Scientific Research Publishing

Open Journal of Soil Science, 2024, 14, 448-470
https://www.scirp.org/journal/ojss
ISSN Online: 2162-5379
ISSN Print: 2162-5360

Effect of Different Rates and Mixtures of Solid Household Waste and Faecal Sludge-Based Composts on Soil Fertility and Productivity of Sunflower (*Helianthus annuus* L.) in Dschang, West Cameroon

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How to cite this paper: Ngnipa Tchinda R., Kenne, R.E., Azinwi Tamfuh, P., Kenfack, J.G., Temgoua Zombou, D., Moundjeu, D. E., Ntangmo Tsafack, H., Tanwi Ghogomu, R., Temgoua, E. and Bitom Oyono, D. (2024) Effect of Different Rates and Mixtures of Solid Household Waste and Faecal Sludge-Based Composts on Soil Fertility and Productivity of Sunflower (*Helianthus annuus* L.) in Dschang, West Cameroon. *Open Journal of Soil Science*, **14**, 448-470.
https://doi.org/10.4236/ojss.2024.147024

Received: June 9, 2024
Accepted: July 21, 2024
Published: July 24, 2024

Abstract

The unbalanced and inadequate use of fertilizers is one of the causes of soil degradation. Combined with the ever-increasing population, it is necessary to find sustainable agricultural production alternatives. The present work aims to determine the effect of different rates and mixtutes of organic amendments on soil fertility and the performance of Sunflower (*Helianthus annuus L.*). In the field, treatments consisted of solid household waste and faecal sludge in the ratios of 3/5 (V1), and a mixture of faecal sludge and household waste in the ratio of 3/5 with 900 worms (V2). At the end of the composting process, V1, V2 composts and the poultry manure (PM) were applied at rates of 4, 5 and 6 $t \cdot ha^{-1}$ in a randomized complete block design with three replications. Soil samples were collected before and after the experiment and analyzed. The main results revealed that at the end of the composting process, there was a progressive improvement in the physico-chemical properties of V1 and V2 composts. In particular, the C/N ratio, phosphorus (P) and total nitrogen (TN) initially at 16.49 ± 0.42 (V1, V2), 21.06 ± 0.07 $mg \cdot kg^{-1}$ (V1, V2), 0.76% ± 0.08% (V1, V2) respectively, increased after 60 days to 12.40 ± 0.41 (V1), 9.74 ± 0.28 (V2) for C/N, 21.94 ± 0.63 mg·kg^{-1} (V1) and 22.04 ± 0.04 mg·kg^{-1} (V2) for P, 0.96% ± 0.0% (V1) and 1.22 ± 0.04 (V2) for TN. The application of 6 t·ha^{-1}of PM had the greatest influence on the diameter and weight of the flower heads (27.16 ± 4.01 t·ha^{-1} and 230.83 ± 2.64 t·ha^{-1}), while 4 t·ha^{-1} of V2 gave the tallest sunflower plants (110.07 ± 73.28 cm) as well as the diameter at the crown (19.30 ± 9.07 cm). However, CEC was most influenced by 4 t·ha^{-1} of V1, while 4 t·ha^{-1} of PM had the greatest effect on organic carbon and phosphorus. However, 5 t·ha^{-1} of PM showed the highest sunflower production and yield (1.67 ± 0.21 t·ha^{-1}). The combination with 900 earthworms is recommended for composting and 5 t·ha^{-1} of PM is recommended to obtain a better sunflower production.

Keywords

Sunflower, Faecal Sludge, Household Waste, Compost, Soil Fertility

1. Introduction

Modern agriculture is often confronted with problems of land degradation mainly caused by nutrient depletion [1]. This leads to an increase in production costs due to the high cost of chemical fertilizers [2]. The current growth rate of agriculture is not keeping pace with population growth [3]. Thus, increasing the productivity and profitability of small farmers in an economically sustainable way is the most effective measure for reducing poverty and hunger in developing countries [4]. The main reasons for the drop in productivity are the physical, chemical, biological and microbiological deterioration of soils [5] [6]. The main causes of soil degradation are unbalanced and inadequate use of fertilizers as well as inadequate or non-existent use of organic fertilizers and crop residues [7]. With intensive agriculture, nutrient removal in soil by crops as well as bushfires far outstrip soil fertility replenishment [8]-[10]. Soil fertility degradation due to overexploitation of nutrients and inadequate replenishment by fertilizers and other sources can only be curbed by adopting new fertility management techniques [11]-[13]. Among the organic sources available, crop residues, compost and poultry manure are one of the most important sources for supplying crop nutrients and improving soil health [14]-[16]. Integrated nutrient management based on low-cost, locally available organic sources is more rational, sustainable and economical [17] [18].

Several technologies (physical, chemical and microbiological) are currently used to eliminate organic wastes [19]. These technologies are, however, time-consuming and costly and thus necessitating to put alternative less complex and cost-effective technologies for nutrient management and crop production at the disposal of farmers. As a result, Vermicomposting is emerging as an accessible, cost-effective and rapid technology for the favorable management of solid and liquid waste [20]-[22]. The use of earthworms for waste management, organic matter stabilization, soil detoxification and vermicompost production has been reported [23]-[25]. Epigeic earthworms accelerate the composting process, producing healthy compost rich in nutrients for plant growth such as legumes, oilseeds, etc., by facilitating the transfer of nutrients to plants [20] [22] [26].

Sunflower (*Helianthus annuus L.),* of the nine oilseeds, is a non-traditional crop introduced in Cameroon in 2000. It now occupies an important place in all agro-climatic zones [14]. It has been estimated that global sunflower seed production exceeds 52.42 million tonnes on 26.5 million hectares of land [27]. In recent years, from 2013 to 2017, its cultivated area increased by about 10.51% and its production increased by about 11.53% [18]. It is very promising due to its short duration, photo insensitivity and high adaptability to different agro-climatic regions and soil types [28] [29]. It can be grown at any time of the year and it is very undemanding in terms of nutrients. The agronomic value of the amendments is one of the most important elements, playing a key role in achieving the desired yield and quality of crop production. The ferrallitic soils of the Western Highlands are deficient in essential elements that can hinder growth and development of sunflower (*Helianthus annuus* L.). The aim of this work was to study the effect of three organic fertilizers (municipal waste compost, faecal sludge compost and poultry manure) on sunflower growth, grain yield, mineral and protein content. This results obtained will enable to be helpful to farmers, agricultural engineering students, industry, community and the research society on the recycling and reuse of organic wastes as soil fertilizers for crop production.

2. Materials and Methods

2.1. Study Site

This study was carried out at the FASA Research and Application Farm (FAR) within the University of Dschang, in the western region of Cameroon (**Figure 1**). Dschang (N5˚25’, E10˚20’, altitude: 1500 m), is the headquarter of the Menoua Division and covers a surface area of 262 km^2. Is characterized by a bimodal rainfall regime with two seasons, a rainy season from March to November and a dry season from December to February. The mean of annual rainfall is 1750 mm and the mean of annual temperature is 22.5˚C [30]. The landscape of the experimental site was characterized by vegetation composed mainly of herbaceous plants, with dominant species such as *Tithonia diversifolia*, *Mimosa pudica* and *Bidens pilosa*. The primary soil classification on the study site corresponds to Ferralsol according to WRB, Oxisol according to USDA, or Ferralitic soil according to CPCS.

2.2. Méthods

The field work (composting and field trials) was carried out over two (2021 and 2022) agricultural seasons. The first year was devoted to the composting process and the second to the application of compost in the field on sunflowers (*Helianthus annuus L.*). The epigean earthworm species Eisenia fetida was chosen for this experiment because of its high tolerance to environmental variables such as

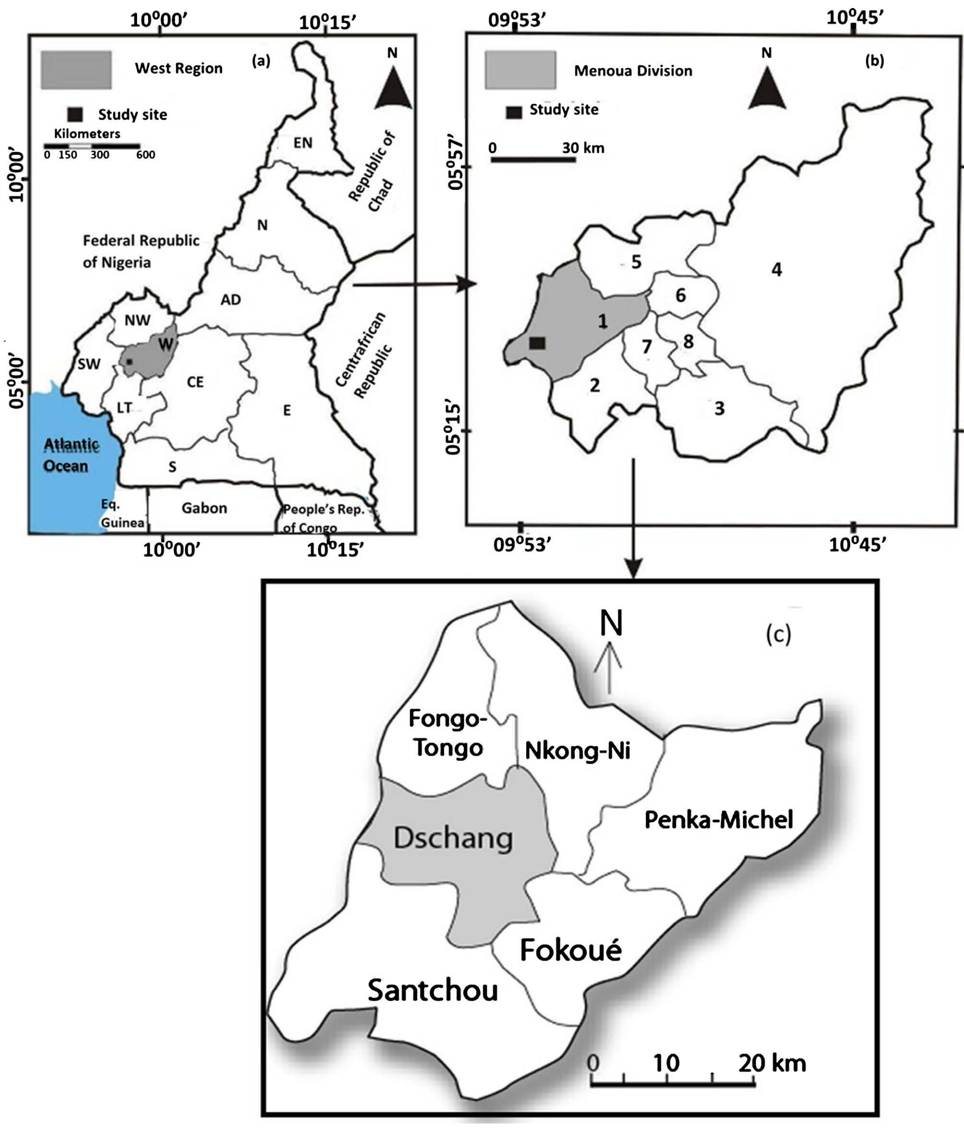

Figure 1. Location of the study site in Cameroon (a), in the West region (b) and in the Menoua department (c). The letters in figure (a) indicate the different territories at regional level in Cameroon: EN-Far North; NW-North-West; N-North; AD-Adamawa; CE-Centre; E-East; LT-Littoral; S-South; SW-South-West; W-West. The figures in figure (b) indicate the different territories within the division of the West Cameroon region: 1-Menoua; 2-Upper-Nkam; 3-Nde; 4-Noun; 5-Bamboutos; 6-Mifi; 7-Upper-Plateau; 8-Koung-Ki [15].

pH, humidity and temperature [31]. Compost samples were taken during the composting process at intervals of 20 days until maturation. Soil samples were taken at the beginning and end of the field trial for laboratory analysis. Sunflower seeds from each treatment were analyzed after harvest to assess their nutritional values.

2.1.1. Fertilizer and Plant Material

The organic waste used in this research came from the rubbish bins in the town of Dschang. The earthworms were collected from under piles of rubbish and incubated for one month in a culture medium consisting of cow dung, faecal sludge and municipal waste to ensure rapid multiplication. Poultry manure purchased on the market and the compost produced were used for the field trial. The plant material used consisted of sunflower seeds of the giant African variety from FASA's FAR. The germination rate of the seeds used for this study was 90%.

2.1.2. Experimental Design

The compost production experiments were conducted in the field on windrows 100 cm long, 90 cm wide and 70 cm high. Each pile had a capacity of 200 kg. The compost heap was made up of different types of substrate mixed in the same ratio, with a variation in the number of worms: 75 Kg faecal sludge + 125 Kg household waste + 0 worms (V1), and 75 Kg faecal sludge + 125 Kg household waste + 900 worms (V2). To avoid exposing the worms to high temperatures during the initial thermophilic phase of pre-composting, they were introduced after 21 days of partial decomposition of the organic waste (temperature between 30˚C and 33˚C). The piles were kept in the shade and covered with banana leaves to avoid direct sunlight and excess water during the rains.

The experimental set-up for the sunflower trial was a completely randomized block design with three replications. Each experimental unit consisted of one rate of a single type of organic amendment and each block consisted of 10 experimental units. The units were separated by 0.5 m. The blocks were separated by a lane 1 m wide. The experimental plots were rectangles measuring 2.50 m × 2.20 m, or 5.5 m^2 per unit. The spacing between rows was 75 cm and 50 cm between bunches for a sowing density of 20 plants per unit. Thus, each experimental unit was composed of a single factor, organic manure, with four modalities representing treatments T1 (4 $t·ha^{-1}$), T2 (5 $t·ha^{-1}$), T3 (6 $t·ha^{-1}$) of V1, T4 (4 $t·ha^{-1}$), T5 (5 $t·ha^{-1}$), T6 (6 $t·ha^{-1}$) of V2, T7 (4 $t·ha^{-1}$), T8 (5 $t·ha^{-1}$) and T9 (6 $t·ha^{-1}$) of PM and T0 (0 $t·ha^{-1}$) as control in each unit. The rates of organic fertilizer were applied per experimental unit in the following quantities: 0 kg for 0 $t·ha^{-1}$; 2 kg for 4 $t·ha^{-1}$; 2.5 kg for 5 $t·ha^{-1}$and 3 kg for 6 $t·ha^{-1}$.

2.1.3. Monitoring the Composting Process and the Field Trial

The composting process began with a three-week pre-composting phase to allow the compost to move from the thermophilic phase (high temperature) to the mesophilic phase (low temperature, minimum 30˚C), in order to encourage the worms to transform the organic matter into humus. Compost samples were taken at different intervals: 0, 20, 40 and 60 days. Day 0 corresponds to the time when the earthworms were introduced into the pre-composted waste piles. The analyses focused on heavy metals and also on certain physico-chemical characteristics of the compost: pH; EC; total nitrogen; organic carbon, etc.

Six plants were selected within each experimental unit as samples for the collection of data on growth and yield variables. Physiological parameters were collected (plant collar diameter, plant height, number of leaves, flower head diameter, flower head dry mass and grain yield). Collection of these growth variables began two weeks after germination and was carried out every fortnight for two months. During vegetative development, height was measured from the ground to the insertion of the last unfolded leaf, while in the reproductive phase, it was measured from the ground to the insertion of the flower head.

2.2. Laboratory Analysis

Soil taken from a depth of 0 - 25 cm before (control) and after the trial and organic amendments were analyzed at the Soil Analysis and Environmental Chemistry Laboratory (LABASCE) of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang using standardized procedures in accordance with Pauwel *et al.* [32]. Analyses included organic carbon (%) determined by calcination in the organic amendments and by Walkley and Black in the soils. Total nitrogen was analyzed by the Kjeldahl method. Exchangeable bases were analyzed by complexometry (Ca and Mg) and photometry (Na and K). Total phosphorus for the organic amendments and available phosphorus (Bray II) for the soil were determined by spectrophotometry. Heavy metals were determined using an atomic absorption spectrophotometer. Samples were disaggregated by wet digestion with strong acids (HNO_3, HCl). Seeds collected after harvesting and oven-dried at 40˚C ± 5˚C for 7 days and crushed using a mill. The ground material was stored in plastic sachets and the analysis of N, P, K, Ca, Mg, Cu, Fe, and Zn were determined according to the methodology of Pauwel *et al.* [32].

2.3. Statistical Analysis

The data obtained were entered using Microsoft Office Excel 2016. Statistical analyses were carried out using R Studio software. Analysis of variance (ANOVA) was performed at the 5% significance level. Means were separated by the least significant difference (LSD) when a significant difference was observed between treatments at the significance level.

3. Results

3.1. Changes in Physical-Chemical Parameters and Agronomic Quality of Vermicompost

Analysis of variance (**Table 1** and **Table 2**) showed that water pH and electrical conductivity (EC) of the vermicompost varied significantly ($P < 0.05$) as a function of time. This variation was observed for EC from day 20, while for pH it was observed from day 40. The C/N ratio and humic substances were influenced by both composting time and the number of worms in the treatments. The chemical fractionation of Humic Acid (HA) and Fulvic Acid (FA) was used to assess the maturity of the composts produced, based on the degree of humification of the organic matter. The HA/FA ratio is highest and increases with composting time. The FA values decrease with time, while the HA values increase with time. Unlike OC and C/N, their levels stabilized from day 60, regardless of the number of worms. The lowest value of the C/N ratio was obtained at the end of the

Table 1. Changes in physico-chemical properties as a function of composting time

Days	Physico-chemical properties			
	pH		EC (mS·cm^{-1})	
	V1	V2	V1	V2
0	8.33 ± 0.04[a]	8.33 ± 0.04[a]	3.34 ± 0.13[a]	3.34 ± 0.13[a]
20	8.30 ± 0.19[a]	8.26 ± 0.11[ab]	2.80 ± 0.64[bc]	2.39 ± 0.18[cd]
40	8.28 ± 0.23[ab]	8.20 ± 0.21[b]	2.62 ± 0.00[bcd]	2.62 ± 0.00[bcd]
60	8.23 ± 0.13[b]	8.20 ± 0.16[b]	2.73 ± 0.10[bc]	2.46 ± 0.30[bcd]

Table 2. Changes in stability properties as a function of composting time.

Days	Stability									
	HA (%)		FA (%)		HA/FA		OC (%)		C/N	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
0	8.20 ± 0.91[b]	8.20 ± 0.91[b]	9.68 ± 0.11[b]	9.68 ± 0.11[b]	0.85 ± 0.09[b]	0.85 ± 0.09[b]	12.53 ± 0.94[a]	12.53 ± 0.94[a]	16.49 ± 0.42[a]	16.49 ± 0.42[a]
20	8.66 ± 0.04[ab]	8.64 ± 0.09[ab]	9.73 ± 0.04[ab]	9.79 ± 0.03[ab]	0.89 ± 0.00[ab]	0.88 ± 0.01[ab]	12.71 ± 0.62[a]	12.85 ± 0.43[a]	14.78 ± 0.78[b]	14.95 ± 0.76[b]
40	9.17 ± 0.00[a]	9.18 ± 0.00[a]	9.73 ± 0.00[ab]	9.75 ± 0.00[ab]	0.95 ± 0.00[a]	0.95 ± 0.00[a]	12.12 ± 0.39[a]	12.28 ± 0.44[a]	13.03 ± 0.00[cd]	13.07 ± 0.84[cd]
60	9.10 ± 0.13[a]	8.96 ± 0.09[ab]	9.81 ± 0.02[a]	9.71 ± 0.13[ab]	0.92 ± 0.01[ab]	0.92 ± 0.00[ab]	12.27 ± 0.34[a]	11.88 ± 0.42[a]	12.40 ± 0.41[de]	09.74 ± 0.28[dg]

process by V2 (9.74 ± 0.28) while the highest value was obtained by V1 (12.40 ± 0.41).

All the nutrients analyzed (Table 3) show a significant difference ($P < 0.05$) according to the collection periods and the number of worms. The highest values for nitrogen, phosphorus and magnesium were obtained at the end of the process by treatment V2 (1.22 ± 0.04; 22.04 ± 0.04; 3.71 ± 0.00). However, treatment V1 had the highest values for potassium, calcium and sodium at the end of the process (1.59 ± 0.00; 5.85 ± 0.29 and 0.48 ± 0.31), although the sodium values were not significantly different. This variation was observed for EC from day 20, while for pH it was observed from day 40. The C/N ratio and humic substances were influenced by both composting time and the number of worms in the treatments. The chemical fractionation of HA and FA was used to assess the maturity of the composts produced, based on the degree of humification of the organic matter. The HA/FA ratio is highest and increases with composting time. The FA values decrease with time, while the HA values increase with time. Unlike CO and C/N, their levels stabilized from day 60, regardless of the number of worms. The lowest value of the C/N ratio was obtained at the end of the process by V2 (9.74 ± 0.28) while the highest value was obtained by V1 (12.40 ± 0.41).

Table 3. Changes in nutrients and heavy metals as a function of composting time.

Days	Nutrients											
	N (%)		P (mg·kg^{-1})		K (mg·kg^{-1})		Mg (mg·kg^{-1})		Ca(mg·kg^{-1})		Na (mg·kg^{-1})	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
0	0.76 ± 0.08^{f}	0.76 ± 0.08^{f}	21.60 ± 0.07^{c}	21.60 ± 0.07^{c}	1.02 ± 0.07^{e}	1.02 ± 0.07^{e}	0.41 ± 0.00^{de}	1.86 ± 1.35^{bc}	1.28 ± 0.00^{e}	1.86 ± 0.00^{de}	0.46^{-} ± 0.21^{a}	0.46^{-} ± 0.21^{a}
20	0.86 ± 0.02^{de}	0.86 ± 0.04^{de}	21.68 ± 0.01^{bc}	21.74 ± 0.23 ^{abc}	1.15 ± 0.17^{cde}	1.25 ± 0.00^{bcde}	0.45 ± 0.00^{cde}	2.57 ± 0.42^{ab}	4.20 ± 0.32^{cd}	3.99 ± 0.42^{cd}	0.36 ± 0.37^{a}	0.48 ± 0.32^{a}
40	0.93 ± 0.00^{cd}	0.94 ± 0.06^{cd}	21.87 ± 0.00^{abc}	21.96 ± 0.00^{ab}	1.35 ± 0.00^{bc}	1.29 ± 0.12^{bcd}	2.69 ± 0.47^{ab}	2.84 ± 0.00^{ab}	5.61 ± 0.00^{ab}	4.79 ± 0.22^{c}	0.26 ± 0.16^{a}	0.44 ± 0.21^{a}
60	0.96 ± 0.01^{c}	1.22 ± 0.04^{a}	21.94 ± 0.63^{ab}	22.04 ± 0.04^{a}	1.59 ± 0.00^{a}	1.42 ± 0.10^{ab}	2.90 ± 0.10^{ab}	3.71 ± 0.00^{a}	5.85 ± 0.29^{a}	4.90 ± 0.22^{c}	0.48 ± 0.31^{a}	0.45 ± 0.28^{a}
	Heavy metals											
	Cr (mg·kg^{-1})		Cu (mg·kg^{-1})		Iron (mg·kg^{-1})		Ni (mg·kg^{-1})		Pb (mg·kg^{-1})		Zn (mg·kg^{-1})	
0	70.00 ± 0.00^{a}	70.00 ± 0.00^{a}	4.49 ± 0.39^{a}	4.49 ± 0.39^{a}	110.99 ± 23.13^{a}	110.99 ± 23.13^{a}	28.76 ± 2.89^{a}	28.76 ± 2.89^{a}	1.55 ± 0.33^{a}	274.99 ± 42.73^{a}	274.99 ± 42.73^{a}	274.99 ± 42.73^{a}
20	69.60 ± 17.69^{a}	65.60 ± 10.69^{b}	3.42 ± 0.12^{ab}	3.54 ± 0.14^{b}	109.39 ± 18.35^{a}	100.72 ± 2.63^{b}	34.72 ± 2.63^{b}	26.32 ± 3.12^{a}	1.30 ± 0.31^{a}	216.32 ± 73.58^{ab}	263.64 ± 84.20^{b}	216.32 ± 73.58^{ab}
40	66.00 ± 0.00^{b}	48.58 ± 0.00^{c}	3.19 ± 0.00^{b}	4.08 ± 0.00^{ab}	106.64 ± 29.82^{a}	93.06 ± 1.18^{a}	27.06 ± 1.18^{a}	26.32 ± 3.12^{a}	1.21 ± 0.39^{a}	114.57 ± 0.30^{b}	126.38 ± 0.00^{c}	114.57 ± 0.30^{b}
60	62.59 ± 8.17^{c}	55.18 ± 4.20^{d}	3.54 ± 0.14^{ab}	3.44 ± 0.09^{b}	100.71 ± 25.07^{a}	90.24 ± 1.02^{a}	25.24 ± 1.02^{a}	12.79 ± 1.08^{b}	1.04 ± 0.25^{a}	76.39 ± 3.04^{c}	149.31 ± 27.29^{d}	76.39 ± 3.04^{c}
NFU 44-051	120		300	nd	60			180			600	

In **Table 4**, the soil has a CEC that varies from 19.5 at the surface (Ap) to 11.5 cmol + kg^{-1} of soil at depth (Bo2 horizon). Bulk density increases with depth, ranging from 0.92 to 1.4 g·cm^{-1} for the Ap and Bo2 horizons respectively. Compost V1 has a pH of 8.8, a percentage of organic carbon of 21.84%, total nitrogen of 1.45%, a C/N ratio of 15 and a P concentration of 21.51 mg.kg^{-1}. Exchangeable cation concentrations were 1.74, 1.94, 3.33 and 0.17 cmol + kg^{-1} for Ca, Mg, K and Na respectively. Electrical conductivity was 2.90 mS·cm^{-1}. Compost V2, on the other hand, had a pH of 7.6, a percentage of organic carbon of 20.44%, total nitrogen of 1.66%, a C/N ratio of 12.31 and a P concentration of 7.25 mg·kg^{-1}. The concentrations of exchangeable cations were 1.87, 3.7, 3.93 and 0.2 Cmol + kg^{-1} for Ca, Mg, K and Na respectively. This compost has an electrical conductivity of 2.44 mS·cm^{-1}. The poultry manure had a pH of 7.3, a percentage of organic carbon of 17.2% and total nitrogen of 2.14%, a C/N ratio of 8.3, available P concentration of 3.14 mg·kg^{-1} and electrical conductivity of 2.10 mS·cm^{-1}. The concentrations of exchangeable cations were 4.22, 2.26, 0.08 and 0.21 Cmol + kg^{-1} of poultry manure, for Ca, Mg, K and Na respectively.

Table 4. Physical and chemical properties of the soil and organic amendments used.

Soil	pH	EC	OC	N	C/N	Phosphorus		Cation exchange				CEC	TC	BD
						Bray II	Olsen	Na	K	Mg	Ca			
Horizon (cm)		mS·cm^{-1}	%	%		(mg·kg^{-1})			Cmol + Kg^{-1}					g cm^{-3}
Ap 0 - 24 cm	5.8	0.41	2.59	0.15	21.6	2.71	-	0.05	0.19	1.84	1.96	19.5	SC	0.92
Bo1 24 - 90 cm	5.6	0.34	1.92	0.1	19.2	0.79	-	0.05	0.16	1.12	1.6	14.5	SC	0.98
Bo2 90 - 200 cm	5.5	0.31	1.89	0.09	21	0.71	-	0.05	0.14	1.02	1.28	11.5	CS	1.4
V1	8.8	2.90	21.84	1.45	15	-	2.51	0.17	3.33	1.94	1.74	-	-	-
V2	7.6	2.60	20.44	1.66	12.31	-	7.25	0.2	3.93	3.7	1.87	-	-	-
PM	7.3	2.10	17.2	2.14	8.3	-	3.14	0.21	0.08	2.26	4.22	-	-	-

BD: Bulk density; TC: Textural class; SC: Sandy-clay, CS: Clay-sand, OC: Organic carbon; N: Total nitrogen; CEC: Cation exchange capacity; EC: Electrical conductivity.

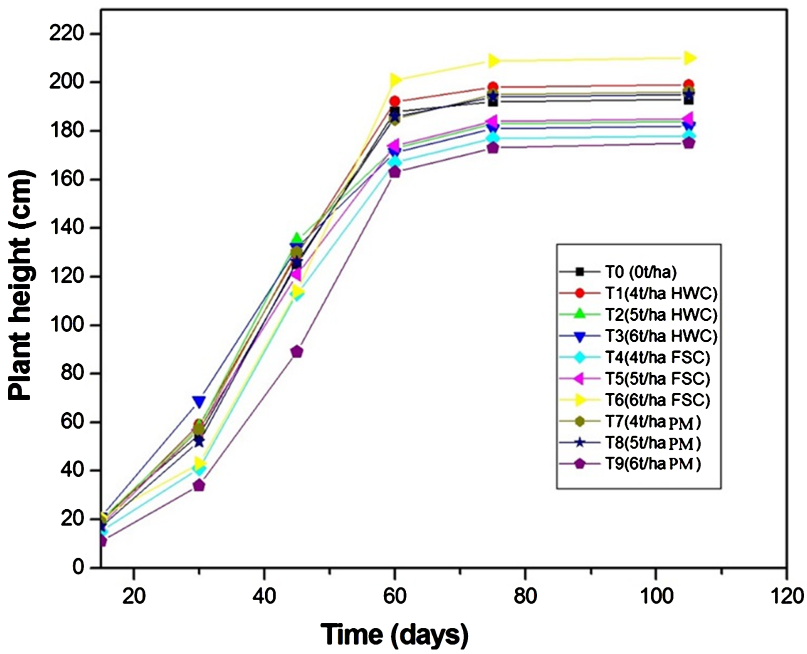

Figure 2. Average height of sunflower plants in function of time.

3.2. Effect of Treatments on Growth and Yield Parameters

The change in average height over time (Figure 2) shows that the size of the plants subjected to the different rates increased progressively over the course of the season, irrespective of the treatment. Growth was slow in the first month at 30 days after application (10 - 75 cm). It became rapid in the second month (75 -

180 cm) and remained constant after 60 days.

Increases in crown diameter and plant height were significantly influenced by the V1, V2 and poultry manure treatments at the end of data collection (Table 5). Although these values ranged from 27.16 ± 13.59 to 29.62 ± 13.59 with the V1 compost, it had no significant effect on the number of leaves. With the diameter at the crown, it can be noted that for V1, the effect is positive with the increase in the rate even if this increase is not significant between 4 and 5 t/ha, it becomes significant from 6 t/ha with a maximum value for T3 (15.88 ± 9.97 cm). This variation is also observed in the poultry manure with a maximum value of 16.46 ± 10.98 cm for T9. However, the variation is the opposite in the V2 compost, with a decrease in this diameter as the rate of fertilizer increases. Values ranged from 19.30 ± 9.07 cm (T4: 4 t·ha^{-1}) to 14.73 ± 8.63 cm (T5: 5 t·ha^{-1}). Plant height values increased proportionally with rate in the V1 and V2 compost treatments, although the variations were not significant with V1. On the other hand, the variation with poultry manure was inversely proportional to the rates of manure. Thus, 4 t·ha^{-1} gave a value of 179.2 ± 11.7 cm for T7, whereas 6 t·ha^{-1} for T9 gave a value of 163.8 ± 22.5 cm.

Table 5. Effect of amendment rates (t·ha^{-1}) on certain sunflower growth and yield parameters

Fertilizers Treatments Parameters /Rate (t/ha)	V1				V2			PM		
	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
	0	4	5	6	4	5	6	4	5	6
Mean number of leaves/plant	28.27^{ab}	27.22^{ab}	27.16^{ab}	29.62^{ab}	33.02^{a}	31.83^{a}	31.97^{a}	30.31^{a}	25.12^{b}	27.22^{ab}
Mean collar diameter/plant (cm)	16.46^{ab}	13.64^{b}	13.75^{b}	15.88^{ab}	19.30^{a}	17.67^{a}	14.73^{b}	14.78^{b}	13.42^{a}	14.90^{b}
Mean height/plant (cm)	86.76^{b}	74.26^{bc}	76.42^{bc}	86.47^{b}	110.07^{a}	101.70^{a}	83.83^{b}	83.37^{b}	68.82^{c}	81.04^{b}
Mean diameter of flower head (cm)	23.91^{b}	25.25^{ab}	23.50^{b}	22.58^{b}	22.58^{b}	25.08^{ab}	25.33^{ab}	26.00^{ab}	25.41^{ab}	27.16^{a}
Mean mass of flower heads (g)	209.16^{ab}	205.33^{ab}	190.25^{b}	137.91^{c}	178.75^{bc}	207.50^{ab}	215.66^{a}	202.91^{ab}	187.25^{b}	230.83^{a}

For each OM source, the values followed by the same letters in the line are not significantly different at the P = 5% probability threshold. (T0: no fertilizer, T1: 4 t·ha^{-1} of V1, T2: 5 t·ha^{-1} of V1, T3: 6 t·ha^{-1} of V1, T4: 4 t·ha^{-1} of V2, T5: 5 t·ha^{-1} of V2, T6: t·ha^{-1} of V2, T7: 4 t·ha^{-1} of PM, T8: 5 t·ha^{-1} of PM, T9: 6 t·ha^{-1} of PM).

The effect of the different treatments on sunflower grain yield is shown in Figure 3. Significant differences were observed ($P < 0.05$). The highest yields were obtained with treatments T8 and T9 and the lowest with treatment T0. At the end of the study, the ranking of treatments according to their positive influence on yield was as follows: T8 = T9 > T6 > T1 > T5 > T7 > T2 > T3 > T4 > T0.

3.3. Effect of Treatments on Sunflower Chemical Composition

Table 6 shows proteins and the macro-element (P, Na, K, Mg and Ca) dry matter content of the seeds in the different treatments. The table shows that the

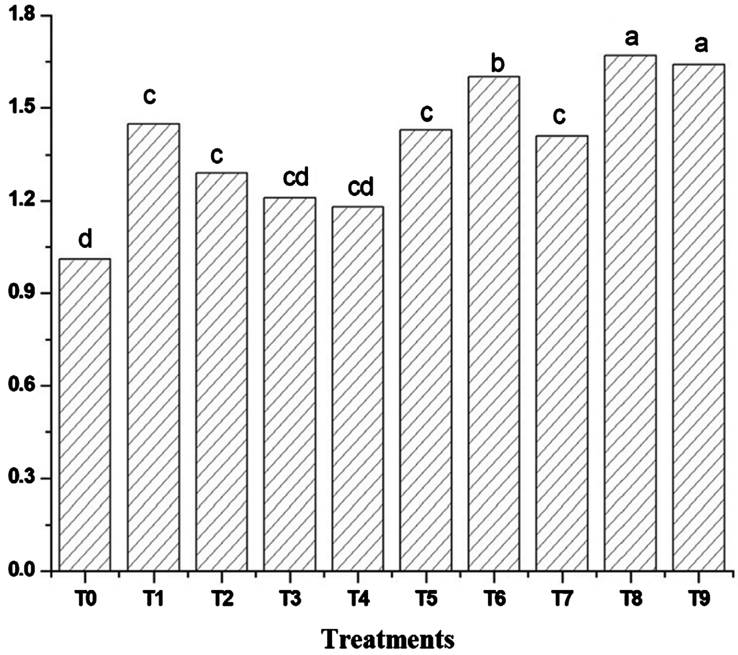

Figure 3. Effect of different treatments on sunflower yields.

Table 6. Proteins and macro-element (P, Na, K, Mg and Ca) content of seeds in the different treatments.

Treatments	Proteins %	P	Na	K	Mg	Ca
		(mg·kg^{-1})				
T0	16.33^{ab}	49.05^{ab}	15.72^{d}	20.4^{a}	31.1^{a}	34.1^{a}
T1	25.81^{bc}	49.45^{ab}	7.53^{bc}	21.8^{a}	30.0^{a}	62.2^{bc}
T2	26.83^{c}	45.28^{a}	8.87^{c}	20.2^{a}	28.8^{a}	56.9^{ab}
T3	19.25^{abc}	46.79^{ab}	7.94^{bc}	21.6^{a}	44.2^{a}	73.6^{bc}
T4	13.56^{a}	48.16^{ab}	8.06^{bc}	21.1^{a}	31.3^{a}	73.6^{bc}
T5	22.75^{abc}	53.22^{b}	8.87^{c}	21.7^{a}	27.4^{a}	88.7^{c}
T6	20.85^{abc}	48.86^{ab}	5.53^{ab}	18.7^{a}	32.3^{a}	83.6^{bc}
T7	20.42^{abc}	51.74^{ab}	5.94^{abc}	20.5^{a}	41.3^{a}	76.0^{bc}
T8	22.60^{abc}	50.37^{ab}	3.28^{a}	15.8^{a}	25.0^{a}	74.8^{bc}
T9	22.75^{abc}	45.06^{a}	12.97^{d}	38.0^{b}	44.0^{a}	64.8^{bc}
Mean	21.12	48.8	8.47	22	32.2	68.8
cv	7.6	0.3	6.8	9.3	3	4.5

Means in the same column followed by the same letter are not statistically different (p 0.05).

sunflower seeds studied contain a large quantity of minerals. The average proteins are 21.12%. The dry matter concentration of calcium (68.8 mg·kg^{-1}) was highest, followed by phosphorus (48.8 mg·kg^{-1}), potassium (22 mg·kg^{-1}) and finally protein (21.12%). The nutrient composition of the different sunflower treatments showed significant variations except for magnesium. However, T5 has the highest calcium values, T9 is richer in potassium, magnesium and sodium, while T2 gives the seeds with the highest protein content (26.83%).

Table 7 shows the dry matter content of the seeds in microelements (Cr, Cu, Iron, Mn and Zn) for the different treatments. The table shows that the sunflower seeds studied contain a large quantity of minerals. The average dry matter concentration of iron (47.1 $mg \cdot kg^{-1}$) was highest, followed by chromium (32.4 $mg \cdot kg^{-1}$), zinc (31.3 $mg \cdot kg^{-1}$), copper (14.18 $mg \cdot kg^{-1}$) and finally manganese (1.64 $mg \cdot kg^{-1}$). The nutrient composition of the different sunflower treatments showed significant variations except for zinc. However, T0 and T6 had the highest iron values, T9 was richer in copper and manganese, while T1 was richer in chromium and zinc.

Table 7. Microelement content of seeds (Cr, Cu, Fe, Mn and Zn) in the different treatments.

Treatments	Cr	Cu	Fe	Mn	Zn
			($mg \cdot kg^{-1}$)		
T0	20.0^{a}	5.70^{a}	58.2^{b}	0.87^{a}	32.6^{a}
T1	49.8^{b}	5.67^{a}	50.4^{ab}	1.33^{abc}	39.7^{a}
T2	31.5^{ab}	17.90^{b}	49.5^{ab}	1.50^{bc}	33.8^{a}
T3	35.4^{ab}	19.00^{b}	41.3^{ab}	1.80^{cd}	27.3^{a}
T4	25.3^{ab}	13.77^{ab}	48.5^{ab}	1.067^{ab}	26.6^{a}
T5	28.1^{ab}	14.80^{b}	44.3^{ab}	1.33^{abc}	39.1^{a}
T6	25.6^{ab}	14.30^{b}	57.3^{b}	1.63^{cd}	26.8^{a}
T7	41.6^{ab}	17.43^{b}	47.8^{ab}	2.00^{de}	37.3^{a}
T8	25.6^{ab}	12.73^{ab}	38.0^{a}	2.30^{ef}	18.3^{a}
T9	41.0^{ab}	20.50^{b}	35.5^{a}	2.60^{f}	31.3^{a}
Mean	32.4	14.18	47.1	1.64	31.3
cv	13	43	8.6	24.4	13.2

Means in the same column followed by the same letter are not statistically different (p 0.05).

3.4. Effect of Treatments on Soil Properties

Table 8 shows the soil results after cultivation. The soil pH was acidic (6.20 to 6.46). Treatments T1, T2, T4, T6 and T8 had the same effect on soil pH. All these treatments contributed to the drop in soil acidity. Treatment T6 had the greatest effect on soil organic carbon (4.33%), increasing it by 1.73%, while T3 had the least effect (2.96%), increasing it by 0.36% compared with the control. Treatment T8 had the greatest influence on soil nitrogen (0.30%), increasing it by 0.13%, while T1 and T2 (0.21) had less influence, increasing the value by 0.04 compared with the control. All the treatments contributed to the fall in the soil

C/N ratio, although treatment T3 (11.04) had the greatest influence on this ratio. The amount of phosphorus in the soil increased in all treatments. T7 (9.04) showed the greatest variation. There was an increase in soil potassium after application of the various treatments, with T6 (0.78) having the greatest influence on this parameter.

Table 8. Soil properties before and at the end of the study (0 - 25 cm)

	pH	OC %	N %	C/N	P	Na	K	Mg	Ca	CEC	C %	S %	S %
				(mg·kg^{-1})		Cmol + kg^{-1}							
Initial	5.8	2.59	0.15	21.6	2.71	0.04	0.19	1.33	2.27	24.5	19.5	27	53.5
Final													
T0	5.43 ± 0.15^{a}	2.60 ± 0.60^{ab}	0.13 ± 0.04^{a}	20.56 ± 0.94^{c}	2.97 ± 0.55^{a}	0.11 ± 0.01^{ab}	0.27 ± 0.08^{a}	5.48 ± 0.60^{bcd}	2.04 ± 1.80^{a}	13.73 ± 3.89^{a}	21.10 ± 5.10^{a}	26.50 ± 1.50^{ab}	52.73 ± 3.65^{ab}
T1	6.47 ± 0.06^{b}	3.70 ± 0.00^{ab}	0.22 ± ^{abc} 0.07^{ab}	17.94 ± 5.43^{bc}	8.28 ± 0.13^{ab}	0.19 ± 0.04^{bcd}	0.56 ± 0.18^{ab}	3.84 ± 0.48^{ab}	6.76 ± 2.92^{cd}	32.00 ± 22.02^{a}	17.10 ± 4.10^{a}	26.50 ± 0.50^{ab}	55.73 ± 3.78^{b}
T2	6.20 ± 0.00^{ab}	3.13 ± 1.05^{a}	0.21 ± 0.05^{bc}	14.34 ± 1.71^{ab}	8.35 ± 1.04^{ab}	0.28 ± 0.10^{d}	0.49 ± 0.05^{ab}	4.48 ± 0.72^{abc}	7.40 ± 1.48^{cd}	23.20 ± 0.80^{a}	17.10 ± 0.10^{a}	25.50 ± 0.50^{ab}	56.73 ± 1.30^{b}
T3	6.43 ± 0.12^{b}	2.97 ± 0.25^{a}	0.27 ± 0.01^{bc}	11.04 ± 1.30^{a}	7.13 ± 0.47^{a}	0.22 ± 0.01^{bcd}	0.66 ± 0.12^{b}	6.60 ± 1.08^{d}	7.36 ± 3.12^{cd}	26.40 ± 4.92^{a}	21.10 ± 1.10^{a}	29.50 ± 0.50^{b}	50.73 ± 2.39^{a}
T4	6.20 ± 0.20^{ab}	3.57 ± 0.06^{ab}	0.27 ± 0.05^{bc}	13.56 ± 2.57^{ab}	8.37 ± 0.82^{ab}	0.19 ± 0.10^{bcd}	0.50 ± 0.16^{ab}	3.72 ± 0.20^{a}	8.24 ± 0.40^{d}	26.40 ± 1.60^{a}	18.10 ± 2.90^{a}	26.00 ± 1.00^{ab}	54.40 ± 3.22^{ab}
T5	6.30 ± 0.00^{ab}	3.50 ± 0.40^{ab}	0.28 ± 0.07^{bc}	13.00 ± 3.54^{ab}	7.92 ± 0.91^{ab}	0.15 ± 0.01^{abc}	0.55 ± 0.11^{ab}	6.64 ± 1.60^{d}	6.84 ± 2.12^{cd}	25.20 ± 2.80^{a}	19.60 ± 1.60^{a}	24.50 ± 1.50^{a}	56.23 ± 0.59^{ab}
T6	6.47 ± 0.15^{b}	4.33 ± 0.75^{b}	0.27 ± 0.05^{bc}	16.41 ± 5.27^{abc}	8.92 ± 1.65^{b}	0.26 ± 0.07^{cd}	0.79 ± 0.13^{b}	5.88 ± 1.32^{cd}	7.04 ± 2.56^{cd}	25.87 ± 6.80^{a}	16.70 ± 0.50^{a}	27.50 ± 1.50^{b}	55.97 ± 1.04^{ab}
T7	6.27 ± 0.06^{ab}	4.10 ± 0.50^{b}	0.28 ± 0.02^{bc}	14.57 ± 2.67^{ab}	9.04 ± 0.91^{b}	0.07 ± 0.06^{a}	0.50 ± 0.25^{ab}	3.88 ± 1.08^{ab}	5.84 ± 4.40^{bcd}	22.40 ± 5.00^{a}	19.70 ± 0.50^{a}	25.50 ± 0.50^{ab}	54.80 ± 0.00^{ab}
T8	6.47 ± 0.06^{b}	3.70 ± 0.00^{ab}	0.30 ± 0.04^{c}	12.29 ± 1.44^{ab}	8.94 ± 0.03^{b}	0.14 ± 0.06^{ab}	0.61 ± 0.31^{b}	4.92 ± 0.60^{abc}	4.52 ± 0.52^{abc}	26.53 ± 2.95^{a}	21.70 ± 3.50^{a}	24.50 ± 1.50^{a}	53.13 ± 5.13^{ab}
T9	5.93 ± 0.55^{a}	4.10 ± 0.10^{b}	0.26 ± 0.05^{bc}	16.32 ± 2.90	8.60 ± 0.27^{ab}	0.18 ± 0.00^{abcd}	0.70 ± 0.07^{b}	4.16 ± 0.40^{ab}	3.32 ± 1.08^{ab}	27.67 ± 6.52^{a}	21.20 ± 2.00^{a}	26.00 ± 0.00^{ab}	53.47 ± 2.31^{ab}

(T0: no fertilizer, T1: 4 t·ha^{-1} of V1, T2: 5 t·ha^{-1} of V1, T3: 6 t·ha^{-1} of V1, T4: 4 t·ha^{-1} of V2, T5: 5 t·ha^{-1} of V2, T6: 6 t·ha^{-1} of V2, T7: 4 t·ha^{-1} of PM, T8: 5 t·ha^{-1} of PM, T9: 6 t·ha^{-1} of PM). Means in the same column followed by the same letter are not statistically different (p 0.05).

4. Discussion

4.1. Changes in Physical-Chemical Parameters and Agronomic Quality of Compost

Water losses, especially at the start of the composting process, could be explained by the high activity of thermophilic micro-organisms in the compost. On the other hand, it could be attributed to the porosity of the compost heaps, which favors rapid loss of water through evaporation due to the high temperatures. According to Yulipriyanto [33] the water content tends to increase through the release of metabolic water by the micro-organisms and to decrease under the combined action of the rise in temperature, aeration and turning. This may justify the variation in humidity on day 20 in the process. Gurav and Pathade [21] showed that a moisture level between 50% to 90% for Eisenia fetida was optimal for Biomass and cocoon production. However, low moisture levels, generally below 50%, are not recommended, as the earthworm's risk shriveling and drying out. These results are in line with those found by Lim *et al.* [34] where moisture decreased with composting time.

The drop in pH is associated with the increase in mineral nitrogen content, changes in the ammonium-nitrate balance and the accumulation of organic acids from microbial metabolism or the production of fulvic and humic acids during decomposition [24] [31] [35]. Similar results on composting of fruit, tuber and vegetable waste were reported by Li *et al.* [26]. The high EC values at the beginning of the process can be attributed to the salinity of the inputs, especially household waste. These values are probably related to the release of different mineral salts in available forms such as ammonium, phosphate and potassium by the decomposition of organic substrates during the pre-composting phase [36]. The decrease in EC during composting could be due to decomposition of organic substrates [37]. In addition, the stabilization of carbon with the maturation of vermicompost helps to fix salts. His results are in line with those found by Li *et al.* [26].

The loss of carbon would be due to better growth of earthworms, respiration of microorganisms and stabilization of OM by earthworms [38]. According to Francou *et al* [39], nearly 40% of the initial carbon content is generally lost during composting. Thus, carbon loss reflects the intensity of organic matter degradation. A C/N value of less than 15 is considered preferable for the agronomic value of the final products as fertilizer [37]. Several authors have shown that the C/N ratio is between 10 and 15 when the compost becomes mature [25] [40]. According to Huang *et al.* [41], HA/FA ratio values greater than 1 are synonymous with mature compost. These results are in agreement with those found by Iglesias-Jiminez and Perez-Garcia [42] and Francou [43]. They showed that the HA/FA ratio increased as a function of the composting phases of organic waste.

Heavy metals in appropriate amounts are essential elements for plant growth and metabolism, although high concentrations can pose a risk to humans and the environment [44]. Total Cr fractions varied little during treatment, meaning that the earthworm sequestered a significant portion of the ion. Similar behavior was also observed for Cu, Fe, Ni, Pb and Zn. It has been shown that one of the reasons for the decrease in the concentration of heavy metals is due to the bioaccumulation of earthworms in their tissues through intestinal absorption, referred to as the intercellular binding mechanism of metals in the chloragogen tissue of earthworms [44]. Some metals can be displaced by Ca, thus detoxified by binding to organic ligands or sequestered by inorganic matrices when they are in toxic concentrations, indicating a decrease in the exchangeable fraction at the same time as a reduction in the total amount [22]. Identical results have been reported by Suthar *et al.* [31].

The variation in the nutrient value of vermicompost at different intervals is statistically significant for all elements except sodium. Earthworms have been shown to improve substrate nitrogen levels by adding their excretory products, mucus, body fluids and enzymes to vermicompost [45]. The increase in phosphorus levels in vermicompost is attributed to the mineralization of feed during the vermicomposting process. Singh *et al.* [46] suggested that the passage of organic matter through the earthworm gut results in the conversion of phosphorus into forms that are readily available to plants. Similarly, Ghosh *et al.* [47] have shown that vermicomposting can be an effective technology for converting unavailable forms of phosphorus into forms readily available to plants. The increase in calcium, magnesium and potassium values can be attributed to the mineralization of food by earthworms, in particular the secretion of the calciferous gland [24].

4.2. Effect of Amendments on Sunflower Growth Variables

Analysis of the growth variables of the treatments using compost showed, on average, greater vegetative development than that of the control (without fertilizer), which could be explained by the fact that the amendments supplied the soil with nutrients, thereby improving the availability of these elements in the soil and their uptake by the plant's root system. They helped to improve the physico-chemical properties of the soil, thereby boosting crop growth and development [48]. The results are similar to those obtained on lettuce and leek, sorghum and sunflower crops, and on barley plants grown by amending the soil with composted faecal sludge, in other countries [49]-[51]. They found that organic amendments increased soil pH and macronutrients, leading to changes in the physico-chemical characteristics and fertility of the soil. This enabled them to conclude that the application of faecal sludge to lettuce, leek, sorghum, sunflower and barley plants considerably stimulated crop growth, development and yield compared with the negative control (without fertilizer). The richness of the amendments in nutrients necessary for plant growth and development confirms their capacity as a biological amendment, as emphasized by several authors [17] [18].

4.3. Effect of Treatments on Sunflower Yield Variables

According to Yerima *et al.* [14] sunflower grain yield is a quantitative component highly influenced by environmental factors. Several researchers have examined the relationships between yield components and have concluded that the selection of sunflower grain yields should largely depend on 1000 seed weight and flower head diameter [52]. In general, fertilized sunflower plants obtained different values of yield variables from the control. This would mean that the fertilizers made up for the nutritional deficit present in the soil studied. They would have corrected, raised and made available the nutrients in the soil, allowing the plant to be progressively fed during its development cycle. This idea is consistent with that put forward by Ainika *et al.* [53], who assert that organic fertilizers are capable of providing sufficient nutrients for optimal plant growth and development. These results concur with those obtained by Yerima *et al.* [14] on sunflower (*Helianthus annuus L.*) cultivation with the use of organic manures. Poultry manure rates that did not significantly influence growth variables were decisive for yield variables and grain yield. All PM rates gave higher yields than the control. This could be explained by the fact that PM at 5 and 6 $t \cdot ha^{-1}$, V2 at 6 $t \cdot ha^{-1}$ provided a greater quantity of available nutrients than that provided by V1. These results are in line with those obtained by Khodaei *et al.* [54] on sunflower (*Helianthus annuus L.*) cultivation and by Lacerda *et al.* [55] with the use of organic amendments and agricultural faecal sludge in other countries.

All the yield parameters of the treatments subjected to V2 fertilization obtained a linear evolution as a function of the increase in the amount of manure. This could be explained by the fact that, despite the richness of this fertilizer in nutritive elements, the quantities applied to the plants are not yet satisfactory for obtaining optimum yield. The rates used in the study would not satisfactorily supply the nutrients that plants need to fully meet their requirements. Some authors [5] [12] obtained similar results for soybean crops at increasing rates of organic fertilizer. Thus, the improvement in growth and yield in terms of weight evolved proportionally with the increase in the quantity of wastewater used.

4.4. Effect of Treatments on Sunflower Quality

The export of nutrients is extremely important in a crop cycle. The results obtained in this study show that macronutrient levels in the seeds were not significantly different compared to phosphorus and protein. However, macronutrient export differed significantly between treatments. These results are similar to those of Akbari *et al.* [11] who show that the different farmyard manure combinations had a significant effect on quality variables such as grain protein content, oil content and fatty acid percentages in sunflower seed oil. Among the macronutrients analyzed, calcium was predominant, followed by phosphorus. This order of predominance of levels corroborates the studies by Sene *et al.* [56]. Similar levels were also reported by Sene *et al.* [57] for sesame in Senegal, making calcium the predominant mineral element. The macronutrient contents of this study are higher than those reported by Lobo and Grassi [17] in sunflower seeds amended by Faecal Sludge. The variation in protein content is generally attributed to genetic and/or environmental factors or to the method of analysis. However, the range of protein levels in our samples is narrower than that reported by Lobo and Grassi [17].

All micronutrients except zinc showed significant differences between treatments. The micronutrient levels obtained in this study are in line with the work reported by Castro *et al.* [58] who reported that iron is the main mineral element in sunflower seeds. Vieira *et al.* [59] showed that in soya plants, the addition of 6 t/ha of sewage sludge did not increase Fe levels in the grains. These results do not corroborate those found by Lobo and Grassi [17] in the application of sewage sludge on the development and nutrition of sunflower plants in Brazil.

4.5. Effect of Treatments on Soil Quality

The initial fertility status of the Oxisol used for the study is low and constrains the production of some perennial and vegetable crops [14]. The acid pH (5.8) and average CEC (19.5 Cmol + kg^{-1} soil) are the main production constraints in traditional production systems. All the deficiencies observed are correlated with the acid pH of this soil [60]. This soil has a negative net charge (pH $H_2O \geq$ pH KCl) like most oxisols in the tropics [61]. The low pH may be associated with low base saturation and acidic parent material (granitic rock). Intense leaching reduces concentrations of exchangeable bases in the soil [14]. The low CEC of this soil (24.5) is correlated with the mineralogy of the clay fraction, consisting mainly of kaolinite and Fe and Al oxyhydroxides with low surface variable loads [30].

Soil nutrients, like all agricultural inputs, need to be managed appropriately to meet the fertility requirements of sunflowers without adversely affecting environmental aspects. The results of the analyses showed that the organic amendment (V1, V2 and PM) redressed the cation balance, improved soil nutrients (N, P, K) and the C/N ratio of the soil in the study [15]. This recovery is highly possible, as these organic amendments provided sufficient quantities of N, P, K, Ca, Mg and OM [62]. During the decomposition and mineralization of the organic matter, the release of nutrients is beneficial to the soil in the study, which is poor in organic matter, nitrogen, phosphorus and exchangeable bases. The OM provided by the organic amendments improves the physical properties of the soil. The increased availability of soil nutrients due to the application of fertilizers increases their uptake by plant roots. The results obtained corroborate those of previous studies, which show that organic fertilizer increases sunflower growth and yields, attributable to the improved chemical and physical properties of the soil [62]

The high concentration of nutrients in the fertilizer was responsible for the improvements in growth. This result is in agreement with that of Zamil *et al.* [60] who demonstrated that poultry manure improves the availability of nitrogen, phosphorus and potassium. Yerima *et al.* [14] demonstrated that the uptake of major elements was significantly increased by the application of poultry manure to the sunflower crop. During OM decomposition, a variety of organic compounds are released by micro-organic decomposers including fulvic acids, humic acids, humus and mineral salts [14].

5. Conclusion

The main objective of this work was to assess the effect of different organic fertilizers on sunflower (*Helianthus annuus L.*) yield and soil physico-chemical parameters. The main results revealed an improvement in growth and yield parameters of the sunflower after the various treatment. However, growth parameter values were higher in plots that had received a mixture of faecal sludge and household waste in the ratio of 3/5 with 900 worms (V2), and treatments 4 $t \cdot ha^{-1}$ of V2 and 6 $t \cdot ha^{-1}$ of V2 stood out. Sunflower yields were higher in plots receiving PM at 5 $t \cdot ha^{-1}$. However, 6 $t \cdot ha^{-1}$ of V2 obtained the best values for growth parameters. The results of the study also show that these amendments significantly improve the physico-chemical properties of the soil, making it more productive. All treatments significantly influenced soil pH, raising it from 5.8 to 6.47. However, CEC was most influenced by 4 $t \cdot ha^{-1}$ of V1, while 4 $t \cdot ha^{-1}$ of PM had the greatest effect on organic carbon and phosphorus. Composted organic fertilizers used to improve the physical, chemical and biological properties of the soil gave satisfactory results in this study. These results are an indicator of the use of faecal sludge and household waste composts in our environment to enrich poorest soils. It would be important for future studies to investigate the residual effect of these fertilizer sources on other crops, in order to assess their full economic potential.

Acknowledgements

The authors would like to extend their sincere appreciation to the University of Dschang (Cameroon) for permitting access into the Teaching and Research Farm and laboratory facilities, which were instrumental in the successful completion of this research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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