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Soil chemical properties and yield response of okra (*Abelmoschus Esculentus* l) to different organic fertilizer sources

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Abstract

Following the increase in Nigeria's population status and the current ban on food importation, there is dire need to increase food production to satisfy local demand. This can be achieved through adequate fertilization. Okra is an essential vegetable in Sub-Saharan Africa which is used in preparing continental dishes, especially in Nigeria. It is a quick-growing plant and has an early maturity period. Despite the usefulness of okra, it has progressively recorded low growth and yield performance. This is due to low soil nutrients associated with soils in the tropics. A study carried out in a greenhouse at the University of Nigeria, Nsukka, investigated the effects of animal manures (Cow Manure, CoM; Chicken droppings, CkD; and Pig Manure, PiM) applied at 15 t ha-1 equivalent rate on the soil and growth performance of okra grown in a degraded ultisol. The treatments (CoM; CoM; PiM and Control unamended) were laid out in a completely randomized design and replicated three times. Animal manure application had significant effects on soil properties. Soil organic matter increased by over 9% in the amended treatment relative to the Control treatment. Except for N, increases in P (circa 14-70%) and K (circa 15-46%) nutrients were higher for CkD treatment than in other treatments. Generally, the amended treatments maintained a significantly higher (p <0.05) plant leave number, stem girth, plant height, okra pod length and yields when compared with the Control treatment. The results obtained indicate that application of animal manure enhanced okra growth performance. The findings of the present study suggest that animal manure application can potentially increase okra yield when grown in degraded soil.

Keywords: Soil fertility, Organic fertilizers, Okra Growth, Yield response, Biomass.

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1.0. Introduction

An important vegetable that is widely cultivated, especially in the tropics and subtropics, for its immature edible green fruit which can either be eaten either raw or cooked, is okra (*Abelmoschus esculentus* L.). Okra plays a critical role in the tropical diet because the soft immature pods contain a glutinous sticky substance that is used as a soup thickener. Okra is a good source of vitamins and minerals, and it also contains a substantial amount of protein, carbohydrate and fat (Abidi, 2014). Okra leaves are medicinal and can be used as a curative medicine against ulcer and haemorrhage (Attigah et al., 2013). Okra is rich in fibre content can also enhance food digestion (Attigah et al., 2013).

One critical challenge facing food (okra) production in the tropics, especially Nigeria, is poor soil health. This has been attributed to continuous cropping of a piece of land for food with inadequate care for the land with respect to external nutrient (organic or inorganic fertilizer) application (Olujobi and Ayodele, 2013, Unagwu, 2019, Unagwu et al., 2019). Undoubtedly, inorganic fertilizers improve crop growth and yield performance. However, there are challenges associated with the use of inorganic fertilizers which make makes continuous use or application of inorganic fertilizers unsustainable. Some of these challenges include high procurement cost, scarcity, N nutrient loss through volatilization, high soil acidity with constant inorganic fertilizer application (Olujugba et al., 2016). Akpan-Idiok et al. (2012) reported that persistence use of inorganic fertilizer has a lasting negative effect on soil properties and soil fertility status due to its effect on soil nutrient balance.

With the challenges associated with inorganic fertilizer application, the use of organic manure to replenish soil nutrient appears a viable alternative. This is because organic manure improves plant nutrient use efficiency, enhances soil conditions by improving the physical, chemical, biological and hydrological properties of the soil (Unagwu, 2014; Olujugba et al., 2016). Organic manure also improves crop yield and reduces the impact of soil degradation (Unagwu, 2019). Crop production with respect to fertilizer application can only be sustained if soil fertility is maintained at a level that marches the crop requirement (Muhammed et al., 2017). Despite the low soil fertility status, most farmers apply an insufficient quantity of NPK fertilizer which is far below the recommended rate. This sort of agricultural practice can further deplete available soil nutrients and negatively affects crop yield performance. The study suggested that the application of manure can improve soil fertility status, increase crop yield and farmer's income (Eifediyi et al., 2015). However, to achieve increased crop yield following manure application, it is necessary to apply an adequate quantity of the manure (Akintomide et al., 2015). To feed the overly growing population, efficient soil management and acceptable agricultural practices are critically essential. This is because crop production is mainly dependent on soil health, and proper soil nutrient management is critical to achieving sustainable crop production. Thus, this study evaluated the effects of the application of organic (animal) manure on soil properties and growth and yield of okra.

2.0 Materials and Methods

A study was set up in a complete randomized design (CRD) with three replications to evaluate the effects of animal manure application on soil properties and growth performance of okra. A 0-15 cm test soil was collected from the Department of Soil Science Research Farm, University of Nigeria, Nsukka, UNN. The animal manure (cow manure, CoM, chicken manure, CkD, and pig manure, PiM) were gotten from Faculty of Agriculture Research Farm, UNN. The study treatments were: CkD applied at 15 t ha^{-1}; CoM applied at 15 t ha^{-1}; PiM applied at 15 t ha^{-1}; and the control, with no amendment application. A 10 kg air-dried test soil sample was weighed out into a polybag containing a pre-weighed animal manure type and was thoroughly mixed to ensure uniformity of the treatments. After application, the treatments were watered for two weeks, after that three okra seeds (Clemson spineless variety) were planted per pot and was reduced to one seedling per treatment pot, after seedling emergence.

The following instruments were used to obtain data on okra plant at two-week intervals for 12 weeks, after seed emergence. A measuring tape calibrated in centimetre (cm) was used to obtain the heights of okra plant which was taken from the stem base up to the plant tip. Data on pod length was obtained by measuring (in cm) from the base of the pod to its tip. The number of plant leaves and many okra pods produced was manually obtained by counting.

2.1. Soil sample analysis

Before treatment application and at the end of the study, soil samples (about 100 g) were taken for chemical analysis. pH meter used to obtain soil pH in a soil: liquid ratio of 1:2.5 suspensions of soil in 0.1 N KCl and distilled water. Organic carbon was determined by the Walkley-Black method (Nelson and Somners 1996) and after that, multiplied by1.724 (a conversion factor) to obtain soil organic matter. Exchangeable potassium was extracted using 1 M ammonium acetate, then read on a flame photometer (Thomas, 1982). Phosphorus was determined using Bray II method (Bray and Kurtz, 1945) while total nitrogen was by the macro Kjeldahl method (Bremner, 1996). The animal manures were also analyzed following the procedures mentioned above.

2.2. Statistical analysis

One-way analysis of variance (ANOVA) was run on the parameters measured using GENSTAT Software Statistical tool. The least significant difference (LSD) was used to separate the mean differences of the soil and plant attributes at 5% probability level.

3.0 Results and Discussion

Before treatment application, the treatment application, the pH of the test soil was moderately acidic and had low Organic matter (OM), N, P and K contents (Table 1). This suggests that animal manure application which is rich in NPK and OM contents (Table 1) will enhance the test soil fertility status and consequently improve crop yields.

3.1. Treatment Effect on soil Properties14 Weeks after Application

Treatments had positive ($p < 0.05$) effect on the soil chemical properties 14 weeks after application (Table 2). CkD Treatment had the highest ($p < 0.05$; 7.8) pH value while the Control treatment, recorded the least ($p < 0.05$; 5.0) pH value. CoM and PiM treatments did not differ significantly on their soil pH content. The high soil pH values associated with the animal manure amended treatments attest to the capability of animal manures in enriching the soil and improving the acidic conditions. The result obtained is similar to a study by Akande et al. (2010) who reported increases in soil pH following application of manure. As anticipated, the total N content in the Control treatment was significantly lower as compared with treatments CkD, CoM and PiM Treatments. The high ($p < 0.05$; 23.8 mg kg^{-1}) total N content in PiM Treatment relative to CkD and CoM Treatments is due to the high N level that is associated with pig manure before its application (Table 1).

Table 1. Chemical properties of animal manures and initial soil sample used in the study

Parameters	Units	Organic amendments			Soil sample
		Cow Manure	Pig Manure	Chicken Manure	
pH (H_2O)		7.1	6.6	8.3	5.4
pH (KCl)		6.1	5.9	8.0	4.7
Total N	(mg kg^{-1})	1920	3180	1800	5.15
Total P	(mg kg^{-1})	210	420	576	7.90
Available K	(mg kg^{-1})	151	250	265	5.95
Organic matter	(%)	22.9	50.4	56.5	1.41

CkD, CoM and PiM Treatments had significantly higher P content as compared with Control treatment. There was over 35% increase in soil P content following animal manure application relative to the Control treatment (Table 2). The data on soil organic matter (OM) showed that the amended treatments had higher ($p < 0.05$) OM content relative to the Control treatment which had the least OM content while CkD treatment had the highest OM content. In a study by Are et al. (2017), they reported about 1.6-2.1 folds increase in soil organic carbon following organic amendment application.

3.3. Treatment Effect on stem girth, number of plant leaves produced and plant height

There were significant but varied effects on okra growth parameters following treatment application. No significant effects on the stem girth were observed across the treatments 28 days after sowing (DAS) (Table 3). But, from 42 DAS and beyond, CkD, CoM and PiM treatments recorded significant ($p < 0.05$) wider stem girth relative to the Control treatment (Table 4). Throughout the plant growth period, animal manured treatments had taller (16-60.4 cm) plant heights as compared with the shortest (14-37 cm) plant height that was recorded for the control treatment (Table 3). CkD treatment consistently maintained taller plant heights relative to all other treatments. The number of plant leaves (NPL) produced varied significantly across the treatments (Table 3). CkD and PiM treatments consistently had significantly higher NPL relative to the Control treatment. However, both (CkD and PiM) treatments did not significantly vary in their NPL produced except at 70 DAS in which the NPL in CkD treatment was significantly higher than PiM treatment. The result of this study is similar to the findings of Adewole and Ilesanmi (2012) who recorded increases ($p < 0.05$) in okra stem girth when compost organic fertilizer was applied relative to the control treatment. The taller plant heights associated with CkD treatment can be attributed to the high P nutrient contents that are contained in the chicken manure applied (Table 1). This is because P nutrient is a critical nutrient required for cell division that increases plant growth (Khandaker, 2017). The results on NPL are supported by a similar study by Olaniyi et al. (2010) who reported a higher number of okra leaves when manure was applied relative to the control unamended treatment. Also, Tiamiyu et al. (2012) reported that poultry manure application increased the

Table 2 Treatment effect on soil chemical properties 14 weeks after application

Treatments	Units	CkD	CoM	PiM	Control	LSD
pH (H_2O)	-	7.8	6.5	6.3	2.0	0.30
Total N	(mg kg^{-1})	13.7	16.6	22.8	0.55	3.01
Total P	(mg kg^{-1})	38.4	9.3	19.3	6.04	2.41
Available K	(mg kg^{-1})	9.16	6.39	6.74	5.20	1.12
Organic matter	(%)	1.39	1.27	1.41	1.19	0.06

CkD, 15 t ha^{-1} Chicken droppings; CoM, 15 t ha^{-1} Cow manure; PiM, 15 t ha^{-1} Pig manure; manure application, CV, Coefficient of variation, LSD, the Least significant difference

Table 3. Effect of manure application on okra stem girth, number of plant leaves and plant height

Treatments	14 DAS	28 DAS	42 DAS	56 DAS	70 DAS	84 DAS
			Stem girth (cm)			
CkD	1.0	1.3	2.3	2.6	3.0	3.2
CoM	0.9	1.2	2.0	2.5	2.7	2.8
PiM	1.0	1.4	2.1	2.6	2.9	3.2
Control	0.8	1.0	1.6	2.0	2.0	2.1
CV	7.4	8.9	8.3	10.1	7.8	5.3
LSD	NS	0.2	0.3	0.25	0.35	0.4
			Plant height (cm)			
CkD	18.0	28.3	43.5	52.0	57.3	60.4
CoM	16.0	25.3	36.7	45.5	46.7	48.0
PiM	17.0	24.0	36.3	46.7	48.7	51.7
Control	14.0	21.5	25.0	32.0	36.3	37.0
CV	5.50	7.6	8.30	9.4	11.9	13.1
LSD	1.03	3.3	4.8	5.2	6.4	8.4
			Number of plant leaves			
CkD	3.50	4.0	5.3	6.6	8.3	9.87
CoM	3.60	4.6	5.0	5.5	5.6	8.30
PiM	3.10	3.6	5.4	6.7	6.5	9.47
Control	2.40	2.6	3.4	4.5	5.2	4.40
CV	5.50	6.6	7.45	7.9	8.9	9.13
LSD	0.10	0.73	1.18	1.12	1.4	1.2

CkD, 15 t ha^{-1} Chicken droppings; CoM, 15 t ha^{-1} Cow manure; PiM, 15 t ha^{-1} Pig manure; manure application, DAS, Day after sowing; CV, Coefficient of variation, LSD, the Least significant difference number of okra leaves by 37.8% as compared with the Control treatment.

3.4. Treatment Effect on other plant parameters and okra yield

The Control treatment had significantly longer days to flowering as compared with CkD, CoM and PiM treatments (Table 4). The treatment effects on the days to flowering of okra is as follows: Control > PiM > CkD > CoM. It is not entirely clear why CoM treatment had the lest days (period) to the flowering of okra. However, the longer days to flowering associated with the Control treatment is linked to low or insufficient nutrient provisioning resulting in the long days to flowering. This is evidenced by the significant ($p < 0.05$) negative correction between soil nutrients (P and K) and days to flowering. This suggests that soil nutrient availability can influence okra flowering initiation and consequently affect okra yield. The amended treatments (CkD, CoM and PiM) had higher ($p < 0.05$) a number of pods produced relative to the Control treatment. No significant difference in the number of pods produced was observed between CkD and PiM (Table 4). A similar trend in the number of pods produced was observed for the okra pod length (Table 4).

Table 4. Effect of manure application on reproductive and yield performance

Treatments	CkD	CoM	PiM	Control	CV	LSD
Days to flowering	39.5	37.2	43.1	48.0	10.7	2.5
Number of pod	2.1	1.8	2.5	1.0	11.4	0.6
Pod length (cm)	9.2	7.0	9.3	6.6	3.1	1.1
Pod yield (g plant^{-1})	11.0	7.87	12.4	5.36	11.2	1.11

CkD, 15 t ha^{-1} Chicken droppings; CoM, 15 t ha^{-1} Cow manure; PiM, 15 t ha^{-1} Pig manure; manure application, DAS, Day after sowing; CV, Coefficient of variation, LSD, the Least significant difference

PiM treatment had weightiest (12.2 g plant^{-1}, $p < 0.05$) pod yield compared with all other treatments except CkD treatment both of which were statistically the same, while the Control treatment had lest yield (5.36 g plant^{-1}). The poor crop performance associated with the Control treatment relative to the animal manured treatments is due to inadequate soil nutrient supply. This is because fertilizers are necessary soil inputs needed to enhance not only crop yield, but they also improve the quantity and quality of crop yields (Akande et al., 2010). This is further supported by the significant ($p < 0.05$) positive correlation between soil nutrients and okra pod yield (Table 5).

Table 5. Correlation between soil properties and okra growth and yield performance

Soil Properties	Days to flowering	Number of leaves	Plant height	Pod length (cm)	Number of pods	Pod yield (g)
Nitrogen	-0.24^{ns}	0.67†	0.59†	0.65†	0.64†	0.67†
Phosphorus	-0.38†	0.58†	0.76††	0.56†	0.56†	0.56†
Potassium	-0.37†	0.78††	0.68†	0.40†	0.44†	0.42†
Organic Matter	-0.12^{ns}	0.5†	0.40†	0.57†	0.53†	0.55†

† and †† indicates significant correlation coefficient at $p < 0.01$ and $p < 0.05$ respectively; ns, not Significant

Soil K nutrient is essential for increased fruit size and crop yields. This is because K contributes to plant photophosphorylation, enzyme activation, and transportation of photo-assimilates from source tissues via the phloem to sink tissues nutrients (Lester et al., 2010). In a similar study, Usman (2015) reported that poultry manure, goat manure and cow manure applied at 20 t ha^{-1} increased tomato yield relative to the control treatment. Tiamiyu et al. (2012) reported higher yield with manure treatment application relative to the Control treatment, which had the least yield.

4.0. Conclusion

This study demonstrated that application of animal manure could positively affect days to okra flowering, okra height, number of okra leaves produced, number of okra pods, pod yields. Also, animal manure treatments had significant positive effects on soil nutrients (NPK) and organic matter content relative to the Control treatment. The data obtained suggest that application of 15 t ha^{-1} poultry manure or pig manure to a degraded soil can enhance okra growth and yield and soil chemical properties.

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