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ORIGINAL RESEARCH

# Animal manure application effects on soil properties and okra (*Abelmoschus esculentus* L) growth and yield performance

**Benedict O Unagwu[1*], Roseline U Ayogu[1]**

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## Abstract

**Purpose** Increase in global population and food demands have necessitated the need to enhance the health status of agricultural soils to overcome retrogresses in crop yields. Thus, amply use of animal manures is critical to improving low fertility status that characterised most agricultural soils in the tropics.

**Method** This study investigated the effects of various animal manure types on soil properties and performance of okra (*Abelmoschus esculentus* L) grown on a degraded coarse-textured ultisol. The treatments were: T1, poultry manure; T2, cow manure; T3, pig manure applied at 702 g pot$^{-1}$ (equivalent to 30 t ha$^{-1}$) to a 10 kg potted soil and T4, control unamended soil.

**Results** Amended treatments had 0.73-10.9% increase in organic matter, 191-370% increase in soil N, 30.4-170% and 25.5-76.5% increase in soil P and K, respectively relative to the control treatment. Amended treatments recorded significantly higher ($p < 0.05$) plant height, stem girth, okra biomass and yields compared with the control treatment. Poultry manure showed superiority over cow manure and pig manure for pH, soil nutrients, okra yield, okra growth and yield parameters measured.

**Conclusion** The results indicate that animal manure application increased okra yield and enhanced the fertility status of a degraded coarse-textured ultisol. Thus, application of animal manures can help overcome low fertility challenges associated with degraded tropical soils.

**Keywords** Animal manures, Organic amendments, Okra, Growth performance, Soil fertility

## Introduction

Okra (*Abelmoschus esculentus* L) is a tall growing plant and an important vegetable, which is grown for its immature green pods. Okra can be consumed either fresh or dry. The pods can be used to neutralize acid substances that cause food indigestion while the fruits, when dried and ground into powder, can be used for cooking soups and salads (Khandaker et al. 2017). Okra seed has a substantial quantity of edible oil, which is rich in vitamins and minerals, unsaturated fat like linoleic acid and oleic acid, and has pleasant taste and odour (Sanda et al. 2018). Okra is a source of income for small- and large-scale farmers. Ekunwe et al. (2018) reported that okra production is a profitable venture and can serve as additional revenue for farmers. Further, okra is a prized vegetable due to its high nutritive value, which is a good source of essential vitamins (e.g., Vitamin C) and minerals such as calcium, phosphorus, magnesium and iron (Haile et al. 2016). Apart from its nutritive value, matured okra fruits and stems contain crude fibre, which are used in paper industry. Despite the usefulness and economic importance of okra, it has a low yield potential in Nigeria. This is chiefly due to low nutrient status of most soils in Nigeria (Adewole and Ilesanmi 2012).

Decline in soil fertility, among other forms of soil degradation, poses critical challenges to crop production in Nigeria (Olujobi and Ayodele 2013; Unagwu 2019; Unagwu et al. 2019). Following increases in the human population, the fallow system, which was orig-

✉ Benedict O Unagwu
benedictunagwu@yahoo.com

[1] Department of Soil Science, University of Nigeria Nsukka, Nigeria

inally used to maintain soil fertility is no longer practised. Low soil fertility has negative effects on crop productivity and the overall food security. Inorganic fertilizers have been used to increase crop productivity due to their high nutrient content that is released in accessible forms for plant uptake. However, the use of inorganic fertilizers is no longer sustainable since inorganic fertilizers is not environmentally friendly (Moyin-Jesu 2008). Excess use of inorganic fertilizer can result in soil nutrient imbalance, nutrient loss, groundwater contamination, soil acidity or alkalinity, which affects microbial population and activity. To overcome the negatives of inorganic fertilizer use, studies currently advocate the use of organic manure as soil amendment (Abdulmaliq et al. 2017).

Organic manure has multiple benefits due to a balanced supply of nutrients, increased soil nutrient due to increased microbial activity, improvement in soil structure as well as increased soil water availability (Unagwu 2014). Manures influence soil organic matter content, a critical indicator of soil quality. Thus, organic manure application can potentially benefit the physical, chemical and biological soil properties (Unagwu 2019). Organic manure is a good source of nitrogen, phosphorus, potassium and other micronutrient compared to inorganic fertilizer (Okubena-Dipeolu et al. 2015). Amhakhian and Isaac (2016) reported that sole application of different animal manures influenced okra growth and yield outputs. Okoli and Nweke (2015) found that animal manure application enhanced the growth and yield of cucumber. Animal manure enhances nutrient availability, keeps the soil physical properties in a condition favourable for plant root growth, and consequently improves crop productivity.

Animal manure reduces soil bulk density, improves soil structure and hydraulic conductivity of the soil (Are et al. 2017). The quality and quantity of organic manure application contribute to its effectiveness in influencing crop yield (Unagwu et al. 2019). Application of high quantity poultry manure and cow dung increased yield of okra (Muhammad et al. 2019). Amhakhian and Isaac (2016) reported that animal manure contains considerable amount of NPK, which is essential for vegetable production. Usman (2015) attributed increases in growth and yield of tomato following animal manure application to the nutrient content of the manure applied. To achieve food security and self-sufficiency in Nigeria, there is a need to enhance the nutrient level of the nation's agricultural soils, which have progressively recorded low crop yields due to their inherent low fertility status. The present study investigated the effects of different animal manure types on okra growth, its yield and soil properties.

## Materials and methods

A greenhouse study on the effects of animal manure application on soil properties and growth performance of okra, grown in a degraded coarse-textured ultisol, was investigated. The study was set up in a completely randomized design (CRD) and was replicated three times. The test soil (0-15 cm depth) was collected from the Department of Soil Science Research Farm, University of Nigeria, Nsukka. Three animal manure types: poultry manure (PM), cow dung (CD) and pig manure (PgM) were sourced from the Faculty of Agriculture Research Farm. Prior to application, the manures were air-dried and sieved with 2 mm sieve, to ensure uniform application. The treatments applied were: T1, poultry manure applied at 30 t ha$^{-1}$; T2, cow manure applied at 30 t ha$^{-1}$; T3, pig manure applied at 30 t ha$^{-1}$; and T4, Control, without manure application. The soil sample was collected, air-dried and thoroughly mixed to ensure soil homogeneity. Thereafter, 10 kg of soil sample was weighed into a polybag containing the pre-weighed animal manure and both thoroughly mixed to ensure uniformity of the treatments. Thereafter, the composite mixture of soil and animal manure was applied on the experimental pot for each of the treatments. Prior to planting, the treatments were watered for a two-week period to activate microbial activities that would help mineralize the nutrients contained in the animal manures. After the two-week incubation period, three okra seeds (Clemson spineless variety) were sown in each treatment pot. After emergence, the seedlings were reduced to one seedling per treatment pot. The treatment pots were watered and kept weed-free throughout the experiment.

### Plant growth parameters (plant height, number of leaves, and stem girth)

With the aid of a measuring tape calibrated in centimetre (cm), the heights of okra plant were measured from the base of the plant stem to the tip of the plant. The number of plant leaves produced was manually obtained by counting. Okra stem girth was measured with the aid of a vernier caliper Micrometer Durable Stainless Steel.

### Number of pods, pod length and pod weight

The number of okra pods was obtained manually by counting. Pod length was obtained by measuring from the base to the tip of the pod with a measuring tape in cm. Pod yield (fresh weight) was recorded by weighing the quantity of pods produced on an electronic balance calibrated in grams (g). The data on the above-mentioned plant parameters were taken bi-weekly for a 12-week period, after seed emergence.

### Soil sample analysis

From each pot, about 100 g of soil sample was taken before manure application and at harvest for chemical analysis. Walkley-Black method (Nelson and Somners 1996) was used to determine organic carbon, which thereafter was multiplied by1.724 (a conversion factor) to obtain soil organic matter. Bray II method (Bray and Kurtz 1945) was used to determine available phosphorus while total nitrogen was by the macro Kjeldahl method (Bremner 1996). Exchangeable potassium was extracted using 1 normal (1 N) ammonium acetate, then read on a flame photometer (Thomas 1982). The pH meter was used to obtain soil pH in soil: water and soil:0.1 N KCl ratios of 1:2.5, respectively. The manures were also analysed following the above-mentioned procedures except for total P and K, which were analysed using the US EPA method 3051 after extraction with nitric hydrochloric acid mixture with the aid of Anton Paar Multiwave 3000 microwave digestion system.

### Statistical analysis

One-way analysis of variance (ANOVA) was carried out on the data obtained using GENSTAT Software Statistical Package. The least significant difference (LSD) at 5% probability level was used to separate the mean of both soil and plant attributes. Correlation and regression analyses were undertaken with aid of Microsoft Excel 2016 Analysis Toolpak.

## Results and discussion

The initial soil data had moderate acidity (pH 5.5) level and low organic matter content (1.37%). The soil's N (5.1 mg $kg^{-1}$), P (7.9 mg $kg^{-1}$), and K (6.0 mg $kg^{-1}$) contents prior to manure application were low, which suggested the need for organic amendment application. In contrast, animal manures (poultry manure, cow dung and pig manure) are rich in NPK and have high percentage of organic matter content (Table 1). It was anticipated that application of these manures would provide okra plant the much-needed nutrients and have positive effect on the soil fertility status and on the overall crop performance.

**Table 1** Initial chemical properties of the animal manures used for the study

| Parameters | pH $H_2O$ | pH KCl | Total N (mg $kg^{-1}$) | Total P (mg $kg^{-1}$) | Total K (mg $kg^{-1}$) | Organic matter (%) |
|---|---|---|---|---|---|---|
| Poultry manure | 8.5 | 8.2 | 1820 | 567 | 259 | 60.5 |
| Cow dung | 7.3 | 6.7 | 1960 | 201 | 147 | 28.9 |
| Pig manure | 6.9 | 6.7 | 3220 | 410 | 260 | 55.4 |

### Effect of animal manure application on soil properties

The data in Table 2 shows that after crop harvest, the treatments applied had positive ($p < 0.05$) effect on the soil chemical properties. Treatment T1 registered the highest ($p < 0.05$; 8.3) pH value while the unamended control treatment, T4, had the least (5.1) pH value. Animal manure application increased the soil pH from 1.5-2.2 pH units (Table 2). Meanwhile, the soil pH decreased slightly in treatment T4 (Table 2) relative to baseline test soil (Table 1), which originally was moderately acidic. Increases in the soil pH following manure application demonstrate the capability of animal manures in ameliorating the acidic conditions of most tropical soils. The present result is akin to that of Akande et al. (2010) who found increases in soil pH following application of manure. Changes in soil pH have huge effects on nutrient availability, mineralization and nutrient delivery (particularly NPK and base cations) (Schulz and Glaser 2012). The total N content in treatment T4 was significantly lower compared with treatments T1-T3. Treatment T3 registered the highest

($p < 0.05$; 23.8 mg kg$^{-1}$) total N content. As anticipated, the P content of treatment T4 was significantly lower as compared with treatments T1-T3. Across the animal manure treatments, treatment T1 had the highest P content, followed by treatments T3 and T2, respectively. There was over 46% increase in the P content with animal manure application compared to treatment T4 (Table 2). The data obtained indicate that animal manure application increased the soil organic matter (OM). It was observed that treatment T3 had the highest ($p < 0.05$) OM content (1.52%), while treatment T4 had the least OM content (1.28%). With respect to treatment T4, treatments T1, T2 and T3 increased the OM content by 13.3%, 7.81%, and 18.8%, respectively. The importance of organic amendment application in OM accumulation and carbon sequestration has been documented (Are et al. 2017). Are et al. (2017) found 1.6-2.1 fold increase in soil organic carbon following application of poultry tea, veticompost and poultry manure.

Soil nutrients (NPK) in treatments T1-T3 were higher than that in treatment T4, which suggests that treatments T1-T3 provided required amount of nutrients that significantly contributed to higher plant growth, development and okra yield (Tables 4-6; Fig. 1). Gulshan et al. (2013) observed that irrespective of the manure type applied, farmyard manure application significantly increased the soil chemical properties; particularly available N and P which increased with increasing rates of manures application.

**Table 2** Effect of animal manure application on soil chemical properties after crop harvest

| Treatments | pH $H_2O$ | pH KCl | Total N (mg kg$^{-1}$) | Available P (mg kg$^{-1}$) | Exchangeable K (mg kg$^{-1}$) | Organic matter (%) |
|---|---|---|---|---|---|---|
| T1 | 8.3 | 7.0 | 14.7 | 42.4 | 10.5 | 1.45 |
| T2 | 7.2 | 5.7 | 17.6 | 10.3 | 7.59 | 1.38 |
| T3 | 6.6 | 5.6 | 23.8 | 21.3 | 7.47 | 1.52 |
| T4 | 5.1 | 4.6 | 0.57 | 7.07 | 5.60 | 1.28 |
| **LSD** | **0.31** | **0.18** | **3.01** | **3.03** | **1.02** | **0.09** |

T1, 30 t ha$^{-1}$ Poultry manure; T2, 30 t ha$^{-1}$ Cow manure; T3, 30 t ha$^{-1}$ Pig manure; T4, Control, without manure application, LSD, Least significant difference.

### Percentage changes in the soil chemical properties after crop harvest

With respect to the initial chemical characteristics of the soil, it was observed that there were changes in the residual soil chemical properties following various animal manures application. For instance, there was about 20-51% increase in soil pH for the animal manure treatments while treatment T4 had about 7.3% decrease in soil pH (Table 3). The soil total N, available P and exchangeable K increased in treatments T1-T3 while treatment T4 recorded 89%, 11% and 6% lower N, P, K contents, respectively as compared to the soil initial values. Further, treatments T1-T3 increased the soil organic matter by 0.73-11% while treatment T4 decreased the soil organic matter by 6.6%. Across the animal manure treatments, it was observed that the treatments had varied effects on the soil properties. For instance, treatment T3 gave the least (25.5%) increases in the K content but had the greatest increases in the N (370%) and organic matter (10.9%) content. The percentage increases in the soil properties associated with animal manured treatments indicate improvement in the soil nutrient (NPK), pH and OM contents. In contrast, the huge percentage decreases (losses) in the soil nutrients, pH and OM observed for treatment T4 (Table 3) is nonetheless due to the negative impact of plant (okra) nutrient uptake without a commensurate external nutrient supplement via either chemical or organic fertilizer application.

### Effect of manure application on stem girth

Different animal manures application had varied effects on okra stem girth throughout the growth period. For instance, 2-8 weeks after sowing (WAS), the stem girth associated with various manure applications did not vary significantly (Table 4). However, from 10 WAS, treatments T1-T3 had significant ($p < 0.05$) wider stem girth while treatment T4 consistently had a significantly narrower stem girth (Table 4). Among the manured treatments, except at 12 WAS where treatment T2 recorded a significantly narrower stem girth compared with treatments T1 and T3, treatments T1-T3 did not vary significantly in their stem girths. It is worth mentioning that at 12 WAS, some okra plants showed signs of senescence. The reduction in treatment T2 stem girth at 12 WAS relative to that obtained at 10 WAS may be due to the setting in of plant senescence. The differential variabilities observed across the treatments are attributed to the variations in the nutrients associated with the animal manures applied (Table 1). The present result is in line with that of Adewole and Ilesanmi (2012), who found increases ($p < 0.05$) in okra stem girth following the application of compost organic fertilizer relative to the control treatment.

**Table 3** Percentage changes in soil chemical properties after crop harvest relative to initial soil characteristics

| Treatments | pH ($H_2O$) (%) | pH (KCl) (%) | Total N (%) | Available P (%) | Exchangeable K (%) | Organic matter (%) |
|---|---|---|---|---|---|---|
| T1 | 50.9 | 48.9 | 191 | 437 | 76.5 | 5.84 |
| T2 | 30.9 | 21.3 | 248 | 30.4 | 27.6 | 0.73 |
| T3 | 20.0 | 19.1 | 370 | 170 | 25.5 | 10.9 |
| T4 | -7.27 | -2.13 | -88.7 | -10.5 | -5.88 | -6.57 |

T1, 30 t $ha^{-1}$ Poultry manure; T2, 30 t $ha^{-1}$ Cow manure; T3, 30 t $ha^{-1}$ Pig manure; T4, Control, without manure application.

## Effect of manure application on number of plant leaves produced

The number of plant leaves (NPL) produced is presented in Table 4. The results show that NPL varied significantly during growing periods and across the treatments applied. At 2 WAS, treatment application had no significant effect on the NPL. Beyond 2 WAS, it was observed that treatment T4 consistently had the least NPL relative to treatments T1-T3 except at 8-10 WAS, where the NPL associated treatments T2 and T4 did not differ significantly. Beyond 8 WAS, treatment T1 had higher

**Table 4** Effect of manure application on okra stem girth and number of plant leaves

| Treatments | 2 WAS | 4 WAS | 6 WAS | 8 WAS | 10 WAS | 12 WAS |
|---|---|---|---|---|---|---|
| | | | **Stem girth (cm)** | | | |
| **T1** | 1.2 | 1.5 | 2.5 | 2.9 | 3.3 | 3.4 |
| **T2** | 1.1 | 1.4 | 2.3 | 2.8 | 3.0 | 2.7 |
| **T3** | 1.2 | 1.6 | 2.4 | 2.9 | 3.2 | 3.5 |
| **T4** | 1.1 | 1.6 | 1.8 | 2.2 | 2.2 | 2.1 |
| **CV** | 6.2 | 9.0 | 7.3 | 14.9 | 8.9 | 6.4 |
| **LSD** | 0.1 | 0.2 | 0.3 | 0.8 | 0.5 | 0.4 |
| | | | **Number of plant leaves** | | | |
| **T1** | 4.0 | 4.3 | 6.3 | 7.0 | 9.3 | 12.7 |
| **T2** | 4.0 | 5.3 | 6.0 | 6.5 | 6.7 | 9.0 |
| **T3** | 4.0 | 4.0 | 6.3 | 7.7 | 7.7 | 11.7 |
| **T4** | 4.0 | 3.3 | 5.0 | 6.0 | 6.3 | 2.0 |
| **CV** | 0.0 | 16.6 | 6.9 | 9.8 | 10.9 | 7.3 |
| **LSD** | 0.08 | 1.3 | 0.8 | 1.2 | 1.4 | 1.2 |

T1, 30 t $ha^{-1}$ Poultry manure; T2, 30 t $ha^{-1}$ Cow manure; T3, 30 t $ha^{-1}$ Pig manure; T4, Control, without manure application, CV, Coefficient of variation, LSD, Least significant difference

NPL relative to the treatments T2 and T3. The results obtained are supported by similar findings by Tiamiyu et al. (2012), who found that by applying poultry manure, the number of okra leaves increased by 37.8% compared to control treatment. Gulshan et al. (2013) found increased number of okra leaves with farmyard manure application. Adewole and Ilesanmi (2012) found that okra plants grown in compost amended plots produced higher ($p < 0.05$) number of leaves relative to the control treatment.

## Effect of manure application on plant height

As shown in Fig. 1, the plant height data indicate that okra was positively affected following animal manure application, but those effects varied ($p < 0.05$) across the treatments applied. Throughout the growing period, plants grown in animal manured pots gave taller (20-55 cm) plant height while the control pot, which received no animal manure treatment, had shorter (17-35 cm) plant height (Fig. 1). From 2 to 12 WAS, treatment T1 constantly had ($p < 0.05$) taller plant heights relative to all other treatments. The taller plant heights associated with treatment T1 is due to the high nutrient contents especially P, which is contained in the poultry manure applied (Table 1), which enhanced root development and nutrient uptake in plant. Phosphorus nutrient is one element that is critically needed for cell division which results in increases in plant growth (Khandaker et al. 2017; Unagwu et al. 2019). This result suggests that the nutrients (nitrogen, phosphorus, and potassium) contained in animal manure applied at 30 t $ha^{-1}$ might be sufficient to enhance okra plant growth and development. Plant height is an important plant characteristic, which has direct link with plant biomass and crop yield (Khandaker et al. 2017; Unagwu et al. 2019). Study has shown that plants essentially require huge amount of NPK nutrients for adequate growth and development, since a deficiency in any of these nutrients (NPK) will hinder plant growth (Gholizadeh et al. 2009). This observation is further evidenced by the significantly ($p < 0.05$) strong correlation ($r = 0.71, 0.89, 0.80$) between plant height and N, P, and K nutrients, respectively (Table 6). The present result is akin to Usman (2015), who reported that plants fertilized with 20 t $ha^{-1}$ poultry manure treatment gave the tallest plant height. The trend in the positive effects on plant height is due to nutrient provisioning via the treatments applied. Our finding is akin to the report by Tiamiyu et al. (2012), who found taller ($p < 0.05$) plant heights with poultry manure (44.5 g) application relative to sheep manure (36.3 g) and cow manure (33.3 g) application, both of which did not differ significantly.

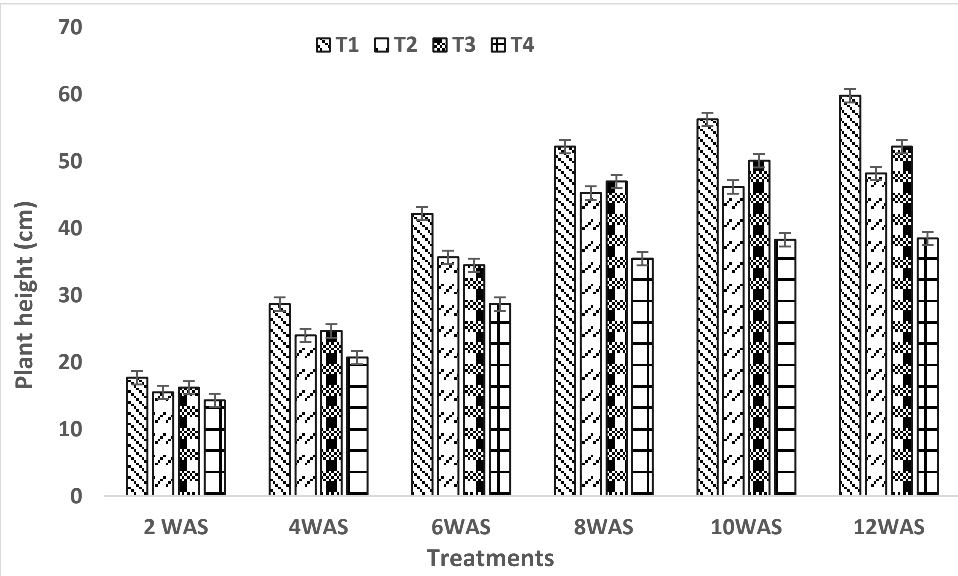


**Fig. 1** Effect of manure application on okra plant height

T1, 30 t $ha^{-1}$ Poultry manure; T2, 30 t $ha^{-1}$ Cow manure; T3, 30 t $ha^{-1}$ Pig manure; T4, Control, without manure application, bars indicate least significant difference at 5% probability ($p < 0.05$).

### Effect of animal manure application on growth phenology and yield of okra

There was significant effect on the days to flowering and days to fruiting following treatment application (Table 5). Treatments T1-T3 had significantly lesser days to flowering and fruiting as compared with treatments T4. Across the manured treatments, treatments T1 and T2 had lesser days to flowering and fruiting relative to treatment T3. The significant ($p < 0.05$), though weak, negative relationships between okra pod yield and days to flowering ($r^2 = 0.113$; $p < 0.05$) and days to fruiting ($r^2 = 0.102$; $p < 0.05$) suggests that reduction in the number of days to flowering and fruiting of okra plant can significantly affect its yield performance (Fig. 2).

The number of okra pod produced varied greatly ($p < 0.05$) across the manure applied treatments (Table 5). All the amended treatments (T1-T3) gave higher ($p < 0.05$) number of pods relative to T4 treatment. Treatments T1-T3 did not differ significantly in the number of pods produced. Gulshan et al. (2013) found increases in the quantity of okra fruits produced following farmyard manure application. Except treatment T2, the pod lengths associated with treatments T1-T3 were longer ($p < 0.05$) than that of treatment T4 (Table 5). Treatment application had no significant effect on okra pod girth except for treatment T3, which gave the widest ($p < 0.05$; 7.4 cm) pod girth. Similarly, the pod length to pod girth ratio did not significantly differ across the treatments except for treatment T1, which had the highest ($p < 0.05$; 1.8) ratio.

Okra pod yield (g) obtained following treatment application varied ($p < 0.05$) under the different manure treatments (Table 5). The highest pod yield (14.1 g plant$^{-1}$) was obtained from treatment T3, although it was not statistically different when compared with treatment T1 (13.0 g plant$^{-1}$). It was also observed that T2 treatment did not significantly give higher okra pod yield relative to T4 treatment even though vegetative-wise T2 treatment outperformed T4 treatment. Perhaps, the nutrient content, especially N, contained in T2 treatment was insufficient to significantly influence okra pod yield. Study has shown that N enhances plant vegetative growth, photosynthesis as well as the accumulation of plant assimilates (Khandaker et al. 2017).

**Table 5** Effect of manure application on reproductive and yield performance of okra

| Treatments | Days to flowering | Days to fruiting | Number of pod | Pod length (cm) | Pod girth (mm) | Pod length to pod girth ratio | Fresh Pod yield (g plant$^{-1}$) |
|---|---|---|---|---|---|---|---|
| **T1** | 49.7 | 51.0 | 2.7 | 12.2 | 6.8 | 1.8 | 13.0 |
| **T2** | 47.7 | 49.0 | 2.3 | 10.0 | 6.4 | 1.5 | 9.7 |
| **T3** | 53.3 | 54.7 | 3.0 | 12.3 | 7.4 | 1.7 | 14.1 |
| **T4** | 58.0 | 59.7 | 1.3 | 9.6 | 6.3 | 1.5 | 8.0 |
| **CV** | 15.7 | 16.5 | 21.4 | 6.1 | 5.7 | 9.1 | 10.2 |
| **LSD** | **3.9** | **2.8** | **0.9** | **1.3** | **1.5** | **0.25** | **2.1** |

T1, 30 t ha$^{-1}$ Poultry manure; T2, 30 t ha$^{-1}$ Cow manure; T3, 30 t ha$^{-1}$ Pig manure; T4, Control, without manure application, CV, Coefficient of variation, LSD, Least significant difference.

Fertilizers are essential inputs required to enhance crop yield. Fertilizers do not only increase crop growth, but they equally improve the quantity and quality of crop yields (Akande et al. 2010; Table 6). Further, the significant ($p < 0.05$) relationships (Fig. 2) that exist between okra pod yield and number of pod ($r^2 = 0.73$), plant height ($r^2 = 0.64$), and biomass ($r^2 = 0.78$) is testament that improvement in the soil health and soil fertility status are critical to increase crop yield (Table 7). Usman (2015) reported that poultry manure, goat manure and cow manure applied at 20 t ha$^{-1}$ treatment increased tomato yield relative to the control treatment. Tiamiyu et al. (2012) reported higher yield with poultry manure (25.5 g) relative to sheep manure (20.8 g) and cow manure (19.0 g) while the control treatment had the least yield (17.4 g).

As presented in Table 6, there are strong ($p < 0.01$) correlations between the soil nutrients, especially N, P, K, and plant height and the number of plant leaves. More importantly, the data indicate that soil N contributed more to okra pod yield as evidenced by the significantly high ($p < 0.01$) positive correlation ($r = 0.79$) that existed between the soil N and pod yield. Soil pH had significant ($p < 0.05$) negative relationships ($r = -0.52$ and $-0.55$) with days to flowering and days to fruiting, respectively (Table 6). All other soil parameters established no significant relationships with days to flowering and days to fruiting except soil P and K, which had significant ($p < 0.05$) negative relationships ($r = -0.37$ and $-0.39$), respectively. Overall, the regression analysis showed that soil N and P contributed significantly to okra yield (Table 7).

Lester et al. (2010) reported that soil nutrients especially K is important in photophosphorylation, enzyme activation, and transportation of photo-assimilates from source tissues via the phloem to sink tissues. The authors suggested that adequate K nutrition is essential for increased fruit size, increased soluble solids and crop yields (Lester et al. 2010). This is further evidenced by the high ($p < 0.05$) correlation ($r = 0.81$, 0.80 and 0.39) observed between K and the number of okra leaves, plant height and pod yield, respectively (Table 6).

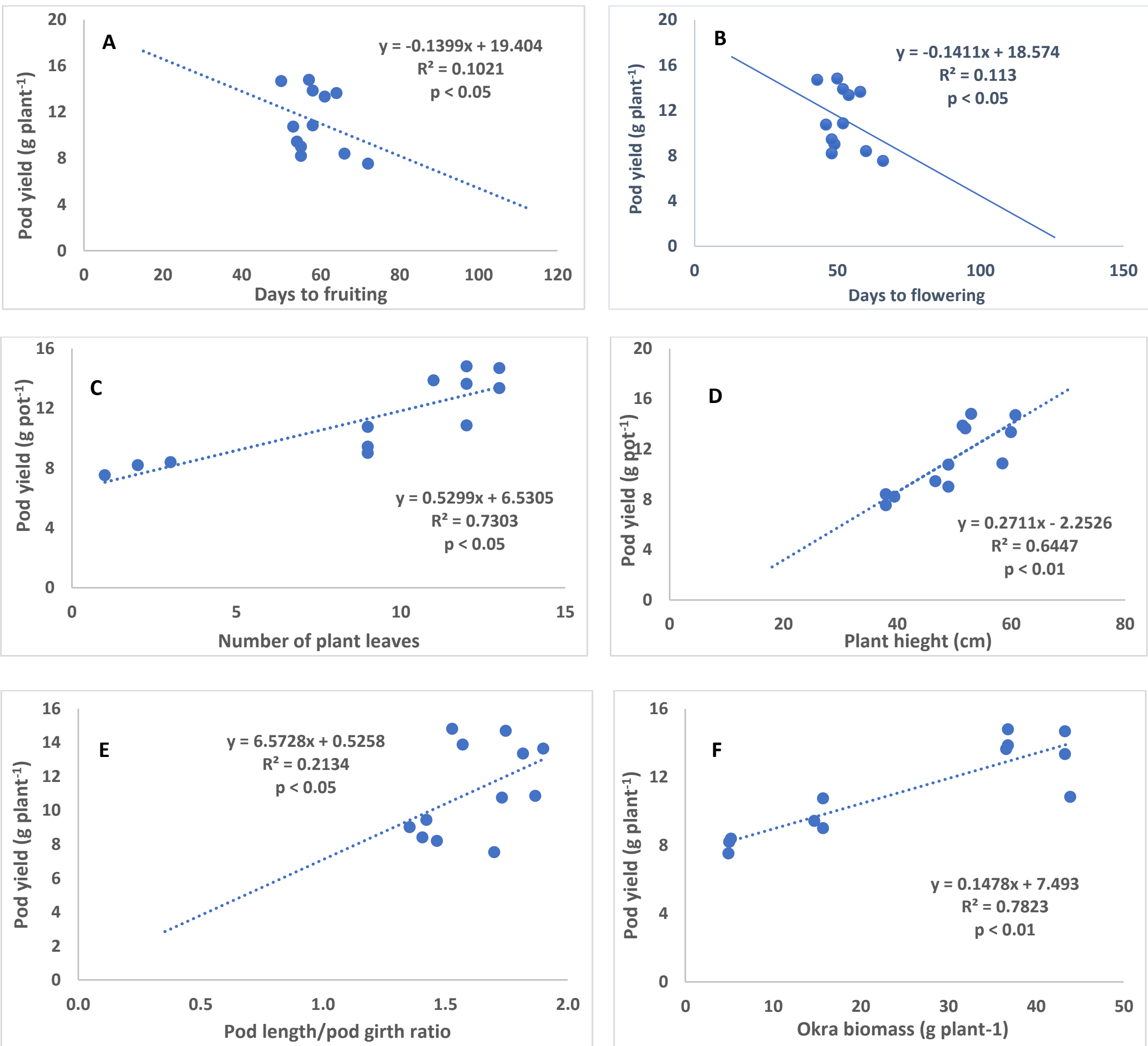


**Fig. 2** Relationship between pod yield and days to fruiting (A), pod yield and days to flowering (B), pod yield and number of plant leaves (C), pod yield and plant height (D), pod yield and pod length/pod girth ratio (E), pod yield and biomass (F)

**Table 6** Correlation between soil properties and okra growth and yield performance

| Soil parameters | Number of leaves | Plant height | Days to flowering | Days to fruiting | Number of pods | Pod length (cm) | Pod girth (cm) | Pod yield (g) |
|---|---|---|---|---|---|---|---|---|
| pH ($H_2O$) | 0.67* | 0.69* | -0.52* | -0.55* | 0.23$^{ns}$ | 0.25$^{ns}$ | -0.11$^{ns}$ | 0.20$^{ns}$ |
| Organic Matter | 0.50* | 0.44* | -0.15$^{ns}$ | -0.06$^{ns}$ | 0.43* | 0.67* | 0.49* | 0.51* |
| Total N | 0.75** | 0.71** | -0.14$^{ns}$ | -0.16$^{ns}$ | 0.67* | 0.62* | 0.51* | 0.79** |
| Av. P | 0.93** | 0.89** | -0.37* | -0.39* | 0.53* | 0.62* | 0.23$^{ns}$ | 0.67* |
| Exc. K | 0.81** | 0.80** | -0.37* | -0.39* | 0.34* | 0.40* | 0.15$^{ns}$ | 0.39* |

*, **, Significant correlation coefficient at $p < 0.01$ and $p < 0.05$ respectively; ns, not Significant.
Av., Available, Exc., Exchangeable.

**Table 7** Coefficients of regression between soil properties and okra yield performance

| Soil parameter | Prediction equation | R² value | R value | P value |
|---|---|---|---|---|
| Organic Matter | $y = 7.1183x + 0.9585$ | 0.5369 | 0.734 | 0.528 |
| Total Nitrogen | $y = 167.82x + 0.5123$ | 0.6288 | 0.793 | 0.002 |
| Available Phosphorus | $y = 0.1363x + 8.4472$ | 0.4468 | 0.668 | 0.017 |

## Conclusion

Our study revealed that animal manure application had positive effects on most of the plant parameters (okra height, number of okra leaves, number of okra pods, pod yields, etc.) measured. Animal manure applied at 30 t ha$^{-1}$ significantly reduced the duration of flowering and fruiting in okra plant, which significantly influenced okra yield performance. Similarly, animal manured treatments significantly improved soil nutrients (NPK) and organic matter content relative to the control (T4) treatment. Comparatively, neither poultry manure nor pig manure application outperformed ($p < 0.05$) each other based on the okra yield components measured, but both manures outperformed cow manure. It is evident, from the data presented, that applying 30 t ha$^{-1}$ of poultry manure or pig manure is promising for okra production in a degraded coarse-textured ultisol. Thus, pig manure, which is relatively in abundance, but not commonly utilized as soil amendment, may be used in place of poultry manure, which is overly sought after by farmers. Further field study is needed to validate the results obtained to make more appropriate and reliable recommendations.

## Compliance with ethical standards

**Conflict of interest** The authors declare that there are no conflicts of interest associated with this study.

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