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Research Article

Coated Micronutrients and Organic Manures Impact on Soil Chemical Properties, Growth and Yield of Okra (*Abelmoschus esculentus* (L.)Moench)

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Abstract
A field experiment was conducted in the 2022 growing seasons at the Kwara State University's Teaching and Research Farm in Malete, Kwara state. The goal was to ascertain how applying organic manure and micronutrient fertilizers together will affect the physicochemical properties of the soil, agronomic performance and Okra production (Abelmoshus esculentus).Treatments consisted of: T1-. Control. T2- 10 t/ha of Poultry manure + 10 kg/ha of Urea coated with Zn. T3- 10 t/ha of Poultry manure + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu). T4- 10 t/ha of Poultry manure + 10 kg/ha of Urea coated with B. T5- 10 t/ha of Cow dung + 10 kg/ha of Urea coated with Zn. T6- 10 t/ha of Cow dung + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu). T7- 10 t/ha of Cow dung + 10 kg/ha of Urea coated with B. T8- 10 t/ha of Goat manure + 10 kg/ha of Urea coated with Zn. T9- 10 t/ha of Goat manure + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu). T10- 10 t/ha of Goat manure + 10 kg/ha Urea coated with B. Application of 10 t/ha poultry manure plus 10 kg/ha of urea treated with zinc had a significant and additive impact on soil nutrients (N, P, K, Org C, Zn and Cu), while application of 10 t/ha poultry manure plus 10 kg/ha of crop mix containing 17% Zn, 18% Mn, 2% B, 1% Fe, and 1% Cu had a significant and additive impact on okra growth and yield (1,393.6 kg/ha). The results of this study showed that manure and micronutrient fertilizer might be combined to boost okra production.

Keywords: Animal manure, Micronutrients fertilizers, Okra, Soil micronutrient, Yield

Introduction

Undoubtedly one of the most significant vegetables grown in Nigeria is okra (*Abelmoschus esculentus* L.). It is an annual crop primarily grown as fruits and leafy vegetables in the tropics, both in their green and dried states. (Tiamiyu *et al*., 2012). Antioxidants, fiber, vitamin C, and folate are all present in the fruits of okra plants. The seeds contain oil that can be used to make soap as well as food for humans (Adekiya *et al*., 2020).

Over 10 million tons of pods are produced worldwide by the okra crop, which is farmed on about 2 million hectares. India is the leading producer with over 6 million tons of freshly harvested pods, followed by Nigeria with approximately 2 million tons (FAOSTAT, 2018.). Over 10% of the world's okra production is consumed in both West and Central Africa. Due to the increased local and global demand for fresh vegetables, medicines, and biofuels, okra's economic significance is expanding (Schafleitner *et al*., 2021). Animal manure is an important source of N, P, and K. When added to soil, it increases the soil's amount of available P, exchangeable K, Ca, and Mg, and improves the

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accessibility of microelements to plants (Magdoff, 1998; Herencia *et al*. (2008). The impact of poultry manure on the growth and productivity of okra has been studied extensively in the past (Ofosu-Anim *et al*., 2006; Ntia et *al*., 2017). Manure has various advantageous effects on the soil's physical characteristics in addition to providing nutrients for crop growth. According to a number of studies, applying organic waste increases soil's structural stability, lowers bulk density by increasing the organic matter in the soil and achieving a balance between fine and coarse pores, and increases soil's moisture retention, rate of water infiltration, and hydraulic conductivity (Eden *et al*., 2017; Abdelrhman *et al*., 2021).

Micronutrients are involved in the number of indispensable processes in plant (Babar *et al*., 2018). The growth, productivity, and quality of vegetable crops are significantly influenced by micronutrient fertilizer. Although plants only need a small amount of micronutrients like Zn, Cu, Mn, Fe, B, and Mo to function normally, they are crucial for metabolic processes like cell wall development, respiration, photosynthesis, chlorophyll formation, enzyme activity, and nitrogen fixation. As a result, they are essential for normal crop production (Polara *et al.*, 2017). Plants need zinc, which is an important micronutrient.

Zinc plays a significant role in the activation of several enzymes, including protease, peptidase, amylase, and phosphohydrolases. The ribosome, RNA, and auxin are developed by zinc, and phosphate protein and carbohydrates are also activated by zinc **(**Akbar *et al*., 2019). Similarly, boron is one of the essential micronutrients that enhance major cellular functions and metabolic actions, which has a positive impact on many plant characteristics and promotes vascular plant growth and development (El-Hamdaoui *et al*., 2003). Coating helps the fertilizer to dissolve gradually in the soils. Due to their synergistic action and increased production of N-protein, Cu and Zn coated urea enabled plants to absorb more nitrogen. According to Shivay et al. (2019), the application of Zn-coated urea increased the yield of aromatic rice grains. According to Abdullah *et al*. (2022), coated Zn results in increasing nitrogen use efficiency and provided zinc micronutrients efficiently to soil and plant along with the improvement in the availability of other soil nutrients.

Most of the coated controlled release urea reported in various studies has not been applicable to okra production, and there is lack of awareness of these coated micronutrients to Nigeria farmers.

In the light of the aforementioned facts, this experiment was design with the intention of using coated urea-based micronutrient fertilizers, which were thought to be more effective in terms of nitrogen use efficiency, have micronutrient components, and contribute positively to the physical and chemical properties of soil. It was anticipated that coated micronutrient fertilizer treatments will increased okra yield when combined with poultry manure.

Materials and Methods

Location of the Experiment and Soil Characteristics

A field experiment was conducted in the Southern Guinea savanna region of Nigeria at the Teaching and Research Farm of Kwara State University in Malete (08^0 42′ 48.5″N and 004^0 26′ 17.9″E). The climate is defined by a mean annual temperature that ranges from 25 to 28.9 ^oC and by both rainy and dry seasons. Additionally, the twofold maximal pattern between April and October of every year is visible in the yearly mean rainfall, which is roughly 1,150 m. The land area of Kwara State University is a portion of the Nigerian basement complex's south-western zone, which is a region of basement plutonism and recurrence of the Pan-African orogeny (Olowoake, 2017).

Soil Analysis

Surface soil samples (0–15 cm depth) were collected from the experimental field to determine the physical and chemical compositions of the soil before and after fertilizer application. The soil samples were air-dried and sieved (<2 mm). Representative samples were examined for pH, particle size (Bouyoucos, 1962), total nitrogen (Bremmner, 1982) and pH using a 1:2 (soil:water) suspension. The contents of the exchangeable cations (K, Ca, Mg, and Na) were extracted with 1M NH_4OAc (pH 7). K was measured using a flame photometer in the filtered extract, whereas Ca, Na, and Mg were measured using an atomic absorption spectrophotometer. Utilizing a colorimeter and the Bray and Kurtz, (1945), method for determining available phosphorus (Bray-1-P) and the method given by (Juo, 1981). Coated Zinc, boron, crop mix, cow dung, poultry manure, and goat manure are some of the fertilizers used. The nutrient analysis of dried and cured cow dung, poultry manure and goat manure are summarized in Table 1.

Field Study

The 10 treatments consisted of 10 t/ha of Poultry manure + 10 kg/ha of Urea coated with Zn, 10 t/ha of Poultry manure + 10 kg/ha of Crop Mix micronutrient fertilizer (17% Zn, 18% Mn, 2% B, 1% Fe and Cu), 10 t/ha of Poultry manure + 10 kg/ha of Urea coated with B, 10 t/ha of Cow dung + 10 kg/ha of Urea coated with Zn, 10 t/ha of Cow dung + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu), 10 t/ha of Cow dung + 10 kg/ha of Urea coated with B, 10 t/ha of Goat manure + 10 kg/ha of Urea coated with Zn, 10 t/ha of Goat manure + 10 kg/haof Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu), 10 t/ha of Goat manure + 10 kg/ha Urea coated with B and control arranged in a randomized complete block design with three replicates. The area was harrowed twice and plowed once. The area was 8.75 m^2 in size, measuring 2.5 m × 3.5 m, with 0.5 m between plots and 1.0 m between blocks. Four seeds were sown with a 0.6 and 0.3 m inter and intra row spacing, respectively. Two weeks after planting (WAP), crops were thinned to two plants per stand. The mineral fertilizer was applied two weeks after planting, while the organic manures were applied two weeks prior to planting. This was followed by manual weeding at 5 WAP to keep the experimental plot weed free. Using a knapsack sprayer, cyhalothrin was used to control insect pests at a rate of 1 ml per liter of water.

Data Collection and Analysis

The days to 50% flowering were noted, along with the plant height at fruiting, stem girth, number of fruits per plant, fruit length, fruit diameter, and fresh fruit weight at each harvest. Fruits were picked eight times, at four-day intervals. The obtained data were statistically analyzed for variance, and Duncan's Multiple Range Test (DMRT) was used to determine whether there were any significant differences between the treatment means at the 5% level of probability.

Results and Discussion

Soil and poultry manure analysis

The soil had a pH of 6.65, which is slightly acidic, as shown in Table 2. Nitrogen, exchangeable K and available phosphorus were all at low levels. The soils belong to the loamy sand textural class. The experimental soil's Nitrogen, available phosphorus, calcium, and magnesium values were below the critical level (Olowoake, 2017), thus making it necessary for the application of soil amendment in form of organic and micronutrient fertilizers. The manures used was slightly richer in nitrogen compared to the un-amended experimental soils of the study location.

Plant growth parameters

Application of coated micronutrient fertilizers along with manures had a substantial impact on the growth of okra (Table 3). In comparison to other treatments, the plots treated with 10 t/ha of Poultry manure with 10 kg/ha of urea coated with Zn (T2) yielded higher values for plant height, number of leaves and stem girth. These values were significantly higher ($P<0.05$) when compared with other treatments. Plots treated with 10 t/ha of Cow dung + 10 kg/ha of Zn-coated urea (T5), and 10 t/ha of Cow dung + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe, and 1% Cu) (T6) and10 t/ha of Cow dung plus 10 kg/ha of urea coated with B (T7) produced statistically better values than T8, T9, and T10.The control without fertilizer had significantly lower plant height as compared to other treatments. The physiology of plants is greatly influenced by micronutrients. According to Polara *et al*. (2017) the role that micronutrients play in fundamental cellular mechanisms and respiration processes may account for the rise in growth features caused by these nutrients. Animal manures have been demonstrated to provide the nutrients plants need, enhance soil quality and water retention, raise microbial population, and encourage plant growth (Aboyeji*et al*., 2018). In line with the findings of Ali *et al*. (2019), they claimed that organic manure is a supplementation dose that increases plant cell division as a result of taller plants being produced, the maximum plant height observed from T2 (10 t/ha of Poultry manure + 10 kg/ha of Urea coated with Zn) is consistent with this assertion. The involvement of Zn in photosynthesis by increasing the amount of chlorophyll in the leaves and making Mg available to the plant may be the cause of the improvement in the development parameters of okra with the use of Zn-fertilizer (Aboyeji *et al*., 2021).

Yield and components of okra yield

According to Table 4, there were significant ($P<0.05$) differences between the fertilizer treatments in terms of the yield and yield components of the okra plants. Similar patterns emerged in all of the fertilizer treatments for days to 50% flowering. When compared to other treatments, the areas where neither fertilizer was administered took longer to flower. Although not statistically significant, the days to flower were shortened for the treatments; T2, T3 and T4. Application of 10 t/ha of poultry manure combined with 10 kg/ha of urea coated with zinc (T2) resulted in noticeably longer fruits than other treatments. Between T5, T6, T7, T8, T9, and T10, the fruit length did not significantly differ. At the control treatment, shorter fruit length was seen. The most fruits were produced per plant in plots treated with 10 t/ha of poultry manure plus 10 kg/ha of urea coated with zinc (T2). The use of T5, T6, and T7 resulted in the production of similar amount of fruits. The control treatment had the fewest fruits recorded (T1). Okra fruit yield was highest (1,393.6 kg/ha) in plot treated with T2. This treatment's recorded fruit yield was significantly different from all the other treatments. Fruit yield was comparable when T3, T5, T6, and T9 were applied. The lowest fruit yield, however, is produced by the control treatment (233.2 kg/ha). The increased okra yield may be the result of more zinc being available, which leads to the biosynthesis of Indole-3-acetic acid (IAA) and its role in the initiation of primordial of reproductive parts and assimilate partitioning towards them, which in turn causes an increase in flowering and fruiting and taps more yield (Sankavi *et al*., 2020).

Effects of integrated of manures and coated micronutrient fertilizers at Harvest

Table 5 shows the residual effect of applying manures and coated micronutrient fertilizers together on the experimental soils at harvest. When the plant (*Abelmoschus esculentus*) was ready for harvest, the pH ranged from 5.25 in the control plot to 6.81 in the 10 t/ha of poultry manure + 10 kg/ha of crop mix (10 t/ha, 17% Zn, 18% Mn, 2% B, 1% Fe and Cu) plot. T3 raised the pH of the soil more than every other treatment, including control. According to Olowoake *et al*. (2013), the increase in the soil pH levels of the plots following crop harvest is a sign of the organic fertilizer's buffering ability. The soil's available P level ranged from 21.92 mg kg^{-1} in the control plot to 78.84 mg kg^{-1} in T3 plot. P was considerably greater in the plot treated with T3 compared to the plots treated with other goat manure (10 t/ha) and cow dung (10 t/ha) with crop mix. The rise could be attributed to poultry manure's high microbial activity, which could promote phosphorous cycling and affect the increase in available P after the application of organic fertilizer and micronutrients. From 1.89 g kg^{-1} in the control plot to 3.74 g kg^{-1} in the T3 plot. From the control to the combined application of organic and micronutrient fertilizers, there is an overall increase in the levels of organic carbon. This is in line with the finding of Olowoake *et al*. (2022), who noted that the usage of organic and mineral mixtures enhanced organic carbon content more than any of them employed alone. Between 0.23g kg^{-1} in the control plot and 0.41g kg^{-1} in the T3 plot, total N varied. The available K content of the soil in the control plot was 0.11 cmol kg^{-1}, whereas it was 0.29 cmol kg^{-1} in the plot treated with 10 t/ha of poultry manure plus 10 kg/ha of crop mix containing 17% Zn, 18% Mn, 2% B, 1% Fe, and 1% Cu. Additionally, the outcome demonstrates that Fe, Cu, and Zn levels rose following harvest. The mineralization of the crop mix and poultry manure (17% Zn, 18% Mn, 2% B, 1% Fe and Cu) may be the cause of these increases. This demonstrates that fertilizers containing micronutrients and poultry manure are effective sources of nutrients for the soil system.

Conclusion

According to the results of the current study, the treatment (10 t/ha of poultry manure plus 10 kg/ha urea coated with Zn) increased okra yield, but the yield from the control treatment was lower. The treatment (10 t/ha of poultry manure and a crop mix with 17% Zn, 18% Mn, 2% B, 1% Fe and Cu) also had a significant and additive impact on soil nutrients (N, P, K, Org C, Zn and Cu). This demonstrated that when organic fertilizer and micronutrients are applied combined, there is a very real possibility for the long-term buildup of residual nutrients in the soil.

Declaration of competing interest.

The author has no material, nonfinancial or financial interests to disclose.

Authors' contributions

The author worked alone to complete this task. The study was conceived by author OAA, who also prepared the protocol, conducted the fieldwork, analyzed the data, oversaw the literature searches, authored the first draft, and gave final approval for publishing.

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Table 1: Chemical composition of cow dung, goat and poultry manure

	Nutrient (%)		
	Nitrogen (N)	**Phosphorus (P)**	**Potassium (K)**
Cow dung	3.19	0.14	0.017
Goat manure	2.35	0.18	0.130
Poultry manure	1.84	0.54	0.015

Table 2: Physicochemical properties of Teaching and Research Farm

Parameters	Values
pH(H_2O)	6.65
Organic Carbon (%)	2.13
Total Nitrogen (%)	0.23
Available Phosphorus (mg/kg)	4.00
Exchangeable bases(cmol/kg)	
Calcium	2.83
Magnesium	0.91
Potassium	0.16
Sodium	0.96
Extractable micronutrients (mg/kg)	
Manganese	96.0
Iron	103.0
Copper	1.27
Zinc	1.40
Sand %	82.0
Silt %	12.0
Clay %	6.0
Textural class	Loamy sand

Table 3: Effect of applying manures and coated micronutrient fertilizers on the growth parameters of okra in 2022 cropping season

Treatment	Plant height (cm)	Number of leaves	Stem Girth (mm)
Control (T1)	30.2e	15.8d	10.5d
10 t/ha of Poultry manure + 10 kg/ha of Urea coated with Zn(T2)	72.3a	26.8a	18.8a
10 t/ha of Poultry manure + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu) (T3)	64.3b	23.2b	18.6a
10 t/ha of Poultry manure + 10 kg/ha of Urea coated with B (T4)	62.0b	21.2b	17.8a
10 t/ha of Cow dung + 10 kg/ha of Urea coated with Zn (T5)	57.1c	18.6c	15.6b
10 t/ha of Cow dung + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu) (T6)	58.5c	18.7c	16.1b
10 t/ha of Cow dung + 10 kg/ha of Urea coated with B (T7)	55.4c	19.1c	16.8b
10 t/ha ofGoat manure + 10 kg/ha of Urea coated with Zn (T8)	49.7d	18.8c	14.6c
10 t/ha of Goat manure + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu)(T9)	47.1d	17.1c	14.8c
10 t/ha of Goat manure + 10 kg/ha of Urea coated with B (T10)	50.2d	17.5c	14.4c

Means having the same letter along the columns indicates no significant difference using Duncan Multiple Range Test at 5% probability level.

Table 4: Effects of combined application of manures with coated micronutrient fertilizers on okra yield and yield components

Treatment	**Days to 50% flowering**	**Fruit diameter (mm)**	**Fruit length (cm)**	**No of fruit per plot**	**Fruit yield (kg/ha)**
T1	40.0a	20.9d	9.0d	18.5e	233.2g
T2	31.0c	55.9a	14.5a	46.9a	1,393.6a
T3	32.0c	41.2b	13.0a	35.7b	939.2b
T4	32.3c	42.5b	12.5a	35.9b	618.3c
T5	36.3b	38.7bc	11.9b	32.7b	747.1c
T6	34.7b	36.5bc	11.7b	29.4c	629.3c
T7	35.3b	39.9b	11.2b	29.6c	546.3d
T8	36.6b	32.5c	10.8c	22.9c	409.6e
T9	37.7b	31.4c	10.9c	23.1d	628.2c
T10	38.2b	30.5c	10.7c	21.8d	467.1f

Means having the same letter along the columns indicates no significant difference using Duncan Multiple Range Test at 5% probability level

Legend:: T1-. Control. T2- 10 t/ha of Poultry manure + 10 kg/haof Urea coated with Zn. T3- 10 t/ha of Poultry manure + 10 kg/haof Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu). T4- 10 t/ha of Poultry manure + 10 kg/haof Urea coated with B. T5- 10 t/ha of Cow dung + 10 kg/haof Urea coated with Zn. T6- 10 t/ha of Cow dung + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu). T7- 10 t/ha of Cow dung + 10 kg/ha of Urea coated with B. T8- 10 t/ha of Goat manure + 10 kg/ha of Urea coated with Zn. T9- 10 t/ha of Goat manure + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu). T10- 10 t/ha of Goat manure + 10 kg/ha Urea coated with B.

Table 5: Physicochemical properties of soil after planting

Treatments	pH (H_2O)	Available P mg kg^{-1}	Org C	N	K cmol kg^{-1}	Clay	Silt	Sand	Fe	Cu	Zn
			g kg^{-1}			%			mg kg^{-1}		
T1	5.25e	21.92d	1.42d	0.23bcd	0.11e	6d	10b	70a	61.30d	5.23c	6.8c
T2	6.59bc	75.88a	2.65b	0.29bc	0.19cd	6d	13ab	81a	81.20a	7.10a	9.6e
T3	6.81a	78.84a	3.74a	0.41a	0.29a	8bc	14a	78a	96.58a	8.16a	13.75a
T4	6.62b	76.4a	2.85b	0.31bc	0.27ab	8bc	14a	78a	74.85b	6.37b	11.8b
T5	6.43cd	37.44c	1.89bc	0.16e	0.18cd	7cd	12ab	81a	67.35c	6.15b	9.25e
T6	6.25cd	45.04b	2.72b	0.3bc	0.23bc	9ab	11b	80a	74.50b	5.45c	7.16f
T7	6.67bc	39.34c	1.80bc	0.2de	0.22bcd	7cd	13ab	80a	61.86	5.28c	7.5f
T8	6.65bc	38.32c	2.38b	0.26bcd	0.17d	8bc	13ab	79a	72.30b	6.86b	10.3cd
T9	6.31d	45.92b	2.21b	0.24cde	0.27ab	8bc	11b	81a	70.65b	5.38c	7.35f
T10	5.95e	39.92c	2.26b	0.34ab	0.26ab	10a	12ab	78a	69.80b	6.35b	10.15d

Means having the same letter along the columns indicate no significant difference using Duncan Multiple Range Test at 5% probability level

Legend: T1-. Control. T2- 10 t/ha of Poultry manure + 10 kg/haof Urea coated with Zn. T3- 10 t/ha of Poultry manure + 10 kg/haof Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu). T4- 10 t/ha of Poultry manure + 10 kg/haof Urea coated with B. T5- 10 t/ha of Cow dung + 10 kg/haof Urea coated with Zn. T6- 10 t/ha of Cow dung + 10 kg/ha of Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu). T7- 10 t/ha of Cow dung + 10 kg/ha of Urea coated with B. T8- 10 t/ha of Goat manure + 10 kg/haof Urea coated with Zn. T9- 0 t/ha of Goat manure + 10 kg/haof Crop Mix (17% Zn, 18% Mn, 2% B, 1% Fe and Cu). T10- 10 t/ha of Goat manure + 10 kg/ha Urea coated with B.