

The Effects of Mineral Fertilizers and Organic Amendments on the Growth and Yield of Sunflower

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Abstract

This study assessed the effects of mineral fertilizer and organic amendments on sunflower (*Helianthus annuus* L.) growth and yield at the University of Dschang research farm in western Cameroon during the 2022 growing season. Six treatments were compared: an untreated control (T0), poultry droppings (T1), compost (T2), mineral fertilizer (NPK 13-13-21; T3), poultry droppings plus mineral fertilizer (T4), and compost plus mineral fertilizer (T5). Leaf number, stem height, and collar diameter were monitored during growth; flower weight, flower diameter, and yield were assessed at harvest. The highest numerical yield was obtained with compost alone (T2; 4.01 t·ha⁻¹), followed by compost plus mineral fertilizer (T5; 3.81 t·ha⁻¹), compared with 3.42 t·ha⁻¹ in the control. The greatest mean leaf number and stem height across the five reported observations occurred under T4, whereas poultry droppings alone (T1) produced the greatest mean collar diameter. These descriptive results suggest that responses to fertilizer sources differed among growth and yield variables. Compost showed potential for sunflower production under the conditions of this single-site, single-season experiment; treatment differences require confirmation using the original plot-level data and appropriately replicated trials.

Keywords

Sunflower, Poultry Droppings, Compost, Fertilizer

1. Introduction

The common sunflower (*Helianthus annuus* L.) is a species within the Asteraceae family, cultivated globally for its diverse nutritional and medicinal advantages. The sunflower seed, while commonly utilized as a snack, salad garnish, and in various baked goods, is predominantly cultivated for oil production. It holds the fourth position globally, accounting for 8% of the 186 million tonnes of oil produced in 2012, following palm oil at 29%, soybean oil at 22%, and oilseed rape at 13% [1]. Sunflower seeds and sprouts are rich in valuable compounds, including antioxidants, antimicrobial agents, anti-inflammatory substances, antihypertensive properties, wound-healing elements, and cardiovascular benefits, along with flavonoids, polyunsaturated fatty acids, and vitamins [2]. This substance is utilized in ethnomedicine for the treatment of various disease conditions, including heart disease, bronchial, laryngeal, and pulmonary infections, as well as coughs, colds, and whooping cough [3]. The significant medicinal, nutritional, and culinary advantages have led to the historical and increasing global popularity of the sunflower and its components. The germination of sunflowers yields significant secondary compounds that may play crucial roles in ecological dynamics, as well as in the physiology, biosynthesis, and biodegradation processes of various organisms. Sunflower (*Helianthus annuus*) is an oilseed crop that originates from North America. This crop is grown globally, with the majority of its products being marketed for culinary uses or as feed for livestock [4]. The ability of sunflowers to adapt to various climatic and soil conditions has significantly improved their cultivation as an oilseed crop globally [5]. The cultivation of sunflowers necessitates nutrient-rich soil, adequate rainfall, and high-quality seeds, among other factors. Among the three primary oilseed crops, soybean, rapeseed, and sunflower, sunflower has emerged as a significant source of high-quality edible oil, which is notably utilized for culinary applications [6]. Sunflower is a significant oilseed crop cultivated globally, recognized for its high-quality oil and dietary fibre, which play a crucial role in enhancing human health [7]. As the human population continues to grow, the demand for edible sunflower seeds, oil, and related by-products has risen correspondingly. To satisfy this demand, it is essential to enhance efforts aimed at increasing sunflower production [8]. The international oilseed market today is primarily characterized by sunflowers and various other oilseed crops, including soybean, rapeseed, peanut, and cottonseed, among others.

Sunflowers possess a wide array of nutritional components. Examples include sunflower meal, cake, and similar products. Sunflower meal or cake, a distinctive by-product derived from the extraction of processed sunflower seeds, constitutes 36% of the mass composition, with protein content varying between 45% and 50% [9] [10]. Sunflower meal consists of vital amino acids, vitamin B, and minerals, along with significant antioxidant properties, making it an intriguing nutritional option for humans and a valuable component in livestock feed [11]. The incorporation of sunflower meals into the human diet is constrained by the presence of anti-nutrients such as saponins, protease inhibitors, and arginase inhibitors, as

well as insoluble fibre and trace amounts of residual solvents following extraction [12]. On the other hand, proper processing of sunflower seeds has led to a decrease in their anti-nutritional components, thereby enhancing their safety for human consumption [13].

Mineral fertilizers provide readily available nutrients, whereas organic amendments can contribute nutrients and organic matter and can modify soil chemical and physical properties. Their combined use may alter nutrient availability and crop responses, but outcomes depend on amendment quality, application rate and soil conditions [14] [15]. Sunflower responses to organic and mineral nutrient sources have also been examined in relation to cultivar performance and soil chemical attributes [16]. Locally relevant comparisons of compost, poultry droppings and mineral fertilizer are therefore needed under the soil and climatic conditions of the western highlands of Cameroon. This study compared the effects of poultry droppings, compost, NPK 13-13-21, and their selected combinations on sunflower growth and yield.

The comparative performance of organic amendments and mineral fertilizer is relevant to nutrient management for sunflower cultivation in western Cameroon. The study evaluated the responses of leaf number, stem height, collar diameter, flower weight, flower diameter, and yield to the selected fertilizer treatments. The intention was to identify treatment responses under the conditions of the study site, rather than to infer long-term soil improvements or economic profitability, which were not measured.

2. Materials and Methods

2.1. Study Area

The study was carried out from February to June 2022 at the Application and Research Farm of the University of Dschang, situated in the West Region of Cameroon, corresponding to agro-ecological zone III of the nation (western highlands). The research plot is located near the amphitheatre 1000 of the University of Dschang, at an elevation of 1410 meters. The geographical coordinates are 5 degrees 20 minutes North latitude and 10 degrees 03 minutes East longitude (Figure 1).

The region experiences a rainy season that spans from mid-March to mid-November, followed by a dry season from mid-November to mid-March. The typical annual precipitation ranges from 1800 to 2000 mm. The annual temperature range spans from 13.02°C to 26.73°C, resulting in an average of 19.87°C, alongside a mean temperature of 13.71°C. The air's relative humidity exceeds 60% [17]. The level of insolation is higher during the dry season, averaging 8.5 hours per day, whereas it decreases to 2.2 hours per day in the rainy season. The annual total of sunshine hours is recorded at 1864 hours per year. The research was carried out on red ferrallitic soil characterized by excellent drainage properties. The soil is acidic, characterized by a high organic matter content, yet it exhibits deficiencies in phosphorus and potassium [18]. The study site is significantly impacted by var-

ious anthropogenic activities and is characterized by a diverse array of plant species. The landscape features a variety of crops, including maize, macabo, vegetables, plantain, and beans, alongside recent fallow land, fish ponds, and office facilities. The site features several plant species, including *Tithonia diversifolia*, *Mimosa pudica*, *Ageratum conyzoides*, *Cyperus esculentus*, *Bidens pilosa*, and *Cynodon dactylon*. The preceding crop cultivated on site prior to this study consisted of beans (*Phaseolus vulgaris*) and carrots. The high-altitude Cameroonian type characterizes the climate of the western highlands.

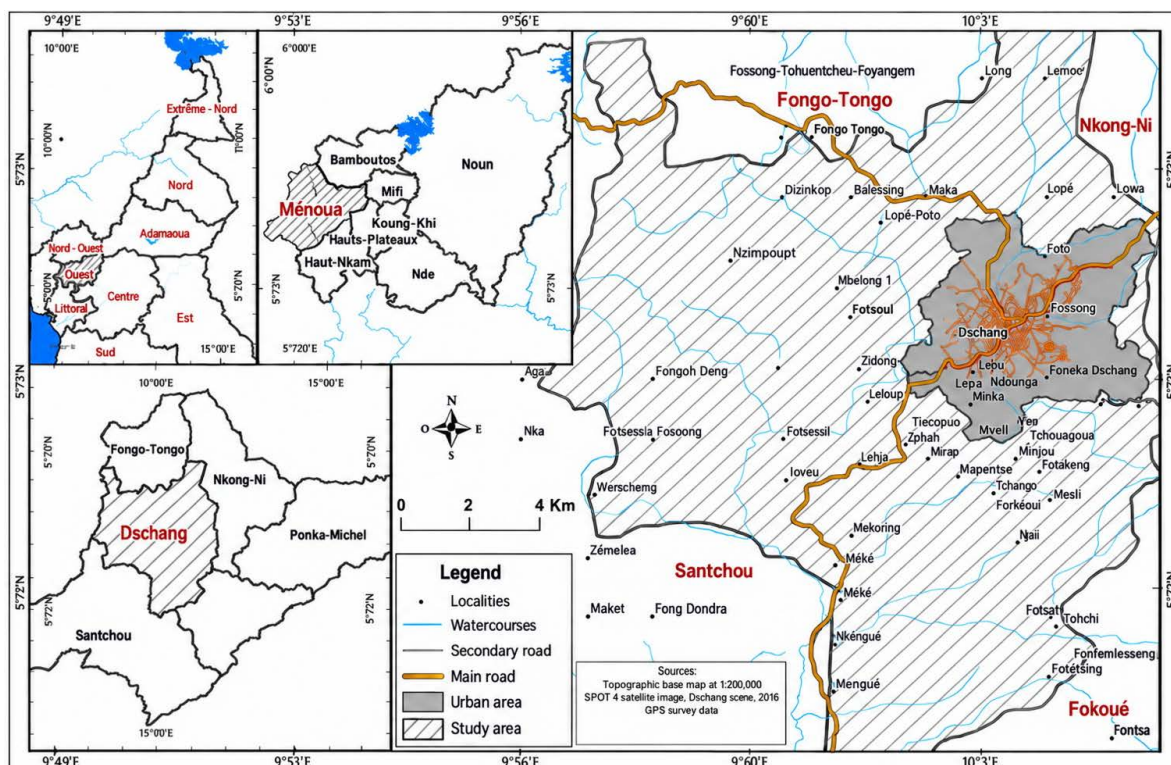


Figure 1. Location of the experimental site. Source: [17].

2.2. Research Design

The field study compared six fertilizer and organic-amendment treatments in the randomized block arrangement described for the experiment. The treatment codes were defined consistently as follows: T0 = untreated control; T1 = poultry droppings; T2 = compost; T3 = mineral fertilizer (NPK 13-13-21); T4 = poultry droppings + mineral fertilizer; and T5 = compost + mineral fertilizer. A treatment denotes the material or combination applied, whereas an experimental unit denotes a plot receiving one treatment, and each treatment was replicated 3 times. The experimental layout is illustrated in **Figure 2**.

The comparison involved sunflower plants of the same seed variety grown under the six treatment conditions. Growth measurements were summarized by treatment over five observation periods, and flower traits and yield were summarized at harvest.

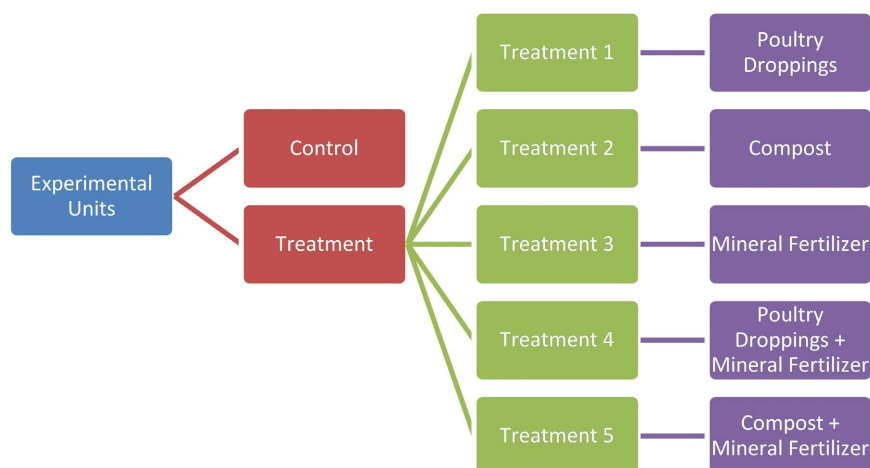


Figure 2. Experimental randomized blocked design.

2.3. Soil Sample Collection

Soil samples were collected in a systematic zigzag pattern across the experimental area using an auger to a depth of 20 cm and stored in labelled polyethylene bags. After oven-drying at 40°C for 48 hours, the soil was sieved through a 2-mm mesh before acidity analysis. Soil pH in water (pH-H₂O) and in KCl solution (pH-KCl) was determined using soil suspensions [18].

The Robinson-Köhn method was utilized for granulometry to determine the particle size distribution of the soil, encompassing sand, clay, and silt. 10 grams of fine earth underwent treatment with hydrogen peroxide to remove organic matter. The sands were separated from the suspended fraction by employing a sieving process in water with a 5-µm sieve. The dispersion of silts and clays was accomplished with sodium carbonate. The clay suspension was neutralized with hydrochloric acid and then flocculated by adding sodium chloride. The clay was thoroughly purified from salts through a systematic series of washings with water and ethanol, ensuring the complete removal of chloride. The silt fraction obtained after decantation of the clay underwent a washing process with water to eliminate any remaining clay and dispersant. The classification of textural classes was performed based on the results and by employing the USDA textural triangle.

The assessment of organic matter was performed using the Walkley and Black method, where the measurement of organic matter (OM) is based on the evaluation of one of its components: organic carbon (OC). The process for quantifying CO involved its oxidation using potassium dichromate in a strongly acidic environment. The relationship between OM and OC is described as follows: OM (%) = OC (%) × 1.724.

2.4. Pedological Parameter

The pedological and land evaluation for this experiment is outlined below (Table 1).

Each experimental plot measured 2 m × 1.5 m (3 m²). The stated spacing was

0.5 m between plots and 1 m between blocks. Land evaluation was described using the parametric approach, in which soil characteristics are assigned values on a 0 - 100 scale [19].

Table 1. Pedological parameters.

Parameter	Units of Measurement
Dimension	2 m × 1.5 m = 3 m ²
Distance between units	0.5 m
Distance between blocks	1 m

2.5. Climatic Parameters

The climatic parameters measured on site prior to the experiment, including temperature, insolation, humidity, and precipitation, are presented as follows (**Table 2**).

Table 2. Climatic parameters.

Period (2022)	Temperature		Insolation	Humidity	Precipitation	
5 months	Min (°C)	Mean (°C)	(kW/m ²)	Relative (%)	(mm)	Irrigation (mm)
February	16	21.6	0.6	64.3	-	-
March	15.5	21.3	0.6	62.5	0	220
April	14.5	21	0.5	75	182	15
May	11.5	20.5	0.5	82.5	78.5	73
June	10.2	19.8	0.4	87.9	184.5	0

The recorded water input over the study period was 753 mm, comprising 445 mm of rainfall and 308 mm of irrigation (**Table 2**). The monthly values show that June had the greatest rainfall (184.5 mm), whereas March recorded no rainfall and received the greatest irrigation input (220 mm). Mean monthly temperature declined from 21.6°C in February to 19.8°C in June; minimum monthly temperature declined from 16.0°C to 10.2°C.

2.6. Soil Parameter

A soil analysis was performed to determine the specific properties of the soil utilized in the experiment, and the subsequent properties were documented (**Table 3**).

Table 3. Soil parameter.

Characteristics	Soil composition
Depth (cm)	0 - 30
Texture (%)	
Clay	18

Continued

Silt	29
Sand	53
Texture class	Sandy loam
Coarse particles (%)	0
Soil reaction	
pH-H ₂ O	5.7
pH-KCl	4.6
Δ pH	-1.1
Organic matter	
CO (%)	3.61
OM (%)	6.23
N tot. (%)	0.13
C/N	27
Exchangeable cations (meq/100g)	
Calcium	8
Magnesium	1.6
Potassium	1.54
Sodium	1.06
Sum of bases	12
Cation Exchange Capacity (meq/100g)	
CEC pH ₇	39
Saturation (%)	31
Available phosphorus	7.02

The soil contained 53% sand, 29% silt and 18% clay and was classified as sandy loam (**Table 3**). It had a water pH of 5.7, organic matter of 6.23%, total nitrogen of 0.13% and a reported C/N ratio of 27. These baseline properties provide context for interpreting the response of sunflower to the amendments.

2.7. Chemical Composition of Poultry Droppings and Compost

The composition measurements of poultry droppings and compost utilized in this study are detailed in **Table 4** as follows.

Poultry droppings and compost had pH values of 7.3 and 8.9, respectively (**Table 4**). Poultry droppings contained 60.5% organic matter, 4.882% total N, 5787.06 mg·kg⁻¹ total P and 22135.6 mg·kg⁻¹ K. Compost contained 33.4% organic matter, 4.322% total N, 4571.74 mg·kg⁻¹ total P and 28097.2 mg·kg⁻¹ K. Thus, the measured nutrient composition differed between the two organic sources; these concentrations alone do not establish the actual nutrient input without the application rates.

Table 4. Chemical composition of poultry droppings and compost.

Characteristics	Droppings	Compost
Code	1	2
pH	7.3	8.9
Organic matter		
OM (%)	60.5	33.4
OC (%)	30.25	16.7
N tot. (%)	4.882	4.322
C/N	6	4
Exchangeable cations (mg/Kg)		
Calcium (mg/kg)	29,330	13,330
Magnesium (mg/kg)	18263	281
Potassium (mg/kg)	22135.6	28097.2
Sodium (mg/kg)	2539.53	2875.52
Cation Exchange Capacity (meq/100g)		
CEC pH ₇	69	71
Total phosphorus (mg/kg)	5787.06	4571.74
Ash (%)	40	67
Moisture content	6	2

2.8. Chemical Composition of Mineral Fertilizer

The formulation of the mineral fertilizer utilized in the experiment is detailed in **Table 5** as follows.

Table 5. Composition of mineral fertilizer.

Composition	Percentage (%)
Nitrogen (N)	13
Ammoniacal Nitrogen (NH ₃ -N)	7.8
Nitrate Nitrogen (NO ₃)	5.2
Phosphorus pentoxide (P ₂ O ₅)	13
Potassium oxide (K ₂ O)	21
Sulphur (S)	3
Zinc (Zn)	0.02
Boron (B)	0.02

The fertilizer utilized in the experiment was NPK 13-13-21, a water-soluble granular complex consisting of 13% nitrogen (N), which includes 7.8% ammoniacal nitrogen (NH₃-N) and 5.2% nitrate nitrogen (NO₃). Additionally, it contains 13% phosphorus pentoxide (P₂O₅) and 21% potassium oxide (K₂O), along with 3% Sulphur (S), 0.02% zinc (Zn), and 0.02% boron (B). This was applied to the

soil with an approximate layer thickness of 2×3 cm.

2.9. Sowing Spacing and Weeding Operations

The details regarding sowing spacing and weeding operations are presented in **Table 6** as follows.

Table 6. Sowing and weeding operations.

Items	Measurement
Sowing Spacing	4 to 9 inches
Weeding (days)	21 and 42 days after sowing

The sowing spacing ranged from 4 to 9 inches, with weeding operations conducted every 21 days following sowing. Consequently, this was carried out on two occasions: specifically on days 21 and 42 after sowing.

2.10. Phytosanitary Treatments

Phytosanitary treatment, which involves the elimination, inactivation, or removal of pests, as well as rendering them infertile or devitalized to a specified efficacy, is a crucial factor in ensuring healthy plant growth and development to achieve the desired results (**Table 7**).

Table 7. Phytosanitary treatments.

Agents	Quantity
Jumper D Fungicide (Dimethomorph and Chlorothalonil)	50 g/kg
Flash One 36 WP (Chlorothalonil 30% + Cymoxanil 6% WP).	50 g/kg
METROSTAR	50 g/kg
PYRAN 5-Carbon	50 g/kg

To mitigate insect damage to the young seedlings. The treatments commenced two weeks post-sowing, coinciding with emergence, implemented as a preventive strategy utilizing a contact fungicide, specifically JUMPER D, which contains copper oxide to combat mildew. Acta-Force serves as an insecticide featuring emamectin benzoate as its active ingredient, effectively combating insect infestations. The process commenced promptly upon the emergence of initial symptoms and signs, for which we incorporated products such as METROSTAR and PYRAN. Phytosanitary treatments were conducted utilizing a 15 L PRESIDENT brand pressure sprayer, which was properly maintained for optimal performance. The final phytosanitary treatment was conducted two and a half weeks prior to the harvest, which occurred on May 12, 2022.

2.11. Data Collection and Measurement of Growth Variables

Leaf number, stem height and collar diameter were measured repeatedly during

sunflower growth. For each variable, observations were based on eight centrally located plants per plot. Leaves were counted, collar diameter was measured with a Vernier caliper, and stem height was measured from ground level. Five observation summaries are reported for each growth variable in **Tables 8-10**. Flower weight, flower diameter and yield were recorded at harvest.

2.12. Method of Data Analysis

The available treatment-level summaries were checked and presented descriptively as means for five growth observation periods and as reported treatment means at harvest. Overall growth means were calculated as the arithmetic mean of the five displayed observation-period means for each treatment. These repeated observations represent successive time points and were not treated as independent experimental replicates. Replicate- and plot-level measurements are required for valid estimation of treatment, observation-time and treatment $\times$ time effects and for inferential comparisons of treatment means; accordingly, unverified ANOVA and Tukey test results are not reported.

3. Results and Discussion

This section outlines the study's results in alignment with its objectives and subsequently engages in a discussion of the findings, organized in the following order.

3.1. Impact of Mineral Fertilizers and Organic Amendments on the Quantity of Sunflower Leaves

Leaf numbers were recorded at five reported observation periods for the six treatments. **Table 8** gives the mean number of leaves at each observation and the arithmetic mean across the five observations; leaf number is a growth measure rather than a yield measure.

Table 8. Mean sunflower leaf number by treatment and observation period.

Treatments	1 Obs.	2 Obs.	3 Obs.	4 Obs.	5 Obs.	Mean across five observations
T ₀	8.54	13.83	20.2	21.87	25.70	18.03
T ₁	9.87	14.83	20.62	22.66	26.16	18.83
T ₂	9.08	14.29	21.50	22.04	26.58	18.70
T ₃	8.29	12.62	19.00	21.20	24.50	17.12
T ₄	9.87	16.08	20.95	22.33	26.83	19.21
T ₅	8.95	14.20	20.25	21.87	26.25	18.30

Source: Field Data 2022.

Across the five reported observations, mean leaf number was numerically highest in T₄ (poultry droppings + mineral fertilizer; 19.21 leaves) and lowest in T₃ (mineral fertilizer alone; 17.12 leaves), compared with 18.03 leaves in the control (**Table 8**). At the fifth observation, mean leaf number ranged from 24.50 in T₃ to

26.83 in T4. These differences are descriptive and should not be interpreted as statistically significant without valid plot-level analysis.

3.2. Influence of Mineral Fertilizers and Organic Amendments on the Stem Height of Sunflower Plants

Stem height was recorded at five observation periods. The means for each treatment and observation period, together with the arithmetic means across the five observations, are shown in **Table 9**.

Table 9. Mean sunflower stem height (cm) by treatment and observation period.

Treatments	1 Obs.	2 Obs.	3 Obs.	4 Obs.	5 Obs.	Mean across five observations
T ₀	14.12	22.94	39.79	65.01	104.96	49.36
T ₁	15.12	24.78	44.43	75.79	113.83	54.79
T ₂	13.12	22.02	39.4	70.37	111.47	51.28
T ₃	11.41	19.66	35.98	62.7	103.58	46.67
T ₄	15.58	25.07	44.39	74.45	114.96	54.89
T ₅	11.54	19.75	37.76	66.17	108.73	48.79

Source: Field Data 2022.

Mean stem height across the five observations was numerically greatest in T4 (poultry droppings + mineral fertilizer; 54.89 cm), closely followed by T1 (poultry droppings; 54.79 cm). T3 (mineral fertilizer alone) had the lowest corresponding mean (46.67 cm), compared with 49.36 cm in the control (**Table 9**). At the fifth observation, T4 also had the greatest mean height (114.96 cm). The available summaries do not permit a valid test of these treatment differences.

3.3. Effect of Mineral Fertilizers and Organic Amendments on the Collar Diameter of Sunflower Plants

Collar diameter was recorded at five observation periods. The treatment means at each observation period and the arithmetic means across observations are presented in **Table 10**.

Table 10. Mean sunflower collar diameter (mm) by treatment and observation period.

Treatment	1 Obs.	2 Obs.	3 Obs.	4 Obs.	5 Obs.	Mean across five observations
T ₀	4.79	6.83	11.2	16.5	18.04	11.47
T ₁	4.66	8.29	14.25	19.04	21.37	13.52
T ₂	4.5	7.25	11.7	18.16	19.16	12.15
T ₃	4.12	6.91	11.93	18.04	19.66	12.13
T ₄	4.12	8.7	12.87	18.75	19.29	12.75
T ₅	4.41	7.41	13.04	18.91	20.79	12.91

Source: Field Data 2022.

Poultry droppings alone (T1) produced the numerically greatest mean collar diameter across the five observations (13.52 mm), followed by T5 (compost + mineral fertilizer; 12.91 mm); the control had the lowest mean (11.47 mm) (**Table 10**). At the fifth observation, T1 and T5 had mean diameters of 21.37 and 20.79 mm, respectively, compared with 18.04 mm in the control. No inference about statistical significance can be made from these summary means alone.

3.4. Influence of Mineral Fertilizers and Organic Amendments on Flower Weight of Sunflower

Flower weight was summarized at harvest for each treatment. The reported treatment means are presented in **Figure 3**.

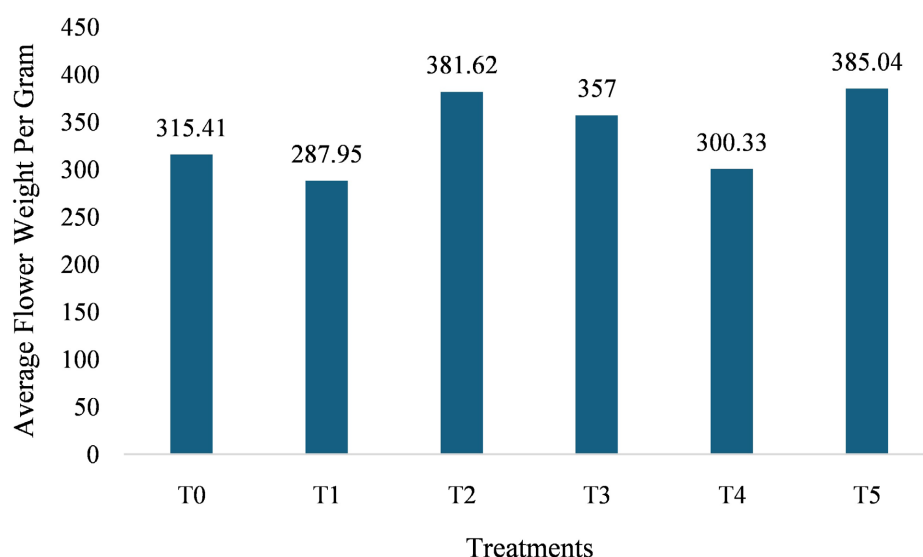


Figure 3. Mean sunflower flower weight at harvest (g). Source: Field Data 2022.

Figure 3 shows that T5 (compost + mineral fertilizer) produced the numerically greatest mean flower weight (385.04 g), closely followed by T2 (compost alone; 381.62 g). The lowest reported mean was recorded under T1 (poultry droppings alone; 287.95 g), compared with 315.41 g in the untreated control. The figure contains treatment means but no measure of within-treatment variability.

3.5. Impact of Organo-Mineral Fertilizers on Sunflower Flower Diameter

Flower diameter was summarized at harvest for each treatment, as shown in **Figure 4**.

The greatest reported mean flower diameter occurred under T5 (compost + mineral fertilizer; 23.37 mm), followed by T3 (mineral fertilizer alone; 23.04 mm). The untreated control had the smallest mean diameter (21.54 mm) (**Figure 4**). These values describe the treatment means; their statistical separation cannot be established from the figure alone.

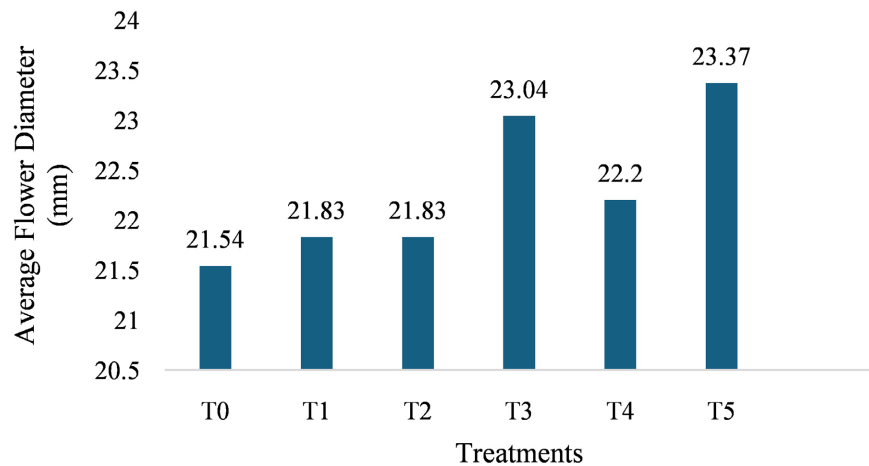


Figure 4. Mean sunflower flower diameter at harvest (mm). Source: Field Data 2022.

3.6. Impact of Mineral Fertilizers and Organic Amendments on Sunflower Yield

Sunflower yield was summarized at harvest by treatment and is presented in **Figure 5**.

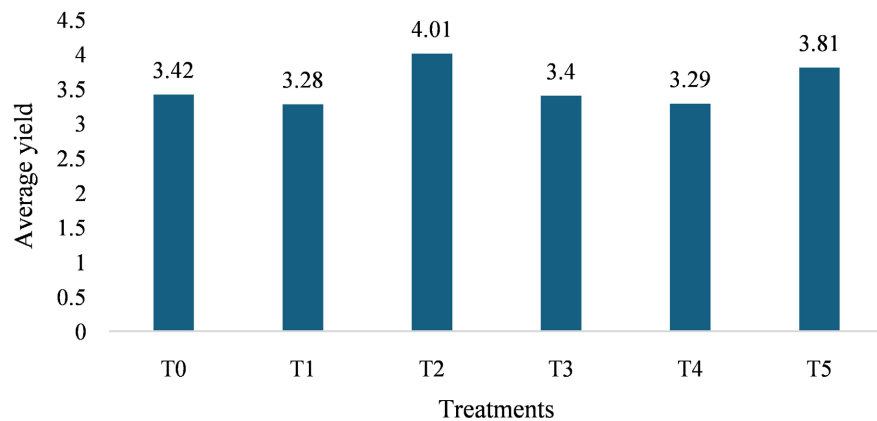


Figure 5. Mean reported sunflower yield by treatment (t·ha⁻¹). Source: Field Data 2022.

The highest reported mean yield was recorded in T2 (compost alone; 4.01 t·ha⁻¹), followed by T5 (compost + mineral fertilizer; 3.81 t·ha⁻¹). The control yielded 3.42 t·ha⁻¹, while T1 (poultry droppings) had the lowest reported mean (3.28 t·ha⁻¹) (**Figure 5**). Relative to the control mean, the compost and compost + mineral fertilizer treatments were numerically higher by approximately 17.3% and 11.4%, respectively. These percentages describe differences between reported means and do not establish statistical significance.

4. Discussion

The treatments showed different numerical responses across vegetative growth and yield variables. Poultry droppings + mineral fertilizer (T4) had the highest mean leaf number (19.21) and stem height (54.89 cm) across the five observation

periods. Poultry droppings alone (T1), however, had the largest mean collar diameter (13.52 mm), indicating that the treatment associated with greater height or leaf number was not necessarily associated with greater stem thickness. These are differences in reported treatment means rather than verified inferential effects, because plot-level variance and the repeated-measure covariance structure could not be recovered from the published summaries.

Compost + mineral fertilizer (T5) showed the greatest mean flower weight (385.04 g) and flower diameter (23.37 mm) at harvest. Compost alone (T2) gave a very similar mean flower weight (381.62 g) and the highest reported yield (4.01 t·ha⁻¹). The separation between treatments therefore depended on the response variable considered. Sunflower research using organic residues and mineral fertilization likewise emphasizes that responses should be assessed across multiple crop and soil variables, rather than assumed to be uniform across growth and production traits [16].

The baseline soil was moderately acidic (pH 5.7), with 6.23% organic matter and 0.13% total N. Poultry droppings had greater measured organic matter (60.5%), total N (4.882%) and total P (5787.06 mg·kg⁻¹) than compost (33.4% organic matter, 4.322% total N and 4571.74 mg·kg⁻¹ total P), whereas compost had greater measured K (28097.2 versus 22135.6 mg·kg⁻¹) and a higher pH (8.9 versus 7.3). The mineral fertilizer contained 13% N, 13% P₂O₅ and 21% K₂O. These differences in amendment composition are relevant to the interpretation of the growth responses, but fertilizer concentration is not equivalent to nutrient delivery: the actual amounts added depend on the unreported application rates and nutrient availability.

The higher numerical yield with compost alone, about 17.3% above the control mean, may be compatible with a combination of nutrient supply and interactions between amendment properties and the acidic experimental soil. It does not demonstrate that compost raised soil pH, improved structure or increased nutrient uptake during the trial, since these post-application outcomes were not measured. Reviews of organic amendments and organo-mineral fertilizers describe possible effects on nutrient-release patterns, nutrient interactions and soil properties, but their magnitude and direction depend on soil conditions, amendment characteristics and management [14] [15].

The combined treatments did not consistently produce the highest reported yield: T5 produced 3.81 t·ha⁻¹ and T4 produced 3.29 t·ha⁻¹, compared with 4.01 t·ha⁻¹ for T2. It would therefore be premature to recommend combining organic amendments and mineral fertilizer as a universally superior approach on the basis of these means. Differences among treatments should be tested with original plot-level observations and should also be interpreted in light of amendment application rates and the crop component used to calculate yield.

Study limitations. This experiment was conducted at one site and during one growing season on the locally described sandy-loam, moderately acidic soil. The reported tables contain treatment-level means rather than the original plot-level

repeated observations or within-treatment variation. As a result, treatment $\times$ time effects, valid confidence intervals, and adjusted pairwise comparisons cannot be reconstructed from the available summaries. The amendment application rates also require confirmation from field records. Post-treatment soil measurements and plant nutrient uptake would strengthen explanation of the observed responses; multi-season and multi-site trials would be needed to assess their wider applicability.

5. Conclusion and Recommendation

The numerical response of sunflower to fertilizer and organic amendments differed among the measured growth and yield variables. Poultry droppings plus mineral fertilizer (T4) produced the greatest mean leaf number and stem height across the five reported growth observations, while poultry droppings alone (T1) produced the greatest mean collar diameter. At harvest, compost plus mineral fertilizer (T5) had the highest reported mean flower weight and diameter, whereas compost alone (T2) produced the highest numerical yield ($4.01 \text{ t}\cdot\text{ha}^{-1}$), compared with $3.42 \text{ t}\cdot\text{ha}^{-1}$ in the untreated control. These observations suggest potential for compost-based nutrient management at the study site, but they do not demonstrate statistically significant treatment effects or changes in soil physical properties. Further trials using documented amendment rates, plot-level analysis, and measurements of post-treatment soil and plant nutrient status are needed before making general fertilizer recommendations for sunflower production.

Author Contributions

Etanke Sylvie Essomo conducted the field experiment, collected the data and prepared the initial manuscript. Doris Besem Arrey and Yannick Afanga Afanga contributed to the study design, methodology, data interpretation, supervision and revision of the manuscript. Barnabas Nehemiah and Steve Ejimbi Efua contributed to data interpretation and critical revision of the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest

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

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