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Influence of Coffee Parchment-Based Compost on Soil Management under Rice Crops in the Department of Man, Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The fertility of tropical acid soils is limited by their acidity, low organic matter content and limited availability of nutrients. However, the composting of coffee husks. is a source of organic matter and nutrients that play an important role in maintaining soil fertility and, therefore, in sustainable agricultural.

Thus, the objective of this study is to evaluate the impact of coffee parchment-based compost on the chemical and biological characteristics of Bofesso soils in Man department.

Various treatments (control, slash-and-burn control, composts (5-10-15 kg) and mineral fertilisation NPK+urea) were applied to the soils. Parameters analyzed include pH, organic matter (OM), organic carbon (OC), total nitrogen (Nt), C/N ratio, available phosphorus (Pass), cation exchange capacity (CEC), exchangeable bases (SEB), base saturation (V), microbial biomass carbon (MBC), dehydrogenase activity (DHA), and micronutrients (Fe, Mn, Cu, Zn). Results show that slash-and-burn temporarily increases pH, CEC, and some micronutrients but reduces OM and microbial biomass. Compost, particularly at 5–10 kg rates, significantly improves CEC, Pass, OM, pH, MBC, DHA, and micronutrient balance, enhancing long-term soil fertility. Mineral fertilization with NPK+urea increases some available nutrients (P, Zn, Fe) but is limited in restoring organic and biological quality.

Compost made from coffee parchment can be used as a bio-fertilizer to improve soil fertility and health. Sustainable management of tropical soils should thus prioritize organic amendments and, ideally, their integration with mineral inputs to reconcile immediate agricultural productivity and long-term sustainability.

Keywords: Compost; coffee parchment; soil fertility; sustainable agriculture.

1. INTRODUCTION

The management of soil fertility is a major challenge in the tropical areas. In fact, these soils were limited by several problem such as acidity, low organic matter content and availability of nutrients (Lal, 2015). Thus, to sustainably restore the fertility of these soils and ensure good agricultural production, different strategies such crop residues integration (Dugué et al., 2024; Zakaria et al., 2024). In Cote d'Ivoire, coffee parchment is one of the most agricultural residues which were less used for soil management. to Raga et al. (2023), the husking of coffee cherries generates around 500,000 tonnes of agricultural waste (128,000 tonnes of coffee husks) in Côte d'Ivoire. This agricultural waste, which should be recycled and reused in various areas such as agriculture in the form of compost, is generally discarded by the inhabitants of production areas who are unaware of its agronomic potential. However, numerous studies have shown that These wastes are rich in cellulose, proteins, minerals, polyphenols (Elida et al. 2020). Their composting is a source of organic matter and nutrients that play an important role in maintaining soil fertility and, therefore, in sustainable agricultural production (Sánchez-Reinoso et al., 2023).

Indeed, the use of coffee grounds as compost improves the availability of nutrients such as organic carbon, phosphorus, nitrogen and, above all, potassium (Gaskin et al 2010; Zhang et al 2016). Compost made from coffee husks increases water retention capacity and aggregate stability: This compost represent an important advantage in mountainous areas where texture and erosion are issues. This helps during dry periods and reduces the risk of erosion on sloping plots (Herath et al, 2013; Igalavithana et al 2017). These benefits include reduced crop risks, higher yields and lower expenditure by farmers on mineral fertilisers.

Studies of Dzung et al (2013) reported that the application of coffee parchment-based compost at a rate of 2 to 3 kg/plant/year for 3 years improved soil fertility and plant growth while reducing the use of chemical fertilizers by 70 to 80% on an industrial coffee plantation in Vietnam. In banana plantations in Côte d'Ivoire, Godefroy (1973) reported that compost made from coffee parchment provided nitrogen (795 kg/ha), phosphorus (30 kg/ha), potassium (798 kg/ha), calcium (331 kg/ha), magnesium (87 kg/ha), manganese (2 kg/ha) and iron (36.5 kg/ha). As well as being an organic fertilizer, this compost is a soil conditioner (Oliveira et al., 2008). Furthermore, according to studies by Kochi et al (2010), composts applied to poor, acidic tropical soils can provide the mineral elements needed for plant growth and development, thereby increasing yields.

Thus, the use of coffee husks as biofertilizer could constitute an integrated solution for soil fertility management for sustainable food production.

Therefore, the purpose of this study was to assess the impact of coffee parchment-based compost on the chemical and biological characteristics of Bofesso soils.

2. MATERIALS AND METHODS

2.1 Study Sites

This study was carried out in the department of Man, in the Tonkpi region in the western Côte d'Ivoire. The experimental sites were located in Bofesso, village of the area of Sandougou-Soba (Fig. 1). The department of Man has a tropical climate with two seasons (a long rainy season and a short dry season) (Goné, 2001). According to the CNRA (National Center for Agronomic Research), ferralitic soils of average chemical fertility predominate in this region. There are also soils developed on basic rocks (potentially rich), hydromorphic soils (lowlands) and mineral soils (mountains).

2.2 Vegetal Material

The plant material consisted of grains of two rice varieties (Oryza sativa L.) commonly grown in western Côte d'Ivoire (Fig. 2). These rice varieties were provided free of charge by the Association des Jeunes Agriculteurs (AJA) cooperative in Bofesso, as part of a project funded by the Fonds pour la Science, la Technologie et l'Innovation (FONSTI). Variety 1 is brown and variety 2 is dark brown. The choice of these varieties was motivated by the taste appreciated by growers.

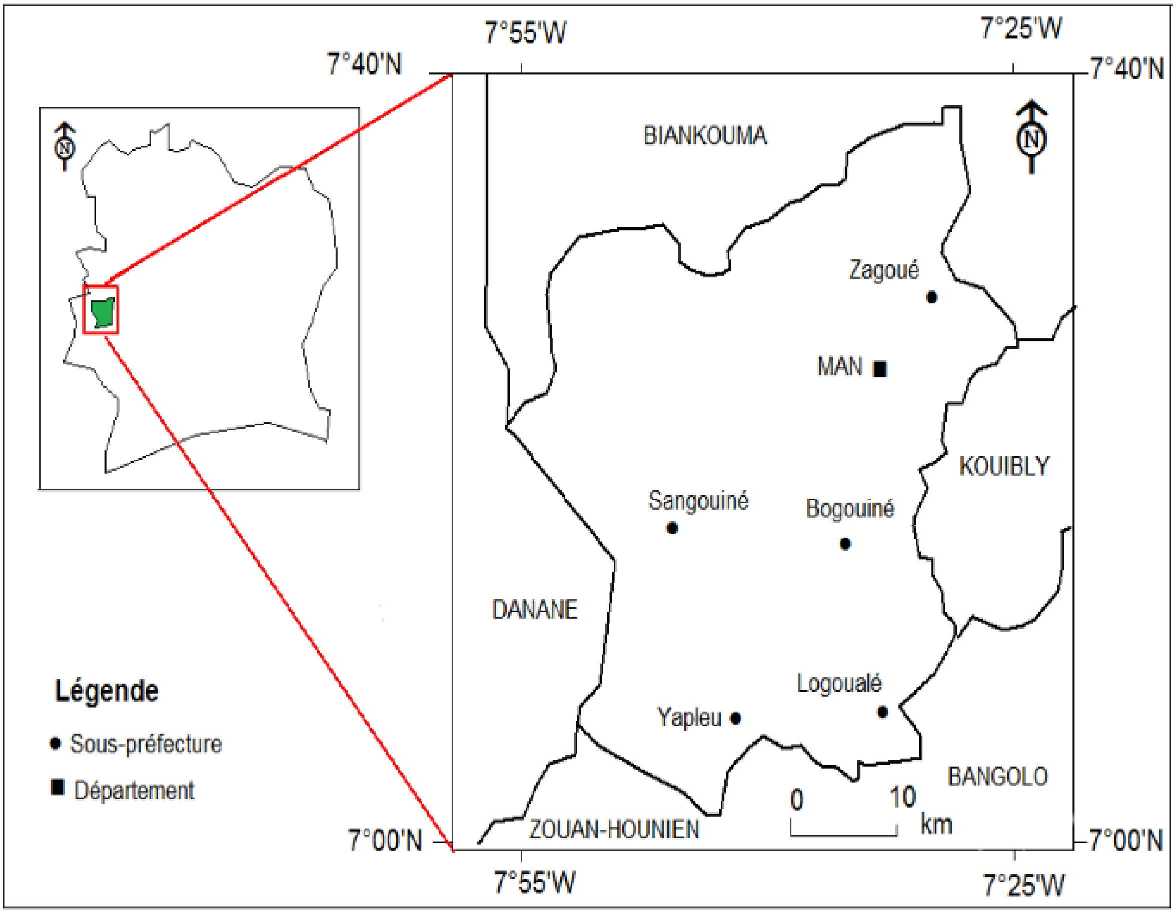

Fig. 1. Man department

Fig. 2. Rice varieties

Table 1. Chemical characteristics of the compost used

				Content (% dm)					Content (ppm)			
pH	**C/N**	**N**	**P**	**K**	**Ca**	**Mg**	**C**	**Mn**	**Cu**	**Pb**	**Zn**	**Fe**
6,6	11,79	2,18	2,56	0,91	0,87	0,415	25,7	8,2	4,1	1,2	7,5	25,1

Compost used: coffee parchments, beef excrement and green plants (50-25-25). C: Carbon, N: Nitrogen, C/N: nitrogen/carbon ratio, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Mn: Manganese, Cu: Copper, Pb: lead, Zn: Zinc, dm: dry matter

2.3 Fertilizer Material

The fertilizing material consisted of compost and chemical fertilisers. The wall compost was obtained after six months (October to April) of composting, with coffee parchment, ox dung and green plants (Pueraria phaleosoïdes) in proportions of 50-25-25. The chemical characteristics of the compost are given in Table 1. The chemical fertilzser consisted of NPK (12-22-22) and urea (46% N). It was supplied by the Agricultural Production Improvement Laboratory, Jean Lorougnon Guédé University.

2.4 Experimental Design

A Fisher block experimental design was adopted to evaluate the effect of compost on soil quality and health in rainfed rice cultivation. Experimental site consisted of two plots, with 18 subplots (6 subplots x 3 replicates) of 10 m² (2 m x 5 m) each per plot. A distance of 1 m was observed between two subplots for one plot. For two plots, a distance of 2 m was observed. The plots were cultivated with two varieties of rice Compost was applied one week before sowing. Sowing was broadcast followed by plowing according to village technique in early May 2024 at a rate of 0.6 kg/10 m². NPK and urea were applied at sowing. The following treatment was adopted: control (unamended rice cultivation), slash-and-burn rice cultivation, NPK+urea (application of NPK (0.2 kg/10 m²) and urea 46% (0.1 kg/10 m²)), compost application at 5 kg/10 m², compost application at 10 kg/10 m², and compost application at 15 kg/10 m².

2.5 Soil Sampling

Samples were collected from the rhizospheres of two rice varieties in October 2024, five months after fertilizer application, during the rice fruiting phase. Samples were taken in accordance with the methodology outlined by Januszek et al. (2015). Using an appropriate probe, 18 elementary samples per plot, or 36 samples in total, of approximately 500 g each, were collected at a depth of 0-20 cm. Immediately after soil sampling, the samples were divided into two parts(subsamples): one part was used for determining biological properties and the other part for determining both chemical properties. In the first case, the soil samples were transferred to the ICentral Laboratory of Soils, Water and Plants of CNRA in polyethylene isothermal bags, where they were immediately sieved to<2mm, thoroughly mixed and then stored at 4C pending analysis. The samples to be analyzed for chemical properties were dried in the laboratory and sieved (<2 mm).

Table 2. Summary of applied soil testing methods

Variables	Methods of determination
Ph	Glass electrode pH meter (Diack & Loum, 2014)
Organic carbon (C)	Walkley et Black method (Diack & Loum, 2014)
Total nitrogen (Nt)	Kjeldahl modified method (Diack & Loum, 2014)
Assimilable phosphorus (Pass)	Olsen modified method (Hilhorst, 2000)
Calcium content (Ca2+)	Atomic absorption spectrometer (Diack and Loum, 2014)
Magnesium content (Mg2+)	
Potassium level (K+)	
Sodium content (Na+)	
Cation exchange capacity (CEC)	
Sum of exchangeable bases (Sbe)	Sbe = Ca2++Mg2++ K++Na+
Base saturation rate (V)	V = Sbe/CEC

2.6 Study of the Chemical Parameters of Soils

Chemical analyses were carried out according to the process described by Bony et al. (2023). The samples to be analyzed for chemical properties were packaged in labelled plastic bags and sent to the Plant and Soil Analysis Laboratory located at the Félix Houphouët-Boigny National Polytechnic Institute. The main task was to carry out the classic soil analyses, i.e. to determine pH, organic carbon, total nitrogen, organic matter, assimilable phosphorus and exchangeable bases (potassium, calcium, magnesium and sodium). The cation exchange capacity of the soil, the sum of exchangeable bases and the base saturation rate were also determined. The methods used to carry out these different analyses are listed in Table 2.

2.7 Analysis of Soil Microbiological Parameters

2.7.1 Determination of soil microbial biomass

The microbial biomass (Cbio) in the soil samples was measured with the chloroform fumigation–extraction method according to ISO 14240-2 (1997).

This method involves releasing microbial organic matter through the lysis of intact microbial cells. Soil samples are fumigated with chloroform for 24 hours. The organic carbon extracted with 0.5 mol/L potassium sulfate is determined in fumigated and non-fumigated samples, and the increase in extracted organic carbon is used to determine the carbon content of the microbial biomass. the amount of carbon in microbial biomass is determined by the following formula.

C (µg/g dry soil) = (C mass of fumigated soil extract - C mass of non-fumigated soil extract) / 0.38

Note: 0.38 = KEC, which corresponds to the extraction efficiency coefficient.

2.7.2 Dehydrogenase activity assay

Dehydrogenase activity (DHA) of each treatment was evaluate according to the method of Casida et al. (1964) was applied. Accordingly, dyes such as triphenyltetrazolium chloride (TTC), which can determine the flow of electrons, are useful indicators of the activity of the electron transport system. By the reduction of TTC, which is a stable, colourless, water soluble heterocyclic organic salt, an insoluble, high-colour red triphenyl formazan (TPF) product is formed and can be quantified calorimetrically at the.range of visible light (485 nm). Briefly, if the red colours of soil samples prepared for spectrophotometric analyses are more intensive, the measured level of DHA is higher (Wolińska & Stępniewska, 2012).

Thus, triphenyltetrazolium chloride (TTC) solution is added to a soil sample and the mixture is incubated at 25°C for 16 h. The released triphenylformazan (TPF) is extracted with acetone and measured photometrically at a wavelength of 485 nm. Dehydrogenase activity is determined by this formula:

DHA (ug.TPF.g^{-1}j^{-1}) = Concentration × Dilution/ Incubation time× soil weight.

2.8 Analysis of the Data

The collected data were entered with the Excel spreadsheet and then processed using R edition software version 4.3.3 through single-factor analysis of variance (ANOVA) assumptions for normality and of distribution and homogeneity of variance. They were secondly verified Fisher's Least Significant Difference test (LSD) to compare the performance of treatments (mean) at a significance level of 5%.

3. RSESUTS

3.1 Chemical Characteristics of Bofesso Soils

3.1.1 Soil acidity, organic status and available phosphorus

The results of the analyses of these parameters are shown in Table 3 and reveal significant differences between treatments.

The control treatment exhibits an acidic pH (4.1–4.9) and moderate organic matter contents (4.42–5.00 g/kg), with relatively low levels of available phosphorus (35–47 mg/kg).

The slash-and-burn treatment is characterized by a marked increase in pH (5.0 in plot 1) and in available phosphorus (48–52 mg/kg), but a reduction in organic matter (2.94–5.96 g/kg).

Compost applications showed the most positive effects on organic matter. The 10 kg compost treatment, in particular, recorded the highest OM values (6.03–6.57 g/kg) along with adequate phosphorus levels (48–51 mg/kg). The 5 kg compost treatment also enhanced OM and maintained a favorable pH. By contrast, the 15 kg compost treatment produced more variable results, with slightly lower OM and more fluctuating Pav values.

The NPK + urea treatment improved available phosphorus (37–50 mg/kg) but did not substantially enhance organic matter (5.00–6.30 g/kg).

3.1.2 Soil exchange complex

The results of the complex adsorption analysis of Bofesso soils highlight clear contrasts between treatments (Table 4).

The control treatment shows low to moderate CEC and SBE values, with a limited base saturation (V) of 33–46%.

The slash-and-burn treatment causes a sharp increase in CEC (22.05 and 16.05 cmol/kg), but paradoxically results in very low base saturation (10–16%).

Composts variably improved CEC and SBE. The 5 kg compost induced a moderate improvement, while the 10 kg compost generated high CEC values (22.5 and 17.7 cmol/kg) but with relatively low V. Conversely, the 15 kg compost showed low CEC but higher base saturation (55% and 36%).

The NPK + urea treatment led to limited improvements in both CEC and V (7.5–10.2 cmol/kg and 26–31%).

3.1.3 Micronutrients

The results of the trace element analysis are presented in Table 5 and show variability between cultivation practices.

The control treatment presented moderate concentrations of Fe (15.51–22.30 mg/kg), Mn (14.18–18.75 mg/kg), Cu (6.30–8.41 mg/kg), and Zn (7.55–8.56 mg/kg).

The slash-and-burn treatment markedly increased Fe and Mn (27.50 and 24.06 mg/kg in plot 1), as well as Zn (11.16–12.49 mg/kg), but reduced Cu (3.95–5.20 mg/kg).

Composts strongly influenced micronutrient contents. The 5 and 10 kg doses raised Fe (22.50–23.33 mg/kg) while reducing Mn and Cu. Zn remained relatively low (6.55–7.96 mg/kg). The 15 kg compost was characterized by reduced Fe (16.84–16.02 mg/kg) but moderate Mn (7.99–9.38 mg/kg).

The NPK + urea treatment increased Fe (18.23–24.50 mg/kg) and Zn (8.68–9.28 mg/kg), but reduced Cu (3.70–3.85 mg/kg) while maintaining relatively high Mn values (12.40–19.85 mg/kg).

3.2 Biological Characteristics of Bofesso Soils

The results of biological activities show significant differences between treatments (Table 6).

The control treatment presented intermediate values of microbial biomass carbon (MBC) and dehydrogenase activity (DHA), reflecting a soil with moderate biological activity.

In contrast, the slash-and-burn treatment strongly reduced MBC in both plots (56.77 and 74.77 µg/g), but induced a slight, temporary increase in DHA in plot 1 (10.96 µg TTF/g/h).

Table 3. Soil acidity, organic status, and available phosphorus in Bofesso soils

	Plot 1						Plot 2					
Treatments	**pH water**	**OC ($g.kg^{-1}$)**	**Nt ($g.kg^{-1}$)**	**Ratio C/N**	**OM ($g.kg^{-1}$)**	**Pav ($g.kg^{1}$)**	**pH water**	**OC ($g.kg^{-1}$)**	**Nt ($g.kg^{-1}$)**	**Ratio C/N**	**OM ($g.kg^{-1}$)**	**Pav ($g.kg^{1}$)**
Control	4.1a	2.57b	0.22b	11.5a	4.42b	35a	4.9a	2.91a	0.27a	10.8a	5.00a	47c
Slash and burn	5.0a	1.71a	0.20a	8.5a	2.94a	52c	4.9a	3.46a	0.27a	12.8a	5.96ab	48c
Compost 5kg	4.9a	2.95c	0.24c	12.2a	5.07cd	49b	4.7a	3.70a	0.29b	12.8a	6.37ab	48c
Compost 10kg	4.7a	3.50d	0.28d	12.5a	6.03d	48b	4.4a	3.82a	0.28ab	13.7a	6.57b	51d
Compost 15kg	4.0a	2.83c	0.21ab	13.3a	4.86bc	61d	4.1a	3.50a	0.27a	13.0a	6.03ab	43b
NPK + urée	4.1a	2.91c	0.22b	13.3a	5.00bc	50c	3.7a	3.66a	0.28ab	13.1a	6.30ab	37a
P-value	0.351	$3.94\ 10^{-11}$	$1.26\ 10^{-5}$	0.667	$3.61\ 10^{-9}$	$2.69\ 10\text{-}^{11}$	0.14	0.644	$5\ 10^{-9}$	0.967	0.036	10^{-9}

For each mean, the values with the same letters on the same column are statistically identical at the 5% threshold according to the Fisher LSD test OM: Organic matter; OC:Organic carbon; Nt: Total nitrogen; C/N ratio:Carbon to total nitrogen ratio; Pav: available phosphorus. P: Probability; averages marked with the same letter in the same column are not significantly different at the α <0.05 threshold

Table 4. Characteristics of the Bofesso soil adsorbent complex

	Plot 1							Plot 2						
Treatments	**CEC ($cmol.kg^{-1}$)**	**Ca^{2+} ($cmol.kg^{-1}$)**	**Mg^{2+} ($cmol.kg^{-1}$)**	**K^{+} ($cmol.kg^{-1}$)**	**Na^{+} ($cmol.kg^{-1}$)**	**SEB ($cmol.kg^{-1}$)**	**V (pc)**	**CEC ($cmol.kg^{-1}$)**	**Ca^{2+} ($cmol.kg^{-1}$)**	**Mg^{2+} ($cmol.kg^{-1}$)**	**K^{+} ($cmol.kg^{-1}$)**	**Na^{+} ($cmol.kg^{-1}$)**	**SEB ($cmol.kg^{-1}$)**	**V (pc)**
Control	5.25a	1.25a	0.95a	0.13a	0.07	2.39a	46d	9.75a	2.302ab	0.77b	0.11a	0.07b	3.25c	33e
Slash and burn	22.05c	1.55a	0.560a	0.12a	0.06a	2.29a	10a	16.05c	1.879a	0.48a	0.10a	0.05a	2.52a	16a
Compost 5kg	8.55b	1.99ab	0.609a	0.16b	0.05c	2.80ab	33c	9.45a	2.045a	0.47a	0.16c	0.04a	2.72a	29d
Compost 10kg	22.5c	2.54b	0.680a	0.12a	0.05a	3.395b	15b	17.7c	2.816b	0.75b	0.14b	0.05a	3.75c	21b
Compost 15kg	3.75a	1.31a	0.57a	0.16b	0.04	2.08a	55^{e}	8.25a	2.208ab	0.56ab	0.13b	0.05a	2.95b	36f
NPK + urée	7.5b	1.59a	0.55a	0.14a	0.03	2. 30a	31c	10.2b	2.022a	0.51ab	0.13b	0.04a	2.70a	26c
P-value	9×10^{-5}	0.003	0.725	0.0135	9.4×10^{-13}	3×10^{-7}	5.31×10^{-16}	3.46×10^{-4}	4×10^{-4}	0.0485	0.0453	3.96×10^{-10}	2.0×10^{-5}	3.7×10^{-11}

For each mean, the values with the same letters on the same column are statistically identical at the 5% threshold according to the Fisher LSD test Ca^{2+}: Calcium; Mg^{2+}: Magnesium; K^{+}: Potassium; Na^{+}: Sodium; CEC: Cation Exchange Capacity and SEB: Sum of Exchangeable Bases, P: Probability; averages marked with the same letter in the same column are not significantly different at the α <0.05 threshold

Table 5. Micronutrient contents of Bofesso soils

	Plot 1				Plot 2			
Treatments	**Fe ($mg.kg^{-1}$)**	**Mn ($mg.kg^{-1}$)**	**Cu ($mg.kg^{-1}$)**	**Zn ($mg.kg^{-1}$)**	**Fe ($mg.kg^{-1}$)**	**Mn ($mg.kg^{-1}$)**	**Cu ($mg.kg^{-1}$)**	**Zn ($mg.kg^{-1}$)**
Control	15.51a	14.18c	6.30c	8.56b	22.30c	18.75c	8.41e	7.55b
Slash and burn	27.50d	24.06d	3.95b	11.16c	20.83b	7.81b	5.20d	12.49d
Compost 5kg	22.50c	6.43a	2.73a	6.77a	19.54b	6.37a	4.26c	5.15a
Compost 10kg	23.33c	6.76a	2.97a	7.96ab	21.50c	7.09ab	3.84b	7.20b
Compost 15kg	16.84a	9.38b	2.61a	6.55a	16.02a	7.99b	3.15a	6.82b
NPK + urée	18.23b	12.40c	3.70b	8.68b	24.50d	19.85c	3.85b	9.28c
P-value	2×10^{-7}	3.86×10^{-11}	6×10^{-7}	10^{-7}	2.4×10^{-6}	4.29×10^{-7}	5.29×10^{-10}	3.53×10^{-10}

For each mean, the values with the same letters on the same column are statistically identical at the 5% threshold according to the Fisher LSD test Fe: Iron; Zn: Zinc; Cu: Copper; Mn: Manganese, P: Probability; averages marked with the same letter in the same column are not significantly different at the α <0.05 threshold

Table 6. Biological activities of Bofesso soils

	Plot 1		Plot 2	
Treatments	**MBC (µg/g)**	**DHA (µg TTF/g/h)**	**MBC (µg/g)**	**DHA (µg TTF/g/h)**
Control	126.93d	9.27b	128.52e	9.5d
Slash and burn	56.77a	10.96d	74.77b	4.1a
Compost 5kg	171.65f	20.73f	131.53f	19.6f
Compost 10kg	146.2e	18.66e	99.82c	8.5c
Compost 15kg	99.61c	14.66c	110.56d	13.8e
NPK + urée	89.43b	7.29a	23.17a	6.1b
P-value	7.33×10^{-14}	8.14×10^{-10}	3.17×10^{-12}	10^{-13}

For each mean, the values with the same letters on the same column are statistically identical at the 5% threshold according to the Fisher LSD test. MBC: microbial biomass carbon, DHA: dehydrogenase activity averages marked with the same letter in the same column are not significantly different at the α <0.05 threshold

Table 7. Correlations (Pearson's r) between biological parameters and chemical parameters, then between microbial carbon biomass and dehydrogenase activity in bofesso soils

	Plot 1		Plot 2	
	MBC	**DHA**	**MBC**	**DHA**
pH	0.14	0.52	0.65	0.09
OM	0.72	0.50	-0.33	0.15
C/N	0.46	0.18	-0.40	-0.02
CEC	-0.17	0.23	-0.19	-0.57
SEB	0.68	0.66	0.35	-0.01
V	0.18	-0.11	0.45	0.61
Pav	-0.34	0.24	0.68	0.17
MBC		0,71		0.68

OM: Organic matter; Nt: Total nitrogen; C/N ratio: Carbon to total nitrogen ratio; Pav: Assimilable phosphorus, V: saturation rate of exchangeable bases, MBC: microbial biomass carbon, DHA: dehydrogenase activity

Compost applications (5, 10, and 15 kg) resulted in the highest values of MBC and DHA, particularly the 5 kg compost (171.65 µg/g and 20.73 µg TTF/g/h in plot 1).

The NPK + urea treatment showed low MBC and DHA values, especially in plot 2 (23.17 µg/g and 6.1 µg TTF/g/h)

3.3 Correlation Between Biological and Chemical Parameters Bofesso Soils

The results show marked differences between the two plots (Table 7). microbial biomass carbon (MBC) is strongly positively correlated with organic matter (r = 0.72), exchangeable bases (, r = 0.68) and C/N ratio (r = 0.46) in plot 1. On the other hand, MBC was negatively associated with available phosphorus (r = -0.34). In plot 2, MBC was positively associated with pH (r = 0.65), base saturation (V, r = 0.45) and available phosphorus (r = 0.68) but negatively associated with organic matter (r = -0. 33) and C/N ratio (r = -0.40).

Dehydrogenase activity (DHA) showed a strong association with exchangeable bases in plot 1 (r = 0.66) and with the degree of base saturation in plot 2 (r = 0.61).

Finally, there was a strong positive correlation between MBC and DHA in both plots (r = 0.73 and r = 0.68).

4. DISCUSSION

To ensure food security for populations through the increase of crop production, it is necessary to identify and propose sustainable soil management strategies such as the use of biofertilizers in fertilization practices for sustainable agriculture.

The objective of this study was to evaluate the effect of coffee parchment-based compost on the chemical and biological parameters of paddy soils in Bofesso.

The parameters analyzed include pH, organic matter (OM), organic carbon (OC), total nitrogen (Nt), the C/N ratio, available phosphorus (Pav), cation exchange capacity (CEC), sum exchangeable bases (SEB), base saturation (V), micronutrients (Fe, Mn, Cu, Zn), microbial biomass carbon (MBC), and dehydrogenase activity (DHA).

The analysis of the different treatments applied to Bofesso soils revealed marked contrasts between traditional practices (control, slash-and-burn control), organic amendments (compost at 5, 10, and 15 kg), and mineral fertilization (NPK+urea). Overall, composts demonstrated a remarkable capacity to simultaneously improve both chemical and biological soil properties, while slash-and-burn, although temporarily correcting pH and releasing nutrients, led to significant losses of organic matter and microbial biomass. Similar results were reported by Sánchez-Reinoso et al. (2023), who demonstrated that coffee-based biochar improved the physical, chemical, and biological properties of soils under coffee cultivation.

Soil pH, organic matter (OM), organic carbon (OC), total nitrogen (Nt), the C/N ratio, and available phosphorus (Pav) are key determinants of soil fertility. In this study, slash-and-burn raised soil pH (up to 5.0) and increased available phosphorus (52 mg/kg) but reduced organic matter. This reflects the effect of ash, which temporarily neutralizes acidity and releases phosphorus, but at the cost of significant organic matter loss due to combustion. Similar findings were reported by Serrani et al. (2024), who showed that slash-and-burn rapidly alters soil chemical properties but progressively depletes organic matter. Composts, particularly at 10 kg, showed the greatest improvements in OM (6.03–6.57 g/kg) and Pass (48–51 mg/kg), while also suggesting that excess organic matter may trigger complex mineralization dynamics. In contrast, NPK+urea increased available P without significant effects on OM, indicating that mineral fertilization improves only short-term nutrient availability without contributing to organic enrichment of the soil. Recent studies (Shifa et al., 2024; Fosu-Mensah et al., 2025) confirmed that composts significantly enhance OM content, phosphorus availability, and chemical stability of acidic tropical soils. Eduah et al. (2025) also emphasized that organic or integrated fertilization strategies are more effective than mineral inputs alone in improving organic carbon stability and long-term soil sustainability.

The soil exchange complex, composed of cation exchange capacity (CEC) and exchangeable cations (Ca2+, Mg2+, K+, Na+), plays a central role in soil chemical fertility and the sustainability of production systems. Results revealed that slash-and-burn significantly increased CEC (22.05 cmol/kg) but reduced base saturation (10–16%). This confirms that slash-and-burn releases active negative charges and temporarily increases CEC, but losses of exchangeable bases limit long-term efficiency. These observations are consistent with Serrani et al. (2024), who emphasized that slash-and-burn rapidly alters soil chemical properties but tends to reduce fertility over time. Compost treatments improved CEC and bases variably, with the 15 kg compost presenting high base saturation (55%). High CEC combined with low V suggests that the release of negative charges is not always accompanied by a proportional increase in exchangeable bases. Conversely, low CEC with high V may reflect higher-quality organic inputs providing more stable exchangeable bases. Recent studies (Shifa et al., 2024) confirmed that organic amendments, even at varying doses, significantly improve CEC and nutrient availability, while modulating base saturation. Similar findings were reported by Singh et al. (2022), who observed that coffee biochar increased pH, OC, and CEC. NPK+urea had limited effects on CEC, highlighting that mineral fertilization alone cannot compensate for organic matter deficits nor sustainably enhance soil exchange properties. Eduah et al. (2025) also reported that mineral inputs alone are insufficient to restore organic carbon stability and cation exchange capacity of tropical soils.

Micronutrients (Fe, Mn, Cu, Zn) play an essential role in plant and microbial metabolism, notably as enzymatic cofactors. Our result Slash-and-burn increased Fe, Mn, and Zn but reduced Cu, indicating a release of certain elements via ash deposition, alongside losses through volatilization or redistribution. Serrani et al. (2024) showed that slash-and-burn rapidly modifies metal availability and disrupts micronutrient balance, with long-term risks of toxicity or imbalance. Compost treatments modulated micronutrient availability, possibly through metal complexation with organic matter from compost, which stabilizes immediate availability. Recent studies (Fosu-Mensah et al., 2025) confirmed that organic inputs influence micronutrient dynamics by enhancing soil retention, reducing losses, and limiting toxicity risks. Usman et al. (2016) also observed that applications of biochar (from Conocarpus wood residues) increased P, K, Fe, Mn, Zn, and Cu concentrations in sandy soil. NPK+urea increased Fe but reduced Cu, illustrating that mineral fertilizers supply certain nutrients but do not stabilize overall micronutrient balance. Eduah et al. (2025) emphasized that mineral fertilizers alone alter micronutrient bioavailability but do not improve their long-term regulation.

Microbial biomass carbon (MBC) and dehydrogenase activity (DHA) are major indicators of soil biological quality (Anderson & Domsch, 1993; Dick, 1994). MBC reflects microbial community size, while DHA indicates microbial metabolic intensity. In this study, slash-and-burn reduced MBC while having limited effect on DHA, likely due to the rapid nutrient release and pH changes after combustion. These findings align with Serrani et al. (2024), who showed that slash-and-burn temporarily modifies microbial activity but tends to deplete microbial biomass over time. Compost, particularly at 5 kg, significantly stimulated MBC (171.65 µg/g) and DHA (20.73 µg TTF/g/h). This confirms that organic amendments improve soil organic matter and strongly stimulate microbial biomass and enzymatic activity, consistent with recent studies by Shifa et al. (2023) and MacCarthy & Mensah (2025), which highlighted the role of compost in enhancing biological and chemical quality of acidic tropical soils. Similar results were reported by Karimi et al. (2020) in infertile soils treated with maize residue biochar, which significantly increased soil respiration and microbial biomass. However, contrasting results were observed by Ge et al. (2020), who found that bamboo branch biochars combined with nitrogen fertilization affected microbial activity differently. Zhou et al. (2017) reported that biochar applications generally increase soil respiration. NPK+urea showed very low values, illustrating the limitations of mineral fertilization alone. In the absence of organic inputs, chemical fertilizers supply immediate mineral nutrition for plants but do not enhance soil organic matter or microbial habitat. Similar findings were reported by Eduah et al. (2025), who demonstrated that organic or integrated fertilization strategies are more effective for sustaining microbial biomass and organic carbon stability.

The study of interactions between biological and chemical properties provides insights into the impact of cultural practices and amendments on soil fertility and sustainability. In this study, positive correlations were observed between MBC, OM, CEC, SBE, and Pass, showing that microbial biomass depends on soil organic matter and exchange capacity. This confirms that carbon substrate and nutrient availability are major limiting factors for microbial development (Insam & Domsch, 1988). In the study, Dehydrogenase activity (DHA), reflecting enzymatic and metabolic activity, was strongly associated with exchangeable bases (SBE) and base saturation (V). These findings underline the close link between nutrient availability and biological activity intensity (Dick, 1994). Finally, the strong MBC–DHA correlation observed under compost confirms that organic management fosters chemical–biological synergy, unlike burned soils or soils amended solely with NPK. According to several authors, microbial biomass and enzymatic activity evolve jointly, making them reliable indicators of soil biological quality (Anderson & Domsch, 1993; Insam & Domsch, 1988).

In sum, the integrated results of this study confirm that coffee parchment-based compost are the best strategy for improving sustainable fertility, in particular 10kg compost for all nutrients (OM, CEC, Pav, trace elements) and 5kg compost for pH correction and the promotion of a climate conducive to soil microbial activity. These results are in line with those of Gupta et al (2020) and Puga et al (2020), who showed the performance of coffee biochar and organic fertilisers in increasing nutrient content and availability in the soil. In addition to improving soil quality, the coffee parchment promotes plant productivity, particularly that of chilli peppers. (Napitupulu, 2023).

5. CONCLUSION

The study of Bofesso soils demonstrates that coffee parchment-based compost represents the most effective strategy to simultaneously improve chemical and biological fertility, through increases in organic matter, CEC, microbial biomass, and enzymatic activity at a dose of between 5 and 10 kg. Slash-and-burn appears as a transient but destructive practice, while mineral fertilization alone (NPK+urea) remains limited. Compost made from coffee parchment can be used as a biofertiliser to improve soil fertility and health. Sustainable management of tropical soils should thus prioritize organic amendments and, ideally, their integration with mineral inputs to reconcile immediate agricultural productivity and long-term sustainability.

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 the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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