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Influence of Cattle Dung and Biochar Amendments on Yield and Oil Content of Sunflower (*Helianthus annus* L.)

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About Article

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ABSTRACT

This research was carried out to investigate the effects of different application levels of cattle dung, cattle dung biochar, and NPK on the yield and oil content of sunflower. Two field experiments were conducted at the Teaching and Research Farm of the University of Ilorin, using split plot arrangement within a randomized complete block designs (RCBD) and replicated three times. The main plots contained nutrient sources (cattle dung and cattle dung biochar), while sub-plots contained varying levels (0, 5, 10, 15, 20 Mgha^{-1} and NPK 300 kgha^{-1}), resulting in 12 treatment combinations. Cattle dung and cattle dung biochar significantly enhanced yield parameters and oil content compared to control. Biochar performed better than cattle dung but mostly not significantly, interaction effects were also not significant. Plots that received 20 Mgha-1 had the highest values for oil content (49.36% and 52.05%), number of seeds per head (929.79, 969.44), yield per plot (3127.96g, 3193.05g), yield per hectare (1251.18kg, 1277.22), and the fastest days to 50% flowering (82.70, 86.54); 15 Mgha-1 had the highest flower head diameter (204.75mm, 220.09mm), while NPK had the highest 1000 seed weight (71.04g, 80.38g). Control consistently had lower values than the averages recorded for the treatments. Both cattle dung and biochar improved seed production without compromising seed size and weight, highlighting their potential as environmentally friendly alternatives to chemical fertilizers.

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1. INTRODUCTION

Sunflower is a valuable oilseed crop known for its premium oil content and nutritional benefits (Khan *et al.*, 2015). As the global population grows, demand for sunflower products has increased. However, production is often limited by nutrient deficiencies, soil acidity, and pests (Adeleke & Babalola, 2020), with poor soil fertility being a primary constraint (Alzamel *et al.*, 2022).

Nitrogen, phosphorus, and sulphur are commonly insufficient for optimal yields, while high-rainfall areas may also lack potassium, calcium, and magnesium. Deficiencies in boron, iron, zinc, copper, and manganese are widespread (North Dakota State University, 2020). Soil type impacts nutrient mobility; for example, sandy soils often require additional potassium (Iowa State University, n.d.). To achieve 2.24 tons of sunflower seed yield per hectare, approximately 32 kg of nitrogen, 11.3 kg of phosphorus, 16.8 kg of potassium, 3.6 kg of sulphur, and 2-3 kg of boron per hectare are needed (Manitoba Agriculture and Resource Development, n.d.).

To meet rising demand, sustainable production methods are necessary (Taher *et al.*, 2017). While farmers have traditionally relied on agrochemicals to boost productivity (Adeleke & Babalola, 2020), this approach has negatively impacted soil quality, water resources, and microbial ecosystems (Elemike *et al.*, 2019). Long-term use of chemical fertilizers can lead to soil carbon depletion, organic matter mineralization, and increased acidity (Oladele *et al.*, 2019). Such issues highlight the need for sustainable practices like using organic amendments.

Cattle dung, rich in nutrients (3-2-1 NPK), is effective for promoting plant growth, potassium content in cattle dung may sometimes exceed phosphorus, aligning with sunflower's higher potassium needs (Harrison, 2016; Iowa State University Extension and Outreach, n.d.). Cattle dung and its biochar form, derived from abundant agricultural waste, show promise for enhancing soil health and boosting sunflower yields.

2. LITERATURE REVIEW

2.1. Synergistic Impact of Cattle Dung and Biochar on Sunflower Cultivation

The combination of cattle dung and biochar as soil amendments has been proposed as a potential strategy to synergistically enhance soil fertility and crop productivity (Khodaeı-Joghan *et al.*, 2018). They reported synergistic effects of cattle dung and biochar on soil properties, including pH, nutrient availability, and microbial activity, leading to improved sunflower growth and yield. Similarly, Langeroodi *et al.* (2022) observed additive effects of cattle dung and biochar on soil nutrient content and sunflower performance, highlighting the potential of combined amendments for sustainable agriculture. The observed impacts of soil amendments on sunflower growth and yield may be attributed to multiple mechanisms, including improvements in soil fertility, structure, nutrient availability, and microbial activity (Adekiya *et al.*, 2020; El-Hamidi & Zaher, 2018). Soil amendments such as cattle dung and biochar enhance soil properties and create a favourable environment for root growth, nutrient uptake, and physiological processes in sunflower plants (Adekiya *et al.*, 2020; El-Hamidi & Zaher, 2018). Moreover, the interactions between soil amendments and sunflower cultivation may involve complex biogeochemical processes, such as nutrient cycling, microbial decomposition, and rhizosphere interactions, which warrant further investigation (Adekiya *et al.*, 2020; El-Hamidi & Zaher, 2018).

2.2. Yield and Oil Content of Sunflower in Response to Amendments

Studies exploring the effects of soil amendments on sunflower growth parameters have consistently demonstrated the potential of cattle dung and biochar to significantly enhance sunflower growth and productivity (Taher *et al.*, 2017; Ezeoha & Ugwuishiwu, 2011). Taher *et al.* (2017) observed notable increases in sunflower plant height, leaf area, and biomass accumulation following the application of cattle dung, indicative of improved nutrient availability and soil fertility. Similarly, Ezeoha and Ugwuishiwu (2011) found that biochar amendment positively influenced sunflower growth parameters, including root development and nutrient uptake, resulting in enhanced crop performance and yield. These findings underscore the pivotal function of soil amendments in optimizing sunflower growth and productivity.

Examining the impact of soil amendments on sunflower yield has revealed varied outcomes influenced by factors such as soil fertility, amendment type, and application rate (El-Hamidi & Zaher, 2018; Alzamel *et al.*, 2022). El-Hamidi and Zaher (2018) documented significant increases in sunflower seed yield following cattle dung application, attributing the improvement to enhanced soil fertility and nutrient availability. Conversely, Alzamel *et al.* (2022) found no substantial differences in sunflower yield between biochar-amended and control plots, suggesting limited effects on crop productivity. Thus, there is a need for further research to elucidate the factors influencing the efficacy of soil amendments in enhancing sunflower yield and to develop optimal management practices for sustainable sunflower production.

3. METHODOLOGY

3.1. Experimental Site

Two field experiments were conducted at different parts of the Teaching and Research Farm of the University of Ilorin, Nigeria (latitude 9° 29' N, longitude 4° 35' E, altitude 307 m). The sites are characterized by a bimodal rainfall pattern, with an annual total ranging from 650 mm to 1,500 mm. The region's vegetation is typical of the southern Guinea savannah, and the soil is sandy loam. Monthly temperatures during the wet season range from 24°C to 27°C, while dry months see temperatures between 29°C and 35°C, with an average annual relative humidity of 85% (Iwena, Oluwanisola & Abdulrahaman, 2018). The field experiments were conducted between August and December and the plants were rainfed.

3.2. Field Preparation and Layout

Each experimental plot (3m × 3m) was prepared through ploughing and ridging, with a 1 m inter-plot pathway. Two weeks prior to sowing, cattle dung and cattle dung biochar were applied. Sunflower seeds were dibbled at a depth of 3-5 cm and thinned to one plant per hole 10 days post-germination, achieving a spacing of 50cm × 50cm.

3.3. Experimental Design

A randomized complete block design (RCBD) was employed in a split-plot arrangement, with main plots assigned to cattle dung and biochar treatments, and subplot factors consisting of treatment levels (0, 5, 10, 15, 20 Mg ha^{-1} and NPK 300 kg ha^{-1}). Twelve treatment combinations were replicated three times.

3.4. Source of Materials

The sunflower variety "Eagle Eye" was obtained from the University of Ilorin Department of Agronomy, while cattle dung was sourced from a local abattoir, and NPK fertilizer from a local agrochemical store.

3.5. Production and Processing of Biochar

Cattle dung was cleaned, air-dried, and oven-dried before being subjected to pyrolysis. The process of pyrolysis was as described by Sukartono *et al.* (2011).

3.6. Soil Sampling

Soil samples were collected pre-treatment and post-harvest using a grid method with a soil auger. Composite samples were prepared for analysis following standard procedures established by the FAO (2020).

3.7. Cultural Practices

Land preparation involved ploughing and ridging, followed by delineation into plots. Seed sowing was performed by dibbling, with subsequent weeding at three-week intervals. Harvesting occurred when flower heads were fully ripe, followed by threshing to separate seeds from chaff.

3.8. Data Collection and Analysis

Yield parameters (days to flowering, head diameter, seed weight, grain yield, and oil content) were assessed at harvest using standard methods. Two-way analysis of variance (ANOVA) at 5% probability level was conducted using GenStat software package 17th Edition.

4. RESULTS AND DISCUSSION

4.1. Physical and chemical properties of soil, cattle dung, and cattle dung biochar

The physical and chemical properties of soils, cattle dung, and cattle dung biochar presented in Table 1. The data indicated that the soils of the experimental sites were loamy sand, slightly acidic, low in organic carbon, organic matter, total nitrogen, phosphorus, potassium, calcium, sodium, and magnesium. The soils were also low in exchangeable acidity. The cattle dung was alkaline, very high in organic carbon and organic matter, moderate in total nitrogen and phosphorus, and high in potassium and calcium. The cattle dung was low in sodium and magnesium. The cattle dung biochar was also alkaline, low in organic carbon and organic matter, moderate in total nitrogen and phosphorus, high in potassium, calcium, and magnesium, and very high in sodium.

Table 1: Physical and chemical properties of soil, cattle dung and cattle dung biochar

Parameters	Experiment 1 soil	Experiment 2 soil	Cattle dung	Cattle dung biochar
pH in H_2O	6.65	6.74		
pH in KCl	6.12	6.09	8.48	8.86
Organic carbon (%)	0.44	0.44	24.19	0.93
Organic matter (%)	0.76	0.76	41.70	1.61
Exchangeable acidity ($cmolkg^{-1}$)	0.56	0.56	-	-
Total Nitrogen ($mgkg^{-1}$)	0.66	0.65	0.86	0.88
Phosphorus ($mgkg^{-1}$)	0.72	0.71	0.81	0.73
Potassium ($cmolkg^{-1}$)	0.15	0.15	3.51	2.27
Calcium ($cmolkg^{-1}$)	0.76	0.77	4.79	4.46
Sodium ($cmolkg^{-1}$)	0.22	0.22	0.22	3.37
Magnesium ($cmolkg^{-1}$)	0.13	0.13	0.30	4.72
Sand (%)	88.16	87.89		
Silt (%)	7.22	7.37		
Clay (%)	4.62	4.74		

Source: Field data

4.2. Flower Head Diameter and Days to 50% Flowering

Cattle dung and biochar amendments improved flower head diameter and reduced days to 50% flowering compared to the control (Table 2m Table 3), consistent with Lipi *et al.* (2023) and Langeroodi *et al.* (2022). Biochar's impact on soil structure and nutrients likely influenced these growth parameters.

4.3. Number of Seeds per Head and 1000-Seed Weight

As shown in Table 2 and Table 3, higher rates of cattle dung and biochar increased seed count per head but did not significantly affect the 1000-seed weight, supporting Lipi *et al.* (2023) and Langeroodi *et al.* (2022) findings on biochar's effect on productivity through enhanced nutrient uptake.

4.4. Yield per Plot and per Hectare

Tables 2 and 3 show that no significant effect of organic biomass type or rate was observed on yield per plot or hectare, possibly due to specific experimental conditions, application rates, or environmental interactions. This contrasts with findings from Alzamel *et al.* (2022) and Sefaoglu *et al.* (2021), which showed fertilizer impact on sunflower yield.

4.5. Oil content

Cattle dung and biochar increased oil content compared to the control (Table 2, Table 3). These results support findings by Ali *et al.* (2021) and Langeroodi *et al.* (2022) on biochar's effect in enhancing oil content, particularly under stress conditions.

Cattle dung versus cattle dung biochar

The results from both experiments indicate no significant difference between the effects of cattle dung and cattle dung biochar on sunflower yield and oil content. This similarity may stem from the short-term nutrient release patterns associated with both amendments.

Table 2: Effects of cattle dung and cattle dung biochar on sunflower yield parameters (Experiment 1)

Treatment	**Flower Head diameter**	**Number of seeds per head**	**1000 seed weight (g)**	**Yield per net plot (g)**	**Yield per hectare (kg)**	**Days to 50% flowering**	**Oil content**
Biomass type							
Cattle dung	147.53	816.55	69.81	3016.17	1163.38	87.84	44.70
Biochar	158.70	839.20	70.72	2908.13	1206.43	87.54	44.87
SED	9.735	23.326	2.086	77.9	31146.5	0.389	0.200
P-Value	0.263	0.342	0.667	0.181	0.181	0.456	0.394
Biomass Rate							
Control	121.05^{b}	750.99^{c}	67.54^{a}	2875.13^{a}	1150.05^{a}	92.50^{a}	40.93^{e}
NPK	141.75^{b}	822.51^{abc}	70.83^{a}	3015.21^{a}	1206.08^{a}	87.85^{bc}	44.93^{c}
Cattle dung 5 Mg	150.30^{b}	879.73^{ab}	71.27^{a}	2827.29^{a}	1130.92^{a}	89.10^{b}	42.66^{d}
Cattle dung 10 Mg	163.80^{ab}	765.29^{bc}	69.31^{a}	2950.29^{a}	1180.12^{a}	87.67^{bcd}	44.82^{c}
Cattle dung 15 Mg	158.85^{ab}	815.36^{abc}	67.26^{a}	2863.17^{a}	1145.27^{a}	86.09^{cd}	46.45^{b}
Cattle dung 20 Mg	149.40^{b}	865.43^{abc}	68.59	2919.54^{a}	1167.82^{a}	83.82^{ef}	48.39^{a}
Biochar 5 Mg	158.40^{ab}	843.97^{abc}	71.75^{a}	3054.50^{a}	1221.80^{a}	88.82^{b}	42.68^{d}
Biochar 10 Mg	158.40^{ab}	765.29^{bc}	66.42^{a}	2989.58^{a}	1195.83^{a}	87.67^{bcd}	44.55^{c}
Biochar 15 Mg	204.75^{a}	922.64^{a}	70.23^{a}	3034.00^{a}	1213.60^{a}	85.72^{de}	46.77^{b}
Biochar 20 Mg	167.85^{ab}	929.79^{a}	73.48^{a}	3127.96^{a}	1251.18^{a}	82.70^{f}	49.36^{a}
SED	23.846	57.137	5.111	190.7	76292.9	0.954	0.490
P-Value	0.678	0.530	0.920	0.902	0.902	0.955	0.580

Means with the same letter are not significantly different from each other ($p<0.05$)

Source: Field data *SED - Standard Error of Difference*

Cattle dung is known for its rapid nutrient release, but these nutrients tend to deplete quickly, resulting in short-term fertility that lasts only a few months (Kiruthika *et al.*, 2022). Nutrient losses from cattle dung can occur through leaching and volatilization. Conversely, biochar releases nutrients gradually, providing a sustained supply of nutrients over the long term (Piash *et al.*, 2021). Its porous structure minimizes leaching and volatilization, thereby enhancing nutrient retention in the soil. In the short term, the quick nutrient availability from cattle dung may effectively offset the gradual release from biochar, leading to comparable results when both are applied at similar rates. While fields fertilized with cattle dung may require frequent applications to maintain fertility, those amended with biochar may not face the same need. However, significant differences in performance may emerge over multiple planting seasons. While previous studies by Ali *et al.* (2021) and Langeroodi *et al.* (2022) have highlighted biochar's long-term benefits for soil properties, these advantages may align with those of raw cattle dung in the short term.

Table 3: Effects of cattle dung and cattle dung biochar on sunflower yield parameters (Experiment 2)

Treatment	Flower Head diameter	Number of seeds per head	1000 seed weight (g)	Yield per net plot (g)	Yield per hectare (kg)	Days to 50% flowering	Oil content
Biomass type							
Cattle dung	151.26	859.38	74.03	3017	1223.547	92.20	46.63
Biochar	165.27	882.27	74.16	3110	1266.605	90.55	46.99
SED	9.793	27.094	2.051	96.9	33252.5	0.968	0.454
P-Value	0.167	0.407	0.950	0.348	0.209	0.101	0.444
Biomass Rate							
Control	124.92[b]	791.04[c]	69.92[a]	2852.84[a]	1141.136[a]	95.17[a]	42.52[f]
NPK	141.94[b]	856.44[abc]	80.38[a]	3145.04[a]	1258.016[a]	92.38[abc]	46.69[cd]
Cattle dung 5 Mg	149.80[b]	921.35[abc]	75.03[a]	2948.62[a]	1179.448[a]	94.58[a]	45.13[de]
Cattle dung 10 Mg	166.36[ab]	807.40[bc]	74.37[a]	3029.34[a]	1211.736[a]	93.80[ab]	46.08[d]
Cattle dung 15 Mg	173.23[ab]	848.65[abc]	71.39[a]	3081.16[a]	1232.464[a]	90.85[abcd]	48.82[bc]
Cattle dung 20 Mg	151.30[b]	931.43[abc]	73.08a	3045.34[a]	1218.136[a]	86.43[d]	50.55[ab]
Biochar 5 Mg	163.82[b]	900.61[abc]	76.73[a]	3026.22[a]	1210.488[a]	94.61[a]	44.93[def]
Biochar 10 Mg	162.17[b]	809.13[bc]	68.67[a]	3063.61[a]	1225.444[a]	91.44[abcd]	46.98[cd]
Biochar 15 Mg	220.09[a]	959.61[ab]	73.96[a]	3134.07[a]	1253.628[a]	88.66[d]	47.49[cd]
Biochar 20 Mg	168.83[ab]	969.44[a]	76.57[a]	3193.05[a]	1277.22[a]	86.54[d]	52.05[a]
P-Value	0.735	0.767	0.815	0.707	0.695	0.695	0.563
SED	23.989	66.366	5.025	237.4	81451.7	2.370	1.111

Means with the same letter are not significantly different from each other (p<0.05)
Source: Field data *SED - Standard Error of Difference*

5. CONCLUSION

This research demonstrates that applying both cattle dung and cattle dung biochar enhances sunflower oil content and yield parameters. High application rates (15-20 Mgha-1) led to larger flower head diameters, a reduction in days to 50% flowering, and an increase in oil content in sunflower seeds. Enhanced seed production was achieved without compromising seed size and weight. Although the type of biomass did not significantly affect the outcomes, both cattle dung and biochar proved effective in improving crop productivity. This finding suggests their potential as environmentally friendly alternatives to chemical fertilizers. Thus, both forms of organic biomass can be utilized interchangeably to achieve similar benefits for soil enhancement and crop production in the short term. Further research is necessary to investigate long-term effects, potential combined uses with other amendments, and the economic feasibility of large-scale implementation.

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