Arecanut and Black Pepper Cropping System

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Authors' contributions

This work was carried out in collaboration betweenboth authors. Both authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Soil microbial biomass carbon, an essential component of soil organic matter, serves as an indicator of microbial activity and can influence soil fertility and overall agroecosystem productivity. The conventional farming practices employed in the cultivation of these crops have raised concerns related to environmental sustainability, soil health and long-term productivity. The present investigation was carried out with an objective to study the impact of organic farming and natural farming practices on soil microbial biomass carbon and enzymatic activities in arecanut-black pepper cropping system at Horticulture Research and Extension Center, Sirsi. The treatments included (1) Integrated nutrient management practices (INM), (2) Organic farming practices, (3) Natural farming practices, (4) Chemical farming practices. The details of the four treatments imposed in arecanut and black pepper are T1: INM (100:40:140 g N/P/K per palm per year + 25 ton of Farm yard manure (FYM) + 5-6 ton of vermicompost + biofertilizers was applied as recommended by the University of Horticultural Sciences, Bagalkot). T2: Organic farming (25 ton of FYM + 5-6 ton of vermicompost + biofertilizers were applied), T3: Natural farming (Ganajeevamrutha 400 kg/acre in split doses during the pre-monsoon (200 kg/acre) and post-monsoon (200 kg/acre) period. Jeevamrutha was sprinkled on soil (200 l/acre) at 15-day intervals) and T4: Chemical farming (100:40:140 g N/P/K per palm per year was applied as recommended by the University of Horticultural Sciences, Bagalkot). Pre-incubation of soil samples was done to restore the normal biological activities. A known quantity of soil was moistened to field capacity (60% of MWHC) and incubated at 37 ± 2 0C in a BOD incubator, three days for dehydrogenise and 7 days for phosphatase.Data obtained during the investigation was subjected for a factorial RCBD. By taking nutrient management practices and soil depth as factors. Statistical analysis was performed at a 5 % level of significance using OPSTAT software. The study reveals that the higher microbial biomass carbon (270.20 mg kg^{-1}), microbial biomass nitrogen (28.42 mg kg^{-1}), dehydrogenase (18.55 ug TPF g^{-1} 24 hr^{-1}) and acid phosphatase (19.22 ug PNP g^{-1} h^{-1}) activity was recorded at the surface soil (0-20cm) of organic farming practice followed by natural farming practice as compared to integrated nutrient management practice and chemical farming practice. The study also reveals that natural farming and organic farming practices contribute positively to soil health by enhancing the soil organic carbon, microbial biomass carbon and enzymatic activities. So, it can be concluded that both organic and natural framing practices contribute to sustainable agriculture by enhancing soil health, which is essential for long-term crop productivity and ecosystem resilience.

Keywords: Arecanut; black pepper; organic farming; natural farming.

1. INTRODUCTION

A diverse range of microorganisms live in soils and are responsible for the decomposition of organic matter and the mobilization of nutrients. Soil carbon cycling happens in three perspectives: metabolic pathways, microbial communities, and environmental influences.It elucidate the roles of different microbial species in carbon cycling and highlights the impact of microbial interactions and environmental factors on carbon cycling (Kumar et al., 2021; Kumbar et al., 2025). Intensification of conventional farming systems has led to extensive usage of agrochemicals, agricultural machinery, and high-demanding varieties, resulting in negative impacts on the environment, such as groundwater pollution and atmospheric contamination that amplifies the greenhouse effect (Padbhushan et al., 2016). The environmental pressure generates a negative effect not only on human health and natural resources but also on the sustainability of agricultural production itself (Mylonas*et al.,* 2020). Arecanut (*Areca catechu*) and black pepper (*Piper nigrum*) are two economically significant tropical crops in Western Ghats of Karnataka. This unique cropping system has gained attention due to its potential for sustainable and diverse agricultural production. The important problems associated with these soils are P fixation, heavy rainfall during monsoon season resulting in nutrient losses through run off, leaching of basic cations and poor nutrient retention capacity due to low CEC (3-15 c mole kg^{-1}) (Tandon & Ranganathan, 1988) However, the conventional farming practices employed in the cultivation of these crops have raised concerns related to environmental sustainability, soil health and long-term productivity (Sujatha & Bhat, 2012). With increasing challenges such as rising input costs, soil degradation, pollution and the spectre of climate change, there is a growing imperative to explore alternative farming systems that harmonize with natural processes and prioritize the well-being of both the agroecosystem and its stewards (Mahanta et al., 2013).

Organic and natural farming practices emerge as a beacon of hope, offering a holistic approach to agriculture that can meet the challenges posed by population growth, environmental degradation and global warming (Ghosh et al., 2010). Organic farming is a special agriculture approach that promotes and enhances agro-ecosystem health, such as soil biological activity, biological cycles and biodiversity. Natural Farming (NF) is considered to be agroecology-based diversified farming system, which integrates crops, trees and livestock, allowing functional biodiversity (Rosset & Martinez-Torres, 2012; Korat &Mathukia, 2022) to drastically cut down production costs by replacing the chemical fertilisers and pesticides with home-grown products like Ganajeevamrutha, Jeevamritha, Beejamritha, Neemastra, etc., and adopting intercropping and mulching (Palekar, 2005; 2006).Organic farming aims to enable the soil to provide the crop with all the nutrients it needs for healthy growth and development (Sharan et al., 2020). These farming systems enhance beneficial microflora to maintain soil quality and soil health and also these microflora act as plant growth promoters (PGP) and biocontrol agents against the phytopathogens (Hongal et al., 2023).The transition from conventional practices to organic and natural farming is a crucial step towards ensuring sustainable food production and safeguarding the environment. One of the critical aspects in evaluating the sustainability of these alternative systems lies in their impact on soil health, particularly in terms of microbial biomass carbon and enzymatic activity. Soil health is a cornerstone of sustainable agriculture;its preservation and enhancement are closely tied to the well-being of soil microbial communities. Soil microbes play pivotal roles in nutrient cycling, organic matter decomposition and the maintenance of ecosystem stability.

Microbial population is always a sign of healthy soil and they helps in soil quality maintenance. This study helps to know which cropping systems helps in soil health and soil quality maintenance. Microorganisms play a crucial part in soil nutrient cycling, maintenance of soil structure, degradation of agrochemicals and pollutants, and plant pest control, hence it has often been indicatedasanimportantcomponentofsoil fertility (Serrano et al., 2024). Soil microbial biomass carbon, an essential component of soil organic matter, serves as an indicator of microbial activity and can influence soil fertility and overall agroecosystem productivity. Enzymes secreted by these microbes are key catalysts in various biochemical processes, including nutrient cycling and organic matter decomposition. By keeping all these points in consideration, the present investigation was carried out with an objective to study the impact of organic farming and natural farming practices on soil microbial biomass carbon and enzymatic activities in arecanut-black pepper cropping system.

2. MATERIALS AND METHODS

The investigation was conducted at Horticulture Research and Extension Center, Sirsi. Geographically Sirsi is located in the agro-climatic Zone 9 (Hilly zone) of Karnataka. The study area lies between 14°37' North latitude and 74° 85' East longitudes. The altitude of the study area is 590 m above mean sea level. The soil of the experimental site was sandy loam to sandy clay loam in texture.

2.1 Experimental Details

The experiment was laid out a randomized block design (RBD) with four treatments and five replications. The treatments included (1) Integrated nutrient management practices (INM), (2) Organic farming practices, (3) Natural farming practice, (4) Chemical farming practices. The details of the four treatments imposed in arecanut and black pepper are T_1: INM (100:40:140 g N/P/K per palm per year + 25 ton of Farm yard manure (FYM) + 5-6 ton of vermicompost + biofertilizers were applied as recommended by the University of Horticultural Sciences, Bagalkot). T_2: Organic farming (25 ton of FYM + 5-6 ton of vermicompost + biofertilizers were applied), T_3: Natural farming (Ganajeevamrutha 400 kg/acre in split doses during the pre-monsoon (200 kg/acre) and post-monsoon (200 kg/acre) period. Jeevamrutha was sprinkled on soil (200 l/acre) at 15-day intervals) and T4: Chemical farming (100:40:140 g N/P/K per palm per year was applied as recommended by the University of Horticultural Sciences, Bagalkot).Additionally, 1kg of lime/palm/year was applied uniformly to all the treatments during the pre-monsoon period as per the recommendation. 1% Bordeaux mixture is also sprayed during the monsoon period.

2.2 Soil Sample Preparation and Analysis

Soil samples were collected at three depths of 0–20, 20–40 and 40-60cm in the root zone at 60 cm from the tree trunk. Soil samples were processed by drying under the shade, powdering with a clean wooden mallet and passing through a 2 mm sieve. The processed samples were stored in polyethene bags for analysis in the laboratory. The soil microbial biomass was determined following the chloroform fumigation incubation method (Jenkinson &Powlson, 1976) and the biomass C was calculated (Jenkinson & Ladd, 1981).

Pre-incubation of soil samples was done to restore the normal biological activities. A known quantity of soil was moistened to field capacity (60% of MWHC) and incubated at 37 ± 2 ^{0}C in a BOD incubator, three days for dehydrogenise and 7 days for phosphatase.The samples incubated were adopted to bring back to the original levels of biological activity (Basavaraj, 1984). Acid phosphatase activity was determined using the method described by Tabatabai & Bremmer (1969). Dehydrogenase activity was determined using TTC (2, 3, 5-triphenyl tetrazolium chloride) as a terminal acceptor of protons and electrons from organic compounds being oxidized (Gerba &Brendecke, 1995).

2.3 Statistical Analysis

Data obtained during the investigation was subjected for two two-factorRCBD. By taking nutrient management practices and soil depth as factors. Statistical analysis was performed at a 5 % level of significance using OPSTAT software.

3. RESULTS AND DISCUSSION

3.1 Microbial Biomass Carbon and Nitrogen

Microbial biomass carbon (MBC) refers to that labile fraction of soil organic matter that constitutes living microorganisms smaller than 5–10 µm^3. The MBC and MBN were differed significantly with depth and nutrient management practices. The surface soil (260.95 mg kg^{-1} and 29.16 mg kg^{-1} respectively) reported significantly higher MBC and MBN as compared to the subsurface soil. The content of MBC and MBN was recorded substantially higher (267.70 mg kg^{-1} and 32.36 mg kg$^{-1,}$ respectively) under organic farming practice, and it was significantly on par with natural farming practice, followed by INM practice. Whereas, the lower (198.44 mg kg^{-1} and 20.15 mg kg$^{-1,}$ respectively) value of MBC and MBN content was recorded under chemical farming practice (Table 1). The variation could be attributed to the difference in microbial population, which was influenced by SOC content. Due to the supply of additional mineralizable and ready hydrolyzable carbon sources through manures resulted in higher microbial activity and higher soil microbial carbon (SMB-C) and nitrogen (SMB-N) in organic farming practice as compared to chemical farming practice. This is in conformity with the results of Banger *et al.,*(2009), Dutta *et al*., (2022) and Katti *et al.*, (2020).

3.2 Dehydrogenase Enzyme Activity

Soil microorganisms produce soil enzymes which play an important role in maintaining soil ecology, physical and chemical properties, fertility and soil health. Soil enzymes convert toxic compounds into non-toxic compounds and also play a vital role in mineral uptake by the plants (Mastiholi*et al.,* 2023). Das and Varma (2010) reported that, among all the enzymes in the soil environment, dehydrogenases are the most important indicator of overall soil microbial activity. Dehydrogenase activity basically depends on the metabolic state of the soil biota.

Among different nutrient management practices, dehydrogenase activity was higher in organic farming practice and natural farming practice (19.52 and 18.61 µg PNP g^{-1} h^{-1}, respectively) compared to INM and chemical farming practice (16.88 and 16.02 µg PNP g^{-1} h^{-1}, respectively) as given in Table 2. The incorporation of organic manure like FYM, vermicompost and liquid organic manures like ghanajeevamruta and jeevamruta and mulching with crop residues enhanced the dehydrogenase activity because degradation of added material provided intra and extracellular enzymes and increased microbial activity in the soil (Bhattacharya & Chakraborty, 2005). Application of organic and natural farming

Table 1. Microbial biomass carbon and nitrogen status in acid soils as influenced by different nutrient management practices in arecanut with black pepper cropping system

Treatments	Microbial biomass carbon (mg kg^{-1})				Microbial biomass nitrogen (mg kg^{-1})			
	Soil depth (cm)				Soil depth (cm)			
	0-20	20-40	40-60	Mean	0-20	20-40	40-60	Mean
T1	270.20	234.38	255.79	253.46	28.42	27.65	26.04	27.37
T2	289.23	269.29	244.57	267.70	34.12	33.54	29.43	32.36
T3	282.76	267.12	239.76	263.21	31.04	28.87	26.82	28.91
T4	201.61	215.61	178.11	198.44	23.06	20.11	17.29	20.15
Mean	260.95	246.60	229.56		29.16	27.54	24.90	
Interaction	M	D	M x D		M	D	M x D	
S. Em.±	2.58	2.23	4.46		0.13	0.11	0.22	
CD at 5%	7.37	6.38	NS		0.37	0.31	NS	

Table 2. Dehydrogenase and acid phosphatase enzyme activity status in acid soils as influenced by different nutrient management practices in arecanut with black pepper cropping system

Treatments	Dehydrogenase (ug TPF g^{-1} 24 hr^{-1})				Acid phosphatase (ug PNP g^{-1} h^{-1})			
	Soil depth (cm)				Soil depth (cm)			
	0-20	20-40	40-60	Mean	0-20	20-40	40-60	Mean
T1	18.55	16.44	15.64	16.88	19.22	17.12	15.02	17.12
T2	22.55	19.53	16.47	19.52	31.23	22.32	16.78	23.44
T3	20.80	18.87	16.17	18.61	26.34	20.10	15.94	20.79
T4	17.00	16.32	14.75	16.02	15.89	14.44	11.22	13.85
Mean	19.72	17.79	15.76		23.17	18.49	14.74	
Interaction	**M**	**D**	**M x D**		**M**	**D**	**M x D**	
S. Em.±	0.29	0.25	0.50		0.14	0.12	0.25	
CD at 5%	0.81	0.70	1.41		0.40	0.35	NS	

T1- Integrated nutrient management, T2- Organic farming practice, T3- Natural farming practice and T4- Chemical farming practice

M- Nutrient management practice, D- Depth, M x D- Interaction between nutrient management practice and depth, NS- non-significant

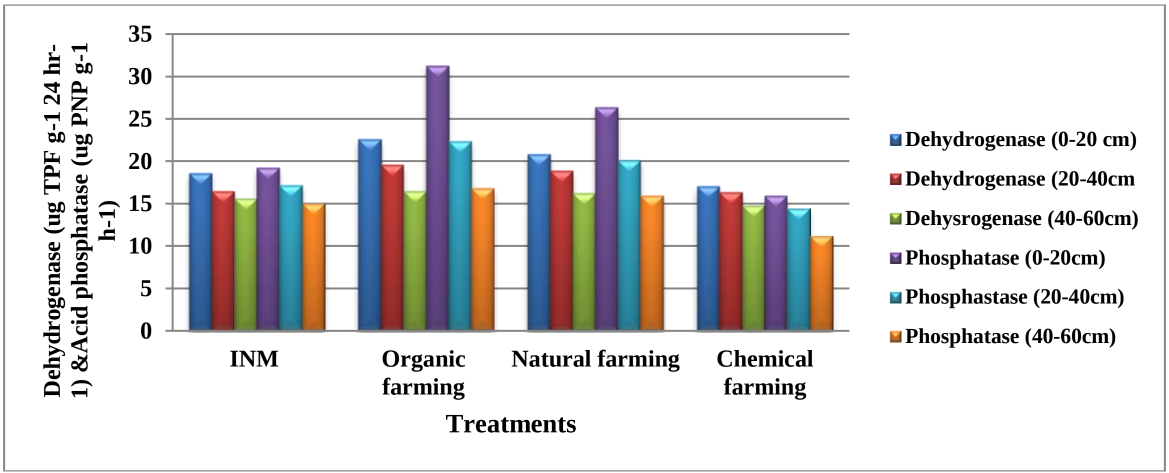

Fig. 1. Dehydrogenase and acid phosphatase enzyme activity influenced by different nutrient management practices in arecanut with black pepper cropping system

Note:*T1- Integrated nutrient management, T2- Organic farming practice, T3- Natural farming practice and T4- Chemical farming practice*

inputs enhanced microbial population and further enzyme production. Hence, application of organic inputs helped in enhancing dehydrogenase activity (Singh & Dhar 2011; Mahanta et al. 2017; Biswas et al. 2018; Małachowska-Jutsz & Matyja 2019).

3.3 Acid Phosphatase Activity

Acid phosphatase is an important enzyme that cleaves the phosphate bound and makes it a simple hexaphosphate group secreted by both plants and microbes (Tabatabai, 1969). The higher (23.44 µg PNP g^{-1} h^{-1}) phosphatase activity was recorded in surface soil compared to the sub-surface soil layer (18.49 and 14.74 µg PNP $g^{-1}h^{-1}$ in 20-40cm and 40-60cm respectively) (Fig. 1). The decrease might be due to the distribution of organic matter content and microorganisms in the soil profile (Khaziev&Burangulova, 1965).

Phosphatase activity was higher in organic farming and natural farming practices (23.44 and 20.79 µg PNP g^{-1} h^{-1}) compared to INM and chemical farming practice (17.12 and 13.85 µg PNP g^{-1} h^{-1}) (Table 2) this might be attributed to the long-term application of organic manures, which has a positive impact on microbial biomass and soil organic carbon, stimulating phosphatase activity and increasing enzyme levels in the soil. These findings are consistent with those of Nannipieri*et al.,*(2011) and Meena *et al.,*(2014), who found that long-term organic manure application to soil can greatly boost phosphatase activity due to the supply of energy sources.

4. CONCLUSION

In conclusion, the present study reveals that natural farming and organic farming practices contribute positively to soil health by enhancing the soil organic carbon, microbial biomass carbon and enzymatic activities. These outcomes suggest a sustainable ecosystem characterized by active nutrient cycling and improved soil fertility, a promising prospect for the long-term sustainability of agriculture.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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