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Agronomic Value of Composts Made from Fecal Sludge and Household Waste and Effect on Maize Production in Dschang (West Cameroon)

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Abstract Managing fecal sludge waste is crucial to prevent potential environmental harm, and one promising approach is its transformation into organic soil amendments. This study aimed to evaluate the quality of compost derived from various organic waste sources and assess its impact on soil fertility, maize growth, yield, and economic viability. Four distinct compost types were generated using two primary organic waste sources: household solid waste (C1) and fecal sludge (FS) combined with solid household waste (SHW) in different proportions (C2, C3, and C4). These composts were then applied at varying rates to maize plots in a randomized complete block design (RCBD) with three replications, resulting in ten treatment groups. The findings revealed a progressive improvement in the physico-chemical properties of the composts from C1 to C4. Notably, phosphorus (P) content increased from 0.29±0.03 (C1) to 0.54±0.07 (C4), and the pH levels shifted from 7.72±0.61 (C2) to 8.00±0.57 (C1). Total nitrogen (TN) ranged between 1.08±0.01 (C1) and 1.23±0.02% (C4). All compost types positively influenced soil parameters. However, the application of 20 $t.ha^{-1}$ of C1 resulted in greater above-ground biomass (48.23±12.64 $t.ha^{-1}$), while the application of 20 $t.ha^{-1}$ of C3 yielded the tallest maize plants (195.88± 7.35cm). Notably, compost C4 at a rate of 10 $t.ha^{-1}$ exhibited the highest maize production and economic returns (7.95±0.26 $t.ha^{-1}$, BCR = 2.81). In summary, treatment T7 (10 $t.ha^{-1}$ of C4 compost) is recommended for achieving enhanced maize production and increased profitability. This study underscores the potential benefits of using organic composts, particularly those derived from fecal sludge and household waste, to enhance soil quality and crop yields in agricultural contexts.

Keywords: *composting, fecal sludge, household waste, soil amendment, crop production, Dschang*

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1. Introduction

Every day, each adult generates approximately 130 grams of feces and expels 1.4 liters of urine [1,2]. While it’s not the most glamorous topic, it’s important to understand the risks associated with poor sanitation. The consequences of inadequate sanitation are significant, posing considerable health and environmental risks that can lead to severe public health and ecological challenges [3]. Recent findings indicate that the global proportion of people using improved sanitation facilities increased from 59% to 68% in 2015. However, up to 2.4 billion people still lack proper sanitation facilities, and 946 million people practice open defecation [4,5]. In sub-Saharan Africa alone, 709 million people lacked basic sanitation facilities in 2017 [6]. In Cameroon, 90% of households rely on individual sanitation systems, comprising latrines and septic tanks. Remarkably, 65% of these systems consist of traditional bottomless latrines [7,8,9,10]. The rich nutrient content found in this sludge offers significant benefits for enhancing soil fertility [11]. Yet, the improper management of fecal sludge can have dire consequences. When this liquid waste is discharged haphazardly into the environment, it can contaminate water, soil, and air, disrupting ecosystem balance and contributing to waterborne diseases [3,13,14].

Most medium-sized towns in developing countries lack a recycling or agronomic value chain for sludge management. However, there is a silver lining. Biological or agricultural recovery, which involves the production of organic fertilizers, is an established technology that can transform sludge into high-value-added products while minimizing pollution risks and production costs [15]. Human waste, including household waste, urine, and fecal sludge, is a rich source of organic matter that can be used to improve soil fertility [1,2]. In fact, according to [16], one person produces enough excreta to grow 250 kg of grain per year, which is enough to cover their annual food needs. By using human feces in agriculture, we can significantly reduce our dependence on synthetic fertilizers and promote more sustainable agricultural production. In addition, Human feces can also improve soil structure and water holding capacity, reduce pests, and neutralize soil toxins and heavy metals [17]. In the context of tropical soils, often severely depleted of nutrients due to leaching, proper management is imperative [18]. However, harnessing the potential of human feces in agriculture still faces social challenges rooted in established habits that need to be addressed [18].

Amidst these challenges, maize emerges as a dietary cornerstone for urban and peri-urban communities [19]. In Cameroon, maize production peaked at 2.3 million tonnes in 2019. Despite this substantial output, it consistently falls short of the national demand, which consistently hovers slightly above 2.8 million tonnes [20]. Consequently, Cameroon grappled with a maize production deficit of over 500,000 tonnes in 2019, a recurring dilemma that forced brewers to rely on imports to bridge the gap [20].

One pressing issue plaguing agricultural production in developing nations revolves around preserving soil fertility under permanent crop conditions. Extensive agricultural practices often lead to reduced productivity and contribute to the physical, chemical, biological, and microbiological deterioration of soils [21,22].

Turning our attention to Dschang, situated in Western Cameroon, the magnitude of the challenge becomes evident with daily solid waste production reaching a staggering 50 tons [22]. Additionally, approximately 9.63 cubic meters of fecal sludge are generated at the Dschang Central Prison. Shockingly, much of this waste is discarded into the environment without prior treatment, and at times, inmates resort to using it directly as fertilizer for their crops. Recognizing the nutrient-rich potential of fecal sludge, effectively harnessing this liquid resource for agricultural purposes becomes crucial. This underscores the paramount importance of mastering the art of composting with appropriate feedstock to effectively close the nutrient cycle [11,23].

To address these multifaceted challenges, the present study aims to assess the impact of two rates of FS/HW on the composting process and the resultant compost quality. Simultaneously, it seeks to evaluate the influence of fecal sludge-based compost on soil fertility improvement and maize production. By connecting these vital elements, we aim to contribute to more sustainable agricultural practices in the context of nutrient-depleted tropical soils.

2. Materials and Methods

2.1. Study Area

The study took place at the FASA Application and Research Farm (FAR) within the University of Dschang, situated in the Western Region of Cameroon. Dschang's sub-Division encompasses a vast area of 5655 hectares and boasts a population of 101,124 inhabitants [24]. Geographically, it falls between Latitudes 5°25' and 5°30' North, and Longitudes 09° 50′ and 10° 20′ East. The region's average altitude reaches approximately 1500 meters above sea level. Climatically, it falls under the Cameroonian-type equatorial climate, characterized by a short dry season lasting five months (from mid-November to mid-March) and a more extended nine-month rainy season (from mid-March to mid-November) [25]. Temperature fluctuations within this region span from 13.4 to 27.5°C, with an average annual temperature of 20.4°C. The area receives an average annual rainfall of 1900 mm. Dominating the landscape at the experimental site are herbaceous vegetation, with prominent species such as Tithonia diversifolia, Mimosa pudica, and Bidens pilosa. The primary soil classification at this site aligns with Ferralsol according to WRB, Oxisol according to USDA, or Ferralitic soil according to CPCS [26].

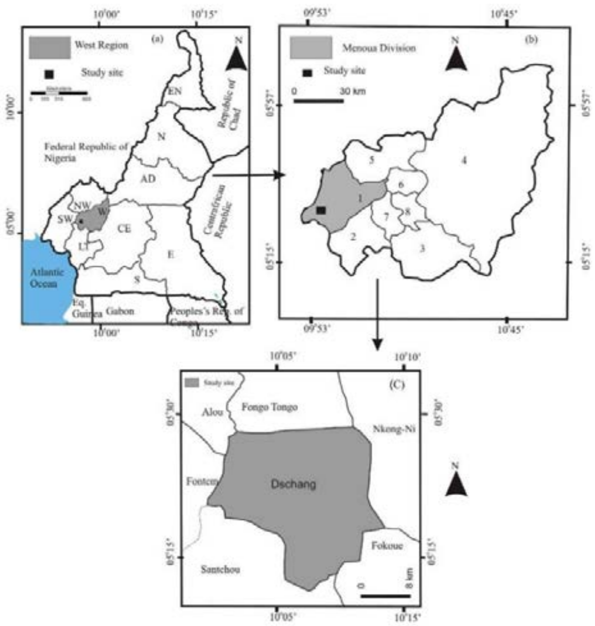

Figure 1. Location of the study site in Cameroon (a), in the West Region (b) and in the Menoua Division (c). The letters in figure (a) indicate the different territories at the regional level of Cameroon: EN–Extreme North; NW–North West; N–North; AD–Adamawa; CE-Centre; E–East; LT–Littoral; S–South; SW–South West; W–West. The numbers in figure (b) indicate the different territories at the divisional scale of the West Region of Cameroon: 1-Menoua; 2-Upper-Nkam; 3-Nde; 4-Noun; 5-Bamboutos; 6-Mifi; 7-Upper-Plateau; 8-Koung-Ki [24, 25]

2.2. Methods

The methodology employed for this study encompassed two years of fieldwork, spanning the 2020/2021 and

2021/2022 cropping seasons. The initial year was dedicated to the composting process, while the subsequent year focused on evaluating the impact of the compost on maize (Zea mays) cultivation. Throughout this research, compost samples were systematically collected during various stages of composting, including maturity assessment. Concurrently, soil samples were procured both at the onset and culmination of the field trial for subsequent laboratory analyses.

2.2.1. Fertilizer and Plant Materials

In terms of raw materials, the organic constituents utilized in this investigation were sourced from the municipal waste bins of Dschang. Over a span of six days, a substantial volume of solid household waste (SHW) was gathered. Fecal sludge (FS) was procured from the septic tanks of the Dschang Central Prison and subjected to a fifteen-day drying process on an unplanted drying bed before being transported to the composting site at the University of Dschang. Within this context, two distinct organic fertilizers were generated and deployed: household waste compost and fecal sludge compost. The plant material employed consisted of hybrid seeds (CHH 101) of Zea mays, produced by AGRO-AFRIQUE Sarl in KAMBO. These seeds boasted an impressive 100% germination rate.

2.2.2. Experimental Design

The experimental design for the composting phase adhered to a randomized complete block design (RCBD). This design incorporated two primary factors: solid household waste and fecal sludge. Within this framework, four distinct treatments were established, each replicated four times. These treatments comprised the following: 200 kg SHW (Control: C1), 25 Kg FS + 175 Kg SHW (C2), 50 Kg FS + 150 Kg SHW (C3), and 75 Kg FS + 125 Kg SHW (C4). These organic materials were meticulously blended using shovels and forks, then fashioned into windrows, each measuring 1m in length, 0.9 m in width, and 0.7 m in height. In cases where adjustment was necessary, 5 to 10 liters of lake water were added to achieve an optimal moisture content ranging from 40% to 60%. To shield the windrows from adverse weather conditions and facilitate the required aerobic fermentation for composting, they were meticulously covered with plastic sheets featuring strategically placed ventilation holes. The comprehensive bacteriological analysis extended to water and sludge entailed the quantification of fecal Streptococci, fecal Coliforms, Total Coliforms, and Escherichia coli.

Conversely, the maize trial embraced a randomized complete block design (RCBD) featuring three replications. Each block incorporated ten distinct treatments or experimental units (EUs). These treatments encompassed a wide range, including a control group (T0) with no compost, varying application rates of compost (ranging from 0 t.ha-1 to 20 t.ha-1), and different compost types (C1, C3, and C4). Each EU occupied an 8 m2 area and comprised five planting lines, each containing five bunches, resulting in a total of twenty plants per EU. This configuration achieved a crop density of 33334 plants per hectare. The spacing between two EUs was set at 0.5 m, while a 1 m gap separated two blocks.

2.2.3. Monitoring of the Composting Process and the Field Trial

Temperature measurements were conducted using a metallic thermometer (D-Werhheim 19, 2008). Moisture content was determined by subjecting samples to 105°C in an oven for a 24-hour duration. Our comprehensive analysis encompassed the evaluation of heavy metal content, including Cu, Zn, Pb, and Fe. Additionally, various physico-chemical attributes of the compost were scrutinized, such as pH, electrical conductivity (EC), total nitrogen, organic carbon (OC), available phosphorus, and exchangeable base cations (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}). All assessments adhered to established standard protocols [27]. To determine pH, a glass electrode pH-meter was employed in a compost solution ratio. Salinity levels within the compost were ascertained by directly measuring electrical conductivity in a suspension of compost diluted with distilled water at a 1:5 ratio. Organic carbon content (%) was quantified through dry combustion, while total nitrogen underwent analysis via the Kjeldahl wet digestion method. Exchangeable cations, encompassing Ca^{2+} and Mg^{2+}, were determined through complexometry, and Na^{+} and K^{+} were quantified using flame photometry. Total phosphorus was assessed using the Bray II method. For heavy metal analysis, the metals were brought into solution via heating in a mixture of strong acids (aqua regia) and subsequently quantified using Atomic Absorption Spectrophotometry.

Within the experimental units, six representative plants were meticulously chosen to serve as samples for data collection regarding growth and yield variables. This comprehensive collection encompassed various physiological parameters, including the collar diameter of the plant at a height of 20 cm above the ground and plant height. The meticulous tracking of physiological growth parameters commenced at the 30-day mark after planting and continued at a bi-weekly frequency until the emergence of male inflorescence. Upon reaching maturity, the six selected plants were carefully harvested, and grain yield was adjusted to account for 15% moisture content.

2.3. Compost and Soil Sampling Analysis

The soil samples collected prior to the trial, already in a dry state, underwent a process of crushing and sieving using a 2 mm sieve. The resulting fine soil particles were appropriately stored in labeled plastic bags. Conversely, the soil samples collected at the conclusion of the trial were subjected to air-drying, followed by crushing and sieving, before being stored in preparation for laboratory analyses. All analyses strictly adhered to established standard procedures [27].

The determination of soil reaction, or pH, involved the measurement of pH-H_2O using a 1:2.5 soil-to-water ratio and pH-KCl using a 1:2.5 soil-to-1N KCl solution, both assessed through a pH-meter. To indirectly gauge the salinity of the compost, electrical conductivity was measured on a suspension of compost diluted in distilled water at a 1:5 ratio.

Organic carbon content (%) was assessed through calcination for the organic amendments, while the Walkley and Black method was employed for the soil samples. Total nitrogen content was analyzed using the

Kjeldahl method. Analysis of exchangeable base cations, including Ca and Mg, was carried out through complexometric methods, whereas Na and K levels were determined using flame photometry. The cation exchange capacity (CEC) was ascertained through the sodium saturation method. Total phosphorus, both in organic amendments and soil, was quantified via spectrophotometry. For heavy metal determination, the metals were first brought into solution by subjecting them to heating in a mixture of strong acids (aqua regia) and subsequently quantified using Atomic Absorption Spectrophotometry.

2.4. Statistical Analyses

Statistical analyses were performed using R Studio software in the year 2020. The analysis of variance (ANOVA) was carried out with a confidence level set at 5%. In cases where a significant difference emerged between treatment means at the chosen significance level, the separation of means was accomplished using the Fisher's protected least significant difference (LSD) method.

2.5. Economic Analysis

The economic analysis of the different treatments was conducted by considering both the cost of the fertilizers and the total yield's value. To determine the total cost of the fertilizers, we included factors such as the market price of fertilizers, transportation expenses, spreading costs, and packaging expenses. Evaluating the economic viability of a fertilizer involved several key factors: the productivity index, net profit, and the benefit-to-cost ratio (BCR). The BCR served as a crucial metric for assessing the profitability of the organic fertilizers employed in the trial. The relationship between BCR and profitability can be expressed as follows:

RT (%) = (BCR - 1) x 100.

Individual treatment profitability was evaluated based on the BCR, following the guidelines of the FAO [28].

3. Results

3.1. Characteristics of Fecal Sludge and Household Waste

Fresh fecal sludge (FFS), dehydrated fecal sludge (DFS), and household solid waste (HSW) exhibited significant levels of essential nutrients, including nitrogen (N), phosphorus (P), and potassium (K), along with organic matter, as indicated in Table 1. These substrate characteristics align with recommended criteria and standards for effective composting. Furthermore, the results reveal that DFS displays a slightly acidic pH, while raw HSW demonstrates an alkaline pH. Notably, the organic matter content exceeds 70% for dehydrated FS and 60% for SHW, making it conducive for microorganism proliferation. The C/N ratio measures 22.2±2.3 for FS and 31.5±1.1 for SHW. Importantly, all metal concentrations within these substrates fall below the threshold limits for composting materials. The dehydration process has proven highly effective in reducing pathogens within the fecal sludge, achieving an impressive 98% reduction in total coliforms, E. *Coli*, and *Streptococci*, as illustrated in Table 2.

Table 1. Physico-chemical parameters of the raw material

Parameters	FFS	DFS	SHW	France Standards NFU44-095
pH	7.60±0.4	6,7±0.1	9.05 ±0.0	>7,5
OM%	18.6±0.2	71±0.2	61.7±0.5	>30%
OC%	10.8±0.2	35.5±0.3	30.9±0.3	-
N%	0.90±0.1	1.6±0.0	0.98±0.0	<3%
C/N	12.01±0.6	22.2±2.3	31.5±1.1	<25
P (mg.kg^{-1})	5.2±0.2	12.4±0.5	45.0±1.1	<3%
Na (cmol+.kg^{-1})	0,19±0.0	0.06±0.0	0.17±0.0	-
K (cmol+.kg^{-1})	1.2±0.0	0.04±0.06	0.17±0.1	<3%
Mg (cmol+.kg^{-1})	1,6±0.3	6.5±0.1	26.1±1.1	-
Ca (cmol+.kg^{-1})	2,1±0.7	4.3±0.1	23.01±1.3	-
Cu (mg.kg^{-1})	76±3	115±12	98±5	300
Zn (mg.kg^{-1})	432±33	323±30	181±10	600
Pb (mg.kg^{-1})	12±0.6	9±0.53	10±0.54	180
Fe (mg.kg^{-1})	900±57	919±59	738±33	nd

FFS: Fresh fecal Sludge, DFS: Dehydrated Faecal Sludge, SHW: Solid Household Waste, nd: not determined.

Table 2. Microbiological parameters of the raw material

Parameters	FC (UFC.100g^{-1})	E. COLI (UFC.100g^{-1})	TC (UFC.100g^{-1})	FS (UFC.100g^{-1})
FES	14 000	12000	546 000	473 200
DFS	2040	155	8330	6600
RR%	85.43	98.7	98.47	98.6

RR: Reduction Rate, EC: *Escherichia* Coli, FC: Fecal Coliforms; TC: Total Coliforms; FS: Fecal *Streptococci*

Table 3. Agronomic values of compost according to treatments (n=3)

Parameters	C1	C2	C3	C4	Standards Norms (WHO, 1993)
	Physico-chemical				
pH	8.00±0.57^{a}	7.72±0.59^{a}	7.90±0.58^{a}	7.90±0.6^{a}	6-9
EC (mS.cm^{-1})	1.87±0.14^{a}	1.71±0.07^{a}	1.70±0.06^{a}	1.77±0.04^{a}	-
	Stability				
OC%	15.73 ±0.7^{a}	15.8 ±0.4^{a}	16.2±0.8^{a}	16.21±0.14^{a}	-
C/N%	14.18±0.8^{a}	14.29±0.61^{a}	14.31±0.7^{a}	14.12±0.7^{a}	10-15
	Nutriments				
N%	1.08±0.03^{b}	1.08±0.04^{b}	1.10±0.03^{b}	1.23±0.02^{a}	0.1-1.8
P (mg. kg^{-1})	0.29±0.03^{a}	0.31±0.02^{a}	0.49±0.05^{a}	0.54±0.07^{a}	0.1-1.7
K (mg. kg^{-1})	0.17±0.02^{b}	0.51±0.06^{ab}	1.19±0.61^{a}	0.42±0.14^{ab}	0.1-2.3
Mg(mg. kg^{-1})	1.60±0.71^{b}	3.52±0.96^{a}	4.20±0.63^{a}	4.15±0.59^{a}	-
Ca(mg. kg^{-1})	1.91±0.05^{b}	1.84±0.26^{b}	2.05±0.35^{a}	2.47±0.58^{a}	-
	Heavy metals				French Norms (NFU-44 051)
Cu (mg. kg^{-1})	67.9±21.0^{a}	42.6±13.9^{a}	47.7±18.1^{a}	56.5±4.8^{a}	300
Zn (mg. kg^{-1})	387.0±65.3^{a}	403.5±54.8^{a}	414.6±39.4^{a}	417.2±41.1^{a}	600
Pb (mg. kg^{-1})	20.72±3.86^{a}	16.2±1.3^{a}	15.8±2.01^{a}	19.74±2.10^{a}	180
Fe (mg. kg^{-1})	812.3±62.3^{b}	793.5±79.7^{ab}	773.4±75.2^{a}	820.29±55.85^{a}	-
FC. EC. TC. helminth eggs	Absent	Absent	Absent	Absent	Absent in 2g of raw material

C1: Control; only household solid waste (HSW); C2: 25 Kg fecal sludge + 175 Kg HSW; C3: 50 Kg fecal sludge + 150 Kg HSW; C4: 75 Kg fecal sludge + 125 Kg HSW

3.2. Evolution of Physico-Chemical Parameters and Agronomic Quality of the Produced Compost

The temperature measurements exhibited a range of 39-60°C during the fermentation phase, which subsequently decreased to 29-38°C in the maturation phase, as depicted in Figure 1. Throughout the composting process, the pH levels fluctuated among the various treatments but generally maintained an alkaline nature. The electrical conductivity initially stood at 4.80 mS/cm and decreased to 1.8 mS/cm by the conclusion of the composting process. Notably, the highest values were observed in C1 composts, while the lowest values were recorded in C2 composts, although these differences did not reach statistical significance, as illustrated in Figure 2. The C/N ratio values exhibited variability throughout the process, as demonstrated in Figure 3. Between the initial and final phases, a substantial reduction in the C/N ratio was observed, stabilizing at approximately 14. The average characteristics of the composts generated in this study are summarized in Table 3. Notably, the nutrient values meet agronomic recommendations, with significant distinctions observed for nitrogen, potassium, and magnesium.

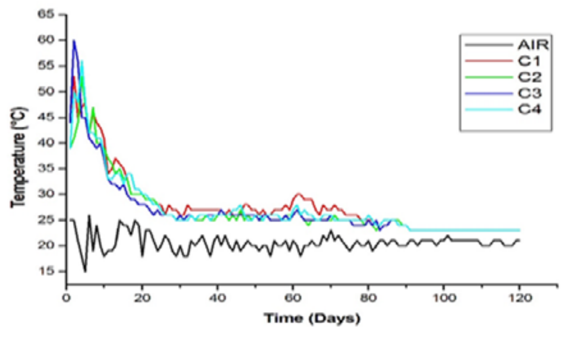

Figure 2. Temperature variations during composting

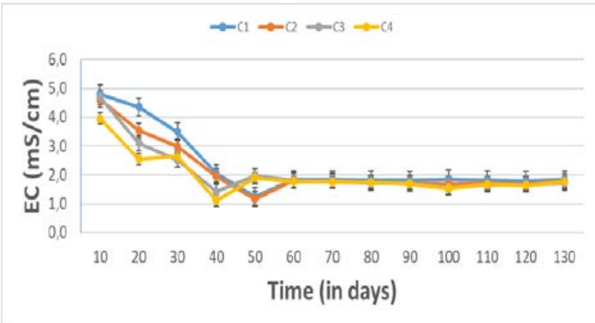

Figure 3. Variations in electrical conductivity during composting

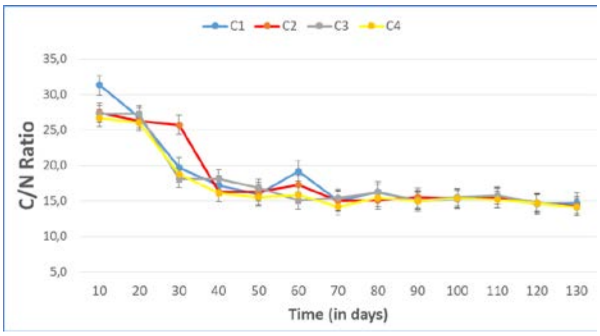

Figure 4. Evolution of the C/N ratio during composting

3.3. Variation of Soil Characteristics with Treatments

The soil characteristics, both before and after the maize treatments, are detailed in Table 4. Notably, there was an increase in pH-H2O for all treatments following the amendments, with the exception of the control group (T0). Among the treatments, the lowest variation was observed in compost 1 (T4), while the highest variation was recorded in Compost 3 (T3). After harvesting, all exchangeable cations in the soil showed substantial increases across the various treatments, except for Mg

(T1, T3; T4 and T8), which exhibited slight decreases in some instances, along with K (T4) and Na (T7). Despite the negative variations in certain treatments, the cumulative sum of base cations generally increased significantly. The CEC in all treatments exhibited notable variations, ranging from 19.4 cmol(+).kg-1 (T4 and T7), representing the smallest change, to 26.4 cmol(+).kg-1 (T3), indicating the largest change.

Furthermore, both organic carbon and total nitrogen in the soils displayed substantial increases in the treated plots. The most significant variation was observed for carbon in T9 (4.4%) and for nitrogen in T5 and T8. However, T1 exhibited the lowest variation in organic carbon (3.6%), while the lowest variation in total nitrogen (0.18%) was recorded in plots T1, T2, and T4. These findings highlight the positive impact of the treatments on soil characteristics, with varying degrees of improvement across the different treatments.

3.4. Effect of Treatment on Growth and Yield Variables of Maize

The final growth and yield variables exhibited statistically significant differences among the treatments (Table 5). The plant height was significantly influenced by the different treatments. T2 and T3 resulted in the tallest plants, while T6 and T9 led to the shortest ones. It's worth mentioning that Compost 3 treatments had a more pronounced impact on plant height. Generally, plant height increased with the dose of C1 compost, whereas it decreased with the dose in the other treatments. This trend was also observed for the heights at the male inflorescence of the plants. However, for the height at the male inflorescence, T7 exhibited a more significant influence on this variable, whereas T6 and T9 had a lesser effect.

Table 4. Soil properties before and at the end of the trial (0 - 25 cm)

	pH-H_2O	pH-KCl	ΔpH	OC	N	C/N	P	Ca	Mg	K	Na	SEB	CEC	CT
				%			(mg/kg)	Cmol(+)/kg						%
Start	5.8	5.1	0.7	3.05	0.15	21.60	13	1.89	1.04	0.85	0.06	3.84	18.5	
End														
T0	5.7	5.0	0.7	3.2	0.14	23	10	1.64	0.46	0.32	0.08	2.50	18.4	
T1	6.1	5.5	0.6	3.6	0.18	21	19	2	0.94	0.88	0.10	3.92	21.4	
T2	6.3	5.4	0.9	3.7	0.18	21	20	6	1.2	1.07	0.09	8.35	23.2	
T3	6.4	5.5	0.9	3.8	0.19	20	24	3.2	0.64	1.17	0.21	5.22	26.4	
T4	6.0	5.4	0.6	3.9	0.18	22	17	2.16	0.96	0.70	0.11	3.93	19.4	AS
T5	6.3	5.4	0.9	4.2	0.24	18	19	6.16	1.12	1.07	0.06	8.41	22.2	
T6	6.4	5.5	0.9	4.2	0.22	19	27	4.0	2.32	1.38	0.06	7.76	25.2	
T7	6.2	5.4	0.8	4.1	0.19	22	23	5.36	1.6	0.97	0.05	7.98	19.4	
T8	6.2	5.5	0.7	4.3	0.24	18	25	5.68	0.72	1.27	0.07	7.74	23.2	
T9	6.3	5.1	0.8	4.4	0.22	20	25	6.16	1.04	1.38	0.06	8.63	24	

T0=Control (0 t.ha-1). T1 = C3 at 10 t.ha-1. T2 = C3 at 15 t/ha. T3 = C3 at 20 t/ha. T4 = C1 at 10 t/ha. T5 = C2 at 15 t/ha. T6 = C3 at 20 t/ha. T7 = C4 at 10 t/ha. T8 = C4 at 15 t/ha. T9 = C4 at 20 t/ha.

Table 5. Effect of treatments on final growth and average yield (n=3)

Growth parameters	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
Plant height (cm)	171.99± 6.51abc	184.22± 3.32ab	190.62± 5.27a	195.88± 7.35a	162.12± 2.04bcd	151.98± 7.08cd	141.34± 8.73d	184.43± 8.95ab	181.17± 7.07ab	140.12± 6.12d
stem diameter (cm)	3.10 ± 0.07c	3.33± 0.14bc	3.37± 0.27bc	3.44± 0.28abc	3.40± 0.19abc	3.47± 0.12ab	3.54± 0.28ab	3.32± 0.26bc	3.33± 0.06bc	3.72± 0.29a
Height Inflorescence Male (cm)	247.18± 6.02abcd	256.58± 7.31abc	258.68± 7.27ab	262.07± 5.43ab	241.46± 6.90bcd	236.91± 8.73cd	228.52± 8.27d	265.98± 5.87a	254.87± 8.13bcd	231.00± 6.64d
Height at ear insertion (cm)	115.16± 5.16ab	117.81± 6.70ab	120.19± 6.38ab	125± 7.90ab	101.18± 1.83b	105.61± 8.69b	157.76± 7.11a	121.56± 7.94ab	114.67± 4.08ab	105.87± 5.12b
Average yields (t/ha)	3.20± 1.11c	6.38± 1.35b	6.52± 0.48b	6.68± 0.85b	6.67± 0.54b	6.19± 1.16b	6.09± 0.74b	7.95± 0.26a	6.88± 0.90b	6.50± 1.17b
Fresh biomass (t/ha)	26.25± 5.49c	30.63± 6.03c	39.38± 11.06b	35.96± 2.42b	36.04± 7.63b	48.23± 12.64a	40.83± 4.73ab	33.33± 5.05b	37.08± 2.53b	41.25± 5.45ab
Dry biomass (t/ha)	8.57± 1.77b	9.75± 1.89b	12.5± 3.51ab	11.42± 0.77ab	11.45± 2.42ab	15.42± 3.90a	13.27± 1.39a	10.59± 1.61ab	11.77± 0.80ab	13.10± 1.73a

a. b. c. d: on the same line. values affected with the same letter do not differ significantly (p>0.05).Values followed by the same letter in the same column are not significantly different at the 5% threshold.

Table 6. Economic implications of the different treatments

Treatments	SC (kg/ha)	TVC (FCFA)	ISI (FCFA)	RIC (FCFA)	RCSC (FCFA)	BCR	Pr (FCFA
T0	0	0	0	0	0	0	0
T1	3320	572682	2929	575611	1162000	2.02	586389
T2	3180	826093	4225	830318	1113000	1.34	282682
T3	3480	1084498	5547	1090045	1218000	1.12	127955
T4	3470	574385	2938	577322	1214500	2.10	637178
T5	2890	822802	4208	827010	1011500	1.22	184490
T6	2990	1078937	5519	1084455	1046500	0.97	37955
T7	4750	588913	3012	591925	1662500	2.81	1070575
T8	3680	831768	4254	836022	1288000	1.54	451978
T9	3300	1082455	5537	1087992	1155000	1.06	67008

SC: Supplementary Crop. TVC: Total Variable Cost. RCSC. Recurrent Cost of Supplementary Crop. II: Investment Interest. RIC: Recurrent Input Cost. BCR: Benefit/Cost Ratio; Pr: Profit (FCFA)

Additionally, collar diameter increased with the quantity of fertilizer in each treatment, with the highest value recorded in T9 (3.72 ± 0.29 cm) and the lowest in T0 (3.10 ± 0.07 cm). Fresh biomass was predominantly influenced by T5 (48.23 ± 12.64 $t.kg^{-1}$), while T1 (30.63 ± 6.03 $t.kg^{-1}$) had the least impact on this variable. Similarly, dry biomass was less affected by T1 (9.75 ± 1.89 $t.kg^{-1}$), while T5, T6, and T9 showed a more pronounced influence on this variable. The maize grain yield reached its peak in T7 (7.95 ± 0.26 $t.kg^{-1}$), with the control group registering the lowest yield (3.20± 1.11 $t.kg^{-1}$). The remaining treatments yielded satisfactorily, with no significant differences observed among T1, T2, T3, T4, T5, T6, T8, and T9.

It's noteworthy that although the yields were not significantly different for most of the treatments (T1, T2, T3, T4, T5, T6, T8, and T9), there was a noticeable trend where values increased with the quantity of compost C3 but decreased with the quantity in compost C1, as well as compost C4. In conclusion, at the conclusion of the study, the ranking of treatments based on their positive influence on performance was as follows: T7 > T8 > T3 > T4 > T2 > T9 > T1 > T5 > T6 > T0.

3.5. Economic Analysis of the Different Treatments

The economic analysis of the various treatments unveiled that treatment T6 (20 $t.kg^{-1}$ of household waste compost) incurred higher costs compared to the other treatments (Table 6). The benefit-to-cost ratio (BCR) exhibited the following variation: T7 > T4 > T1 > T8 > T2 > T5 > T3 > T9 > T6. With the exception of T6, all treatments proved to be profitable, with T7 emerging as the most profitable, yielding a profit of 1,070,575 FCFA and boasting a BCR of 2.81. In contrast, T6 displayed the lowest marginal net return (37,955 FCFA) and a BCR of 0.97.

4. Discussion

4.1. Monitoring of the Composting Process and Evaluation of Compost Maturity

The quality of compost is inherently influenced by the composition of the initial substrate. If these raw materials are not properly sanitized beforehand, they can potentially contaminate soils and agricultural products [29]. The substrates examined in this study exhibited minimal pathogen levels after the dehydration of fecal sludge (FS), signifying the highly positive impact of dehydration in reducing pathogens. Specifically, there was a remarkable reduction rate of 98.7% for E. Coli and 85.43% for fecal Coliforms (CF). Dehydration exhibited a more pronounced impact on electrical conductivity (EC), total Coliforms (TC), and Streptococci (SF) compared to CF. These findings are consistent with previous research conducted during the co-composting of domestic fecal sludge in Senegal [30]. In an aerobic composting process where temperatures approach 60°C, pathogens are efficiently destroyed [31]. In our study, similar temperatures (between 50 and 60°C) were achieved in various treatments, likely resulting in the complete elimination of pathogens that had resisted dehydration, thus explaining their absence at the end of the process.

The variations and differences in pH recorded during composting can be attributed to the initial composition of the substrates [31]. The decline in pH can be elucidated by the generation of organic acids during the degradation of carbohydrates, lipids, and other humic substances [30]. Additionally, the production of CO_2 during aerobic degradation contributes to environmental acidification through the formation of carbonic acid, further contributing to pH reduction [30]. These pH values align with those reported in numerous studies [33,34,35]. The decrease in electrical conductivity (EC) may be attributed to the binding of salts by organic matter and the leaching of metallic cations due to the addition of low-salinity lake water during compost hydration [36]. The initial low salt content in raw fecal sludge from septic tanks could explain the low EC values in FS treatments [30]. The decrease in the C/N ratio in the treatments likely results from microbiological activity that decomposes organic matter and mineralizes it into nitrogen. Similar decreases in the C/N ratio were observed in a study on co-composting raw fecal sludge and market organic waste in Nigeria [35]. These findings also parallel those of a study involving composting of cocoa residues with Tithonia diversifolia in Central Cameroon [37]. The final compost exhibited a C/N ratio below 15 in all treatments, underscoring that the composting process leads to organic matter decomposition and carbon and nitrogen consumption, resulting in a decreased C/N ratio [38].

4.2. Agronomic Quality of Composts

The concentrations of nitrogen (N), potassium (K), and magnesium (Mg) are significantly higher in the final composts with lower fecal sludge (FS) content compared to those with C1 compost. Although phosphorus (P) and calcium (Ca) values are not significantly different, there is an observable increase in their concentrations in treatments corresponding to higher FS quantities. Composts C3 and C4, which contain more FS, exhibit greater quantities of these nutrients. The elevated agronomic value of these composts may be attributed to the larger proportions of FS in their composition. These nutrient levels align with international standards [30] and surpass those reported by a previous study in Central Cameroon, which involved co-composting sewage sludge with *Echinochloa pyramidalis* [39]. Additionally, the nutrient concentrations in the present study exceed those obtained from co-composting raw fecal sludge and market organic waste in Nigeria [35]. In accordance with international standards [40], the final composts boast high organic carbon (OC) and total nitrogen (TN) contents, along with low C/N ratios. However, they exhibit average concentrations of phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). These outcomes may be attributed to the nature of the initial organic substrates and the composting process employed [41]. The FS-to-household solid waste (HSW) ratios likely account for the variations in nutrient content among the composts, with higher FS proportions leading to elevated OC and mineral element concentrations in composts such as C4. Such nutrient-rich compost is highly beneficial and is expected to significantly contribute to the nutritional requirements of plants during growth and development when applied in the field.

4.3. Variation of Soil Characteristics with Treatment

Following the application of compost, a minor increase in the initial soil pH was observed, consistent with findings by [42] in Togo. This pH elevation could be attributed to the presence of hydroxyl groups from certain ions in the composted waste materials, as suggested by [43]. Initially low levels of exchangeable cations in the soil before maize cultivation increased after harvesting, with a few exceptions. This increase is likely associated with the addition of compost, which potentially released these cations into the soil. In some cases, a decrease in exchangeable cations after harvest was observed, as seen with magnesium (Mg) in treatments T1, T3, T4, and T8, as well as potassium (K) in treatment T4. This decrease could indicate an augmented uptake of basic cations by the plants, in agreement with the findings of [44,45].

Available phosphorus levels increased for all treatments except T0, which is highly favorable for maize production. This increase may result from the release of this element into the soil due to compost application during plant growth. Similar results were reported by [46], who demonstrated that compost influences phosphorus availability in three ways: as a source of soluble and exchangeable phosphorus to the soil, by enhancing soil phosphorus availability through its impact on phosphorus complexation and metabolism, and by reducing phosphorus leaching through adsorption and improved retention by the soil, thereby facilitating its uptake by plants. The presence of an optimal level of available phosphorus is crucial for crop growth and yield, particularly in tropical regions, where regular rainfall occurs [47].

The diverse findings collectively indicate that the composts corrected the cation balance and C/N ratio of the soil under study. This correction is highly beneficial since these composts supplied ample amounts of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and organic matter (OM) [48]. The increased availability of soil nutrients following manure application enhances their uptake by plant roots. These results align with previous studies showing that compost derived from household waste and fecal sludge can enhance maize growth and yields, primarily due to improved chemical and physical soil properties [49,50].

4.4. Effects of Treatments on Yield

The results obtained for yield and plant size in various treatments were significantly different from the control. The addition of different composts positively influenced growth and yield, with the extent of this improvement depending on the concentration applied. Notably, plants treated with sludge-based compost (C3) exhibited the highest values for plant height at male flowering and height at cob insertion. This increase in plant height is likely attributed to the availability of essential nutrients for plant growth in compost C3 compared to compost C1 or C4. Nitrogen, a crucial element for plant growth, and calcium, which enhances cell division, are abundant in fecal sludge composts (FS), promoting cell multiplication and optimal vegetative growth. This finding aligns with previous studies that have reported increased growth and crop yields with compost treatment [51,52]. Additionally, the pH increase due to compost application likely contributed to enhanced plant height. Elevated pH may facilitate the release of nutrients that support maize growth, as major cations can raise soil pH, creating a favorable environment for nutrient availability [51].

The results for total grain yields ($t.kg^{-1}$) indicated a significant difference ($P<0.05$) among the various treatments. The positive impact of organic matter on yield, as demonstrated in this study, is consistent with previous research [53]. Organic matter significantly increased barley yields compared to the control. The average yields obtained in this study (5 - 10 $t.kg^{-1}$) are in line with those observed in a similar humid tropical ecosystem in Cameroon by [54]. These yields are also higher than the national averages reported in Burkina Faso [48], the Democratic Republic of Congo [55], and Togo [56], where maize yields ranged from 4 to 5 $t.kg^{-1}$. While highly significant yield differences were not observed, the results suggest that the addition of organic matter leads to yield increases. Therefore, the incorporation of organic matter is essential to maintain or enhance soil productivity, as supported by [54] and [57].

Regarding the economic profitability of maize cultivation using organic matter, particularly compost, only treatments T1, T4, and T7 (10 $t.kg^{-1}$) were found to be profitable, with benefit-cost ratios (BCR) of 2.02, 2.10, and 2.81, respectively, covering the producers' expenses. The BCR decreased with increasing concentration. These results indicate that profitability is excellent at low concentrations of 10 $t.kg^{-1}$, suggesting that profitability is not solely determined by the quantity applied [58]. These findings align with recommendations from [59] and [60], who advised the use of small quantities of compost in various crops. According to these studies, the optimal economic rates for profitable use of organic fertilizers depend on resource availability and market price variations for crops. Inputs of 10 $t.kg^{-1}$ can be recommended to farmers with a high probability of acceptance. However, considering the limited purchasing power of most farmers in the study area, option T7 (7.95± 0.26 $t.kg^{-1}$of C4 compost), which exhibited the highest profitability, is the most recommendable choice. Similar studies [19,57] have also demonstrated that low concentrations of organic fertilizers, such as *Tithonia diversifolia* compost, can increase crop profitability.

5. Conclusion

This study has demonstrated the potential of using household solid waste (SHW) and dehydrated fecal sludge (DFS) to produce organic soil amendments for agricultural purposes. Four compost types were created from organic waste materials collected from the Dschang Central Prison. These composts included one made solely from SHW and others made from mixtures of dehydrated fecal sludge and SHW. The characterization of these composts revealed that C1 compost (household waste) had the lowest nutrient concentrations, while C4 (household waste + maximum fecal sludge) had the highest nutrient concentrations. Importantly, all four compost types met WHO standards for nutrient content.

Field applications of these composts, including C1, C3 and C4, at various rates had significant positive effects on maize growth, yield, economic profitability, and soil properties. Fecal sludge compost (C3) had a particularly beneficial impact on soil pH and cation exchange capacity (CEC), while household waste compost (C1) had a lesser influence on these parameters. Compost C4 had the most substantial influence on soil carbon and nitrogen levels.

The study also demonstrated that differences in compost types and application rates had a significant effect on plant height, yield, and economic profitability of maize. For example, compost C3, applied at a rate of 20 $t.kg^{-1}$, produced the tallest plants, while the 15 $t.kg^{-1}$ rate of compost C1 resulted in the highest fresh and dry biomass. Compost C4, applied at a rate of 10 t/ha, produced the highest maize yield and economic return.

Overall, this research highlights the potential benefits of using composted organic fertilizers to enhance the physical, chemical, and biological properties of soil, particularly in regions with poor, nutrient-depleted soils like the humid tropics. These findings suggest that fecal sludge and household waste composts have promising agronomic advantages and can be valuable tools for sustainable agriculture in such areas.

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