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Research Article

Different Rates of Chicken Manure and NPK 15-15-15 Enhanced Performance of Sunflower (*Helianthus annuus* L.) on Ferruginous Soil

V. I. Abumere,[1] O. A. Dada ,[1,2] A. G. Adebayo,[3] F. R. Kutu,[4] and A. O. Togun[1]

[1]*Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria*
[2]*Food Security and Safety Niche Area Research Group, North-West University, Mafikeng Campus, Private Bag X2046, Mmabatho 2735, South Africa*
[3]*National Horticultural Research Institute, Ibadan, Nigeria*
[4]*University of Mpumalanga, Private Bag X11283, Mbombela 1200, South Africa*

Correspondence should be addressed to O. A. Dada; oadada247@yahoo.com

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Utilization of adequate fertilizer rate enhances soil physical and chemical properties, minimizes soil nutrient imbalance, and promotes better crop growth and development. The study investigated the influence of varying rates of chicken manure and NPK fertilizers as it affected growth, nutrient uptake, seed yield, and oil yield of sunflower on nutrient-limiting soil. Field experiments were carried out during 2014 and 2015 planting seasons for both main and residual studies. There were eight treatments comprising four rates of chicken manure (5, 10, 15, and 20 $t{\cdot}ha^{-1}$), three rates of NPK (30, 60, and 90 $kg{\cdot}N{\cdot}ha^{-1}$), and control. The experiment was laid out in a randomized complete block design with three replicates. Growth, yield, dry matter and proximate, nutrient uptake concentration, and oil content were determined following standard procedures. Data were analyzed using ANOVA, and means were compared with the Duncan multiple range test (DMRT) at $p \leq 0.05$. Performance of sunflower was superior on the field fertilized with 10 $t{\cdot}ha^{-1}$ chicken manure which was comparable to 90 $kg{\cdot}N{\cdot}ha^{-1}$ NPK fertilizer. Sunflower seed yield and oil quality were superior in plots supplied with 10 $t{\cdot}ha^{-1}$ chicken manure which was comparable to 60 $kg{\cdot}N{\cdot}ha^{-1}$ NPK. Growth, yield, dry matter, and proximate content were least in the unfertilized plots.

1. Introduction

Sunflower (*Helianthus annuus* L.) is the fourth most important oil seed crop cultivated for the high concentration (900 $g{\cdot}kg^{-1}$) of unsaturated fatty acids in its oil [1]. The head or the floral part which confers the aesthetic attribute varies in size and colour changes from cream to yellow among different cultivars [2]. The crop was introduced from North America into Nigeria shortly after the independence [3]. Lately, it has grown in importance as an oil crop second to soybean as a source of edible vegetable oil. It is a successful crop both in irrigated and in rainfed areas, with adequate sunlight, well loosed, and properly drained sandy loam soil [4]. Sunflower has a deep tap root system in addition to proliferation of surface lateral roots which make the crop fairly drought tolerant [4]. Sunflower seeds are excellent source of vitamins E, B_1, B6, folate, and niacin. In addition, the seeds are a good source of Cu, Mn, Se, P, and Mg. Sunflower contains phytosterols which helps to reduce cholesterol in serum through cholesterol excretion to alter cholesterol synthesis [5].

Furthermore, sunflower oil has diverse industrial uses in the manufacture of paints, varnishes and plastics, and soaps and detergents. Sunflower oil is also used as a pesticide carrier and in production of agrochemicals and surfactants. Utilization of sunflower oil in the manufacture of adhesives, plastics, fabric softeners, lubricants, and coatings has been explored. It is also a potential source of alternative fuel source in diesel engines [6]. In livestock feed and forage, sunflower plant residue has also been used as a source of silage. Sunflower seed is an alternative protein and energy supplement for farmers located in marginal areas where soybean and maize cannot be grown successfully [5].

According to FAO [7], sunflower cultivation covers 22.3 million ha with an average seed yield of almost 27.7 M tons globally. The average sunflower seed production is 27.7 million tons, while the mean yield was about 1.2 t·ha^{-1}. The information on yield of sunflower in Nigeria is inconsistent. However, some reports have shown that more than one t·ha^{-1} seed yield was recorded in some farms [7]. It performs well in both the rainforest and savanna agroecologies especially when grown under adequate fertilizer application [8].

The soils of most part of humid tropical agroecologies in Nigeria according to FAO/UNESCO genetic classification are classified as leached tropical ferruginous soil. These were formed from strongly weathered pre-Cambrian basement complex rock overlain by Aeolian drift with different depths [9]. Also, Mohamed-Saleem [10] showed that Ferruginous tropical soils cover approximately half the Nigerian subhumid zone. These soils are generally characterized by a sandy surface horizon overlying a weakly structured clay accumulation. They are of poor productivity under traditional management, highly erodible with weak water-holding capacity.

Arable lands in most part of Nigeria are inherently low in nutrient as a result of constant usage without adequate soil fertility management strategies leading to poor growth and reduction in crop yield. Abuse of the inorganic fertilizer use due to poor knowledge of crop requirement and soil fertility status resulting in environmental pollution is common among small holders. Besides, common constraints to realizing good yield are basically poor soil environment with marginal organic matter, nutrient loss caused by erosion, nutrient leaching, and poor cultural practices. In fact, continuous harvest without nutrient reuse through organic matter recycling affects crop yield negatively (2003).

Utilization of the optimum fertilizer rate enhances soil physical and chemical properties, minimizes nutrient imbalance, and promotes better crop growth and development. However, reports on optimum rates of organic and inorganic fertilizer for sunflower growth on nutrient deficient soil in many sunflower growing countries such as Egypt [11], India [12], Sudan [13] including southwestern Nigeria [14] are scanty. The study intends to ascertain possibility of cultivation of sunflower with a minimal fertilizer input. This informs the need for an assessment to ascertain if the residual nutrient of the previously applied amendment would suffice for growing subsequent season of sunflower cultivation. There is insufficient information on fertilizer requirement for optimum growth, dry matter partitioning, and yield of sunflower in Nigeria. Therefore, the effect of different rates of chicken manure and NPK 15-15-15 fertilizer on growth, nutrient uptake, seed yield, and oil yield of sunflower (*Helianthus annuus* L.) on soil with marginal nutrients was investigated.

2. Materials and Methods

The study was a two field trial carried out at the Horticultural Research Institute (NIHORT), Ibadan (7°25′N and 3°52′E). The first trial was carried out between December, 2014, and February, 2015, while the residual trial was carried out between March and May, 2015. Before sowing, the soil sample (0–15 cm) was collected from the experimental field and its physicochemical properties were analyzed using standard procedures.

The experiment, laid out in a randomized complete block design (RCBD), had three replicates. There were eight treatments comprising four levels of chicken manure and three rates of the NPK 15 : 15 : 15 fertilizer with a control. The chicken manure sourced from the dump site of chicken pen located within the vicinity of the experimental site was applied at the rates of 5, 10, 15, and 20 t·ha^{-1} two weeks before sowing (WAS). The application was based on N content of the chicken manure. The samples collected were air-dried by spreading them under a shed until they were well dried. The dried samples were cured by decontaminating them of unwanted nonbiodegradable materials. The inorganic fertilizer was applied at two WAS at the rates of 30, 60, and 90 kg·N·ha^{-1}. Plots where no chicken manure or NPK fertilizer was applied (0 t/ha) served as the control.

Variety SL805 A, a drought tolerant genotype collected from National Horticultural Research Institute (NIHORT), was used for the study. Each plot which has 3 m × 3 m separated by 1 m spacing contained 49 plant stands resulting in 54,444 plant stands ha^{-1}. Two to four seeds were sown at the depth of 2–4 cm per hole by dibbling at a spacing of 50 cm × 50 cm. Plants were later thinned to one plant per stand at two weeks after sowing. Missing stands were supplied at one week after sowing to ensure the target plant population per unit area. Weed removal from the plots was done manually with hoe at three week intervals, while insect pests were managed by spraying lambda cyhalothrin 2.5% EC a.i./ha at the rate of 30 ml/15 liters water with 15 L knapsack sprayer.

3. Data Collection

Growth parameters, yield and yield components, dry matter partitioning, proximate composition, and nutrient uptake data were collected. Data on growth were collected fortnightly, while yield and biochemical data were determined at physiological maturity.

3.1. Determination of Chlorophyll and Proximate Constituents. The procedure of Wintermans and Mots [15] was employed for chlorophyll content determination. Ash, moisture, and crude fibre content were determined following the procedures of AOAC [16]. Total protein was determined by the Kjeldahl method, as modified by Katherine et al. [17]. Soxhlet extraction technique described by Redfern et al. [18] was used for determination of the oil content.

3.2. Determination of Plant Nutrient Uptake. The procedure described by Bilbao et al. [19] was used for determination of nitrogen constituent in plant tissue. One gram of the ground sample of each treatment was weighed into crucibles and ashed in a Gallenkamp muffle furnace at 600°C for 3 hours. The samples were allowed to cool and then 10 ml of 2 M nitric acid was added after which samples were filtered. The Mn, Fe, Cu, and Zn constituents in the plant tissue were determined using the atomic absorption spectrophotometer.

3.3. Residual Trial. The field was prepared for residual trial of three months after the first planting. The experimental procedures were the same as in the first trial, except that no fresh chicken manure or NPK fertilizers were applied. The plot for each treatment was retained and used for the residual trial.

3.4. Data Analysis. Descriptive statistics and analysis of variance (ANOVA) of the Statistical Analysis System (SAS) were used to analyze the parameters collected. Differences in means were separated with Duncan's multiple range test (DMRT) at $P \leq 0.05$.

4. Results

4.1. Physiochemical Properties of the Soil and Chicken Manure Used for the Study. The soil used for the study was slightly acidic (6.8) and low in nitrogen but high in phosphorus and potassium compared to the constituents of chicken manure (Table 1). However, the organic carbon, nitrogen, and calcium in the chicken manure were higher than in the soil. The soil was described as ferruginous tropical soils [10].

The ANOVA of the response of sunflowers on marginal soil supplying different rates of NPK fertilizer and chicken manure is indicated in Table 2. All the parameters measured were significantly affected by the imposed treatments.

4.2. Growth and Development of Sunflowers as Influenced by Varying Rates of Chicken Manure and NPK. Application of different rates of chicken manure and NPK fertilizer affected height of sunflowers significantly (Figure 1(a)). Tallest plants (130.3 cm) were observed in plots treated with 10 t·ha^{-1} chicken manure, but this was not significantly different from plots treated with 60 kg·N·ha^{-1}. Unamended plots (control) had significantly least plant height (84.0 cm). Sunflower produced highest number of leaves (35.1) in plots fertilized with 60 kg·N·ha^{-1}, but this was not significantly different from plots supplied with other rates of either chicken manure or NPK (Figure 1(b)). Leaf area (cm^2) of sunflower plants was statistically influenced by application of varying rates of chicken manure and NPK fertilizer all through the sampling period.

Residual effect of application of different rates of chicken manure and NPK fertilizer significantly influenced the height of sunflower. Tallest sunflower plant (217 cm) was observed in plots previously fertilized with 20 t·ha^{-1} chicken manure which was compared significantly with plots earlier supplied with 90 kg·N·ha^{-1} NPK. Unamended plots had significantly least plant height (149.1 cm) (Figure 1(c)). Residual effect of different rates of chicken manure and NPK fertilizers had a significant effect on number of leaves formed. Number of leaves produced by sunflowers was highest (45.3) in plots earlier fertilized with 20 t·ha^{-1} chicken manure. This was however not significantly different from plots supplied with other rates of either chicken manure or NPK (Figure 1(d)).

The leaf area of sunflower plants was not significantly different in plots supplied with 60 kg·N·ha^{-1} NPK, as well as 10 and 20 t/ha chicken manure (Table 2). Sunflowers had significantly highest leaf area (190.2 cm^2) in plots supplied with 60 kg·N·ha^{-1} NPK but not significantly different from that obtained in plots supplied with 10 t/ha chicken manure. The leaf area of sunflowers was significantly highest (715.2 cm^2) in plots earlier augmented with 90 kg·N·ha^{-1} NPK, and this was significantly different from results obtained in plots treated with 20 and 10 t·ha^{-1} chicken manure. The least leaf area (231.0 cm^2) was observed in the control plot (Table 3).

Also, the girth (cm) of sunflower stem was significantly influenced by application of different rates of chicken manure and NPK fertilizers. At 4 WAS, application of 10 t·ha^{-1} chicken manure produced highest stem girth (3.3 cm) which was significantly different from plots amended with 90 kg·N·ha^{-1} NPK and 5 t·ha^{-1} chicken manure. At 6 and 8 WAS, sunflowers had widest stem girth in plot supplied with 10 t·ha^{-1} chicken manure relative to the control plots. At maturity, highest stem girth (5.8 cm) was observed in plots augmented with 10 t·ha^{-1} chicken manure, whereas least stem girth was recorded in the control plots (Table 4).

Similarly, the earlier applied chicken manure and NPK fertilizers significantly influenced stem girth of sunflower. At 4 WAS, plots earlier supplied with 10 t·ha^{-1} chicken manure had the highest stem girth (3.3 cm) and this was not significantly different from other plots except plot supplied with 90 kg·N·ha^{-1} NPK and 5 t·ha^{-1} chicken manure. At 6, 8, and 10 WAS, previous amendment of the sunflower plot with 20 t·ha^{-1} chicken manure enhanced formation of the highest stem girth which was significantly different from the other treatments. The highest (11.27 cm) stem girth was observed in plots earlier amended with 20 t·ha^{-1} chicken manure, whereas least (7.32 cm) stem girth was recorded in the control plots (Table 4).

4.3. Yield and Yield Components of Sunflowers as Influenced by Different Rates of Chicken Manure and NPK Fertilizer. Sunflowers grown on plots amended with 10 t·ha^{-1} chicken manure produced widest head (17.9 cm), but this was not significantly different from plots amended with 15 or 20 t·ha^{-1} chicken manure. The least head diameter (13.3 cm) was obtained from plots supplied with 5 t·ha^{-1} chicken manure (Table 5). Sunflower plants augmented with 20 t·ha^{-1} chicken manure had head with the highest weight (71.9 g) which was significantly different from all other treatments. The head with lowest weight (33.1 g) was obtained in the control plots (Table 5). Similarly, number of seeds/head was significantly influenced by different rates of chicken manure and NPK fertilizers. Sunflowers grown on soils supplied with 20 t·ha^{-1} chicken manure produced the highest (285.7) number of seeds/head, and this differed

Table 1: Physical and chemical properties of the soil and chicken manure used for the experiment.

Chemical properties	pH	Organic C	N	Available P	Exchangeable base (cmol/kg)				Micronutrients (mg/kg)			
			(g/kg)		K	Ca	Mg	Na	Mn	Fe	Zn	Cu
Soil	6.8	27.8	1.2	21.6	4.2	0.5	1.4	0.7	57.0	77.7	56.3	1.9
Chicken manure	5.9	68.5	1.5	0.5	2.2	0.8	0.5	0.4	32.5	0.2	58.0	7.0

Table 2: ANOVA table of effects of chicken manure and NPK on performance of sunflowers on ferruginous soil.

Source of variation	PH	NLV	LA	SG	WH	HD	NSD	WSD	100SD	YL/HA
Main cropping										
Treatments	4.73*	2.58 ns	2.94*	3.99*	104.44*	10.17*	23.50**	56.58**	0.90 ns	110.73**
Mean	103.70	33.58	152.70	4.96	51.61	15.82	53.90	44.32	12.45	1.12
SEM	3.39	0.34	8.14	0.14	2.95	0.35	3.08	3.33	1.30	0.05
CV	13.49	4.14	20.6	10.27	4.192	5.56	10.03	8.59	3.43	3.43
Residual cropping										
Treatments	12.89**	2.58*	2.55*	3.99*	104.44*	10.17**	18.36**	56.68**	0.86*	86.37**
Mean	184.01	37.10	427.29	9.31	310.41	20.00	458.88	65.05	11.03	3.5
SEM	5.47	0.94	38.88	0.32	17.37	0.77	21.10	4.79	0.57	0.26
CV	7.1	4.15	20.6	10.27	4.92	5.55	10.02	8.59	52.55	1.64

*Significant at $p \leq 0.05$; **significant at $p \leq 0.01$; ***significant at $p \leq 0.001$; ns = not significant; PH = plant height; NLV = number of leaves; LA = leaf area; SG = stem girth; WH = weight of head; HD = head diameter; NSD = number of seeds; WSD = weight of seed; 100SD = 100-seed weight; YL/HA = yield/hectare.

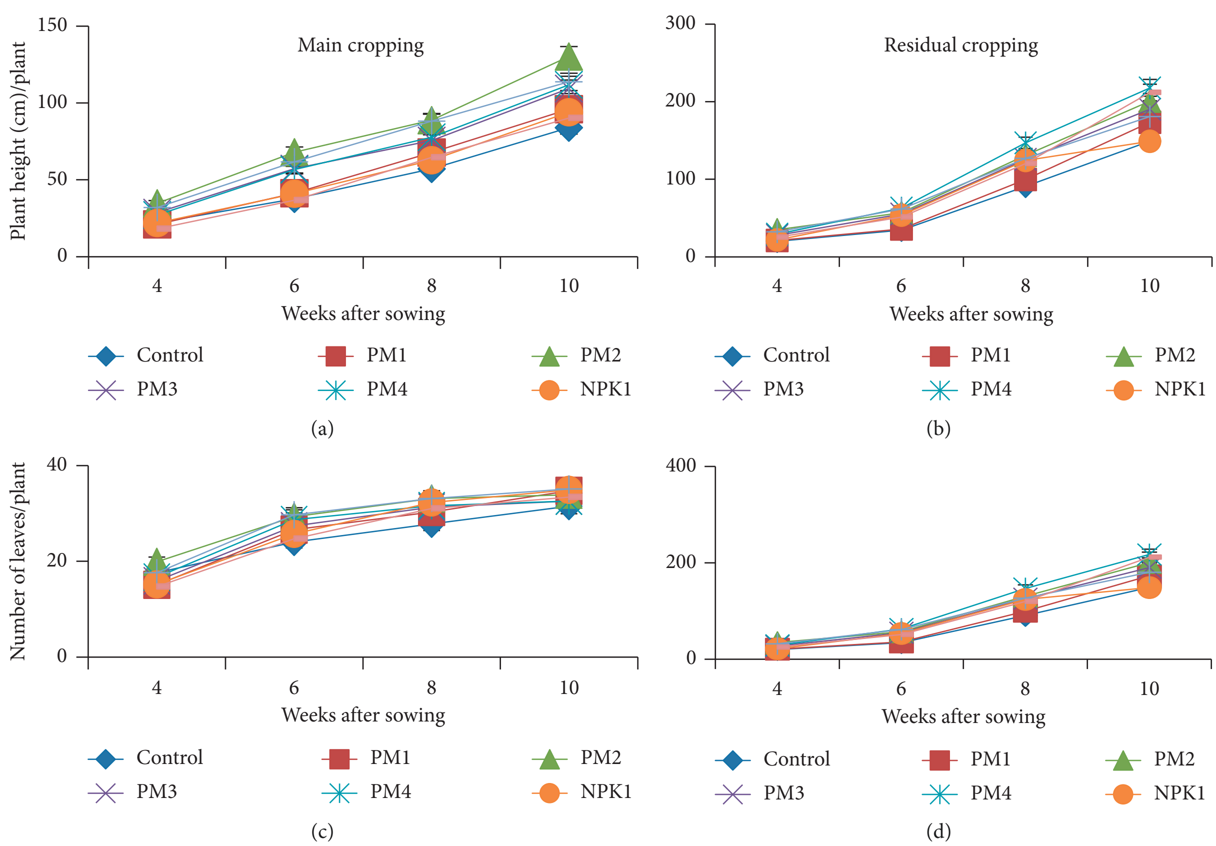

Figure 1: Effects of different rates of chicken manure and NPK fertilizers on (a) plant height (cm) and (b) number of leaves of sunflowers during main and residual cropping. PM1 = chicken manure 5 t·ha^{-1}; PM2 = chicken manure 10 t·ha^{-1}; PM3 = chicken manure 15 t·ha^{-1}; PM4 = chicken manure 5 t·ha^{-1}; NPK1 = NPK 30 kg·N·t·ha^{-1}; NPK2 = NPK 60 kg·N·t·ha^{-1}; NPK3 = NPK 90 kg·N·t·ha^{-1}.

significantly compared to the NPK fertilizer rates and the control. Least (136.6) number of seeds/head was obtained from plots augmented with 90 kg·N·ha^{-1} NPK (Table 4). Highest 100-seed weight was observed in plot supplied with 20 t·ha^{-1} chicken manure, but this was not statistically different other treatments except the control (unamended)

Table 3: Effect of different rates of chicken manure and NPK fertilizers on the leaf area (cm^2) of sunflowers.

Treatments	Main cropping				Residual			
	Weeks after sowing				Weeks after sowing			
	4	6	8	10	4	6	8	10
Control	$29.6^{ab} \pm 0.67$	$66.71^{f} \pm 0.59$	$96.3^{g} \pm 1.18$	$117.5^{b} \pm 0.78$	$29.6^{ab} \pm 8.99$	$49.8^{c} \pm 3.32$	$140.0^{c} \pm 7.8$	$231.0^{e} \pm 7.74$
PM1	$32.9.0^{ab} \pm 0.60$	$115.6^{b} \pm 0.83$	$166.4^{a} \pm 0.68$	$173.2^{ab} \pm 2.06$	$31.9.0^{ab} \pm 8.22$	$43.0^{c} \pm 0.79$	$152.9^{c} \pm 16.1$	$244.4^{e} \pm 7.98$
PM2	$67.9^{a} \pm 0.55$	$108.7^{c} \pm 0.21$	$163.3^{b} \pm 0.50$	$180.1^{a} \pm 0.05$	$68.9^{a} \pm 18.68$	$84.3^{b} \pm 0.86$	$200.7^{bc} \pm 39.1$	$252.9^{cd} \pm 21.9$
PM3	$49.9^{ab} \pm 1.46$	$81.33^{e} \pm 1.99$	$102.2^{f} \pm 0.89$	$130.8^{ab} \pm 0.83$	$49.9^{ab} \pm 2.90$	$61.1^{c} \pm 1.21$	$237.5^{a} \pm 47.0$	$466.4^{ab} \pm 62.5$
PM4	$42.7^{ab} \pm 0.16$	$101.1^{d} \pm 0.68$	$152.1^{d} \pm 0.38$	$179.9^{a} \pm 0.74$	$42.7^{ab} \pm 8.82$	$74.4^{b} \pm 7.75$	$233.2^{ab} \pm 14.2$	$715.1^{a} \pm 18.6$
NPK1	$25.2^{b} \pm 1.55$	$58.4^{g} \pm 0.44$	90.4 ± 1.31	$115.9^{b} \pm 0.30$	$26.2^{b} \pm 12.48$	$57.4^{b} \pm 4.16$	$212.9^{bc} \pm 12.2$	$290.9^{d} \pm 6.68$
NPK2	$65.6^{a} \pm 0.40$	$130.7^{a} \pm 2.30$	$154.3^{cd} \pm 0.21$	$190.2^{a} \pm 0.98$	$65.6^{a} \pm 21.19$	$80.5^{a} \pm 10.8$	$220.7^{abc} \pm 10.6$	$402.5^{bc} \pm 46.3$
NPK3	$24.7^{c} \pm 0.61$	$81.53^{e} \pm 0.20$	$115.5^{e} \pm 0.98$	$134.1^{ab} \pm 0.07$	$38.8^{c} \pm 4.11$	$79.4^{b} \pm 7.01$	$220.5^{abc} \pm 34.7$	$715.2^{a} \pm 3.46$

PM1 = chicken manure 5 t·ha^{-1}; PM2 = chicken manure 10 t·ha^{-1}; PM3 = chicken manure 15 t·ha^{-1}; PM4 = chicken manure 5 t·ha^{-1}; NPK1 = NPK 30 kg·N·t·ha^{-1}; NPK2 = NPK 60 kg·N·t·ha^{-1}; NPK3 = NPK 90 kg·N·t·ha^{-1}. Means ± standard deviations with the same letter on the same column are not significantly different at $P > 0.05$ using DMRT.

Table 4: Effect of different rates of chicken manure and NPK fertilizers on girth (cm) of sunflower plants.

Treatments	Main cropping				Residual			
	Weeks after sowing				Weeks after sowing			
	4	6	8	10	4	6	8	10
Control	$2.4^{ab} \pm 0.17$	$2.9^{b} \pm 0.04$	$3.5^{c} \pm 0.31$	$4.1^{c} \pm 0.93$	$2.47^{ab} \pm 0.18$	$2.50^{d} \pm 0.09$	$4.13^{d} \pm 0.07$	$7.32^{e} \pm 0.17$
PM1	$2.4^{bc} \pm 0.24$	$3.3^{ab} \pm 0.13$	$3.6^{bc} \pm 0.18$	$4.9^{abc} \pm 0.17$	$2.41^{bc} \pm 0.19$	$3.21^{e} \pm 0.04$	$5.25^{cd} \pm 0.46$	$8.15^{cde} \pm 0.16$
PM2	$3.3^{a} \pm 0.01$	$3.7^{a} \pm 0.18$	$4.8^{a} \pm 0.57$	$5.8^{a} \pm 0.20$	$3.33^{a} \pm 0.30$	$3.75^{cd} \pm 0.03$	$6.97^{cd} \pm 0.60$	$9.69^{bc} \pm 0.27$
PM3	$2.9^{abc} \pm 0.18$	$3.4^{ab} \pm 0.85$	$4.1^{abc} \pm 0.03$	$4.9^{abc} \pm 0.83$	$2.9^{abc} \pm 0.20$	$3.70^{cd} \pm 0.05$	$7.69^{bcd} \pm 0.83$	$10.27^{ab} \pm 0.68$
PM4	$3.0^{abc} \pm 0.70$	$3.9^{a} \pm 0.44$	$4.7^{ab} \pm 0.05$	$5.7^{a} \pm 0.66$	$3.04^{abc} \pm 0.17$	$4.60^{a} \pm 0.10$	$8.74^{a} \pm 0.03$	$11.27^{a} \pm 0.85$
NPK1	$2.5^{abc} \pm 0.08$	$3.2^{ab} \pm 0.66$	$3.9^{abc} \pm 0.80$	$4.6^{bc} \pm 0.51$	$2.52^{abc} \pm 0.40$	$3.60^{b} \pm 0.04$	$6.32^{cd} \pm 1.06$	$8.01^{de} \pm 0.10$
NPK2	$3.2^{ab} \pm 0.25$	$3.7^{a} \pm 0.02$	$4.5^{ab} \pm 0.51$	$5.1^{ab} \pm 1.83$	$3.27^{ab} \pm 0.38$	$3.80^{b} \pm 0.02$	$7.69^{bc} \pm 0.37$	$8.97^{cd} \pm 0.16$
NPK3	$2.3^{c} \pm 0.46$	$3.2^{ab} \pm 0.74$	$3.9^{abc} \pm 0.06$	$4.7^{bc} \pm 0.89$	$2.39^{c} \pm 0.07$	$2.70^{c} \pm 0.08$	$7.77^{ab} \pm 0.28$	$10.76^{ab} \pm 0.96$

PM1 = chicken manure 5 t·ha^{-1}; PM2 = chicken manure 10 t·ha^{-1}; PM3 = chicken manure 15 t·ha^{-1}; PM4 = chicken manure 5 t·ha^{-1}; NPK1 = NPK 30 kg·N·t·ha^{-1}; NPK2 = NPK 60 kg·N·t·ha^{-1}; NPK3 = NPK 90 kg·N·t·ha^{-1}. Means ± standard deviations with the same letter on the same column are not significantly different at $P > 0.05$ using DMRT.

plots. Ferruginous soil amended with 10 t·ha^{-1} chicken manure produced seeds with the highest seed yield (t·ha^{-1}), but this was not significantly different from yield obtained in plots supplied with 15 or 20 t·ha^{-1} chicken manure. However, seeds with least weight were obtained from the unamended plot which was not statistically different from yield harvest from plots fertilized with 90 kg·N·ha^{-1} mineral fertilizer (Table 5).

The residual effect of previously applied different rates of chicken manure and NPK fertilizer on sunflower fields had a significant influence on number of seeds/head formed. Sunflowers grown on soils supplied with 15 t·ha^{-1} chicken manure produced the highest number of seeds/head (96.2 g) which was statistically comparable to results obtained in plots earlier supplied with 60 kg·N·ha^{-1} NPK. The residual effect of different rates of chicken manure and NPK fertilizer earlier applied on soil significantly influenced the weight of sunflower seeds. Plots amended with 20 t·ha^{-1} chicken manure had highest weight of head (96.2 g) which was significantly different from other treatments, except plots previously fertilized with 90 kg·N·ha^{-1} NPK. Previous soil augmentation with both chicken manure and NPK fertilizer influenced the weight of 100 seeds of sunflower plants. Amendment with 90 kg·N·ha^{-1} had the highest 100-seed weight (32.6 g) which differed significantly from other treatments except in plots earlier supplied with 20 t·ha^{-1} chicken manure. Significant and highest seed yield (5.25 t·ha^{-1}) was harvested from plots previously supplied with 10 t·ha^{-1} chicken manure relative to other treatments (Table 5).

4.4. Dry Matter Accumulation by Sunflowers as Influenced by Different Rates of Chicken Manure and NPK Fertilizer. Sunflowers grown on plots amended with 60 kg·N·ha^{-1} NPK had highest weight of dry root (19.6 g), while plots fertilized with 90 kg·N·ha^{-1} had least dry root weight (7.3 g). The plots supplied with 10 t·ha^{-1} chicken manure had significantly highest weight of dry shoot (66.7 g), but this was not significantly different from plots supplied with 15 t·ha^{-1} chicken manure (Table 6). Weight of the sunflower dry root was significantly influenced by the residual chicken manure or NPK fertilizer earlier applied. Sunflowers grown on plots amended with 60 kg·N·ha^{-1} during the first trial had a significantly highest weight of dry root (11.7 g). The least weight of dry root (2.23 g) was observed in plots amended with 90 kg·N·ha^{-1}.

Residual effect of earlier applied 90 kg·N·ha^{-1} NPK had a significant effect on the weight of dry shoot of sunflowers. Highest weight of dry shoot (80.7 g) was observed in plots

Table 5: Effect of different rates of chicken manure and NPK fertilizers on components of yield of sunflowers.

Treatments	Main cropping					Residual				
	Head diameter (cm)	Weight of head (g)/plant	Number of seeds/head	100-seed weight (g)	Seed yield (t·ha^{-1})	Head diameter (cm)/head	Weight of head (g)/plant	Number of seeds/head	100-seed weight (g)	Seed yield (t·ha^{-1})
Control	$14.1^{de} \pm 1.55$	$35.7^{e} \pm 3.37$	$144.7.^{c} \pm 36.8$	$7.20^{b} \pm 0.01$	$1.04^{c} \pm 0.01$	$15.8^{cd} \pm 0.73$	$35.7^{e} \pm 3.37$	$389.6^{e} \pm 0.38$	$17.20^{c} \pm 0.04$	$1.66^{h} \pm 0.01$
PM1	$13.3^{e} \pm 0.79$	$33.1^{e} \pm 0.92$	$279.7^{a} \pm 39.6$	$7.89^{a} \pm 0.06$	$0.79^{d} \pm 0.04$	$16.3^{bc} \pm 1.29$	$33.1^{e} \pm 0.92$	$486.7^{b} \pm 5.04$	$17.89^{c} \pm 0.09$	$2.19^{g} \pm 0.01$
PM2	$17.9^{a} \pm 0.11$	$65.8^{b} \pm 4.75$	$272.7^{a} \pm 70.4$	$12.70^{a} \pm 0.05$	$1.36^{a} \pm 0.06$	$21.3^{b} \pm 1.33$	$65.8^{b} \pm 4.75$	$394.2^{d} \pm 0.67$	$22.70^{bc} \pm 0.35$	$5.25^{a} \pm 0.01$
PM3	$17.4^{ab} \pm 0.54$	$62.4^{b} \pm 0.91$	$268.1^{a} \pm 68.1$	$11.58^{a} \pm 0.15$	$1.30^{a} \pm 0.04$	$20.3^{bc} \pm 0.65$	$62.4^{b} \pm 0.91$	$717.5^{a} \pm 15.88$	$21.58^{bc} \pm 0.25$	$2.64^{f} \pm 0.01$
PM4	$17.1^{ab} \pm 0.30$	$71.9^{a} \pm 1.45$	$285.7^{a} \pm 71.9$	$16.43^{a} \pm 0.12$	$1.36^{a} \pm 0.04$	$25.2^{a} \pm 0.46$	$71.9^{a} \pm 1.45$	$426.5^{b} \pm 0.83$	$26.43^{ab} \pm 0.92$	$5.17^{b} \pm 0.01$
NPK1	$15.5^{dc} \pm 0.38$	$51.3^{d} \pm 1.90$	$251.3^{b} \pm 51.3$	$10.91^{a} \pm 0.05$	$1.09^{c} \pm 0.04$	$15.7^{d} \pm 0.65$	$51.3^{d} \pm 1.90$	$397.3^{c} \pm 1.72$	$20.91^{bc} \pm 0.65$	$3.42^{e} \pm 0.01$
NPK2	$15.9^{bc} \pm 0.36$	$56.1^{c} \pm 2.34$	$256.1^{b} \pm 56.10$	$9.10^{a} \pm 0.02$	$1.21^{b} \pm 0.02$	$21.7^{a} \pm 0.65$	$56.1^{c} \pm 2.34$	$525.7^{b} \pm 0.22$	$23.10^{b} \pm 0.02$	$3.59^{d} \pm 0.01$
NPK3	$15.9^{bc} \pm 1.36$	$36.7^{e} \pm 0.24$	$136.7^{c} \pm 36.6$	$19.57^{a} \pm 9.87$	$0.79^{d} \pm 0.04$	$23.9^{a} \pm 0.65$	$36.7^{e} \pm 0.24$	$356.3^{f} \pm 0.13$	$32.57^{a} \pm 0.87$	$4.42^{c} \pm 0.01$

PM1 = chicken manure 5 t·ha^{-1}; PM2 = chicken manure 10 t·ha^{-1}; PM3 = chicken manure 15 t·ha^{-1}; PM4 = chicken manure 5 t·ha^{-1}; NPK1 = NPK 30 kg·N·t·ha^{-1}; NPK2 = NPK 60 kg·N·t·ha^{-1}; NPK3 = NPK 90 kg·N·t·ha^{-1}. Means ± standard deviation with the same letter on the same column are not significantly different at $P > 0.05$ using DMRT.

Table 6: Effect of different rates of chicken manure and NPK fertilizers on dry matter partitioning by sunflowers.

Treatments	Main cropping		Residual	
	Root dry weight (g)	Shoot dry weight (g)	Root dry weight (g)	Shoot dry weight (g)
Control	$9.6^{ab} \pm 0.06$	$32.3^{dc} \pm 3.26$	$7.53^{c} \pm 0.48$	$55.7^{e} \pm 1.21$
PM1	$12.8^{ab} \pm 10.3$	$44.5^{c} \pm 3.60$	$11.27^{b} \pm 0.37$	$75.3^{c} \pm 1.21$
PM2	$13.2^{ab} \pm 1.94$	$66.7^{a} \pm 1.72$	$9.73^{b} \pm 1.03$	$75.3^{c} \pm 1.53$
PM3	$12.9^{ab} \pm 1.35$	$62.4^{ab} \pm 1.40$	$11.3^{a} \pm 0.40$	$77.3^{b} \pm 1.77$
PM4	$13.3^{ab} \pm 1.20$	$58.4^{b} \pm 11.6$	$6.03^{d} \pm 0.33$	$43.5^{ef} \pm 0.87$
NPK1	$10.9^{ab} \pm 1.83$	$22.0^{e} \pm 1.75$	$6.40^{d} \pm 0.32$	$63.3^{d} \pm 2.03$
NPK2	$19.6^{a} \pm 14.5$	$30.2^{de} \pm 3.15$	$11.70^{a} \pm 0.3$	$80.7^{a} \pm 1.22$
NPK3	$7.3^{b} \pm 0.34$	$21.1^{e} \pm 5.01$	$2.23^{b} \pm 0.23$	$38.3^{f} \pm 1.89$

PM1 = chicken manure $5\,t{\cdot}ha^{-1}$; PM2 = chicken manure $10\,t{\cdot}ha^{-1}$; PM3 = chicken manure $15\,t{\cdot}ha^{-1}$; PM4 = chicken manure $5\,t{\cdot}ha^{-1}$; NPK1 = NPK $30\,kg{\cdot}N{\cdot}t{\cdot}ha^{-1}$; NPK2 = NPK $60\,kg{\cdot}N{\cdot}t{\cdot}ha^{-1}$; NPK3 = NPK $90\,kg{\cdot}N{\cdot}t{\cdot}ha^{-1}$. Means ± standard deviation with the same letter on the same column are not significantly different at $P > 0.05$ using DMRT.

previously amended with $60\,kg{\cdot}N{\cdot}ha^{-1}$. The least weight of dry shoot (38.3 g) was obtained in plots amended with $90\,kg{\cdot}N{\cdot}ha^{-1}$ (Table 6).

4.5. Different Rates of Fertilizer Influenced Leaf Chlorophyll Contents of Sunflowers. The highest concentration of chlorophylls a and b (74.35 and $99.26\,mg{\cdot}g^{-1}$) were recorded in plots supplied with $90\,kg{\cdot}N{\cdot}ha^{-1}$ NPK, but plots supplied with $15\,t{\cdot}ha^{-1}$ chicken manure equally had statistically comparable chlorophyll a and b contents (70.59 and 96.23 $mg{\cdot}g^{-1}$), respectively (Figure 2).

4.6. Effect of Different Rates of Chicken Manure and NPK Fertilizers on Proximate Constituents of Sunflowers. Application of diverse rates of chicken manure and NPK fertilizer influenced crude protein content of sunflower seeds. The crude protein content ranged from 17.7% in plots amended with NPK $60\,kg{\cdot}N{\cdot}ha^{-1}$ to 21.7% in plots amended with 20 t/ha chicken manure (Table 7). The plots amended with $15\,t{\cdot}ha^{-1}$ chicken manure had highest crude fibre (18.4%) and ash (15.7%) contents. The moisture content (11.8%) and nitrogen-free extract (36.8%) were highest in the control plots and plots amended with 5 t/ha chicken manure, respectively. The crude lipid ranged from 3.8% in plots supplied with $30\,kg{\cdot}N{\cdot}ha^{-1}$ NPK to 4.6% in plots amended with $15\,t{\cdot}ha^{-1}$ chicken manure.

4.7. Shoot Nutrient Uptake by Sunflowers on Ferruginous Soil Fertilizer with Different Rates of Chicken Manure and NPK Fertilizer. Shoot nutrient uptake of sunflower under the influence of different rates of chicken manure and NPK fertilizer is shown in Table 8. Highest nitrogen uptake was observed in plots amended with $20\,t{\cdot}ha^{-1}$ chicken manure. Sunflower had highest potassium ($0.85\,cmol{\cdot}kg^{-1}$), sodium ($0.40\,cmol{\cdot}kg^{-1}$), magnesium ($0.28\,mg{\cdot}g^{-1}$), and iron ($0.27\,mg{\cdot}g^{-1}$) uptake in plots amended with $5\,t{\cdot}ha^{-1}$ chicken manure (Table 8). Application of $60\,kg{\cdot}N{\cdot}ha^{-1}$ NPK fertilizer enhanced highest copper uptake. However, in the unamended plot (control), sunflowers had the highest manganese ($139.45\,mg{\cdot}g^{-1}$) uptake.

4.8. Effect of Different Rates of Chicken Manure and NPK Fertilizer on Oil and Crude Protein Contents of Sunflower Seeds. Percentage crude protein and oil contents in sunflower seeds as influenced by application of varying rates of chicken manure and NPK fertilizer is presented in Table 9. Crude protein in the seed of sunflower was highest (29.5%) in plots amended with $20\,t{\cdot}ha^{-1}$ chicken manure but was not significantly higher than protein content obtained in seeds of sunflower grown in plots amended with $90\,kg{\cdot}N{\cdot}ha^{-1}$. Similarly, sunflower seeds harvested from plots amended with $20\,t{\cdot}ha^{-1}$ chicken manure had significantly highest (33.8%) percentage oil content (Table 9).

5. Discussion

Applying chicken manure to ferruginous soil enhanced growth and development of sunflowers. The improved performance observed in sunflowers grown on nutrient deficient soil amended with chicken suggests that chicken manure is a good alternative to mineral fertilizer. The use of chicken manure in improving soil fertility promotes nutrient recycling and thus minimizes environmental pollution resulting from disposal of chicken manure. Applying chicken manure to nutrient deficient soil is beneficial to minimizing to the barest minimum deleterious effect of the inorganic fertilizers in agricultural field. The effect of supplying of $10\,t{\cdot}ha^{-1}$ chicken manure was comparable to the recommended NPK rate of $60\,kg{\cdot}N{\cdot}ha^{-1}$ for optimum performance of sunflowers.

This study demonstrated that applying fertilizer from organic sources had a residual effect on the sunflower performance. The crop grown on field supplied with chicken manure benefited from the previously applied organic material compared to inorganic materials. This is probably because microorganisms in the soil aided decomposition of the residual organic material into absorbable form, which might have encouraged slow release of nutrients over a longer period. Similar observation had been reported by Kihanda et al. [20], Shahzad et al. [21], and Mahmood et al. [22]. Augmentation of marginal soil with organic fertilizer enhances organic matter content in the soil resulting in a considerable effect on soil microbes, nutrient availability, and uptake by sunflower plants.

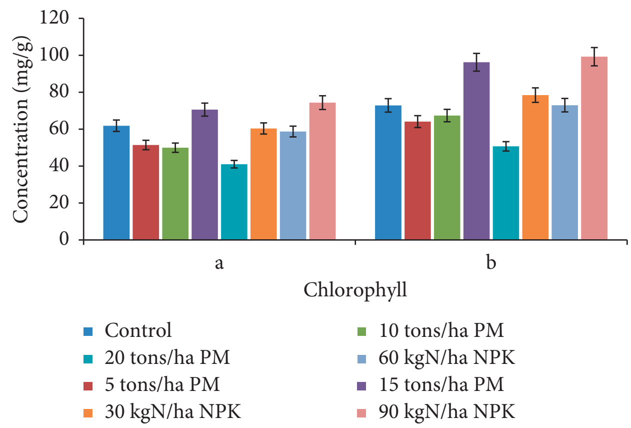

Figure 2: Effect of different rates of chicken manure and NPK fertilizers on chlorophyll contents of sunflower.

Table 7: Proximate constituents of sunflowers as influenced by different rates of chicken manure and NPK fertilizers.

Treatments	Percentage composition (%)					
	Crude protein	Crude fibre	Crude lipid	Ash	Moisture content	Nitrogen-free extract
Control	21.25	17.40	4.45	15.35	11.78	30.14
Chicken manure 5 $t{\cdot}ha^{-1}$	20.87	14.99	3.83	14.73	11.75	36.75
Chicken manure 10 $t{\cdot}ha^{-1}$	17.95	16.37	4.17	15.09	11.57	33.25
Chicken manure 15 $t{\cdot}ha^{-1}$	19.55	18.42	4.64	15.73	11.70	27.88
Chicken manure 20 $t{\cdot}ha^{-1}$	21.73	16.96	4.40	15.3	11.69	31.04
NPK 30 $kg{\cdot}N{\cdot}ha^{-1}$	20.63	16.13	3.79	14.64	11.35	36.36
NPK 60 $kg{\cdot}N{\cdot}ha^{-1}$	17.73	15.43	4.07	15.27	11.66	34.52
NPK 90 $kg{\cdot}N{\cdot}ha^{-1}$	19.05	17.47	4.51	15.41	11.23	30.27

Table 8: Effect of different rates of chicken manure and NPK fertilizers on plant nutrient uptake by sunflowers.

Treatments	Nutrient uptake							
	(g/kg)	(cmol/kg)		(mg/g)				
	N	K	Na	Mg	Mn	Cu	Zn	Fe
Control	0.36	0.56	0.20	0.18	139.45	52.75	48.25	0.25
Chicken manure 5 $t{\cdot}ha^{-1}$	0.66	0.85	0.40	0.29	118.31	7.00	90.45	0.27
Chicken manure 10 $t{\cdot}ha^{-1}$	0.75	0.63	0.23	0.19	91.01	7.30	59.01	0.23
Chicken manure 15 $t{\cdot}ha^{-1}$	0.80	0.73	0.29	0.24	134.21	4.73	62.75	0.14
Chicken manure 20 $t{\cdot}ha^{-1}$	0.85	0.79	0.31	0.21	71.78	75.25	56.01	0.25
NPK 30 $kg{\cdot}N{\cdot}ha^{-1}$	0.40	0.75	0.35	0.28	75.32	88.00	105.75	0.24
NPK 60 $kg{\cdot}N{\cdot}ha^{-1}$	0.53	0.76	0.22	0.15	116.81	93.50	64.31	0.15
NPK 90 $kg{\cdot}N{\cdot}ha^{-1}$	0.70	0.70	0.24	0.20	99.50	71.50	94.00	0.26

Table 9: Effect of different rates of chicken manure and NPK fertilizers on percentage crude protein and oil contents of sunflower seeds.

Treatments	Percentage composition (%)	
	Protein	Oil
Control	$22.59^{e} \pm 0.78$	$28.25^{c} \pm 0.64$
Chicken manure 5 $t{\cdot}ha^{-1}$	$27.5^{b} \pm 0.35$	$31.48^{b} \pm 1.25$
Chicken manure 10 $t{\cdot}ha^{-1}$	$27.64^{b} \pm 0.75$	$31.75^{b} \pm 0.03$
Chicken manure 15 $t{\cdot}ha^{-1}$	$24.88^{d} \pm 0.89$	$26.99^{d} \pm 0.07$
Chicken manure 20 $t{\cdot}ha^{-1}$	$26.6^{c} \pm 0.87$	$33.77^{a} \pm 0.88$
NPK 30 $kg{\cdot}N{\cdot}ha^{-1}$	$27.23^{b} \pm 0.65$	$30.09^{bc} \pm 1.07$
NPK 60 $kg{\cdot}N{\cdot}ha^{-1}$	$29.46^{a} \pm 0.77$	$28.91^{c} \pm 0.1$
NPK 90 $kg{\cdot}N{\cdot}ha^{-1}$	$28.92^{ab} \pm 0.56$	$24.6^{e} \pm 0.65$

Superfluous nutrient supply with respect to organic fertilizer would have been beneficial to sunflowers in the subsequent cropping season. The residual organic materials could have been held in the soil matrix until needed by the subsequent crop. In this study, supplying 20 $t{\cdot}ha^{-1}$ chicken manure was beneficial to the subsequent crops during the second cropping cycle, whereas excess unutilized nutrients by the main crop in plots fertilized with mineral fertilizer was likely to have been leached down the soil horizon or run-off, thereby causing environmental menace [23].

The yield response of sunflower to the applied organic and inorganic fertilizer showed that the yield components increased with increasing rates of fertilizer. It thus suggests that sunflower efficiently converted the translocated nutrients to economic yield better than biological yield, as reflected in its improved yield and yield components. Earlier application of varying rates of chicken manure and NPK fertilizer on sunflower fields greatly increased number of seeds/head formed and weight of sunflower seeds. Application of mineral fertilizer enhanced accumulation of dry matter better than organic fertilizer. This could be linked to a faster rate at which mineral fertilizers releases nutrient compared to organic-based fertilizers. Hence, dry matter accumulation was accelerated, but this did not translate to better yield compared to the influence chicken manure. On the contrary, accumulation of dry matter into shoot of sunflower was better in plots amended with organic fertilizers than inorganic fertilizers. It suggests that organic fertilizers enhanced dry matter accumulation necessary for photoassimilate partitioning into economic yield better than mineral fertilizer. This agrees with the findings of Mehasen et al. [24] that application of sheep manure compost contributed greatly to the cotton growth compared to control. The beneficial effects of organic manure on crop have also been well reported [25–27].

The higher plant growth observed in plots amended with chicken manure may be associated with the fact that the materials released considerable amount of nutrients especially nitrogen for plant use. Nitrogen is one of the essential minerals for chlorophyll and protoplasm formation [28, 29], and its deficiency can cause yellowing of leaves and stunted growth of plants [30]. Reports of Cambui et al. [31] and Zongmin et al. [32] indicated that nutrient availability particularly nitrogen determines plant vegetative development and yield. Hence, the better sunflower morphological growth in plots supplied with organic fertilizers could be linked directly to nutrient availability. The consistent poor performance of sunflowers grown under native nutrients and those grown under suboptimal nitrogen rate suggests that when nutrients supply are inadequate, plants growth becomes retarded and perform poorly. Bittenbender et al. (1998) reported significant reduction in plant growth parameters when soil is deficient in nutrient, most especially nitrogen as they are often required for chlorophyll and protoplasm formation.

The improved plant growth and dry matter yield in plots fertilized with chicken manure over NPK fertilizers suggests that chicken manure conserve nutrients which were made available for morphological development like enlarged leaf area which improved higher photoassimilate. Higher photoassimilate has been reported to be directly associated with higher dry matter accumulation [33]. This might be the reason for the taller plant height, better leaf formation, wider leaves area, and larger stem girth/plant produced in plots amended with chicken manure over that of NPK treated plots. Similar observations had been reported by Swarup and Yaduvanshi [34] and Yadana et al. [33] in rice plants.

Application of chicken manure to marginal soil was superior to mineral fertilizers both in the short and long run. Sunflowers demonstrated superior performance during the second planting cycle perhaps due to the residual effect of the applied manure. It became clearer that continuous cropping on ferruginous soil which relied on indigenous mineral nutrient without adequate soil fertility management in form of fertilizer application would cause poorly developed crop and low yield. Application of suboptimal mineral or organic fertilizers reduced performance of sunflowers significantly on soil low in native plant nutrients. On the contrary, superfluous application often encourages biological growth at the expense of economic yield. In this trial, application of chicken manure beyond 10 ha^{-1} showed no significant improvement in the performance of the crop. Any chicken manure rate beyond 10 ha^{-1} may likely result in nutrient imbalance or toxicity which could have resulted in the poor performance recorded.

The residual impact of chicken manure in improving the performance of sunflowers on marginal soil over control and inorganic fertilizer plot was obvious. The growth and yield of *Amaranthus cruentus* were enhanced when degradable household trash was applied [35]. Similarly, application of farm yard manures had great residual influence on performance of *Cucumis sativus* [36] on poor soil. These agree with our summation that residual chicken manure enhanced performance of sunflower on ferruginous soil.

6. Conclusion

It is concluded that higher sunflower yield, oil quality, and nutrient uptake were obtained from the plants supplied with 10 $t{\cdot}ha^{-1}$ chicken manure over the control. Therefore, in order to maintain soil health and optimum sunflower yield, application of 10 $t{\cdot}ha^{-1}$ chicken manure is recommended for tropical ferruginous soil.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

Regarding the publication of this manuscript, the authors declare no conflicts of interest.

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