



# Effects of Organic Amendments on Soil Chemistry, Fauna Diversity, and Pepper Growth in Côte d'Ivoire, West Africa

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## Authors' contributions

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript. Author GKEG did the conceptualized, wrote original draft, read and approved the final manuscript. Author BBEB did acquired fund, conceived and carried out the statistical processing, analysis of the data. Author OMD did investigated and collected the data in the field. All authors read and approved the final manuscript.*

## Article Information

DOI: <https://doi.org/10.9734/ijpss/2024/v36i74808>

## Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/119155>

**Original Research Article**

**Received: 03/04/2024**  
**Accepted: 30/06/2024**  
**Published: 05/07/2024**

## ABSTRACT

Soil is a non-renewable resource that performs many vital functions. Over-exploitation of soil by farmers leads to soil degradation such as acidification or organic matter lost. To find sustainable soil fertility management techniques, three types of organic matter (compost, compost combined with fungi, bacteria and yeast, and biochar) were applied to the soil. This study evaluates and compares the effect of various organic amendment on the soil fertility under pepper. A field trial was carried out in a randomized block design with four treatments (T0, T1, T2 and T3) and repeated three times in the Agboville department, located in Côte d'Ivoire. Growth and productivity parameters were

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**Cite as:** Edwige-Gwladys, Gnimassoun Kawojou, Bolou-Bi Emile B., and Ouattara Miyeni Djakaridja. 2024. "Effects of Organic Amendments on Soil Chemistry, Fauna Diversity, and Pepper Growth in Côte d'Ivoire, West Africa". *International Journal of Plant & Soil Science* 36 (7):955-68. <https://doi.org/10.9734/ijpss/2024/v36i74808>.

measured during the experiment. At the end of the experiment, soil and plant samples were taken for chemical analysis and to determine soil fauna. The results show that the various treatments had little impact on soil chemical parameters. As for the soil fauna, results indicated a low level of biological activity under all treatments. However, a comparison of organic matter types shows that the compost-based treatment (T1) had a relative positive impact on pepper growth and production parameters, compared with the biochar treatment (T3), microorganism-based compost (T2) and control (T0) treatments. With a view to intensifying pepper production, it would be advisable to continue this work with long-term experiments while increasing the doses of organic matter applied to the soil.

*Keywords: Soil fertility; organic matter; peppers; Agboville; Côte d'Ivoire.*

## 1. INTRODUCTION

Overexploitation of soils in tropical zones has harmful consequences for their productivity. These adverse consequences are erosion and chemical degradation, progressively destroying topsoil over time. According to FAO [1], around 33% of soils are degraded or in the process of being degraded, reducing the area available for cultivation. This exploitation of soils is partly linked to agricultural activities such as change in agricultural practices, deforestation and soil fertilization modes. The reduction in fertility and degradation of cultivated soils reduce agricultural production in tropical Africa. It is likely to compromise the sustainability of production systems [2]. In the humid tropics, soil degradation is closely associated with soil acidification. These processes are natural phenomena whose consequences have a direct impact on the soil's physical, chemical and biological properties [3-6]. In these areas, soil degradation is essentially the result of two processes: (i) the surface horizon leaching through selective erosion of organic matter or nutrients, and (ii) the rapid mineralization of organic matter, more active under tropical hot and humid climate.

Organic matter is an essential component of soil fertility. Its mineralization in soils depends on soil properties, both physicochemical and biological, as well as on interactions with plants. The loss of organic matter in soils leads to a decline in fertility. Several studies show that recycling organic residues is a prerequisite for improving soil fertility to ensure sustainable agricultural production in tropical zones [7-14]. However, current agricultural practices without recycling harvest residues results in a rapid decline in the level of organic matter in soils, leaching of bases ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$  and  $\text{Na}^+$ ) followed by an increasing of aluminum toxicity. Although many

technologies for the integrated management of soil fertility through organic matter have been developed, very few farmers use them during cropping cycles, particularly under new crops introduced into rural areas. The aim of all these techniques is to maintain the soil's fertility over time, thereby promoting good plant growth and yields through agroecological practices. Moreover, reliable data on the effect of some rare family-type farming practices in sub-Saharan Africa on soil quality and crop productivity are lacking. This research was carried out, with the overall aim of assessing the impact of various organic matter inputs on the fertility (chemical and biological) of a pepper-grown soil.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site

The experiment was carried out in the open field at the university's experimental site in M'Brou, located in the department of Agboville, in southern Côte d'Ivoire. The experiment site coordinates of the site are  $5^{\circ}35'50.3''\text{N}$  and  $4^{\circ}21'40.3''\text{W}$  (Fig.1). The topography of the department is relatively flat, with altitudes ranging from 0 to 200 m. The climate is equatorial type, with four seasons (two dry seasons and two rainy seasons). Average annual rainfall is 1,700 mm, with an average annual temperature of  $27^{\circ}\text{C}$ . Vegetation cover is dominated by mixed ombrophilous forest and mesophilous forest, dominated by tulip trees and cheese trees. The study site is located on the boundary of the sedimentary basin and the crystalline basement. The basement formations encountered in the area consist of Birimian and Precambrian formations (schists, metaarenites and metasilstones). Leached ferralsols, have exclusively developed on these rocks.

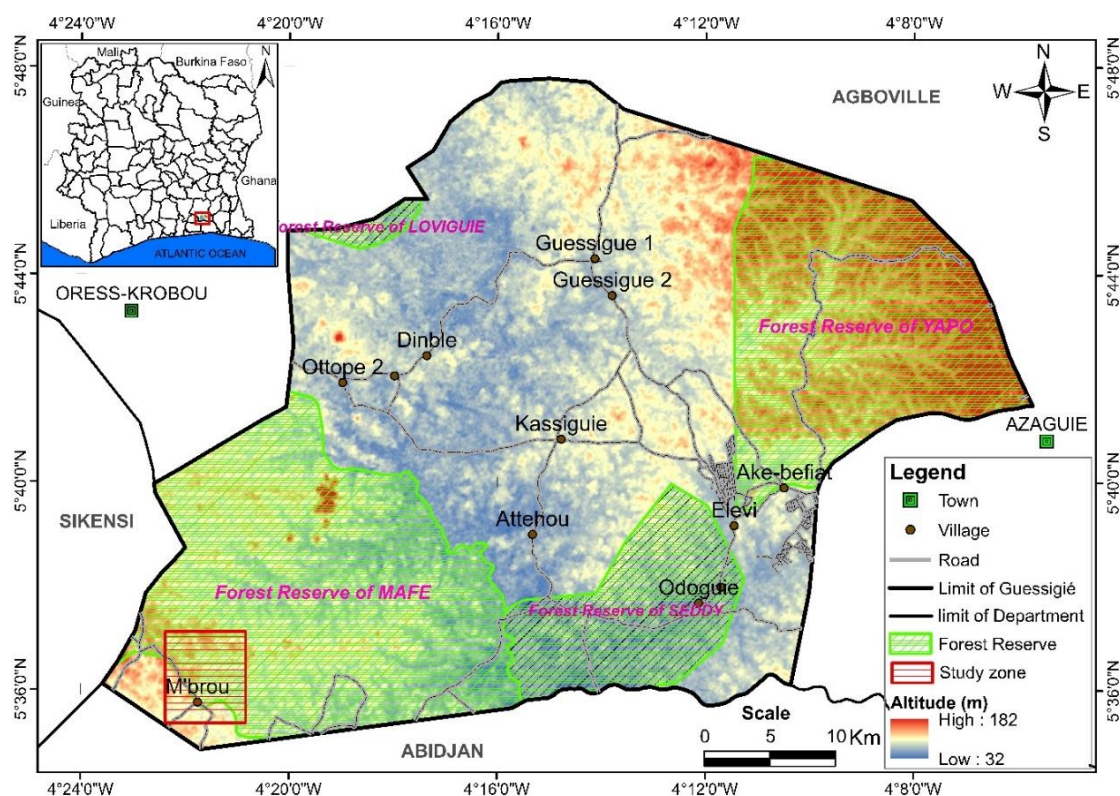


Fig. 1. Location of study site

## 2.2 Plant Material

The plant material used for this study is the pepper (*Capsicum annum*), variety called Yolo Wonder<sup>+</sup> from Technisem<sup>®</sup>. The performance of this pepper variety is influenced by climatic conditions. This variety is highly resistant to disease. Its characteristics are given in Table 1.

## 2.3 Organic Matter

In this study, three types of organic matter were applied to the soil. These were classical compost, compost combined with microorganisms (fungi, bacteria and yeast) and biochar. The biochar used in this study was produced from a mixture of guinea fowl droppings and dried straw in a conventional pyrolysis furnace. Approximately 40 kg of dried guinea fowl droppings and 4 kg of dried straw were combusted without oxygen in

the pyrolysis furnace to produce 15 kg of biochar. To achieve this, the manure and straw were placed in 4 alternate layers (10 kg by 1 kg) in a small hermetically sealed drum and inserted into the pyrolysis furnace. Pyrolysis took place at an average temperature of 400°C for 24 hours. The compost used in this study was supplied by a local company, Green Countries<sup>®</sup>. The compost was obtained from the fermentable fraction of household waste, livestock effluents (manure, slurry) and crop residues. This was mixed with green waste from the local authority's green spaces. The compost associated with the microorganisms was supplied by Lab of plant production of the University Nangui Abrogoua, Abidjan. This compost was obtained from the composting of a mixture of various biodegradable materials composed of animal dung (poultry droppings) and legumes (*puraria*), mixed with mycorrhizal fungi and bacteria extracted from grass (*Panicum maximum*) roots.

Table 1. Characteristics of the used Yolo Wonder pepper variety

Pepper variety	Cycle (days)	Yield (t ha <sup>-1</sup> )	Agronomic characteristics	Fruit characteristics
Yolo wonder	120 - 150	60-70	Tolerant and disease-resistant	Green square shape

## 2.4 Plant Growing Setting up and Monitoring

Pepper (*Capsicum annuum*) seeds were germinated on sterile mixture fiber and coconut chips obtained from Cocosol®. The substrate was abundantly watered until total immersion, then after wiping, two seeds were sown at a depth of 0.5 cm and covered with a thin layer of coco chips. The germination system was watered every three (3) days until the 4-leaf stage before transplanting.

Then, the seedlings, at the 4-leaf stage, were transplanted on raised beds (3 m<sup>2</sup>) at a rate of eight seedlings per bed spaced 70 cm apart. The beds were prepared by spreading various organic amendments. Organic matter was spread on the surface beds using the following treatments:

- Control treatment (T0): no organic matter added to the soil,
- Treatment with compost (T1): application of 5 kg of compost,
- Treatment with compost combined with microorganisms (T2): application of 5 kg of compost,
- Biochar treatment (T3): application of 5 kg biochar.

Each treatment was repeated four times in an experimental design of four complete randomized blocks.

During cultivation, no biocide was applied either to the soil or to the plants. The plants were manually irrigated three times a week with a watering until the end of the experiment. Manual weeding was carried out every week during the vegetative phase of the plants. Data were collected throughout the experiment. It

began as early as 14<sup>th</sup> days after transplanting, and was carried out every week thereafter. All plants were used for data collection for each treatment, with each replicate covering eight plants per treatment on the centered observation units.

To assess the effect of different types of organic amendments on plant growth, the following parameters were measured:

- Diameter of measured stems,
- Plant height from crown to apical bud,
- The number of fully unfolded leaves,
- Number of flowers and fruit per plant.

Total yield for the first harvest was determined by the weighting of fruit per plant. At the end of cultivation, soil samples were taken from each bed for chemical and biological analysis at a depth of 5 cm using an auger. Fresh samples were used to determine soil fauna diversity. A second part of the soil samples was dried at room temperature and sieved to 2 mm. The fine soil obtained was mixed in equivalent mass to obtain composite samples. These composite soil samples were split into two (2) fractions for chemical analysis. The first fraction was used to determine soil acidity. The second fraction was transferred to the laboratory for the others chemical analyses.

## 2.5 Sample Analysis

The number and diversity of soil fauna were determined by observation and counting using the Berlese funnel. Chemical analyses were carried out at the pedology laboratory of the Institut National Polytechnique Félix Houphouët-Boigny in Yamoussoukro, Côte d'Ivoire. These analyses concerned the parameters listed in Table 2.

**Table 2. Soil chemical parameters chosen and analyzed in this study**

Parameters	Units	Methods	Description
pH		AFNOR	Solution-soil contact + agitation and centrifugation + pH meter measurement.
Organic carbon	(%)	Spinger Klee (modified)	Oxidation with K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> in hot acid medium + titration of excess oxidant with Mohr's salt.
Total nitrogen	(%)	Kjeldahl	Mineralization with concentrated H <sub>2</sub> SO <sub>4</sub> (96%) + Distillation of the ammonia produced and entrapment in boric acid and titration of (NH <sub>4</sub> ) <sub>3</sub> BO <sub>3</sub> with HCl 0.1N
Available phosphore	(%)	Olsen	Soil extraction with NaHCO <sub>3</sub> 0.5N at pH 8.5 + shaking (30 mn) + colorimeter measurement.

Parameters	Units	Methods	Description
Exchangeable cation (Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> , K <sup>+</sup> )	cmol <sup>+</sup> kg <sup>-1</sup>	Ammonium acetate	Saturation with 1M ammonium acetate pH7 (shaking) + Centrifugation (10 min) + Spectrophotometer measurement of supernatant.
Cation Exchange Capacity (CEC)	cmol <sup>+</sup> kg <sup>-1</sup>	Ammonium acetate	Saturation with 1M ammonium acetate pH7 (shaking) + Measurement of CEC by measuring NH <sup>+</sup> bound to exchange complex.

## 2.6 Statistical Data Processing

Data collected during experimentation and sample analysis were subjected to analysis of variance (ANOVA) to identify the significance of the effect of organic matter input. Statistical analysis was carried out using SAS.9 software at a significance level of 5%, using the Student and Newman-Keuls (SNK) test to compare the means observed for each parameter.

## 3. RESULTS

### 3.1 Initial Soil Characteristics

The soils on the study site are deep, homogeneous and made up of fine elements. These soils are subject to temporary hydromorphic waterlogging at the surface. Coarse elements are rare, with an average content of 0.10%. The textural characteristics of these soils were dominated by a sandy-clay texture (Table 3).

Total organic matter content varies from 2.30 to 2.50%, with an average of 2.43%. Total nitrogen

content varies little, with an average of 0.12%. Soils on the experimental site are highly acidic. The pH values ranged from 4.83 in the depth horizons to 5.38 in the surface horizons.

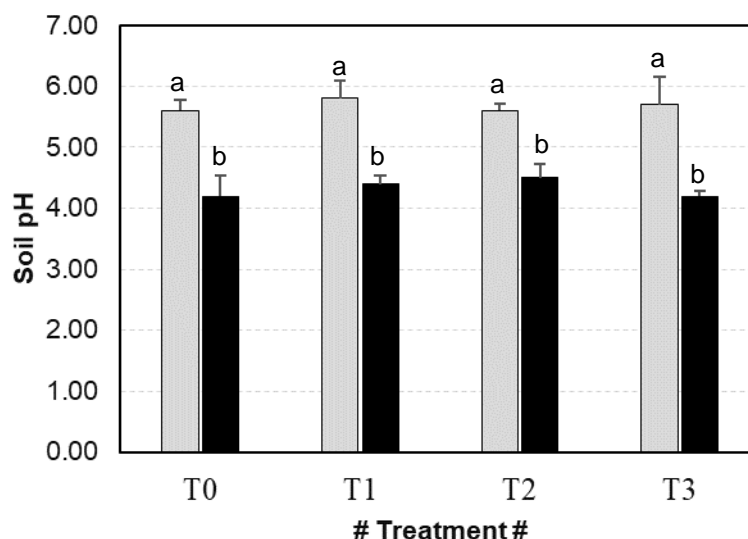
The sum of exchangeable bases on the surface is low to moderately low. Calcium (Ca<sup>2+</sup>) is the dominant cation among exchangeable bases. The saturation rate also remains low, not exceeding 30% of the soil's CEC. Lastly, the soil has low levels of available phosphorus, averaging less than 3%.

### 3.2 Soil Fertility Indicators after Organic Matter Application

Indicators of soil chemical fertility are given by parameters such as pH, nitrogen (N), exchangeable bases, CEC and available phosphorus (P). Fig.2 shows the pH values determined in soils of various treatments. It shows that the pH (water extraction) is on average 1.40 pH units higher than the pH (KCl solution extraction), but pH values (water and KCl) are similar between all treatments to another.

**Table 3. Initial soil chemical characteristics**

Parameters	0-20 cm	20-40 cm
Clay (%)	11.37±1.06	11.03±2.63
Silt (%)	11.25±0.64	7.25±1.63
Sand (%)	77.18±1.17	81.62±1.92
Organic matter (%)	2.53±0.46	2.33±0.45
Carbon (%)	1.51±0.27	1.38±0.27
Nitrogen (%)	0.13±0.02	0.12±0.02
C/N	11.87±0.21	11.05±0.07
pH	5.58±0.72	4.83±0.77
Ca <sup>2+</sup> (cmol <sup>+</sup> .kg <sup>-1</sup> )	2.46±0.26	0.80±0.27
Mg <sup>2+</sup> (cmol <sup>+</sup> .kg <sup>-1</sup> )	0.49±0.06	0.13±0.07
K <sup>+</sup> (cmol <sup>+</sup> .kg <sup>-1</sup> )	0.26±0.05	0.24±0.06
Na <sup>+</sup> (cmol <sup>+</sup> .kg <sup>-1</sup> )	0.04±0.01	0.02±0.01
CEC (cmol <sup>+</sup> .kg <sup>-1</sup> )	9.90±0.36	7.30±1.57
S	3.25±0.16	1.19±0.16
T (%)	32.83±0.72	16.24±1.32
P (ppm)	2.94±0.68	2.03±0.61



**Fig. 2. pH obtained with water (grey) and KCl solution (black) extraction in amended soil**

Table 4 reports data on soil chemical parameters at the end of experiment. The results show that the total nitrogen content is similar in all amended soils, with an average of  $0.18 \pm 0.06\%$ , slightly higher than in the control soil with insignificant difference. Exchangeable bases remain low after soil amendment, but measured levels are higher than initial levels, except for  $\text{Na}^+$ , whatever the treatment. Bases are dominated by  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ , whose levels are highest in T1 treatment soils. The CEC in these soils is also fairly low, with values below  $12 \text{ cmol}^+ \cdot \text{kg}^{-1}$ . Saturation levels seem to have improved in the amended soils, with saturation levels rising from 30% in the control to an average of 50% in the amended soils. Finally, in these soils, the available phosphorus content of the treated soils is all higher, on average 55%

higher, than the phosphorus content of the control soil.

Table 5 reports the results of soil biological fertility indicators under pepper crops. The data show a low level of organic matter in the soils. Organic matter levels are slightly higher in treated soils (T1, T2 and T3). The difference in organic matter content increased from 4% to 33% in treatments T1 to T3, compared with the organic matter content in the control soil.

The same applies to organic carbon levels, which are also low in these soils. The calculated C/N ratio shows fairly similar values, below 12 in the control and treated soils (T1 and T2), whereas the ratio in the soil under treatment T3 is above 12.

**Table 4. Chemical pepper-growing soils fertility indicators following treatments**

Treatment	N (%)	$\text{Ca}^{2+}$	$\text{Mg}^{2+}$	$\text{K}^+$	$\text{Na}^+$	CEC	P (%)
		----- (cmol <sup>+</sup> .kg <sup>-1</sup> ) -----					
T0	0.13	2.44	0.59	0.28	0.04	9.80	2.52
T1	0.26	4.54	0.89	0.80	0.04	12.20	4.61
T2	0.15	2.48	0.58	0.28	0.02	7.40	3.58
T3	0.14	3.44	0.73	0.74	0.07	8.60	4.55

**Table 5. Biological pepper-growing soil fertility indicators following treatments**

Treatment	MO %	OC %	C/N
T0	2.65	1.54	11.9
T1	2.78	1.62	10.8
T2	3.17	1.84	11.5
T3	3.52	2.05	14.6



### 3.3 Soil Fauna Diversity

The number and diversity of living organisms in the soils are shown in Fig. 3. The compost-based treatment (T1) has the highest number of organisms per 100g of fresh soil, followed by treatments T2 and T3 with an average of 12 organisms. Finally, the control has the lowest number of organisms per 100g of soil. Soil fauna diversity in these soils is very limited. In fact, four (4) classes of organisms were observed in the soils, particularly in treatment T1. In the other treatments, three (3) classes of organisms were detected per 100 g of soil. Hexapods were abundant (62%-70%) in control and T3 soil, while insect larvae and annelids were most abundant in T1 and T2 soil. In addition to these different classes, mollusks (T0), crustaceans (T1) and myriapods (T3) were also distinguished in soils.

### 3.4 Plant Growth Indicators

Fig. 4 shows the evolution of plant height over the growing period. Results show a significant difference in height between the different treatments. Significant growth in plant height was

observed with treatment T1, with an average height of  $25.06 \pm 4.67$  cm at the 63<sup>rd</sup> day after transplanting, higher than the height of plants with treatments T2 and T3. Plants harvested with these two treatments had mean heights of  $18.07 \pm 3.58$  cm and  $17.62 \pm 2.49$  cm, respectively. Plants from amended soils have higher average heights than those from the T0 control soil, whose plants have the lowest average height at  $12.23 \pm 3.48$  cm at the 63<sup>rd</sup> day after transplanting.

Fig. 5 shows the evolution of diameter of the stem over the field trial period. Analysis of the data shows a significant difference in stem diameter between the different treatments. There was a significant increase in plants with treatment T1, with a final mean diameter of  $6.67 \pm 2.07$  mm at the 63<sup>rd</sup> day after transplanting, greater than the stem diameters of plants with treatments T2 and T3, given mean diameters of  $4.80 \pm 0.98$  mm and  $4.50 \pm 0.98$  mm respectively. Plant stem diameters in all three amended soils were higher than stem diameter of plant harvested with treatment T0, whose plants had the smallest diameter at  $3.00 \pm 0.87$  mm at the 63<sup>rd</sup> day after transplanting.

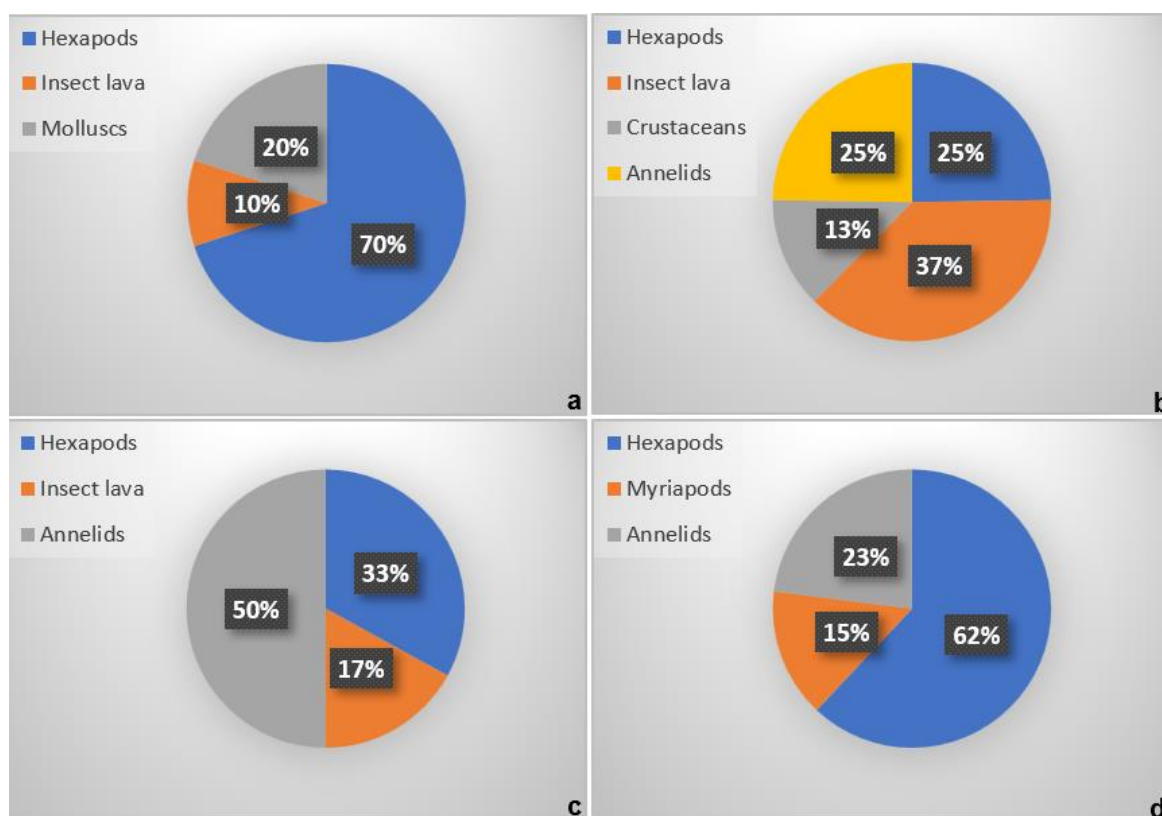
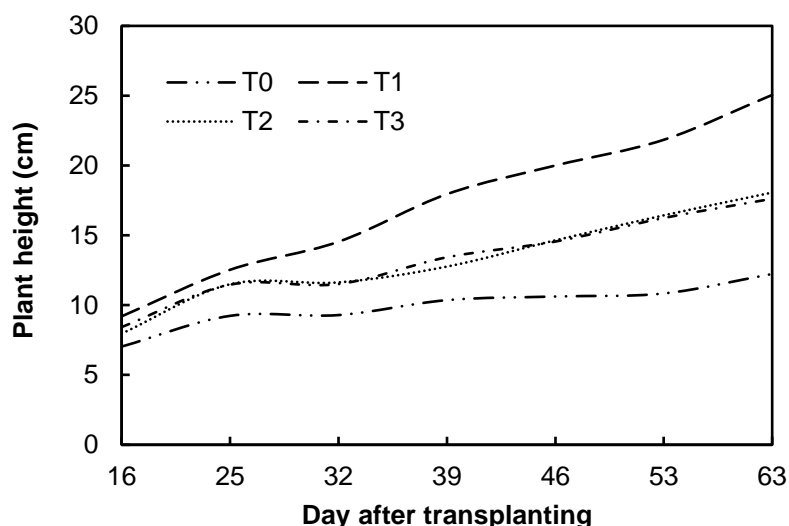
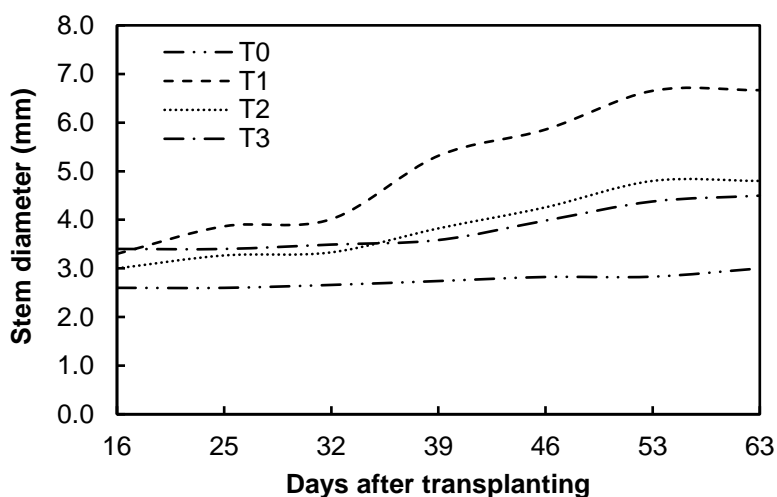


Fig. 3. Soil diversity of fauna of amended soil with control (a), compost (b), compost + microorganisms (c) and biochar (d)



**Fig. 4. Growth rate in height of pepper plant with time**



**Fig. 5. Stem diameter increasing of pepper plants with time**

Fig. 6 shows the evolution of the number of fully unfolded living leaves of plants over experiment period. Similar to the first two parameters studied, the data show a significant difference in the number of leaves between the different treatments. Plants from treatment T1 showed a higher number of leaves throughout the field trial period than plants from treatments T2 and T3. At the 63<sup>rd</sup> day after transplanting, plants had average leaf numbers of  $20 \pm 1.37$ ,  $13 \pm 6.00$  and  $10 \pm 3.57$  leaves respectively for T1, T2 and T3. The number of leaves on plants in these three treatments is higher than in treatment T0, where plants had an average of  $8.67 \pm 3.06$  leaves at the end of trial.

### 3.5 Total Plant Biomass

Shoot and root biomass as well as total biomass produced by the plants at the end of experiment are shown in Fig. 7 and Table 6. Results of shoot and root biomass show a significant effect of treatments. Shoot and root biomass decreased from treatment T1 to treatments T2 and T3. These plants have higher biomasses than plants from the T0 control treatment (Fig. 7).

The relative proportion of root biomass to shoot biomass is equal to 30 for plants from control treatment T0 and treatment T3, whereas it is less than 30 for the other two treatments (T1 and T2)



(Table 6). The total biomass of plants from the T0 treatments was 83%, 76% and 40% lower than that of plants from treatments T1, T2 and T3 respectively (Table 6).

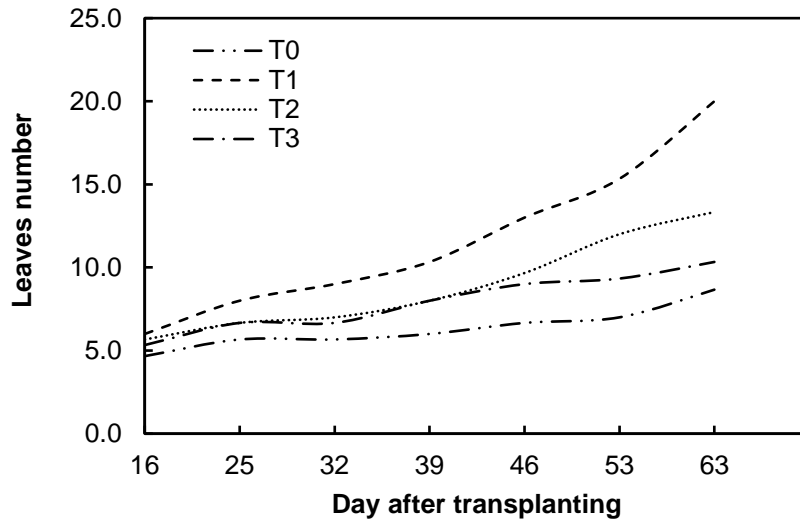


Fig. 6. Number of fully unfolded leaves of pepper plants with time

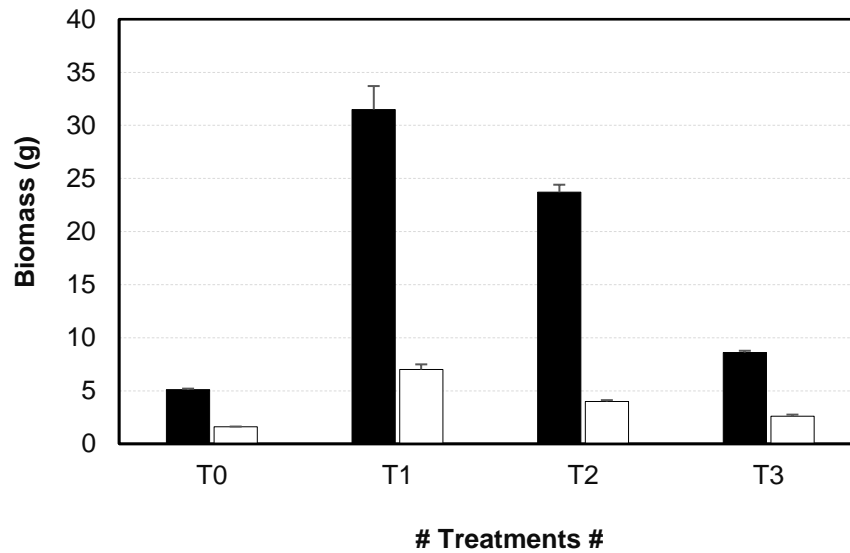


Fig. 7. Shoot and root biomass of pepper plants

Table 6. Root and shoot biomasses and root/shoot ratio per plant

Treatments	Shoot biomass	Root biomass	Total biomass	Root/Shoot ratio
	----- (g) -----			
<b>T0</b>	5.10	1.60	6.70	31
<b>T1</b>	31.50	7.00	38.50	22
<b>T2</b>	23.70	4.00	27.70	17
<b>T3</b>	8.60	2.60	11.20	30

### 3.6 Yields of Pepper

Production per plant and total yield of the pepper crop in this study are given in Table 7. Production per plant shows a significant effect in relation to treatment. Production per plant follows the general trends of morphological parameters. Plants from amended soils yielded 6-, 3- and 2-times higher fruit per plant, for treatments T1, T2 and T3 respectively, compared to plants from control soils. Among the treatments, plants from treatment T1 had the highest production per plant, followed by T2 and T3. This production results in highly variable total yields per treatment, with the highest yield obtained with treatment T1 and the lowest with control T0.

## 4. DISCUSSION

### 4.1 Effect of Organic Matter on Chemical Fertility and Soil Biodiversity

In this study, three types of organic matter were applied to the soil as an amendment for organic pepper cultivation. Each of these organic materials has specific properties for soil conditioning. Indeed, according to various studies, the addition of organic matter in the form of compost or biochar improves soil properties [15-18]. One of the immediate properties improved is the soil's acid-base status [19,20]. In this study, the pH values of the control and amended soils were similar. These results therefore seem contradictory to those observed in the literature. However, it should be noted that the effect of organic waste products on pH depends on their chemical composition and the transformations in the soil. The nitrogen and organic sulfur contain in applied organic matter contribute to soil acidification. Their transformation by biological oxidation leads to the production of nitric acid ( $\text{HNO}_3$ ) and sulfuric acid ( $\text{H}_2\text{SO}_4$ ). Acidification is complete when the nitrate ( $\text{NO}_3$ ) and sulfate ( $\text{SO}_4$ ) produced by acid dissociation are leached out. This process is quite realistic given the high rainfall in the area. But organic products also contain organic anions whose negative charge is neutralized by cations (potassium, calcium, magnesium and sodium). The biological oxidation of these organic anions has an effect similar to that of the bases contained in basic mineral amendments [21]. The second possible explanation would be the low doses of organic products applied to the soil in this study. In fact, pH improvement in soil amended with organic matter is proportional to the dose of organic matter applied to the soil

[18]. The result is a more marked improvement in soil pH as the amount of composted organic matter applied increases. The optimal dose of  $90\text{t}\cdot\text{ha}^{-1}$  over three years is recommended for acid soils as solid composts (dry matter) [22]. In this study, the amount of organic matter added was well below this value.

Total nitrogen, organic carbon and available phosphorus levels in the treated soils, although slightly higher than in the control soil, remained statistically similar. This suggests that organic matter inputs did not improve soil levels of these nutrients. These results are quite contradictory to what is known about the effect of organic matter inputs on soil properties. This could be explained by the very short experimental time needed to ensure proper mineralization of the organic matter. According to Angers et al. [23], time and the nature of the organic matter are key factors in the mineralization of organic products. This mineralization is reflected in the soil's C/N ratio. The C/N ratio obtained after the trial is below 12 for the soils in treatments T0, T1 and T2, in contrast to the soil in treatment T3, which has a value of 14.60 C/N. Values below 12 indicate that the soil is functioning well, with good mineralization of nitrogen into plant-available nitrates ( $\text{NO}_3$ ). On the other hand, C/N values above 12 suggest an imbalance between nitrogen and carbon, and could indicate a soil with a low rate of organic matter mineralization or with high organic matter inputs [24].

Soil organic matter amendments also improve the exchange complex and the rate of exchangeable bases in the soil [25,20]. This is due to the fact that organic matter contributes to the constitution of the cation exchange capacity of soils, and this contribution is primordial in tropical soils with low exchange activity. It will therefore increase the soil's ability to store and return the necessary cations (K, Mg, Ca, Na) to plants in an easily assimilated form. In this study, the exchange complex and the rate of exchangeable bases appear to be insensitive to the addition of organic matter. The values of these two parameters are indistinctly similar to those of the control soil. Various studies show a very close relationship between organic matter content, CEC and soil pH. As pointed out by Tan and Dowling [26], it is important to distinguish between the permanent cation exchange capacity (pCEC) and the pH-dependent variable cation exchange capacity (vCEC) in soils, as it illustrates the contribution of organic matter and mineral phases to soil CEC. Most soils carry both

**Table 7. Fruit production per plant and total yield**

Treatments	Fruit production per plant (g)	Total Yield (t.ha <sup>-1</sup> )
T0	69.30±6.90	1.85±0.18
T1	416.00±62.4	11.09±1.66
T2	208.00±16.60	5.55±0.44
T3	138.70±4.20	3.70±0.11

types of charge, resulting in the classic observation that soil CEC tends to increase with increasing pH due to the deprotonation of functional groups as pH increases [27]. The CEC<sub>p</sub> is considered to be derived from the mineralogical fraction, while the CEC<sub>v</sub> is considered to be derived from soil humus. The contribution of humus to CEC can vary between 25% and 90%, as it possesses strong negative charges provided by functional groups (mainly carboxylic and phenolic acids). In the acid soils, the rapid degradation of organic matter associated with high rainfall means that the soil is unable to develop and set up variable loads. As a result, CEC in these soils is mainly due to permanent loads. For this reason, any addition of organic matter should be sufficient to allow any variation in CEC and exchangeable base levels

Similar to chemical fertility indicators, soil fauna appears to be little affected by organic matter inputs, contrary to the observations of Wang et al. [28] and Yan et al. [29]. These previous works show that soil fauna, including protozoa and invertebrate groups such as nematodes, mites and earthworms, are also strongly influenced by organic amendments. This effect on soil fauna is a consequence of changes in pH and soil physical properties (aggregation and porosity) [30]. In this study, the low variation in the number and diversity of organisms in the control and amended soils could therefore be explained by the low impact of organic matter input on soil chemical properties.

#### 4.2 Effect of Organic Matter on Morphological Parameters and Pepper Yields

The peppers (*Capsicum annuum*) are very demanding in terms of soil quality. This plant prefers deep, well-drained, warm soil with a good supply of humus and easily-available nutrients. In this study, organic matter inputs in various forms did not substantially improve the chemical fertility and biological diversity of the soil. This resulted in insufficient yields, as less than 15 t.ha<sup>-1</sup>. However, it should be noted that yield was

improved under treatment T1 with the application of compost compared with the other two treatments, compost associated with microorganisms and biochar, and the control. Plants in this T1 treatment also showed the highest morphological parameters (plant height, stem diameter, number of leaves). This could be due to the quality of the compost applied. The C/N ratio is the most commonly measured parameter for assessing compost maturity. The data show that for treatment T3 (biochar), the ratio is above 12, suggesting that decomposition of organic matter is very limited and consequently has a limited impact on soil properties, unlike treatment T1. The C/N ratio of soils from this T1 treatment is very close to 10, as carbon is lost through mineralization more rapidly than nitrogen, so that the C/N ratio decreases over time and tends towards a value characteristic of humus formed under different conditions. Under these conditions, microorganisms thrive and induce accelerated mineralization of the organic matter present, with the amount of CO<sub>2</sub> produced depending on the microbial population, their diversity, the metabolic enzymes secreted and the composition of the amendments applied [31]. Mineralization of organic matter is a fundamental process, as it leads to its transformation into simple elements, the only ones that can be assimilated by plants. As a result, soils in treatment T1 had high potassium levels and average nitrogen and phosphorus levels. The better plant growth and yield obtained with T1 treatment could therefore be explained by better plant nutritional conditions. Indeed, vegetative plant growth and yields are positively correlated with nutrient uptake, particularly nitrogen, which plays an important role in increasing leaf index and production, as well as photosynthetic activity [32]. The presence of potassium observed in the soils of treatment T1 may have contributed to flower bud initiation and fruiting, as suggested by Sardans and Peñuelas [33]. Potassium also promotes root development. As a result, plants in this treatment were very efficient in biomass production and soil nutrient uptake, resulting in an average BR/BA ratio. Treatments T2 and T3 produced fairly low yields

with average morphological parameters. Compared with treatment T1, these results suggest low to medium mineralization of compost coupled with microorganisms and biochar, resulting in low release of mineral elements accessible to plants.

## 5. CONCLUSION

The aim of this study was to evaluate the effect of various organic matter inputs on the fertility of a pepper-grown soil. A single dose of 1kg/m<sup>2</sup> was used for all treatments: T0: control, T1: compost, T2: compost combined with microorganisms and T3: biochar made it possible to assess the effect of each organic matter on the chemical and biological properties and on the growth and productivity of pepper plants. The different organic materials influenced chemical and biological properties, as well as growth and production parameters, compared with the T0 control.

The results show that the various organic matter treatments had little impact on the chemical properties (total organic carbon, total nitrogen, assimilable phosphorus, CEC, exchangeable bases and pH (water + KCl) of the soil. In addition, the soil fauna did not seem to be affected by the different organic matter treatments, as it did not have a long time to be mineralized. In addition, growth parameters (height, diameter at collage, number of leaves) and productivity were greatly influenced by treatment T1, unlike the other treatments. This study indicates that the compost-based treatment (T1) is the best for pepper cultivation in our study area.

## 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 manuscripts.

## ACKNOWLEDGEMENT

We thank Mr. ADOU Kouao for his assistance in the laboratory and Dr. Bouadou Oi Bouadou for his valuable comments and suggestions on the initial version of the manuscript. This research was supported by the annual research program fund of the Félix Houphouët-Boigny University (Abidjan).

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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