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Research Article

Impact of urban compost manure on the soil physical properties, growth, yield and quality of lettuce

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ABSTRACT- Most soils close to urban centers are often degraded due to intensive cultivation, resulting in low organic matter content and low plant nutrients. Remnants of vegetable materials are frequently abandoned in urban markets in Nigeria and their disposal by local councils is expensive; these materials therefore constitute a nuisance to the environment. However, these materials can be composted and used as soil amendment. A field experiment was conducted at the Teaching and Research Farm of the University of Ilorin, Ilorin, Nigeria during the 2018 and 2019 cropping growing seasons to evaluate the effects of urban wastes as compost on the growth, yield and nutritional composition of lettuce. The experiment was laid out in a randomized complete block design replicated four times. The rates of compost application were as follows; 0, 5, 10, 15, 20 Mg/ha and NPK at the rate of 300 kg ha^{-1}. Data were collected on vegetative parameters (plant height, number of leaves, leaf area index), yield parameters (yield per net plot, yield per hectare), and the vitamin composition (Vitamins A and C). The results showed that the application of compost manure improved the soil physical and chemical properties such as the water holding capacity, which was improved by 27.77% and 29.43% in the first and second growing seasons respectively. The application of 20 Mg ha^{-1} produced superior growth and yield (34.93 and 33.64 Mg ha^{-1}) in the first and second growing seasons, respectively. Farmers are therefore encouraged to plant their lettuce crop using compost manure especially in urban areas.

INTRODUCTION

The soil of the southern Guinea savannah zone of Nigeria is inherently infertile, and this low soil fertility is caused by low elemental contents of the parent materials, erosion, and reduction in fallow periods as a result of an increase in population in urban centres (Eifediyi et al., 2021). This has prompted the cultivation of crops using inorganic fertilizers by farmers.

In spite of the fact that inorganic fertilizers have played a significant role in increasing crop production since the era of the green revolution (Hijbeek et al., 2018); they are not a sustainable solution for the maintenance of crop yield (Akinnifesi *et al.,* 2010), as long-term overuse of chemical fertilizers will accelerate soil acidification. This will affect both the soil biota and biogeochemical processes, thus posing an environmental risk and decreasing crop production (Khan et al. 2019; Aciego Pietri and Brookes, 2008).

Although Ayodele (1983) recommended the use of 300 kg ha^{-1} of NPK 15:15:15 fertilizer for vegetables in southwestern Nigeria, most farmers in the Guinea savannah zone could not afford inorganic fertilizer; while the negative consequences of inorganic fertilizer on the crop and soil were well-documented. In addition, the yield of crops from farmers' fields has been on the decline due to the under-application of inorganic fertilizer due to high cost. However, several alternatives have been proposed for improving soil fertility for vegetable crops**.** These involved the use of organic manure in the form of green manure in carrots (Agbede *et al.,* 2017), and farmyard manure in cucumbers (Eifediyi and Remison, 2010). Chondie (2015) has emphasized that organic manures are good sources of macro and micronutrients, which are needed for the growth and yield of crops.

Many organic wastes that are remnants from the sale of leafy, fruit vegetables, and other plant-based materials are found in markets in villages and urban towns in Nigeria. These markets are the major sources of waste and the quantity and type of them depend on the locality in which the materials are sourced. Nevertheless, these materials are not properly disposed of or harnessed as organic amendments but are incinerated. During this process, harmful gases are emitted into the atmosphere, and this depletes the ozone layer which is reported to increase global warming (Bhat et al., 2019). Sometimes, these materials are left to decompose in the marketplace. This creates a breeding ground for houseflies (*Musca domestica*) and other insects and rodents, which transmit diseases such as dysentery, cholera, Lassa fever, etc. The quantities of these materials vary from one market to the other, and the cost of removal, incineration, and transportation to landfills is enormous. However, these materials can be composted and used as organic manures, which can serve as soil amendments.

Compost consists of organic materials that have been allowed to decompose under the anaerobic processes by microorganisms, and thereafter used as an organic amendment (Toledo et al., 2018). The use of these materials as a soil amendment can increase soil organic matter content (Luo et al., 2017); decrease bulk density, increase water holding capacity, and improve hydraulic conductivity (Kranz et al., 2020). Compost, apart from its use as a soil amendment, is also useful for bioremediation (Ventorino et al., 2019) and pollution prevention (Uyizeye et al., 2019).

Lettuce (*Lactuca sativa*), a member of the Asteraceae family, because of the superficial nature of its roots is cultivated on fertile loamy soil that has a high organic matter content. The crop is grown for its leaves that are either eaten alone or in accompaniment with other vegetables as a salad; the vegetable is rich in antioxidants, minerals, and vitamins (Norman 1992, Hanafy et al., 2000, Sanni and Adesina, 2012,) can ameliorate sleep disorder in some people because of the presence of lactucin (Kim *et al*., 2017). In addition, this vegetable is considered an important source of phytochemicals, which are anti-carcinogenic (Masarirambi et al., 2010).

Deficiencies in the minerals and vitamins can have a negative consequence on the growth and development of children (Aphane et al., 2002), especially for the inhabitants of the area of this study whose diets consist mainly of cassava, yams, maize, Guinea corn, etc., which are deficient in the minerals and vitamins. Therefore, there is a need for the cultivation, consumption, and sale of lettuce among farmers to alleviate poverty, which is pervasive in the area.

Dimas *et al.* (2008) posited that compost can meet the nutrient needs of vegetable crops by increasing soil fertility and high crop yield. In addition, it will also reduce the use of synthetic fertilizers, and more importantly, improve the quality of lettuce due to the reduction in nitrate accumulation which is identified as one of the main problems facing lettuce cultivation (Midan and Sorial, 2011). The consumption of vegetables high in nitrate may be deleterious to human health by causing gastric cancer in adults and methemoglobinemia in children (Chan 2011; Song *et al*., 2015). The use of remnants of vegetable materials as compost will not only reduce the waste in the market, and reduce the rate of burning, but also increase the amount of organic matter content of the soil when used as an amendment. Therefore, this study aimed to investigate the effect of compost manure on the growth, yield, and nutrient content of lettuce.

MATERIALS AND METHODS

Site Description

A field experiment was conducted at the Teaching and Research Farm, University of Ilorin, Ilorin, Nigeria (8^{o} 29^{1}N 04^{o}35^{1}E, 307 m above sea level), during the 2018 and 2019 cropping seasons. The soil was an Alfisol belonging to the Bolodunro Series (Ogunwale *et al*., 2002). The surface soils are coarsely textured, and low in organic matter content. In addition, topsoil erosion is common, leading to low soil fertility. The rainfall pattern of the area is bimodal, starting in late March, with the first peak in late July followed by a break in August. The second part of the rainy season usually begins in late August, peaks in late September, and ends in late October. The annual rainfall for the location was 991 mm in 2018 and 1432.92 mm in 2019. The experiment was carried out during the rainy seasons of 2018 and 2019, hence no irrigation was conducted.

Composting

Five compost pits measuring 100 x 100 cm and 120 cm deep (Fig. 1), were dug in a corner of the experimental plot. Materials for compost making included market wastes such as remnants of the leaves of Amaranths *(Amaranthus cruentus)*, Celosia (*Celosia argentea*), Jew mallow (*Corchorous olitorius)*, Fluted pumpkin (*Telfaria occidentalis*), cabbage (Brassica oleraceae), and fruit vegetables such as eggplant (*Solanum melongena* L*)*, paw-paw (*Carica papaya*), and squash (*Curcubita melo*). Other materials were watermelon (*Citrillus vulgare*), tomato (*Solanum esculentum*), carrot (*Daucus carota*), okra (*Abelmoschus esculentus*), groundnut (*Arachis hypogae*), cowpea haulms (*Vigna unguiculata*) and poultry manure which were collected from markets in Ilorin metropolis. These materials were cut into small sizes to facilitate the composting process, and ground eggshells and wood ash were added to them before they were deposited into the first compost pit. Then water was sprinkled following the procedure of FAO (2010). The pits were covered with soil to prevent smell, flies, and other small animals visiting the pits. A small stick called a starter was inserted on top of each pit; this was done to find out if the decomposition process was going well. The contents in pit A were moved into pit B after two weeks and pit A was refilled with another batch of market wastes. This process continued until the last pit which was the storage pit (Fig. 1).

Nursery

Seed trays were filled with a mixture of loamy soil mixed with well-decomposed poultry manure. Lettuce seeds (cv Paris Island), which were obtained from an Agro-shop in Ilorin Metropolis, were sown in the nursery and all cultural practices such as watering, mulching, pests, and disease control were observed. The seedlings were transplanted in the third week when they had attained the 3 - 4 leaf stage.

Land Preparation and Transplanting

The field was ploughed and harrowed, before being marked out into raised seedbeds measuring 1.5 x 3 m, with a 0.5 m avenue, and the amendment was applied to the treatments three weeks before transplanting, to allow mineralization to take place. The seedlings were transplanted in each plot, using the ball of earth method at a spacing of 0.3 x 0.3 m to give a plant density of 50 plants, which is also known as the gross plot. 24 plants in the middle rows of the plot constituted the net plot, while the remaining 26 plants formed the discard. Therefore, the plant population on a per-hectare basis was 111,111 plants.

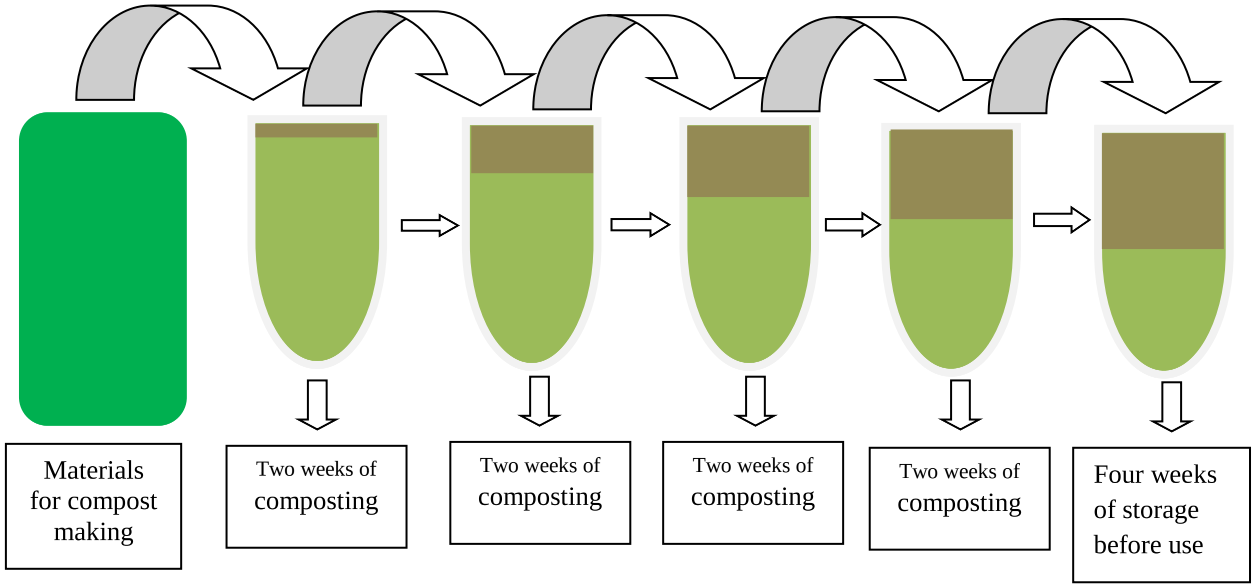

Fig. 1. Diagrammatic representation of the compost-making process

Experimental Design and Treatments

The experiment was laid out in Randomized Complete Block Design (RCBD), with four replications. The treatments imposed were compost manure at the rates of 0, 5, 10, 15, 20 Mg ha^{-1}, and NPK 15:15:15 (300 kg ha^{-1}). The NPK fertilizer was applied 2.5 cm away from the plants two weeks after transplanting. This rate of NPK application is based on the recommendation of Ayodele (1983) for south-western Nigeria.

Soil and Compost Manure Analyses

Soil samples from the experimental plots were collected at a depth of 0 – 30 cm from a 2.5 x 2.5 m grid, bulked. A composite was taken for physical and chemical analyses before compost manure incorporation and transplanting. At the end of the growing season, soil samples were collected from individual plots.

The collected soil samples were air-dried, ground, and passed through a 2 mm sieve. The sieved soil samples and compost manure were analyzed as described by Carter and Gregorich (2007). Soil pH was measured (soil: water ratio, 1:2), using a glass electrode; Particle-size analysis was done using the hydrometer method (Gee and Or, 2002). Soil organic carbon was determined by the procedure of Walkley and Black, using the dichromate wet oxidation method (Nelson and Sommers, 1996). Organic matter was estimated by multiplying carbon (C) by 1.724 (Allison, et al., 1965). Total nitrogen was determined by Micro-Kjeldahl digestion and distillation techniques (Bremner, 1996). Available phosphorus was determined following Bray No 1 (1N NH_4F + 0.5N HCl) extractant, using vanadomolybdophosphoric acid method (Kuo, 1996). The soil textural class was determined using a textural triangle and extraction of exchangeable bases was done by using IN ammonium acetate; exchangeable potassium was determined by using flame photometry, while calcium and magnesium were analyzed by atomic absorption spectrophotometry (Zhang et al., 2012).

Soil Moisture Determination

The moisture of the soil was determined by using the gravimetric method (Reynolds, 1970).

Vitamin A and C Contents

At the harvest, five matured leaves of uniform size were randomly collected from each plot and analyzed for vitamins A and C contents. Vitamin A was determined by the procedure of spectrophotometric method while vitamin C content was determined by using the indophenol dye method (Singh et al., 2007).

Vegetative Traits

At 4, 6, and 8 weeks after transplanting (WAT), plant height was assessed as the distance from the soil level to the terminal point of the stem in ten randomly selected tagged plants in the net plot using a measuring tape. At the same time, the number of leaves was determined, by visual assessment of the green plants, and leaf area estimation was done by the use of the dry weight method (Kaushik et al., 2021). To calculate the leaf area index (LAI) using the formula below, the leaves of 5 plants whose leaves were removed from the stems were used at each sampling period.

$$LAI = \frac{\text{Total leaf area of plant}}{\text{Ground area covered by plant}}$$

The "ground area covered" is the sum of inter and the intra row spacing between two plants (0.3 x 0.3m).

At harvest, plants from the net plots (24 plants in each net plot) were harvested by uprooting the entire plants, and their weights were taken by using a sensitive balance. The result of the net plots was later extrapolated to yield per hectare.

Statistical Analysis

Data for the two years of the experiment (growing seasons 1 and 2) were analysed using the analysis of variance (ANOVA), Genstat statistical package, 17th Edition (Genstat, 2015). Means were separated using the new Duncan multiple range test at $p < 0.05$.

Table 1. Physical and chemical properties of the soil and compost manure before planting in the first growing season

Parameters	Soil	Compost manure
pH in water	6.1	7.09
Organic carbon (%)	0.53	3.45
Organic matter (%)	0.92	5.97
Nitrogen (%)	0.073	0.61
Phosphorus (mg kg^{-1})	5.99	7.24
Potassium ($cmol^{+}$ kg^{-1})	4.66	0.52
Calcium ($cmol^{+}$ kg^{-1})	0.41	8.96
Magnesium ($cmol^{+}$ kg^{-1})	0.51	2.20
Sand (%)	86.61	-
Silt (%)	7.11	-
Clay (%)	6.28	-
Textural class	sandy loam	-
Soil classification	Alfisol	-

RESULTS

Physical and Chemical Composition of Soil and Compost Before Planting

The soil of the study site was low in most of the nutrients analyzed before planting (Table 1). The pH of the soil was slightly acidic, while the organic matter content was low. The nitrogen, and phosphorus contents were very low, the potassium and the calcium were also very low, while the magnesium content was moderate. The nutrient composition of the compost indicated that it was slightly alkaline, while the nutrients varied from moderate to high (Table 1).

The Effects of Compost Manure and NPK Fertilizer on Soil Physical and Chemical Properties After Harvest

The effects of compost manure and NPK fertilizer on the physical and chemical properties of soil are presented in Table 2. The NPK-treated plot produced the highest pH while the organic matter contents were similar in all the treatments. The compost-treated plots produced similar values with respect to the nitrogen content which was significantly different (p <0.05) from the NPK-treated plot and the control plot. The phosphorus content was highest in the 15 Mg ha^{-1} compost manure-treated plot. However, there was no significant difference (p <0.05) in the phosphorus content between this plot and other treatments except the 20 Mg ha^{-1} compost manure-treated plot. The 20 Mg ha^{-1} compost manure-treated plot produced the highest calcium, magnesium (no significantly different from the 15 Mg ha^{-1} compost manure-treated plot), electric conductivity (no significantly different from the 15 Mg ha^{-1} compost manure-treated plot), and potassium values.

The Effects of Compost Manure and NPK Fertilizer on the Properties of Soil and Lettuce

Moisture Content of the Soil

The effects of compost manure and NPK fertilizer on the moisture content of the soil at 4, 6, and 8 weeks after transplanting (WAT) are presented in Table 3. At 4 WAT, the 20 Mg ha^{-1} treated plot had the highest moisture content which was at par with the 15 Mg ha^{-1} but had approximately 30.14% and 31.46% more moisture content than those of the control treatments in the first and second growing seasons, respectively. A similar trend was observed at 6 WAT, and the 20 Mg ha^{-1}-treated plot had the highest moisture content, which was approximately 20.35% and 35.98% more than those of the control-treated plots in the first and second growing seasons respectively. At 8 WAT, the 20 Mg ha^{-1} treated plot produced the highest moisture content which was approximately 18% higher than that of the control treatment. In the second growing season, the 20 Mg ha^{-1} treated plot also had the highest moisture content, which was approximately 14.85% higher than the NPK-treated plot.

Plant Height of Lettuce

The effects of compost manure and NPK fertilizer on the plant height of lettuce at 4, 6, and 8 WAT are presented in Table 4. At 4 weeks after transplanting the 20 Mg ha^{-1}-treated plots outperformed the other treatments significantly (p <0.05), by producing the tallest plants, in both growing seasons, which were approximately 50.21 % taller than that of the control plants in the first growing season and, approximately 45.58% taller than that of the control plants in the second growing season. At 6 WAT, the early advantage of the 20 Mg ha^{-1}-treated plot was maintained by producing plants that were approximately 47.78% and 44.18% taller than those of the control plants in the first and second growing seasons, respectively. A similar trend was observed at 8 WAT. The 20 Mg ha^{-1}-treated plants consistently outperformed the control plots with approximately 33.30% and 30.92 % improvement in the plant height in the first and second growing seasons, respectively.

The Number of Leaves of Lettuce Plants

The number of leaves of tested lettuce plants at 4, 6, and 8 WAT is presented in Table 5. The 20 Mg ha^{-1}-treated plants produced the highest number of leaves, which were significantly (p <0.05) different from the corresponding control plants at the three sampling periods. At 4WAT, the number of leaves produced by the 20 Mg ha^{-1}-treated plants was approximately 8.65%, and 9.05% higher than the corresponding control plants in the first and second growing seasons, respectively. At 6 WAT, the 20 Mg ha^{-1}-treated plants had 46.87% and 39.88% advantage over the control plants in the number of leaves in the first and second growing seasons, respectively.

At 8 WAT, the NPK, 15 Mg ha^{-1}, and 20 Mg ha^{-1}-treated plants produced statistically similar results in the number of leaves which each were approximately 42.01% different from those of the control plot in the first growing season, while in the second growing season, the 15 Mg ha^{-}

1- and 20 Mg ha^{-1}-treated plots also statistically produced similar number of leaves which were approximately 35.46% different from those of the control plot.

The Leaf Area Index of Lettuce

The leaf area index of lettuce are presented in Table 6. The 20 Mg ha^{-1}-treated plots produced the highest leaf area index values at all the sampling periods of 4, 6, and 8 WAT which were significantly (p <0.05) different from those of the control treatment At 4WAT in the first growing season, the 20 Mg ha^{-1} and the 15 Mg ha^{-1} amended plots produced similar leaf area index which was approximately 10.65% higher than that of the control plot while in the second growing season, the NPK treated plot, 15 and 20 Mg ha^{-1} compost manure produced statistically similar leaf area index which was approximately 12.04 % different from that of the control plot.

At 6 WAT, the 20 Mg ha^{-1} amended plot produced the highest leaf area in the first growing season whereas in the second season, the 15 Mg ha^{-1} and the 20 Mg ha^{-1} amended plots produced similar values which were significantly (p<0.05) different from that of the control plot.

At 8 WAT, the NPK, 15, and 20 Mg ha^{-1}-treated plots produced statistically similar leaf area in the first growing season. The difference in this index between the 20 Mg ha^{-1}-treated plot and that of the control plot was approximately 10.91% in the first growing season. In the second growing season, the 20 Mg ha^{-1}-treated plot compost amended plot also produced the highest leaf area index, which was approximately 14.84% higher than that of the control plot.

Table 2. Effect of composted market waste and NPK fertilizer on physical and chemical properties of soil after harvest

Treatment (Mg ha^{-1})	pH in H_2O	OC %	OM %	N %	P Mg kg^{-1}	Ca (cmol$^+$ kg^{-1})	Mg (cmol$^+$ kg^{-1})	EC %	K (cmol$^+$ kg^{-1})
Control	6.43b	0.42	0.72	0.06b	7.45a	0.78c	0.19b	2.91c	0.17c
NPK (kg ha^{-1})	6.53a	0.41	0.71	0.06b	7.79a	0.91b	0.18b	5.86b	0.30b
Comp. 5	6.23d	0.60	1.03	0.11a	8.64a	0.83c	0.19b	3.90c	0.18c
Comp. 10	6.33c	0.62	1.06	0.15a	7.11a	0.70d	0.11c	4.58bc	0.09d
Comp. 15	6.40b	0.64	1.10	0.16a	8.89a	0.56e	0.22a	7.49a	0.08d
Comp. 20	6.46ab	0.66	1.13	0.19a	6.18b	1.46a	0.24a	7.82a	0.40a
SED (p<0.05)	0.069	Ns	ns	0.081	2.29	0.05	0.017	1.736	0.016

*Values followed by the same letter do not differ significantly at p <0.05. Comp. = Compost. SED = Standard error of the difference of means, Ns = not significant

Table 3. Effect of compost manure and NPK fertilizer on the soil moisture content (%) of the soil of lettuce at 4, 6, and 8 weeks after transplanting (WAT) in the two growing seasons

		4 WAT		6 WAT		8 WAT	
		Growing season					
Treatment	Rate (Mg ha^{-1})	1	2	1	2	1	2
Control	0	25.74c	24.05d	23.20d	22.88d	22.77d	25.15d
NPK (kg ha^{-1})	300	27.45c	24.07d	23.78d	22.92d	23.29d	25.06d
Comp. manure	5	30.57b	31.37c	25.25c	31.02c	26.05c	27.38c
Comp. manure	10	32.61b	33.11b	26.77b	33.45b	26.96b	28.30b
Comp. manure	15	36.50a	34.52a	28.28a	34.92a	27.60a	29.28a
Comp. manure	20	36.85a	35.09a	29.13a	35.65a	27.77a	29.43a
SED (p<0.05)		0.986	0.507	0.553	0.423	0.250	0.323

*Values followed by the same letter do not differ significantly at p <0.05. Comp. = Compost, SED = Standard error of the difference of means

Table 4. Effect of compost manure and NPK fertilizer on the plant height (cm) of lettuce at 4, 6. and 8 weeks after transplanting (WAT) in the two growing seasons

		4 WAT		6 WAT Growing season		8 WAT	
Treatment	Rate (Mg ha^{-1})	1	2	1	2	1	2
Control	0	4.71f	5.67f	6.01f	6.96f	8.21f	9.16f
NPK (kg ha^{-1})	300	5.81c	6.76c	8.46c	9.42c	9.86c	10.82c
Comp. manure	5	5.40e	6.35e	6.17e	7.13e	9.33e	10.27e
Comp. manure	10	5.73d	6.67d	6.97d	7.93d	9.62d	10.57d
Comp. manure	15	7.51b	8.46b	9.52b	10.47b	10.96b	11.93b
Comp. manure	20	9.46a	10.42a	11.51a	12.47a	12.31a	13.26a
SED (p<0.05)		0.011	0.011	0.010	0.009	0.008	0.011

*Values followed by the same letter do not differ significantly at p <0.05. Comp. = Compost, SED = Standard error of the difference of means

Table 5. Effect of compost manure and NPK fertilizer on the number of leaves of lettuce at 4, 6 and 8 weeks after transplanting (WAT) in the two growing seasons

		4 WAT		6 WAT Growing season		8 WAT	
Treatment	Rate (Mg ha^{-1})	1	2	1	2	1	2
Control	0	6.54e	6.63e	8.32d	9.57e	9.66c	10.92d
NPK (kg ha^{-1})	300	6.84c	6.95c	15.02b	15.23c	16.66a	16.35b
Comp. manure	5	6.66d	6.79d	14.33d	14.92d	16.01b	16.24c
Comp. manure	10	6.83c	6.96c	14.66c	14.57e	16.02b	16.26bc
Comp. manure	15	7.01b	7.13b	15.02b	15.26b	16.66a	16.92a
Comp. manure	20	7.16a	7.29a	15.66a	15.92a	16.66a	16.93a
SED (p<0.05)		0.115	0.045	0.124	0.09	0.115	0.440

*Values followed by the same letter do not differ significantly at p <0.05. Comp. = Compost, SED = Standard error of the difference of means

Table 6. Effect of compost manure and NPK fertilizer on the leaf area index of lettuce at 4, 6, and 8 weeks after transplanting (WAT) in the two growing seasons

		4 WAT		6 WAT Growing season		8 WAT	
Treatment	Rate (Mg ha^{-1})	1	2	1	2	1	2
Control	0	1.51e	1.46d	2.08f	2.15e	2.53d	2.41e
NPK (kg ha^{-1})	300	1.67b	1.64ab	2.51c	2.53b	2.80ab	2.75bc
Comp. manure	5	1.54d	1.51c	2.30e	2.40d	2.72c	2.65d
Comp. manure	10	1.62c	1.61b	2.44d	2.46c	2.75bc	2.71c
Comp. manure	15	1.69a	1.63ab	2.56b	2.59a	2.82ab	2.78b
Comp. manure	20	1.69a	1.66a	2.68a	2.60a	2.84a	2.83a
SED (p<0.05)		0.007	0.019	0.014	0.023	0.030	0.017

*Values followed by the same letter do not differ significantly at p <0.05. Comp. = Compost, SED = Standard error of the difference of means

The Yield of Lettuce Per net Plot and Per Hectare

The yield of lettuce per net plot as affected by compost manure and NPK fertilizer is presented in Table 7. In the first and second growing seasons, the excellent trend exhibited by the 20 Mg ha^{-1} amended plot was maintained by producing the highest yield per net plot, which was approximately 57.17% and 65.52% higher than that of the control plot in the first and second growing seasons, respectively. It was closely followed by the yield of 15 Mg ha^{-1}-treated plots which were approximately 55.39% and 64.64% higher than that of the control plot in the first and second growing seasons, respectively.

The 20 Mg ha^{-1}-treated plots produced the highest yield, which were approximately 57.17% and 65.64% higher than that of the control plot in the first and second growing seasons respectively. This was closely followed by the yield of 15 Mg ha^{-1}-treated plots, which were approximately 53.16% and 64.60% greater than that of the control plot in the first and second growing seasons, respectively. Whereas the difference between the control plot and NPK-treated plots were approximately 52.70% and 64.37% in the first and second growing seasons respectively. Overall, the yield of control plot was significantly different ($p<0.05$) from the other treatments in both growing seasons.

Vitamins A and C Contents of Lettuce

The effects of compost manure and NPK fertilizer on the lettuce's vitamin A and vitamin C contents are presented in Table 8. The 20 Mg ha^{-1}-treated plot produced the highest vitamin A content, which was significantly different from the control in the first and second growing seasons. The difference between the vitamin A contents of the 20 Mg ha^{-1}-treated plot and the control plot was approximately 14% and 29.50% in the first and second growing seasons, respectively.

The 20 Mg ha^{-1}-treated plot also produced the highest vitamin C content, which was approximately 3.03% and 1.29% higher than that of the control plot in the first and second growing seasons, respectively.

Table 7. Effect of compost manure and NPK fertilizer on the yield of lettuce in the two growing seasons

		Yield/net plot (g)		Yield (Mg ha^{-1})	
		Growing season			
Treatment	Rate (Mg ha^{-1})	1	2	1	2
Control	0	32.31f	25.02f	14.96f	11.58f
NPK (kg ha^{-1})	300	68.33c	64.76c	31.63c	29.9 8c
Comp. manure	5	55.62e	57.02e	25.75e	26.40e
Comp. manure	10	64.47d	63.00d	29.85d	29.17d
Comp. manure	15	72.42b	70.66b	33.53b	32.71b
Comp. manure	20	75.45a	72.67a	34.93a	33.64a
SE ($p<0.05$)		0.401	0.396	0.186	0.184

*Values followed by the same letter do not differ significantly at $p<0.05$. Comp. = Compost, SED = Standard error of the difference of means

Table 8. Effect of compost manure and NPK fertilizer on vitamin A and C contents of lettuce in the two growing seasons

		Vitamin A (mg 100g^{-1})		Vitamin C (mg 100g^{-1})	
		Growing season			
Treatment	Rate (Mg ha^{-1})	1	2	1	2
Control	0	0.086d	0.086d	20.16	20.56
NPK (kg ha^{-1})	300	0.099a	0.104b	20.78	20.82
Comp. manure	5	0.089c	0.091c	20.61	20.61
comp. manure	10	0.097b	0.099b	20.70	20.74
Comp. manure	15	0.100a	0.122a	20.75	20.78
Comp. manure	20	0.099a	0.091c	20.79	20.83
SE ($p<0.05$)		0.000812	0.0097	Ns	Ns

*Values followed by the same letter do not differ significantly at $p<0.05$. Comp. = Compost, SED = Standard error of the difference of means, Ns = not significant

DISCUSSION

The low nutrient composition of the soils of the study site is because of the low organic content and this is in line with the report of Eifediyi *et al.* (2016). This forms the basis for the inability of meaningful cultivation to take place in this area, especially for vegetables and cereals crops without the use of organic and inorganic fertilizers. At the end of the growing season, there was an improvement in the soil's physical and chemical properties due to the application of compost manure in the experiments of this study. This is corroborated by Parwada et al. (2020) who observed that the application of compost manure would increase the quality, and yield of agricultural products, and also enrich soil fertility, and improve the physical and chemical properties. In addition, Eifediyi et al. (2016) reported that the application of poultry manure, which is a form of organic manure, improved the physical and chemical properties of the soil of the study site.

The high moisture retention capacity of the soils treated with compost manure could be attributed to an increase in the organic matter content of the soil, and the proliferation of microorganisms (Vengadaramana and Jashothan, 2012) in the soil, which engaged in burrowing thereby creating macro pores spaces in the soil. This explains the treatment's ability to hold water and nutrients. The high organic matter content of the treated plots is what is lacking in the soils of the study site and the main reason why the soils have low water retention capacity. Compost is a valuable product that improves organic matter content, improved soil structure, nutrient availability, and water-holding capacity (Benabderrahim et al., 2018; Mostafa et al., 2019).

The increase in the plant height could be attributed to the availability of plant nutrients to the crop for physiological processes in the crop. This effect could be due to the presence of phytohormones in organic fertilizers that stimulates plant growth (Nogales et al., 2005). These nutrients in the form of N, P, and K and micronutrients are needed for cell elongation, cell division, multiplication, and other metabolic activities. It has been shown that the use of amendment improve the growth, thereby improving the quality, of plants (Zandvakili et al., 2019a; 2019b). The use of amendment has been found to improve the plant height of crops for proper display of its leaves for photosynthesis (Zulfiqar et al., 2021).

The increase in the number of leaves of lettuce in the amended plots across the sampling occasions meant that, with more leaves, the crop could have the capability of capturing and utilizing more solar energy (Martin and Marsh, 2006), which in turn, provided more energy which was utilized for photosynthesis. This further underscores the importance of manure in the growth and development of crops. In addition, the increase in number of leaves per plant in the compost-amended plots could be linked to the presence of nutrients in adequate amounts during the growth period of the crop. Similar results have been reported by Eifediyi et al. (2022) who used *Tithonia diversifolia* and cattle manure in sesame, and by Aboyeji (2019) who used cattle manure in radish.

The high leaf area index (LAI) of the amended plots could be attributed to the nutrients, which were available for the photosynthetic activities of the plant and other physiological activities. The LAI obtained in the current study was within the range of what was reported for lettuce in California USA by Miller (2022) by using medium and high fertilizer. The high leaf area index per plant might be due to the increase in soil organic matter content, which can increase the soil fertility as well as retain moisture and release nutrients slowly for crop uptake as well as food for soil microorganisms (Negi *et al*., 2017; FAO, 2002). The result was also in agreement with the findings of Masarirambi *et al.* (2012), who reported that poultry manure increased the leaf area of lettuce compared to inorganic fertilizer.

The increase in the lettuce yields and the differences in lettuce development noticed because of compost manure incorporation in this study could be explained by the increase in the organic matter improvement of the soil. The yield of lettuce was therefore within the range of 20–40 Mg ha^{-1} which has been reported by the International Fertilizer Industry Association (IFA 1991), which is the average yield of lettuce globally. The higher the manure application rate, the higher the yield. This explains why farmers agitate for the application of organic manure for their vegetables due to the abundance of macro and micronutrients (Wang *et* al., 2016). The increase in yield could be ascribed to the improvement of the physical and chemical properties of the soil. This was in agreement with the findings of Boutchich *et al*. (2018) and Xu *et al.* (2005) who also reported that vegetables cultivated using high levels of organic manures grew better and gave a higher total yield than those grown treated with inorganic fertilizers.

The vitamins contents further validate the findings of Chiesa *et al.* (2009) who observed the presence of vitamins A and C in significant amounts in lettuce and also reported that the content of vitamin C (ascorbic acid) is higher with the amended plots compared to the control.

CONCLUSIONS

Lettuce is becoming one of the most important vegetables in Nigeria as well as in other tropical countries, and the use of compost manure is an essential factor for the growth of the crop. Thus, selection of a suitable rate is important, especially with the increasing cost of inorganic fertilizer. In this study, the use of compost manure at the rate of 15 and 20 Mg ha^{-1} was better than the use of inorganic fertilizer, as the two manure rates demonstrated their importance in the improvement of the growth and yield of lettuce. The compost manure also improved the physical and chemical properties of the soil as well as the vitamin contents. Farmers are therefore encouraged to use compost manure for the improvement of the growth and yield of lettuce, as the cost of inorganic fertilizer is soaring.

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تأثیر کود کمپوست شهری بر خصوصیات فیزیکی خاک، رشد، عملکرد و کیفیت کاهو

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چکیده - بیشتر خاک های نزدیک به مراکز شهری اغلب به دلیل کشت فشرده تخریب می شوند و در نتیجه مقدار مواد آلی کم و مواد مغذی گیاه کم می شود. بقایای مواد گیاهی اغلب در بازارهای شهری در نیجریه رها می شوند و دفع آنها توسط شوراهای محلی گران است. بنابراین این مواد باعث ایجاد مزاحمت برای محیط زیست می شوند. با این حال، این مواد را می توان کمپوست کرد و به عنوان اصلاح کننده خاک استفاده کرد. یک آزمایش مزرعه ای در یک مزرعه آموزشی و تحقیقاتی دانشگاه ایلورین، ایلورین، نیجریه در طول فصل زراعی ۱۳۹۸ - ۱۳۹۷ برای ارزیابی اثرات زباله های شهری به عنوان کمپوست بر رشد، عملکرد و ترکیب تغذیه ای کاهو انجام شد. آزمایش در قالب طرح بلوک های کامل تصادفی چهار بار تکرار شد. میزان مصرف کمپوست شامل ۰، ۵، ۱۰، ۱۵، ۲۰ میلی گرم در هکتار و NPK به میزان ۳۰۰ کیلوگرم در هکتار بود. داده ها بر روی پارامترهای رویشی شامل ارتفاع بوته، تعداد برگ و شاخص سطح برگ و پارامترهای عملکرد شامل عملکرد در کرت خالص، عملکرد در هکتار و ترکیب ویتامین های A و C جمع آوری شد. نتایج نشان داد که کاربرد کود کمپوست باعث بهبود خواص فیزیکی و شیمیایی خاک از جمله ظرفیت نگهداری آب شد بطوریکه ظرفیت نگهداری آب در فصل های زراعی اول و دوم به ترتیب ۲۷/۷۷ درصد و ۲۹/۴۳ درصد بهبود یافت. استفاده از کمپوست ۲۰ میلی گرم در هکتار به ترتیب در فصل زراعی اول و فصل زراعی دوم رشد و عملکرد بهتری (۳۴/۹۳ و ۳۳/۶۴ مگا در هکتار) داشت. در نتیجه، کشاورزان، به ویژه در مناطق شهری، می توانند محصول کاهو خود را با استفاده از کود کمپوست بکارند تا عملکرد بیشتری داشته باشند.