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Research Article

Growth and Yield Response of Okra (*Abelmoschus esculentus*) to Organic and Inorganic Fertilizers on Degraded Upland Soil in Kori Chiefdom, Moyamba District, Sierra Leone

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Abstract
The declining soil fertility resulting from continuous cultivation of farmlands, the unbearable cost of chemical fertilizers and the need to conserve and build natural resources capital and biodiversity coupled with the popular call for organic farming, have led to renewed interest in the use of organic nutrient resources for soil fertility management in Sierra Leone. This study investigates the growth and yield response of Okra (*Abelmoschus esculentus*) to organic fertilizer on degraded upland soil and also determines the application rate of poultry manure for high productivity of okra. Five levels of treatment were used in a randomized complete block design (RCBD) with three replications. ANOVA statistical analysis at P = 0.05 was used to determine the level of significance. Okra morphological characteristics and yield were exceptionally better under poultry manure at 5t/ha application rate and 1500kg/ha of Fertiplus compared with 250kg/ha NPK 15-15-15 fertilizer. At 5t/ha application rate of poultry manure, and 1500kg/ha of Fertiplus sowing showed robust growth parameters and produced highest yield, suggesting that, these application rate synchronizes nutrient availability and nutrient uptake in okra production. In conclusion, poultry manure applied at 5t/ha and 1500kg/ha of Fertiplus are recommended for high productivity of okra in the study area.
Keywords: Degraded Soil, Okra, Organic Fertilizers, Yield.

Introduction

Okra (*Abelmoschus esculentus* L.) belongs to the Malvaceae family and is one of the most popular fruit vegetables cultivated in Africa (Schippers, 2000). The West and Central Africa region accounts for more than 75% of okra produced in Africa but the average productivity in the region is very low (2.5 t/ha) compared to East Africa (6.2 t/ha) and North Africa (8.8 t/ha) (FAOSTAT, 2006). Nigeria is the largest producer (1,039,000 t) followed by Cote d'Ivoire and Ghana (FAOSTAT, 2008). Okra cultivation requires nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na) and sulphur (S) for fertility maintenance regular fruiting, subsequent pricking and crop production (Premeskhar and Rajashree, 2009).

In Sierra Leone, okra is cultivated both during the rainy and dry seasons and is usually grown in backyard gardens and smallholder farmlands; with the fruits sold in almost all local markets across the country. The demand for okra in Sierra Leone is always high, especially, during the dry season when most local leafy vegetables are in short supply. Despite the wide cultivation, the market supply of okra does not meet the demand and it is therefore always expensive, particularly during the dry season in the urban areas of Sierra Leone. Nutritionally, okra contains 2.1% protein, 0.2% fat, 18.6% calcium, 13.3% iron, 3.15% vitamin B, and 15.6% vitamin C in a 100g of fresh fruits. Okra is also associated with so many nutritional and medicinal benefits. It can be used to treat goitre, diabetes, ulcer, asthma, and other ailments (Gemede *et al.,* 2015).

Dry fruit skin and fibers are used in manufacturing of paper, cardboard and fibers. It ranks first before other vegetable crops (Babatunde *et al.,* 2007) due to its nutritional benefit in human diet, and it has contributed immensely to the economic status of farmers especially those that engaged in large scale production of the crop in dry season. Okra is a heavy yielder and therefore, requires nutrients in the amount and type adequate for vigorous growth and development (Mayhew and Penny, 1988). Despite its high value, okra

yield is often low in Sierra Leone, due to deficiencies of certain mineral elements in the soil. To overcome poor soil conditions, chemical fertilizers are often used to boost production. However, long-term use of synthetic fertilizers can cause soil toxicity and affect production sustainability (Ojoniyi, 2013). In addition, chemical fertilizers are expensive, not readily available, and negatively affect the environment (Peyvast *et al.,* 2003). Hence, local farmers have resorted to the use of alternatives such as organic fertilizers to increase the production of okra.

Organic fertilizers such as poultry manure are suitable for use in crop production because of the minimal negative effect they have on the environment (Fawole *et al.,* 2010). Organic manures improve soil moisture, soil nutrient retention, and soil physical properties. They enhance soil structure and texture, increase beneficial microorganisms in the soil, maintain soil pH, and suppress crop diseases (Yafan and Barker, 2004). However, inappropriate use of poultry manure can reduce itself efficiency and negatively affect soil productivity. Thus, to maximize the optimal potential of poultry manure, it should be applied at the right time, in suitable amounts and using a method that matches with nutrient needs of crops (Steward, 2006).

Many studies have shown that poultry manure is good for okra cultivation. However, the method and time of application are yet to be investigated in the study area. Therefore, the objective of this study was to investigate the response of Okra (*Abelmoschus esculentus*) to organic fertilizers on degraded upland soil to determine the appropriate application rate of poultry manure during the cultivation of okra, in order to achieve optimum growth and yield. The findings of this study would guide the use of poultry manure and reduce possible losses and environmental problems during okra cultivation.

Methodology

Description of Study Area

The present investigation on growth and yield response of okra to organic fertilizers was carried out at the Nursery Sites of the Department of Horticulture, School of Natural Resources Management, Njala University in 2017. Annual rainfall in the trial area ranges from 2000-3000 mm with average temperature of 20^0C. Two rainfall peaks make two growing seasons possible for okra production. There is favorable rainfall in June and July followed by another period of appreciable rainfall from September and October. The experimental site was cultivated with Pepper and Garden eggs before the trial was established. During the trial period mean temperature and relative humidity were 27^0C and 85% respectively. The soil classified as Orthoxic Plehumults (van Vuure, 1972) was gravelly loamy clay with a pH of about 5.6.

Planting Materials

Okra (*Abelmoschus esculentus* L.) (Clemson Spineless) seeds for the experiments were obtained from Seed Tech International, Sierra Leone (a general supplier of imported and local agricultural seeds and seedlings).

Land Preparation and Experimental Design

The experimental plot was cleared and ploughed using hand hoe and shovel on the 28th January 2017. The area was lined, pegged and seed beds were constructed. The plot size was 80ft x 30ft (24.38m x 9.14m) with five (5) experimental units per replication. The size of each treatment unit was 3.05m x 5.49m (10ft x 18ft) with 0.6m path between beds and 0.9m between replications. Each plot consisting of 4 rows with 8 plants stands per row. The experiment was laid out in Randomize Complete Block Design (RCBD) with three replications and five treatments in this design.

Manure and Fertilize Rate, Method of Application and Management

In this experiment, four (4) levels of organic fertilizer (Fertiplus, Codafol, DI Grow and Poultry Manure) were used. 1500kg/ha of Fertiplus were applied one (1) week after germination, Codafol and DI Grow were applied by foliar application using Knapsack Sprayer 3 times after germination at rate of 3L/ha. Poultry manure was potted at designated planting spot one week before planting commence at application rate of 5t/ha. 250kg/ha recommended rate of inorganic fertilizer NPK 15-15-15 was used as a control for the research. The fertilizer was split applied to the appropriate plots, one-half at two weeks after planting and the other half at the onset of flowering. Three hand weeding were carried out at 3, 6 and 8 weeks after planting. Other normal routine field management practices such as pest and disease control were carried out as recommended by the Ministry of Agriculture, Forestry and Food Security (MAFFS) in Sierra Leone.

Data Collection

Eight plants were randomly selected per treatment for measuring morphological characteristics. Hence the number of leafs, leaf area, total plant height and stem girth of the plants were measured weekly from the

third week after planting until flowering. Leaf area index was determined at the mid-flowering stage using the portable leaf area meter model LI-3000A, with base scanner serial number PAM 1684. The number and weight of fresh fruits were determined at horticultural maturity. Phenological data such as the number of days to 50% flowering and fruit-setting were recorded.

Statistical Analysis

Statistical analyses were carried out in the Statistical Analysis System (SAS) environment for Microsoft Windows Release 6.10 (SAS, 1991). The analysis of variance was used to determine differences in mean of treatments. Significantly different means were separated using the Student-Newman-Keuls (SNK) test at $p < 0.05$ level of significance.

Results and Discussion

Effect of Selected Organic Fertilizer on Growth and Yield of Okra

Morphological Characteristics of Okra

The results in table 1 shows that okra growth parameters such as plant height, stem girth, leaf number and leaf area were influenced by different organic fertilizers. Okra plants treated with poultry manure produced taller plants, bigger stems, plenty leaves and broader leaves followed by those treated with Fertiplus and then N.P.K 15:15:15. Plants treated with DI Grow produced the least of the above-mentioned morphological characteristics. The height of plants treated with poultry manure was 31.25cm as compared with those treated Fertiplus (22.43cm) and then N.P.K 15:15:15 (20.79cm). Stem girth of plants treated with poultry manure was 0.95cm as compared with those of Fertiplus (0.74cm) and N.P.K 15:15:15 (0.65cm). Moreover, leaf number and area for poultry manure were (6.81) and (708.13cm^2) whereas those for Fertiplus and N.P.K 15:15:15 were (5.83) and (236.64cm^2) and (5.23) and (213.65cm^2) respectively.

Table 1. Effect of different application of organic fertilizers on morphological characteristics of okra (*Abelmoschus esculentus*).

Morphological characteristics				
Treatment	**Plant height (cm)**	**Stem girth (cm)**	**Leaf number (cm)**	**Leaf area (cm^2)**
N.P.K 15:15:15	20.79±1.1a	0.65±0.05a	5.23±0.1a	213.65±80.1a
Fertiplus	22.43±1.0a	0.74±0.05a	5.83±0.4a	236.64±23.2a
Codafol	19.36±1.2a	0.60±0.07a	5.34±0.5a	184.06±29.5a
Di grow	18.77±4.6a	0.60±0.17a	5.15±1.1a	174.13±83.5a
Poultry manure	31.25±2.5b	0.95±0.14b	6.81±0.3b	708.13±59.5b
Treatment means in a column followed by different letters are significant at $P < 0.05$				

Phenology of Okra

There was difference in 50% days to flowering as well as 50% days of fruit set among the different organic fertilizers. The result in table 2 shows that 50% days to flowering and fruit set were earlier in plants treated with poultry manure than in N.P.K 15:15:15 treated plants. Plant treated with poultry manure flowered 27 days after planting (DAP) followed by Fertiplus (29 days) and then N.P.K 15:15:15 fertilizer (32 days). Days to 50% fruit set also follow similar pattern as days to 50% flowering. Plants treated with poultry manure set fruits earlier than those treated with N.P.K 15:15:15 fertilizer. Days to 50% fruit set was recorded in plants treated with poultry manure on 35 DAP whereas those treated with Fertiplus organic fertilizer and N.P.K 15:15:15 fertilizer were observed on the 37 and 38 DAP respectively. From table 2, it is clear that plants treated with poultry manure and Fertiplus flowered and set fruit earlier than those treated N.P.K 15:15:15 fertilizer.

Table 2. Effect of different application of organic fertilizer on the phenology of okra (*Abelmoschus esculentus*).

Plant phenology		
Treatment	**50% days flowering**	**50% days fruit set**
NPK 15:15:15	32	38
Fertiplus	29	37
Codafol	34	43
DI grow	36	43
Poultry manure	27	35

Fresh Fruit Number and Weight

Variations do exist in fresh fruit number and weight of okra among the different organic fertilizers. The best fruit number, fruit weight and subsequently yield were recorded for plants treated with poultry manure followed by Fertiplus and then N.P.K 15:15:15. The least yield was recorded for plants treated DI Grow organic fertilizer. The fresh fruit weight for plants treated with poultry manure was 1122.39kg/ha while those treated with Fertiplus was 710.45kg/ha and that of N.P.K 15:15:15 was 549.25kg/ha. DI Grow organic fertilizer which was the least produced 513.43kg/ha.

Table 3. Effect of various organic fertilizers on fresh fruit number and weight of okra (*Abelmoschus esculentus*).

Fresh fruit number and weight		
Treatment	**Fruit number**	**Fruit weight (kg/ha)**
NPK 15:15:15	353	549.25±22a
Fertiplus	448	710.45±11b
Codafol	391	549.25±48a
DI grow	358	513.43±60a
Poultry manure	602	1122.39±53c
Treatment means in a column followed by different letter are significant at P < 0.05		

Discussion

Effect of Selected Organic Fertilizer on Growth and Yield of Okra

Morphological Characteristics of Okra

Organic fertilizers have been reported by many researchers to give significant improvement in crop growth. This has been largely attributed to the improvement of soil physical properties, such as aggregation, increased soil aeration and lower bulk density, increased water retention and supply plant nutrients (Yafan and Barker, 2004). The results of this study are consistent with these findings, showing that poultry manure and Fertiplus accelerated the vegetative growth of okra plants more than chemical fertilizer (N.P.K 15:15:15). The plants height and the stem diameter were bigger in the plants treated poultry manure and Fertiplus. Also, the leaf number and size of plants treated with poultry manure and Fertiplus increased considerably compared to those treated with N.P.K 15:15:15. Such pattern was also observed in total yield (Fresh fruit number and weight), with poultry manure and Fertiplus treatments producing higher fruit number and weight than N.P.K 15:15:15 treatment. The results indicate that poultry manure and Fertiplus at a rate of 5t/ha and 1500kg/ha have the potential to improve okra yields significantly over N.P.K 15:15:15. These organic fertilizers may serve as an alternative to chemical fertilizer at the rate used in this study and may be recommended.

The potential of poultry manure and Fertiplus over other organic fertilizers to increase okra yield could be attributed to the method of application. Poultry manure and Fertiplus were directly incorporated in the soil while Codafol and DI Grow organic fertilizers were sprayed on leaves of okra. Such method of application could have helped improve the soil physical properties, such as aggregation, increased soil aeration and lower bulk density, increased water retention and supply plant nutrients (Yafan and Barker, 2004), hence producing taller plants, bigger stems, plenty leaves and broader leaf area and consequently, higher yield.

Phenology of Okra

Differences do exist among the plants treated with various organic manures in terms of 50% day to flowering and fruit set. Plants treated with poultry manure and Fertiplus attained 50% days to flowering and fruit set earlier than those treated with N.P.K 15:15:15 fertilizer. Plants treated with poultry manure took 27 days after planting to flower and 35 days set fruit followed by Fertiplus 29 and 38 days after planting respectively. Plants treated with N.P.K 15:15:15 reached 50% days flowering and fruit set at 32 and 38 days. From the result, there was 5 days difference for flowering and 3 difference for fruit set between poultry manure treated plants and the N.P.K 15:15:15 treatment plants. This implies that the pepper plants treated with N.P.K 15:15:15 takes somehow longer time to shift from vegetative to reproductive stage as compared to the poultry manure treated plants.

The shorter days of reproductive development has a market advantage, as early flowering means early fruit set and maturity leading to early introduction of produce in the market that commands higher market price. Number of days to 50% flowering is a function of nitrogen concentration (Dauda and Samari, 2002). Early reproductive development in okra plants subjected to poultry manure and Fertiplus organic fertilizer as compared to that of N.P.K 15:15:15 could largely be attributed to high nitrogen and phosphorus supplied by

the former than the latter nutrient sources. It could be that the poultry manure applied was able to supply the required amount and type of nutrients for the rapid growth and development okra plants which resulted to early flowering.

Fresh Fruit Number and Weight of Okra

Variation in fresh fruit number and weight was observed among the treatments used in this study. Table 3 shows that the yield of plants treated with poultry manure and Fertiplus were higher than that of the N.P.K 15:15:15 fertilizer. Fresh fruit number and weight for plants treated with poultry manure and Fertiplus were 602 fruits and 1122.39kg/ha^{-1} and 448 and 710.45kg/ha^{-1} respectively. Those of N.P.K 15:15:15, Codafol and DI Grow were 353 and 549.25kg/ha^{-1}; 391 and 549.25kg/ha^{-1} and 358 and 513.43kg/ha^{-1} respectively. The results suggest that poultry manure treatment substantially increase okra yield (both fruit number and weight) than N.P.K 15:15:15 fertilizer. Okra plants under the poultry manure treatment were exceptionally healthy, taller, as well as having stronger stems and increased leaf number. The accelerated growth rate of the vegetative organs was also accomplished by an increased development of the generative organs. This could have led to the production of many heavier fresh fruits in the poultry treatment than those under N.P.K 15:15:15 fertilizer. Interestingly, fresh fruit numbers were many in plants treated with Codafol and DI Grow than those treated with N.P.K 15:15:15 treated plants were pronounced in dry matter accumulation than those of Codafol and DI Grow. The vigorous and robust nature of okra plants under the poultry manure and Fertiplus treatments as compared to other organic fertilizers including N.P.K 15:15:15 fertilizer treatment (Table 1) may have contributed to the high fresh fruit yield. Perhaps more photosynthetic could have been produced because of many broad leaves that could have translocate manufactured food into the sink and therefore, higher fresh fruit yield in poultry manure and Fertiplus treatments. This suggests that morphological characteristics such as plant height, stem girth, leaf number and leaf area tend to contribute much in the accumulation of dry matter content and the subsequent total yield in okra plants.

The fruit weight shows similar trend as the leaf number and area wherein plants treated with poultry manure produced heavier fresh fruit weight (1122.39kg/ha^{-1}) followed by Fertiplus (1122.39kg/ha^{-1}) and then N.P.K 15:15:15 (549.25kg/ha^{-1}). This indicates that there is a positive correlation between fresh fruit weight (Table 3) and leaf number and leaf area index (Table 2). This is not surprising as leaf is the major site of photosynthesis that subsequently manufactures food. Therefore, many larger leaves mean more area exposure to light, more photosynthetic activity, more assimilate partitioning and higher fruit yield. Organic fertilizers added to soil may stimulate the activity of bacteria which promote the released availability of N, P and the other nutrients in the soil and enhances nutrients absorption and high yield (Bertand and Cleyetmarel, 2008). The results noted in this study are consistent with those observed by Berova *et al.,* (2010), who concluded that organic fertilizer enhanced high yield of pepper.

Summary

The studies were carried out to assess the effect of organic and inorganic fertilizers on growth and yield of okra (*Abelmoschus esculentus*) on degraded upland soil. Organic manure type, application rate significantly influenced morphological characteristics, phenotypic characteristics and yield components of okra grown during the 2017 cropping season at Njala University. Poultry manure application rate at 5t/ha^{-1} has the potential to improve on yield of okra.

Conclusion

Based on the findings, the following conclusions were made:

- Poultry manure and Fertiplus enhanced the growth, development and yield of okra and are therefore, valuable organic fertilizers whose uses need to be encouraged. Plants treated with such organic fertilizers were exceptionally healthy, taller and produced plenty bigger leaves than those treated with 200kg/ha^{-1} of N.P.K 15:15:15 fertilizer.
- An application rate of 5t/ha^{-1} and 1500kg/ha^{-1} of poultry manure and Fertiplus, respectively, were capable of increasing yields by more than 34% over N.P.K 15:15:15 fertilizer.
- The yield of okra was positively influenced by the poultry manure at 5t/ha^{-1} than the other application rates.
- Poultry manure at 5t/ha^{-1} rate of application has the potential to promote better plant growth, development and yield of okra and are therefore, important organic manure whose uses need to be encouraged.
- Okra plants treated with 5t/ha^{-1} rate of poultry manure flowered, set fruit and reach economic maturity earlier than plants subjected to other application rate.

Recommendations

On the basis of the conclusion, the following recommendations are made:

- Since poultry manure and Fertiplus organic fertilizers proved to be very satisfactory for the nutritional needs, okra growers within the Njala community are encouraged to adopt the use of these organic manures for high productivity.
- An application rate of 5t/ha^{-1} and 1500kg/ha^{-1} are recommended for okra production within the Njala community as they have the potential to increase yields.
- Okra farmers, especially small and limited resource farmers (SLRFs) within Njala community are encouraged to use poultry manure at 5t/ha^{-1}, in the production of okra as it has the potential to increase yield.
- The trials should be repeated in a number of locations using higher number of okra cultivars to confirm the results obtained in this study.

Declarations

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