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Coffee Pulp and Husk Residue Compost Improve the Growth of Robusta Coffee (*Coffea canephora*) Seedlings in the Nursery

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ABSTRACT

Background: Compost made from coffee husk and pulp residues could serve as a sustainable alternative to chemical fertilizers for fertilizing coffee fields.

Methods: This study was conducted to determine the agronomic value of seven compost formulations based on coffee residues [Husk residues+chicken manure (3:1); Husk residues+chicken manure (2:1); Husk residues+chicken manure (1:1); Husk residues+pig slurry (3:1); husk residues+pig slurry (2:1); pulp residues+chicken manure (3:1); and husk residues+pig slurry (1:1)] mixed in equal proportion with potting soil on the vegetative growth of coffee seedlings in the nursery. The experimental design employed was a completely randomized design with one factor.

Result: Six months after planting, the compost based on husk residues+chicken manure (3:1) and the compost based on husk residues+pig slurry (3:1) were found to be more effective. The former led to rapid growth in plant height (46.85 cm compared to 27.1 cm) and diameter. It is followed in terms of effectiveness on height growth by the compost based on husk residues+Pig slurry in proportion (3:1). These composts also had a positive impact on the fresh and dry biomass (aboveground and root) of coffee plants. This can be explained by the high content of organic matter, nitrogen, potassium, calcium and phosphorus in these composts. These two composts mixed in equal proportion with potting soil are recommended for coffee plant production in the nursery. Furthermore, field experimentation would confirm their effectiveness.

Key words: Chicken manure, Compost, Growth, Husk residues, Pig slurry, Pulp residues, Robusta.

INTRODUCTION

Côte d'Ivoire is a country whose economy is largely based on agriculture. Coffee is one of its key export products. In Côte d'Ivoire, coffee production reached 320,000 tons of merchantable coffee in 1980 (CNRA, 2017). However, Ivorian coffee production has experienced a drastic decline and currently stands at around 92,300 tons of merchantable coffee (MINADER, 2023; ICO, 2023). Coffee cultivation in Côte d'Ivoire faces significant challenges, including the low utilization of selected plant materials by coffee farmers, with less than 30% adoption (Eponon *et al*., 2017), aging orchards, pest pressuresand declining soil fertility. Regarding fertilization, less than 10% of coffee farmers use mineral fertilization (Eponon *et al.,* 2017). In this context of soil degradation and declining soil fertility, new, cost-effective agricultural practices such as compost amendments from food waste or crop residues are recommended. These practices align perfectly with the principles of sustainable development (Golueke, 1977; Attrasi *et al.,* 2005). Indeed, significant amounts of harvest residues are generated during the post-harvest processing of coffee, either by hulling or pulping (Pinon and Godefroy, 1973). Hulling is the dry post-harvest processing phase of coffee, which transforms the coffee husk into merchantable coffee. These residues, consisting of coffee husks, decompose slowly and accumulate near coffee hulling centers throughout Côte d'Ivoire. The same is true for pulping residues, mainly from the wet processing of coffee. Pulping generates wet residues that rapidly acidify and can be a significant source of pollution. In order to valorize these coffee hulling and pulping residues into organic fertilizers, aerobic composting was carried out at the National Center for Agronomic Research (CNRA) to produce various composts. The resulting compost could thus serve as a sustainable alternative to chemical fertilizers for fertilizing coffee fields and promote the revival of coffee production in Côte d'Ivoire. Therefore, before field testing, it is planned to evaluate the effectiveness of these compost formulations based on coffee hulling and pulping residues on Robusta coffee seedlings in a greenhouse in order to select the best ones.

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MATERIALS AND METHODS

Experimental site

The trial was conducted at the nursery of the research station of the National Center for Agronomic Research (CNRA) in the Man region in October 2023. The nursery site is located in the western region of Côte d'Ivoire (7°19.130′N; 8°19.452′W). The climate in this region is characterized by a single dry season from October to March and a rainy season from April to September. The average temperature is 25°C with an annual average rainfall of 1703 mm over the past ten years (2014-2024). The rainfall pattern in the Man area is monomodal. The soils in the Man area are ferritic soils.

Plant material and technique

The plant material used consisted of one-month-old Robusta coffee seedlings derived from improved seeds from the CNRA. For the proper conduct of the trial, we needed technical equipment. This included a vernier caliper and a measuring tape for growth parameter measurements. An oven was used for determining dry biomass.

The process of manufacturing composts from coffee husk and pulp

The process of making compost from coffee husk and pulp residues involves several steps. To produce one ton of compost from coffee husks, the following ingredients are required: 750 kg of husk or dry pulp residues, 250 kg of an activator (chicken manure, pig manure, or coffee pulp slurry), 10 kg of urea (46% N) and 10 kg of ash from complete combustion of coffee husks (gray in color). The quantities of "Husk Residues-Activator" varied in proportions (3:1, 1:1, 2:1). The composting process involves layering coffee husk residues, coffee pulp slurry, poultry manure, or pig manure, urea and ash from coffee husks successively until reaching a height of one meter. The mixture is then watered until saturated and covered with a black plastic film to retain moisture and heat until compost maturation.

Seven types of compost were produced for this trial, namely:

- Compost based on husk residues + chicken manure (3:1).
- Compost based on husk residues + chicken manure (2:1).
- Compost based on husk residues + chicken manure (1:1).
- Compost based on husk residues + pig slurry (3:1).
- Compost based on husk residues + pig slurry (2:1).
- Compost based on pulp residues + chicken manure (3:1).
- Compost based on husk residues + pig slurry (1:1).

The physico-chemical analysis of the substrates

The pH, as well as the nitrogen, phosphorus (P), potassium (K), carbon (C) and exchangeable bases (Ca^{2+}, Mg^{2+}) content of the composts were determined at the soil analysis laboratory of the National Polytechnic Institute of Yamoussoukro (INPHB). Their composition was analyzed based on the pH interpretation standards of INRA (1995) and the interpretation standard of Calvet and Villemin (1986) for nitrogen, phosphorusand exchangeable bases. Organic matter (OM) was calculated according to international convention using the following formula:

$$OM\ (\%) = carbon \times 1.724.$$

The interpretation standard for organic matter is presented in the following classes: OM < 1 Very low in organic matter; OM: 1 to 2 Low in organic matter; OM: 2 to 4 Moderate in organic matter; OM: > 4 High in organic matter. The C/N ratio, deduced from the values of total carbon and nitrogen, was calculated. It provides indications on the evolution of organic matter, soil biological activityand nitrogen fertilization management. The distribution in classes is as follows: C/N: < 8 Low = Rapid decomposition of organic matter; C/N: 9 to 11 Normal = Good decomposition of organic matter; C/N: >12 High = Reduced biological activity and difficulties in mineralization. A C/N ratio below 8 is considered low; a C/N ratio between 8 and 12 is considered normal; a C/N ratio above 12 is considered high (Gagnard *et al*., 1988). The higher the C/N ratio (>12), the lower the biological activity and the more difficulties in mineralization. This indicates anaerobic conditions and excessive acidity.

The experimental setup

The experimental setup used is a complete randomization with 1 factor (Substrate). Each experimental unit consists of one plant. 10 plants were used for each treatment. The substrates containing compost will be made up of a mixture of potting soil + compost in a 1:1 ratio. In total, 08 substrates, including the control substrate, were tested. These are:

- Control (S1): Potting soil.
- Compost 2: Coffee husk residues + chicken manure (3:1).
- Compost 3: Coffee husk residues + chicken manure (2:1).
- Compost 4: Coffee husk residues + chicken manure (1:1).
- Compost 5: Coffee husk residues + pig slurry (3:1).
- Compost 6: Coffee husk residues + pig slurry (2:1).
- Compost 7: Coffee pulp residues + chicken manure (3:1).
- Compost 8: Coffee husk residues + pig slurry (1:1).

Data collection for growth analysis

Data were collected 6 months after the trial was set up. Various agronomic parameters were collected, including plant vigor and biomass. Plant vigor, expressed through height (cm) and diameter (mm) at the base of young coffee plants, was measured for each plant per treatment and per replication using a graduated ruler and a caliper. Regarding biomass, 3 coffee plants per treatment were selected 6 months after the trial setup for biomass determination. To evaluate the fresh and dry biomass of the organs, each plant was dissected and separated into two compartments: stem + leaves biomass and root biomass. To determine the dry biomass, these organs were placed in envelopes, dried in an oven at 70°C for 48 hours and then weighed using a precision electronic balance to determine the biomass.

Statistical analyses

The collected data are processed using STATISTICA 7.1 software. For each variable, an analysis of variance

(ANOVA) was conducted. The significance test for differences, Fisher's LSD test at the 5% threshold, is used to compare the means obtained to assess significant differences among them.

RESULTS AND DISCUSSION

Determination of physico-chemical characteristics of mature compost

The analysis shows that the physico-chemical characteristics of the composts (Table 1) used in the trial have a basic to neutral water pH (6.1-7.2). These composts have higher organic matter contents compared to potting soil. Compost 2, based on coffee husk residues chicken manure (3:1), has the highest levels of nitrogen (2.17% dry weight), potassium (1.705% dry weight), calcium (2.11% dry weight)and the second-best phosphorus content (0.38% dry weight). Its organic matter content of 25.8 is higher than that of potting soil but lower than all the other composts. The compost based on coffee husk residues + pig slurry (3:1) ranks second in terms of organic matter with 29.3. This compost has values of N, P, K, Ca higher than the control but lower than the compost based on coffee husk residues + chicken manure (3:1). The compost based on coffee pulp residues + chicken manure (3:1) has the highest organic matter content at 118.9% dry weight. Substrates based on composts generally stand out from potting soil due to their high content of N, P, K, Ca and organic matter.

Effect of compost on plant vigor

Data analysis (Table 2) reveals that the substrates have an effect on the growth parameters of coffee plants such as height (F=12.46; P=0.000) and collar diameter (F=9.44; P=0.000). Out of the eight substrates tested, two substrates, "Compost 2: coffee husk residues + chicken manure (3:1)" and "Compost 5: coffee husk residues + pig slurry (3:1)," are considered more effective compared to the control potting soil and the other substrates. Compost 2: coffee husk residues + chicken manure (3:1) led to rapid plant growth with the highest plant heights (46.85±6.3 cm) and collar diameters (6±0.73 mm). This compost is followed in terms of effectiveness by compost 5: coffee husk residues + pig slurry (3:1), which impacted plant height growth (41±7.3 cm). Potting soil was the only substrate that had the weakest effect on coffee plant growth in the nursery. Composts 3, 4, 6, 7 and 8 had intermediate effects between potting soil and composts 2 and 5.

Effect of compost on fresh biomass

In addition to height and collar diameter, the substrate factor also had a significant effect on the fresh biomass of leaves and stems (F=7.45; P=0.000) and root fresh biomass (F=2.9; P=0.036) compared to the control (Table 3). The highest fresh biomasses of leaves and stems were obtained in descending order with compost 2: coffee husk residues + chicken manure (3:1); compost 5: coffee husk residues + pig slurry (3:1); and compost 6: coffee husk

Table 1: Average physico-chemical characteristics of mature composts.

Number	Substrates	Water ph	% d.m							
			C	C/N	M.O	N	P	K	Ca	Mg
Control substrate	Potting soil	6.7	1.99	11.7	3.43	0.17	0.30	0.157	0.072	0.789
Compost 2	Coffee husk residues + chicken manure (3:1)	7.2	15	17	25.8	2.17	0.38	1.705	2.118	0.400
Compost 3	Coffee husk residues + chicken manure (2:1)	6.4	15.80	16.13	27.18	0.98	0.36	1.516	0.998	0.345
Compost 4	Coffee husk residues + chicken manure (1:1)	6.5	22.58	14.6	38.8	1.54	0.42	1.224	0.975	0.312
Compost 5	Coffee husk residues + pig slurry (3:1)	6.3	17	17	29.3	1	0.34	0.6	0.88	0.23
Compost 6	Coffee husk residues + pig slurry (2:1)	6.1	17.59	19.63	30.26	0.90	0.33	0.677	0.891	0.223
Compost 7	Coffee pulp residues + chicken manure (3:1)	7.1	69	34.5	118.9	2.00	0.26	1.108	1.765	0.382
Compost 8	Coffee husk residues + pig slurry (1:1)	6.6	19.89	17.76	34.21	1.12	0.29	0.991	0.935	0.236

% d.m : Dry matter; C/N: Carbon/Nitrogen ratio; M.O: Organic Matter; N: Nitrogen; P: Phosphorus; K: Potassium; Ca: Calcium; Mg: Magnesium.

residues + pig slurry (2:1) with 27.55±3.87 g, 25.3±4.2 g and 23.57±4.6 g, respectively. These three composts also positively impacted root biomass with 14.97±3.16 g for compost 2, 14.85±9.8 g for compost 6 and 9±1.4 g for compost 5 compared to the control. Composts 3, 4, 7, 8 had lower results than composts 2 and 5 but higher than potting soil concerning the fresh biomass of leaves and stems. The positive impact on root fresh biomass of these composts compared to potting soil was not observed.

Effect of compost on dry biomass

The analysis of dry biomass shows the effectiveness of compost 2 and compost 5 on root dry biomass and dry biomass of leaves and stems (Table 4). Data analysis yielded 11.17±1.7 g for aerial dry biomass and 7.04±1.61 g for root dry biomass for compost 2 based on Coffee Husk Residues + Chicken Manure (3:1). For compost 5 based on Coffee Husk Residues + Pig Slurry (3:1), a quantity of 10.2±0.84 g for aerial dry biomass and 4.94±0.92 g for root dry biomass was obtained. Unlike its positive effect on fresh root biomass, compost 6 "Coffee Husk Residues + Pig Slurry (2:1)" did not have a positive effect on root dry biomass compared to the control. Composts 3, 4, 7, 8 had lower results than composts 2 and 5. They did not have a significant effect on root dry biomass compared to the control.

The application of compost based on coffee pulp and husk residues had a positive effect on the growth of robusta coffee plants in the nursery six months after planting. Detailed analysis of the data revealed that this efficacy depends on the composition and formulation of the compost used. Out of the 07 composts tested compared to the control substrate potting soil, two substrates "Compost 2: Coffee Husk Residues + Chicken Manure in proportion (3:1)" and "Compost 5: Coffee Husk Residues + Pig Slurry in proportion (3:1)" were found to be more effective compared to the potting soil and other substrates. Compost 2: Coffee Husk Residues + Chicken Manure in proportion (3:1) resulted in rapid growth of plants in height and diameter. It was followed in terms of height growth effectiveness by Compost 5: Coffee Husk Residues + Pig Slurry in proportion (3:1). These composts also positively impacted the fresh and dry biomass (aboveground and root) of coffee plants compared to the control plants. These results are consistent with previous studies that have demonstrated the direct positive impacts of compost on plant growth (Guittonny-Larchevêque, 2004; Tartoura, 2010; Nasar *et al*., 2019 ; Yoruk *et al*., 2023). Pinon and Godefroit, (1973) demonstrated the effectiveness of coffee pulp in fertilizing banana plantations. Indeed, coffee pulp had a beneficial effect on soil fertility elements as well as banana fruit yield in Azaguié, Côte d'Ivoire. According to their study, this was due to the enrichment in potassium and organic matter.

The physicochemical characteristics of coffee residue-based composts used in our experiment reveal their richness in organic matter and mineral elements compared to potting soil. The compost based on coffee husk residues

Table 2: Effect of compost based on coffee husk and pulp residues on the height and diameter of coffee plants in the nursery.

Number	Substrates	Height (cm)	Diameter (mm)
Control substrate	Potting soil	27.1±4.12^{e}	3.6±0.49^{d}
Compost 2	Coffee husk residues + chicken manure (3:1)	46.85±6.3^{a}	6±0.73^{a}
Compost 3	Coffee husk residues + chicken manure (2:1)	40.87±6.5^{b}	4.8±0.9^{c}
Compost 4	Coffee husk residues + chicken manure (1:1)	38.62±8.28^{bc}	4.93±0.77^{bc}
Compost 5	Coffee husk residues + pig slurry (3:1)	41±7.3^{b}	5.5±0.8^{ab}
Compost 6	Coffee husk residues + pig slurry (2:1)	33.08±7.7^{d}	4.53±0.71^{c}
Compost 7	Coffee pulp residues + chicken manure (3:1)	36.05±4.3^{cd}	4.73±1.12^{c}
Compost 8	Coffee husk residues + pig slurry (1:1)	41.62±5.36^{b}	4.93±1.12^{bc}
Probability and LSD test		F=12.46; p=0.000	F=9.44; p=0.000

F: F-statistic; p: p-value.

Table 3: Effect of compost based on coffee husk and pulp residues on the fresh biomass of coffee plants in the nursery.

Number	Substrates	Fresh biomass leaves + stem	Fresh biomass roots
Control substrate	Potting soil	7.8±0.53^{e}	1.76±0.23^{b}
Compost 2	Coffee husk residues + chicken manure (3:1)	27.55±3.87^{a}	14.97±3.16^{a}
Compost 3	Coffee husk residues + chicken manure (2:1)	17.88±3b^{c}	7.49±2.63^{ab}
Compost 4	Coffee husk residues + chicken manure (1:1)	20.65±3.64^{abc}	7.6±2.7^{ab}
Compost 5	Coffee husk residues + pig slurry (3:1)	25.3±4.2^{a}	9±1.4^{ab}
Compost 6	Coffee husk residues + pig slurry (2:1)	23.57±4.6^{ab}	14.85±9.8^{a}
Compost 7	Coffee pulp residues + chicken manure (3:1)	14.93±2.43^{c}	3.817±1.18^{b}
Compost 8	Coffee husk residues + pig slurry (1:1)	17.17±2.04^{bc}	5.06±1.31^{ab}
Probability and LSD test		F=7.45; p=0.000	F=2.9; p=0.036

Table 4: Effect of compost based on coffee husk and pulp residues on the dry biomass of coffee plants in the nursery.

Number	Substrates	Dry biomass leaves + stem	Dry biomass roots
Control substrate	Potting soil	3.33±0.3^{e}	0.94±0.22^{d}
Compost 2	Coffee husk residues + chicken manure (3:1)	11.17±1.7^{a}	7.04±1.61^{a}
Compost 3	Coffee husk residues + chicken manure (2:1)	6.8±1.18^{cd}	3.47±1.8^{bcd}
Compost 4	Coffee husk residues + chicken manure (1:1)	8.14±1.35^{bc}	3.99±1.54^{bc}
Compost 5	Coffee husk residues + pig slurry (3:1)	10.2±0.84^{ab}	4.94±0.92^{ab}
Compost 6	Coffee husk residues + pig slurry (2:1)	8.1±1.57^{bc}	3.13±1.07^{bcd}
Compost 7	Coffee pulp residues + chicken manure (3:1)	5.4±0.96^{de}	1.90±0.57^{cd}
Compost 8	Coffee husk residues + pig slurry (1:1)	7.16±1.22^{cd}	3.07±0.9^{bcd}
Probability and LSD test		F=8.28; p=0.000	F=4.81; p=0.004

+ chicken manure (3:1) has the highest contents of nitrogen (2.17% dry weight), potassium (1.705% dry weight), calcium (2.11% dry weight) and the second-best phosphorus content (0.38% dry weight). The coffee residue-based compost thus improves the mineral nutrition of coffee plants and, consequently, their growth and biomass (Changkija, 2018; Hema *et al.,* 2024). Organic amendment with compost also improves the structure, chemicaland physical properties of the soil (texture, particle size distribution, moisture content, pH, redox potentialand ionic conductivity) (Pedra *et al.,* 2007; Movahedi and Cook, 2010), increasing its water retention capacity and permeability (Bresson *et al.,* 2001). Similar results were observed by Ngom *et al.* (2017) following an efficacy test of compost on tomatoes. However, the effects of composts on coffee plants depend directly on the nature of the composted waste and the formulation, as demonstrated by Francou (2003) and Koledzi *et al.* (2011). Not all coffee husk-based composts have the same efficacy. Plant productivity is closely related to the nature of the compost's base materials and the degree of maturity of the organic matter (Petruzzelli, 1989). For example, the compost based on coffee pulp residues + chicken manure in proportion (3:1) has the highest organic matter content at 118.9% dry weight, but its impact on growth is not significant. The proportion of organic matter, phosphorus and potassium in the substrate are decisive for nursery plant production. In the context of our study, the best compost formulations based on coffee residues that promote the growth of coffee plants in the nursery are "Compost 2: Coffee Husk Residues + Chicken Manure in proportion (3:1)" and "Compost 5: Coffee Husk Residues + Pig Slurry in proportion (3:1)".

CONCLUSION

This study has demonstrated that the use of composts based on coffee pulp or husk residues promotes the vegetative growth of coffee plants in nurseries. It also highlights that the effectiveness of coffee residue-based composts is strongly linked to the nature of the compost's base materials and formulation. In our study, "Compost 2: Coffee Husk Residues + Chicken Manure in proportion (3:1)" and "Compost 5: Coffee Husk Residues + Pig Slurry in proportion (3:1)" were found to be the best compost formulations based on coffee residues. These two composts, when mixed in equal proportion with potting soil, are recommended for coffee plant production in nurseries. Therefore, field experimentation with these two best composts would confirm their efficacy.

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Conflict of interest

No potential conflicts of interest have been reported by the authors.

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