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

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)wereappliedtothesoil. This studyevaluatesandcomparestheeffect ofvariousorganicamendment on the soilfertilityunderpepper.Afield trialwascarriedoutinarandomizedblockdesignwithfourtreatments(T0,T1,T2andT3)and repeated three times in the Agboville department, located in Côte d'Ivoire. Growth and productivity parameters were measured during the experiment. At the end of the experiment, soil and plant samples were taken for chemicalanalysisandtodeterminesoilfauna.Theresultsshowthatthevarioustreatmentsh ad little impact on soil chemical parameters. As for the soil fauna, results indicated a low level of biologicalactivity under all treatments.However,acomparison oforganicmatter types shows thatthecompost-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.Withaviewtointensifyingpepperproduction,itwouldbeadvisable to continue this work with long-term experiments while increasing the doses of organic matter applied to the soil.

Keywords: Soilfertility,Organicmatter,Peppers,Agboville,IvoryCoast

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]. 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 [4-11]. However, current agricultural practices without recycling harvest residues results in a rapid decline in the level of organic matter in soils, leaching of bases (Ca^{2+}, Mg^{2+}, K^{+} and 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

TheexperimentwascarriedoutintheopenfieldattheuniversitysexperimentalsiteinM'Brou, located in the department of Agboville, in southern Côte d'Ivoire. The experiment site coordinates of the site are 5°35'50.3 "N and 4°21'40.3 "W(Figure 1).The topography of the department isrelativelyflat,withaltitudesrangingfrom0to200m.Theclimateisequatorial type,withfourseasons (two dry seasons and two rainy seasons). Average annual rainfall is 1,700 mm, with an average annual temperature of 27°C. Vegetation cover is dominated by mixed ombrophilousforestandmesophilousforest,dominatedbytulip trees and cheese trees. The study site is located on the boundary of the sedimentary basin and the crystallinebasement.ThebasementformationsencounteredintheareaconsistofBirimiana nd Precambrian formations (schists, metaarenites and metasiltones). Leached ferralsols, have exclusively developed on these rocks.

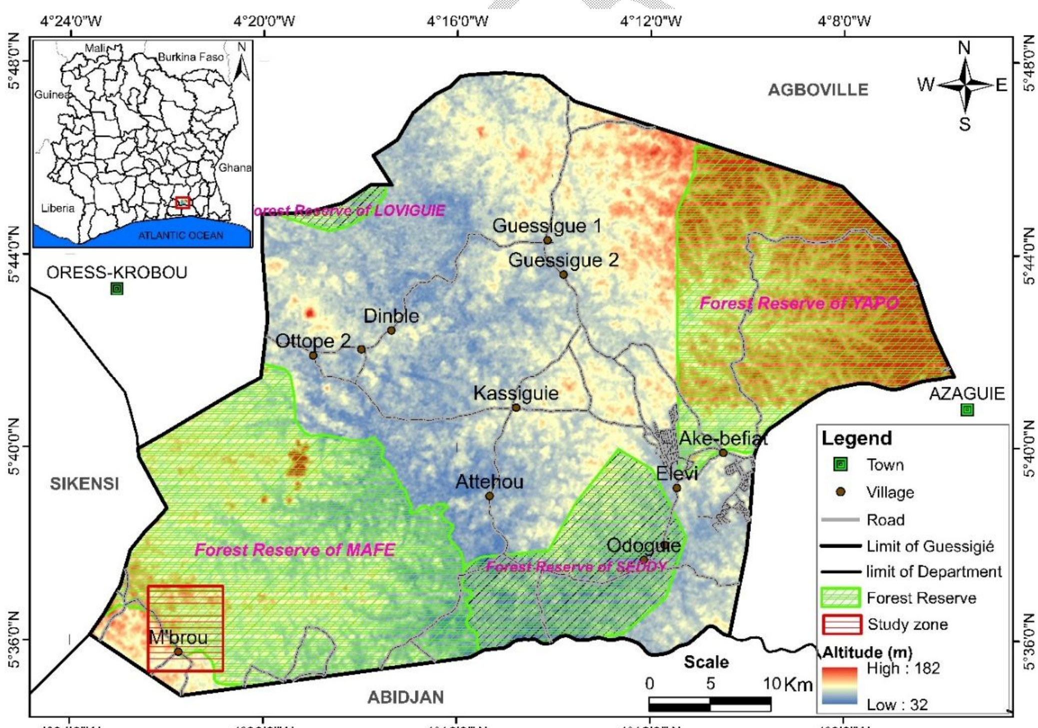

Figure1:Locationofstudysite

2.2. Plant material

The plant material used for this study is the pepper (*Capsicum annuum*), variety called Yolo Wonder^{+} from Technisem®.Theperformanceofthispeppervarietyisinfluencedbyclimaticconditions.This variety is highly resistant to disease. Its characteristics are given in Table 1.

Table 1: Characteristics of the used Yolo Wonder pepper variety

Pepper variety	**Cycle (days)**	**Yield (t ha^{-1})**	**Agronomic characteristics**	**Fruit characteristics**
Yolo wonder	120 - 150	60-70	Tolerantand disease-resistant	Greensquareshape

2.3. Organic matter

Inthisstudy,threetypesoforganicmatterwereappliedtothesoil.Thesewere classical compost, compost combined with microorganisms (fungi, bacteria and yeast) and biochar.Thebiocharusedinthisstudywasproducedfromamixtureofguineafowldroppingsa nddried strawinaconventionalpyrolysisfurnace.Approximately40kgofdriedguineafowldroppings and4kgofdriedstrawwerecombustedwithoutoxygeninthepyrolysisfurnacetoproduce15 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®. The compost was obtained from the fermentable fraction of household waste, livestock effluents (manure,slurry)andcropresidues.Thiswasmixedwithgreenwastefromthelocalauthority's green spaces. The compost associated with the microorganisms was supplied by Lab of plant production of the University NanguiAbrogoua, Abidjan. This compost was obtained from the compostingofamixtureofvariousbiodegradablematerialscomposedofanimaldung(poultr y droppings) and legumes (*puraria*), mixed with mycorrhizal fungi and bacteria extracted from grass (*Panicum maximum*) roots.

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 untiltotalimmersion, thenafter wiping, two seedsweresown atadepth 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^2) atarate ofeight seedlings perbed spaced70 cmapart. The beds were prepared by spreading various organic amendments. Organic matter was spread on the surface beds using the following treatments:

- Controltreatment(T0):noorganicmatteraddedtothesoil,
- Treatmentwith compost(T1):applicationof 5kgof compost,
- Treatment with compost combined with microorganisms (T2): application of 5 kg of compost,
- Biochartreatment(T3):applicationof5kgbiochar.

Eachtreatmentwasrepeatedfourtimesinanexperimentaldesignoffourcompleterandomized 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 14rd 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:

- diameterofmeasured stems,
- plantheightfromcrownto apicalbud,
- Thenumberoffullyunfoldedleaves,
- Numberofflowersandfruitperplant.

Totalyield forthefirstharvestwas determined by the weightingof fruit perplant. 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.Asecondpartofthesoilsampleswasdriedatroomtemperatureandsievedto2mm. 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

Thenumberanddiversityofsoilfaunaweredeterminedbyobservationandcountingusingth e Berlese funnel. Chemical analyses were carried out at the pedology laboratory of the Institut National Polytechnique Félix Houphouet-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)	Oxidationwith$K_2Cr_2O_7$inhotacidmedium+ titration of excess oxidant with Mohr's salt.
Total nitrogen	(%)	Kjeldahl	MineralizationwithconcentratedH2SO4(96%)+ Distillationoftheammoniaproducedandentrapment inboricacidandtitration of$(NH_4)_3BO_3$ with HCl 0.1N
Available phosphore	(%)	Olsen	Soil extraction with $NaHCO_3$0.5NatpH8.5+shaking(30 mn) +colorimetermeasurement.
Exchangeable cation (Ca^{+2}, Mg^{+2}, Na^+, K^+)	$cmol^+ kg^{-1}$	Ammonium acetate	Saturationwith1MammoniumacetatepH7(shaking) + Centrifugation(10min)+Spectrophotometer measurementofsupernatant.
Cation Exchange Capacity (CEC)	$cmol^+ kg^{-1}$	Ammonium acetate	+ Measurementof CECbymeasuring NH^+bound to exchange complex.

Saturationwith1MammoniumacetatepH7(shaking) is the first line of the CEC description.

2.6. Statistical data processing

Data collected during experimentation and sample analysis were subjected to analysis of variance(ANOVA)toidentifythesignificanceoftheeffectoforganicmatterinput.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).

Totalorganicmattercontentvariesfrom2.30to2.50%, with an average of 2.43%.Totalnitrogencontent 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^{2+}) is the dominant cation among exchangeablebases.Thesaturation ratealso remains low, notexceeding 30% of the soil's CEC. Lastly, the soil has low levels of available phosphorus, averaging less than 3%.

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^{2+} ($cmol^{+}.kg^{-1}$)	2.46±0.26	0.80±0.27
Mg^{2+}($cmol^{+}.kg^{-1}$)	0.49±0.06	0.13±0.07
K^{+}($cmol^{+}.kg^{-1}$)	0.26±0.05	0.24±0.06
Na^{+}($cmol^{+}.kg^{-1}$)	0.04±0.01	0.02±0.01
CEC ($cmol^{+}.kg^{-1}$)	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

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). Figure 2 shows the pH values determinedinsoilsof varioustreatments.ItshowsthatthepH (water extraction)isonaverage1.40pHunits higher than the pH (KCl solution extraction), but pH values (water and KCl) are similar between all treatments to another.

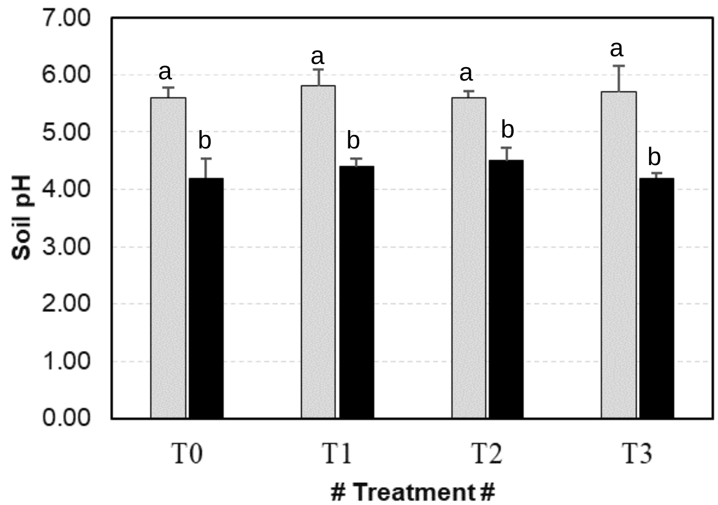

Figure2:pH obtained with water (grey)andKCl solution (black) extraction in amended soil.

Table4reportsdataonsoilchemicalparametersat the end of experiment.Theresultsshow that the total nitrogen content is similar in all amended soils, with an average of 0.18±0.06%, slightly higher than in the control soil with insignificant difference. Exchangeable bases remain low aftersoilamendment, but measured levels arehigherthaninitiallevels, exceptforNa^{+}, whateverthetreatment.BasesaredominatedbyCa^{2+}andMg^{2+},whoselevelsarehighestinT1 treatment soils. The CEC in these soils is also fairly low, with values below 12 cmol^{+}.kg^{-1}.

Saturationlevelsseemtohaveimprovedintheamendedsoils,withsaturationlevelsrisingfrom 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 4: Chemical pepper-growing soils fertility indicators following treatments.

Treatment	N	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	P
	(%)	----------- ($cmol^{+}.kg^{-1}$) -----------					(%)
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 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 higherintreatedsoils(T1,T2andT3).Thedifferenceinorganicmattercontentincreasedfrom 4%to33%intreatmentsT1toT3,comparedwiththeorganicmattercontentinthecontrolsoil. 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 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

Thenumberanddiversityoflivingorganisms inthesoils areshowninFigure3.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 100gofsoil. Soil faunadiversityinthesesoilsisverylimited.Infact,four(4)classesoforganisms wereobservedinthesoils,particularlyintreatmentT1.Intheothertreatments,three(3)class es of organisms were detected per 100 g of soil. Hexapods were abundant (62%-70%) in control andT3soil,whileinsectlarvaeandannelidsweremostabundantinT1andT2soil.Inaddition to these different classes, mollusks (T0), crustaceans (T1) and myriapods (T3) were also distinguished in soils.

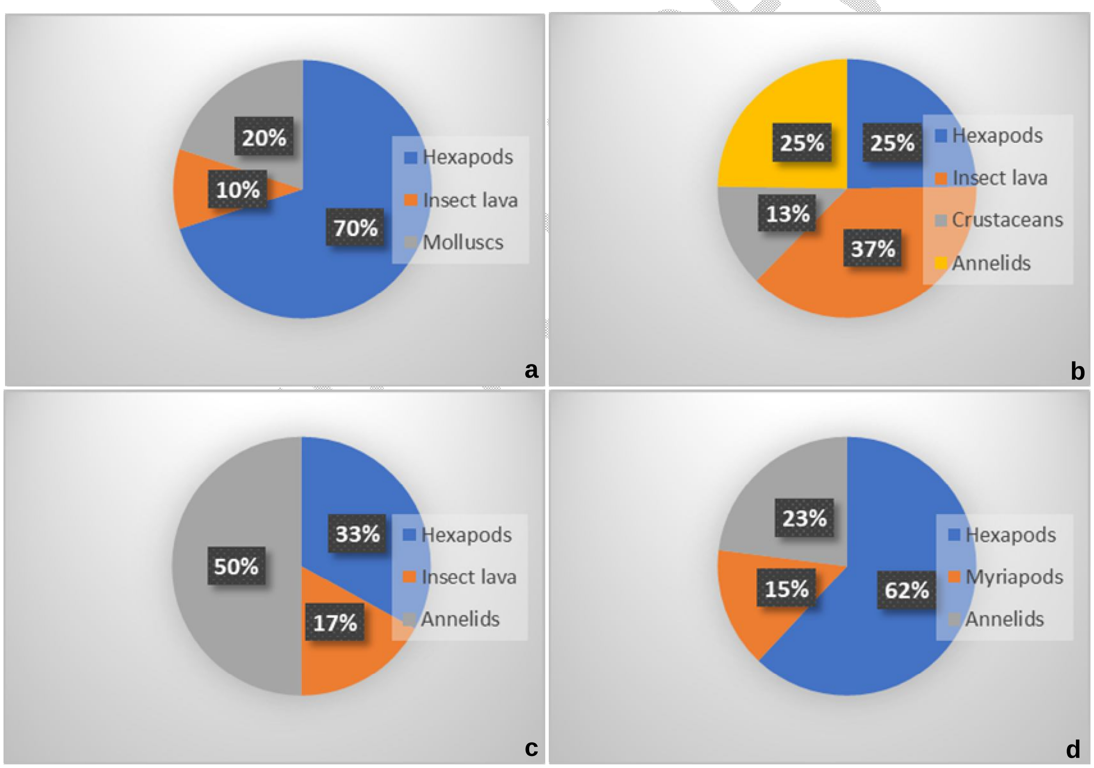

Figure3: Soil diversity of faunaof amended soil with control (**A**),compost (**B)**,compost + microorganisms (**C)** **a**nd biochar (**D**).

3.4. Plant growth indicators

Figure 4 shows the evolution of plant height over the growing period. Results showasignificantdifferenceinheightbetweenthedifferenttreatments.Significantgrowthin plant height was observed with treatment T1, with an average height of 25.06±4.67 cm at the 63rd day after transplanting,higherthantheheightofplantswithtreatmentsT2andT3.Plantsharvested with thesetwotreatments had mean heights of 18.07±3.58 cm and 17.62±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±3.48 cm at the 63rd day after transplanting.

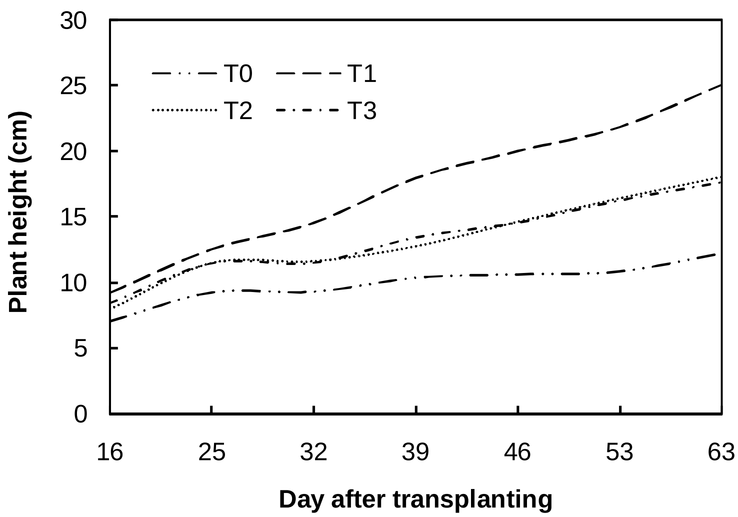

Figure4:Growth rate in height of pepper plant with time.

Figure5showstheevolutionofdiameter of the stemoverthefield trialperiod.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 diameterof6.67±2.07mmat the 63rd day after transplanting,greaterthanthestemdiametersofplantswith treatments T2andT3, given meandiametersof4.80±0.98mmand4.50±0.98mmrespectively. Plantstem diameters inallthree amended soils werehigherthanstem diameter of plant harvested withtreatmentT0,whoseplantshadthesmallest diameter at 3.00±0.87 mm at the 63rd day after transplanting.

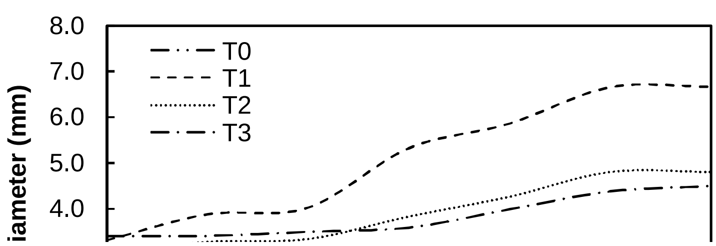

Figure 5: Stem diameter increasing of pepper plants with time.

Figure 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 showedahighernumberofleavesthroughoutthefield trialperiodthanplantsfromtreatments T2 and T3. At the 63rd day after transplanting, plants had average leaf numbers of 20±1.37, 13±6.00 and 10±3.57 leavesrespectivelyforT1,T2andT3.Thenumberofleavesonplantsinthesethreetreatment s is higher than in treatment T0, where plants had an average of 8.67±3.06 leaves at the end of trial.

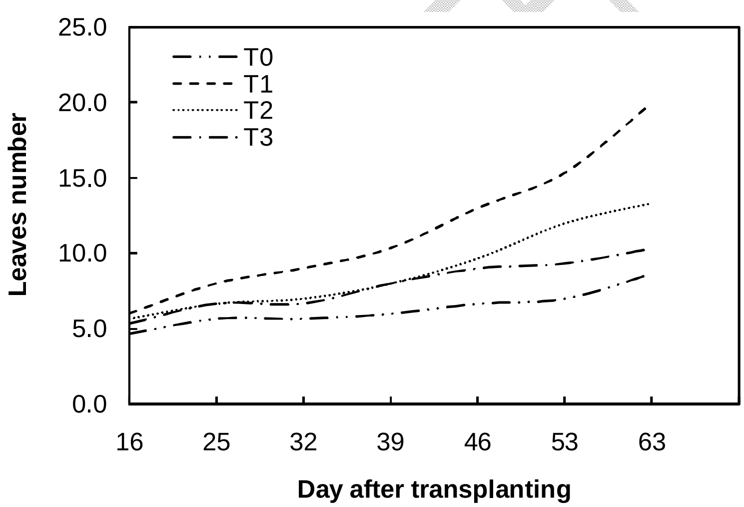

Figure6:Numberof fully unfoldedleaves of pepper plants with time

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 Figure 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 (Figure 7).

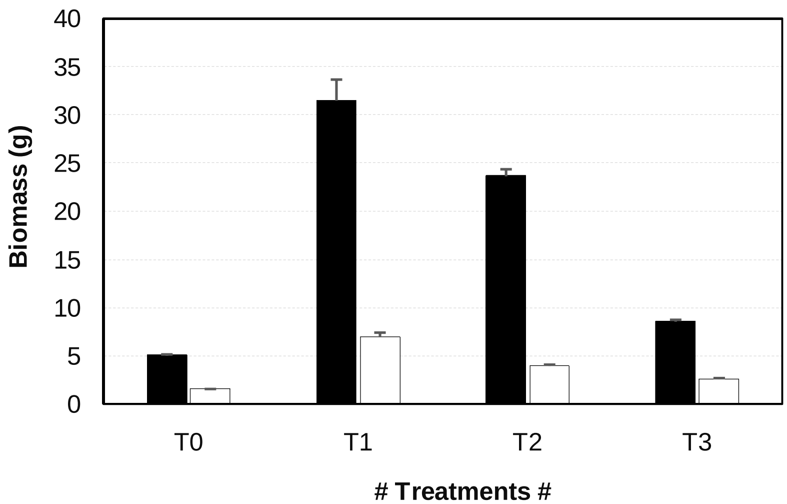

Figure7:Shootandrootbiomass of pepper plants.

Therelativeproportionofrootbiomasstoshootbiomassisequalto30forplantsfrom 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%lowerthanthat ofplants fromtreatments T1, T2 andT3 respectively (Table 6).

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

Treatments	**Shoot biomass**	**Rootbiomass**	**Total biomass**	**Root/Shoot ratio**
	------------------------------ (g) ---------------------------------- -			
T0	5.10	1.60	6.70	31

T1	31.50	7.00	38.50	22
T2	23.70	4.00	27.70	17
T3	8.60	2.60	11.20	30

3.6. Yields of pepper

ProductionperplantandtotalyieldofthepeppercropinthisstudyaregiveninTable 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.

Table 7: Fruit production per plant and total yield.

Treatments	**Fruit production per plant** (g)	**Total Yield** ($t.ha^{-1}$)
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

4. Discussion

4.1. Effect of organic matter on chemical fertility and soil biodiversity

Inthisstudy,threetypesoforganicmatterwereappliedtothesoilasanamendmentfororganic peppercultivation.Each of these organic materialshasspecificpropertiesforsoilconditioning.Indeed,accordingtovariousstudies,th e addition of organic matter in the form of compost or biochar improves soil properties [12-15]. One of the immediate properties improved is the soil's acid-base status [16-17]. 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 thattheeffectoforganicwasteproductsonpHdependsontheirchemicalcomposition 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 (HNO_3) and sulfuric acid (H_2SO_4). Acidification is complete when the nitrate (NO_3) and sulfate (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, magnesiumandsodium).Thebiologicaloxidationoftheseorganicanionshasaneffectsimil ar to that of the bases contained in basic mineral amendments [18]. 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 [15]. The result is a more marked improvement in soil pH as the amount of composted organic matter applied increases. The optimal dose of 90t.ha^{-1} over three years is recommended for acid soils as solid composts (dry matter) [19]. 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 thatorganicmatterinputs did not improvesoillevels of these nutrients. These results arequite contradictorytowhatisknownabouttheeffectoforganicmatterinputsonsoilproperties.This couldbeexplainedbytheveryshortexperimentaltimeneededtoensurepropermineralizatio n of the organic matter. According to Angers*et al*. [20], time and the nature of the organic matterarekeyfactorsinthemineralizationoforganicproducts.Thismineralizationisreflecte d inthesoil'sC/Nratio.TheC/Nratioobtainedafterthetrialisbelow12forthesoilsintreatments T0,T1andT2,incontrasttothesoilintreatmentT3,whichhasavalueof14.60 C/N.Values below 12 indicate that the soil is functioning well, with good mineralization of nitrogen into plant-available nitrates (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 [21].

Soil organic matter amendments also improve the exchange complex and the rate of exchangeablebasesinthesoil[22, 17].Thisisdue tothefactthatorganicmattercontributes totheconstitutionofthecationexchangecapacityof soils, and this contribution is primordial in tropical soils with low exchange activity. It will therefore increase thesoil's ability to storeandreturn thenecessary 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 TanandDowling[23],itisimportantto distinguishbetweenthepermanentcationexchange capacity (pCEC) and the pH-dependent variable cation exchange capacity (vCEC) in soils, asitillustratesthecontributionoforganicmatterandmineralphasestosoilCEC.Mostsoilscarry both 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 [24]. The CECpisconsideredtobederivedfromthemineralogicalfraction,while the CECvisconsideredto be derived from soil humus. The contribution of humus to CEC can vary between 25% and 90%,asitpossessesstrongnegativechargesprovidedbyfunctionalgroups(mainlycarboxylic and phenolic acids). In the acid soils, the rapid degradation of organic matterassociatedwithhighrainfallmeansthatthesoilisunabletodevelopandset upvariable loads. As a result, CEC in these soils is mainly due to permanent loads. For this reason, any additionoforganicmattershouldbesufficienttoallowanyvariationinCECandexchangeable base levels.

Similartochemicalfertilityindicators,soilfaunaappearstobelittleaffectedbyorganicmatter inputs, contrary to the observations of Wang *et al.* [25] and Yan *et al.* [26]. These previous works showthatsoilfauna,includingprotozoaandinvertebrategroupssuchasnematodes,mitesand earthworms,arealsostronglyinfluencedbyorganicamendments.Thiseffectonsoilfaunais a consequence of changes in pH and soil physical properties (aggregation and porosity) [27]. 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 $t.ha^{-1}$.However,itshouldbenotedthatyieldwasimproved 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,numberofleaves).Thiscouldbeduetothequalityofthecompostapplied.TheC/N ratioisthemostcommonlymeasuredparameterforassessingcompostmaturity.Thedatashow thatfortreatmentT3 (biochar),theratio isabove12,suggestingthatdecompositionoforganic matterisverylimitedandconsequentlyhasalimitedimpactonsoilproperties,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_2produced depending on the microbial population, their diversity, the metabolic enzymes secreted and the composition of the amendments applied [28].Mineralizationoforganicmatterisafundamentalprocess,asitleadstoits transformationintosimpleelements,theonlyonesthatcanbeassimilatedbyplants.Asaresult, 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 [29]. ThepresenceofpotassiumobservedinthesoilsoftreatmentT1mayhavecontributedtoflow er bud initiation and fruiting, as suggested by Sardans and Peñuelas[30]. Potassium also promotes root development.Asaresult,plantsinthistreatmentwereveryefficientinbiomassproductionand soilnutrientuptake,resultinginanaverageBR/BAratio.TreatmentsT2andT3producedfairly lowyieldswithaveragemorphologicalparameters.ComparedwithtreatmentT1,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

Theaimofthisstudy wastoevaluatetheeffectofvariousorganicmatterinputsonthefertility of a pepper-grown soil. A single dose of 1kg/$m^2$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.

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