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Growth and Yield Response of Okra to Method and Time of Poultry Manure Application Under Rain-fed Conditions

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Abstract

Matching nutrient demand with supply is critical for plant growth, development and yield. This study investigated the growth and yield response of okra (*Abelmoscus esculentus*) to the method and time of poultry manure application, in order to match the time of optimum nutrient release with nutrient uptake by the okra plants. A randomized complete block design with six treatments and three replicates was used for the study. The poultry manure was applied at three different times: During planting (0-DOP), two weeks after planting (2-WAP), and four weeks after planting (4-WAP) using two application methods: surface-broadcasting and plow-incorporation. Results showed significant differences in method and time of application of poultry manure. The application of poultry manure, using plow-incorporation method on the day of planting (0-DOPI), significantly improved growth and yield (5.88 t ha^{-1}) of okra. Also, 0-DOPI treatment took fewer days to attain 50% flowering (55 days) and fruit setting (58 days). This indicated that the match between nutrient demand and supply was most evident under 0-DOPI treatment. However, the surface broadcasting method at 2-WAP and 4-WAP, could not match release and supply of nutrients with critical developmental stages of okra. Hence, poultry manure incorporation at time of planting could improve okra production in the study area.

Keywords: Crop demand, Nutrient supply, Nutrient Synchrony, Poultry manure, Okra yield.

Introduction

Okra (*Abelmoschus esculentus* (L) Moench) is an annual herbaceous vegetable cultivated in the tropical, sub-tropical, and warm temperate regions of the world (Purseglove, 2008). It belongs to the family Malvaceae with its origin in Africa. It is a pleasant sauce eaten in Africa, Europe, and Asia. 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 100 g 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).

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 (Peyvast *et al*., 2003; Ojoniyi, 2013). In addition, chemical fertilizers are expensive, not readily available, and negatively affect the environment (Smil, 2001; 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 its 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 determine the appropriate method of application and suitable time of application 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.

Materials and Methods

Experimental Site Description

The experiment was conducted at the Teaching and Research Farm of the School of Natural Resources Management, Njala University, Sierra Leone. The growth trials were carried out during the early (April – June) and late (September – November) cropping seasons of 2020. Annual rainfall in the area is 1500–2000 mm and the average temperature is 26 °C. The bimodal rainfall in the study area has made it possible to grow okra twice a year. There is heavy rainfall in June and July, followed by another period of appreciable rainfall in September and October. Cassava was earlier cultivated and harvested on the experimental site before the growth trial was established. During the growth trial, mean temperature and relative humidity were 31 °C and 85%, respectively (Table 1). The soil type on the study site is loamy clay (Orthoxic Plehumult soil) with a pH of 5.6 (Vuure *et al.,* 1972).

Table 1: Climatic and soil characteristics at the experimental site of Teaching and Research Farm, Njala University, Sierra Leone

Climatic Characteristics	First Cropping Season	Second Cropping Season
Rainfall (mm)	1954.30	1791.30
Minimum temperature (°C)	26.70	27.30
Maximum temperature (°C)	31.40	31.60
Minimum Relative humidity (%)	73.50	74.20
Maximum Relative humidity (%)	85.40	85.30
Soil Characteristics	**First Cropping Season**	**Second Cropping Season**
pH (1:1 H_2O)	5.80	5.60
pH (1:1 KCl)	5.40	5.70
EC (µS/cm)	0.15	0.14
Sand (%)	10	15
Silt (%)	25	20
Clay (%)	65	65
Organic Carbon (%)	0.12	0.12
Nitrogen (mg kg^{-1}soil)	1.07	1.03
Phosphorus (mg kg^{-1} soil)	0.92	0.91
Texture	Clay loam	Clay loam
Other Characteristics	**First Cropping Season**	**Second Cropping Season**
EAc (meq/100g soil)	2.50	2.60
EAl (meq/100g soil)	1.40	1.50
CEC (meq/100g soil)	4.20	4.00

Note: Exchangeable Acidity = EAc, Exchangeable Aluminium = EAl, Cation Exchange Capacity = CEC, Electrical Conductivity = EC

Experimental Design

The experimental plot was ploughed with a tractor and harrowed with hand hoes. The area was lined, pegged, and seed beds constructed. The plot size was 11.00 m x 36.00 m with six (6) treatment units. The size of each treatment plot was 3.00 m x 5.50 m, with 0.60 m footpath between plots and 1.00 m between replicates. Each treatment plot consisted of four rows, with eight plant stands per row. A two-factor factorial experiment in a randomized complete block design (RCBD), with two levels of manure application and three levels of application time as well as three replicates, were used for this study (Figure 1). The two methods of manure application were the surface-broadcasting method (poultry manure uniformly spread over the surface of the experimental plot), and the plow-incorporation method (poultry manure put in planting holes). The three levels of poultry manure application times were: poultry manure applied on the day of planting: 0-DOP; poultry manure applied 2 weeks after planting: 2-WAP and poultry manure applied 4 weeks after planting: 4-WAP. In each treatment plot, an equivalent of 5 t ha^{-1} of poultry manure was applied.

Figure 1: Experimental layout showing replications and treatment units for poultry manure application to okra under rain-fed cultivation

Planting Materials and Harvesting

The Clemson Spineless Okra was used in the study. The okra seeds were purchased from Seed-Tech International in Freetown, Sierra Leone. Planting was done on 14 June (first cropping season) and 20 September (second cropping season) in 2020. Three seeds were planted per hole at 60 cm x 60 cm plant spacing and later thinned to two seedlings per stand to achieve a density of 55,555 plants/ha. A 95% seed germination rate was observed within four to six days after planting and hand weeding was done in the 3rd and 6th week after planting. Each treatment plot was harvested, fresh fruits counted, weighed and the cumulative results recorded.

Data Collection

Twelve plants were randomly selected per treatment for measuring morphological characteristics. Hence, the number of leaves, leaf area, total 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. 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 $p \leq 0.05$ level of significance.

Results and Discussion

Morphological Characteristics of Okra

The method and time of application of poultry manure influenced the morphological characteristics of the okra plants (Table 2). The plow-incorporation of manure had a significantly higher effect on the growth of okra than the surface-broadcasting method. For the time of application, significant differences only existed between 0-DOP and 2-WAP for plant height and number of leaves under plow-incorporation treatments.

Treatment 0-DOP under plow-incorporation had the highest values for morphological characteristics, while 4-WAP treatment had the least. The leaf area and stem girth did not differ significantly among the treatments for time of application (Table 2).

Generally, plow-incorporation of poultry manure produced better growth variables than surface-broadcasting, across all treatments.

The higher growth parameters in plow-incorporation method compared to surface-broadcasting method could be attributed to rainwater. These might have washed away some of the manure from the soil surface after broadcasting, thereby reducing the amount of nutrients available for release (Gana, 2011).

Another reason for higher growth values under plow-incorporation method could be that poultry manure had decomposed and become mineralized, thus supplying the required nutrients to support the growth of okra (Ozores-Hampton, 2012). Poultry manure can improve soil physical properties such as aggregation, aeration, bulk density, water retention, and plant nutrients (Yafan and Barker, 2004).

Hence, the plow-incorporation of poultry manure probably improved soil physical properties resulting in the accelerated growth of the okra plants (Table 2). The findings in this study were consistent with those of Adekiya and Agbede (2016), who reported that the broadcast of manure was not as effective for crop production as plowing it into the soil.

As okra is a short-duration crop, producing fruits in approximately 60 days, poultry manure application under 2-WAP and 4-WAP treatments may not be useful to the plant in terms of nutrient supply. This is because the time of nutrient release from the manure may not coincide with the period of growth and development of the plant. Furthermore, the low morphological characteristics observed for plants in the 4-WAP treatment may be attributed to delayed mineralization and release of nutrients in poultry manure for use by the okra. For maximum optimal value, poultry manure should be applied early enough to match with the nutrient needs of okra (Ozores-Hampton, 2012).

Table 2: Effect of method and time of poultry manure application on morphological characteristics of okra (*Abelmoschus esculentus*)

Treatment		Plant height (cm)	Stem girth (cm)	Number of Leaves	Leaf area (cm^2)
Method	**Time**				
Surface-broadcasting	0-DOPS	19.70±0.7b	0.88±0.1b	4.88±0.5b	244.02±105b
	2-WAP S	15.93±5.3c	0.82±0.2b	4. 19±0.6b	162.11±9.7b
	4-WAP S	16.74±1.8c	0.82±0.2b	4.02±0.7b	217.11±35b
Plow-incorporation	0-DOPI	28.91±2.7a	1.28±0.2a	6.71±1.1a	352.94±100a
	2-WAP I	18.98±1.7b	1.00±0.1a	4.90±0.6b	333.19±145a
	4 WAP I	18.53±1.5b	0.90±0.1a	4.47±0.7b	234.88±70a

Columns with the same letter were not significantly different at $P \leq 0.05$ (SNK); 0-DOP = day of planting; 2-WAP = 2 weeks after planting; 4-WAP = 4 weeks after planting, S = Surface-broadcasting, I = Plow-incorporation

Table 3: Effect of method and time of poultry manure application on phenological characteristics of okra (*Abelmoschus esculentus*)

Treatment		Day to 50% Flowering	Day to 50% Fruit-setting
Method	Time		
	0-DOPS	60.00±1.0d	63.00±1.0e
Surface-broadcasting	2-WAPS	60.30±1.0d	70.33±1.5b
	4-WAPS	70.33±0.6a	72.00±1.0a
	0-DOPI	55.33±0.5e	58.00±1.0f
Plow-incorporation	2-WAPI	62.33±0.5c	67.00±0.1d
	4-WAPI	65.00±1.0b	69.66±0.5c

Columns with the same letter were not significantly different at $p \leq 0.05$ (SNK); 0-DOP = day of planting; 2-WAP = 2 weeks after planting; 4-WAP = 4 weeks after planting, S = Surface-broadcasting, I = Plow-incorporation

Phenological Characteristics of Okra

The method of application and time of application generally enhanced the flowering and fruit-setting of okra (Table 3). There were significant differences in the number of days required to attain 50% flowering and fruit-setting across the treatments. Plow-incorporation on the day of planting resulted in flowering at 55.33±0.5 days and fruit-setting at 58.00±1.0 days. Surface-broadcasting resulted in flowering at 60.00±1.0 days and fruit-setting at 63.00±1.0 days. Flowering and fruit-setting occurred five days earlier for plants treated with plow-incorporation method than those treated with surface-broadcasting method. For time of application, flowering and fruit-setting were earlier for 0-DOP treatments, followed by 2-WAP and then 4-WAP treatments (Table 3). A similar trend was observed for the flowering and fruit-setting of okra subjected to surface-broadcasting method.

Okra plants treated with plow-incorporation method attained their phenological development earlier than those treated with surface-broadcasting method. This may be attributed to the increased access to nutrients for plow-incorporated crops thus shortening the time of shift from vegetative to reproductive stages (Ozores-Hampton, 2012). It has been shown that the number of days to 50% flowering is a function of nitrogen concentration (Dauda *et al.,* 2008). Hence, the earlier reproduction of okra under plow-incorporation method could be attributed to rapid release of nitrogen and phosphorous into the soil (Havlin *et al.,* 2005). In this study, the nutrient release may have coincided with the specific phenological demands of okra in plow-incorporation treatments (Adekiya and Agbede, 2016). Ammonium ($NH4^{+}$) in manure becomes highly volatile when exposed. Thus, plow-incorporation into soil helps to reduce ammonia (NH_3) loss via volatilization by 50–90%, when compared with surface-broadcasting application (Havlin *et al.,* 2005; Jokela and Meisinger, 2008). The surface-broadcasting application at 4-WAPS limited the release of nutrients. This affected the shift from vegetative to reproductive stages of the okra plants. Thus, it possibly resulted in late flowering and fruit-setting.

Yield Characteristics of Okra

Okra yield was significantly influenced by both the method and time of application of poultry manure (Table 4). On the average, the number of fruits from the plow-incorporation method was 25% higher than those from the surface-broadcasting method. Similarly, the fresh weight of okra fruits from plow-incorporation treatment was 29% higher. The time of application also influenced okra yield, but only 0-DOPI and 2-WAPI treatments significantly differed. The 0-DOP treatment under plow-incorporation had a higher number of fruits (211 fruits) and fresh weight (5.88 t ha^{-1}) than those of 0-DOP treatment under surface-broadcasting method (107 fruits and 2.13 t ha^{-1}, respectively). However, for the surface-

Table 4: Effect of method and time of poultry manure application on the number and weight (t ha^{-1}) of fresh okra (*Abelmoschus esculentus)* fruits

Treatment		Fruit Number	Fresh Fruit Weight (t ha^{-1})
Method	**Time**		
Surface-broadcasting	0-DOPS	107.00±47.5b	2.13±1.0b
	2-WAP S	76.66±28.4b	1.65±0.6b
	4-WAP S	93.00±43.8b	2.64±1.8b
Plow-incorporation	0-DOPI	211.33±58.1a	5.88±1.9a
	2-WAP I	139.66±73.3b	3.52±2.0b
	4-WAP I	119.66±9.5b	2.49±1.3b

Columns with the same letter were not significantly different at $p \leq 0.05$ (SNK); 0-DOP = day of planting; 2-WAP = 2 weeks after planting; 4-WAP = 4 weeks after planting, S = Surface-broadcasting, I = Plow-incorporation

broadcasting method, no significant differences existed in the yield for different times of application. Nevertheless, the 4-WAPS treatment produced the highest yield (Table 4).

The findings indicate that the method of application was more critical in determining yield than the time of application of poultry manure. The higher okra yield in plow-incorporated plots was consistent with the morphological characteristics, particularly plant height and the number of leaves. This suggests that the growth variables contributed to high productivity probably through high photosynthetic assimilation and dry matter accumulation. Okra leaves under plow-incorporation were higher in number and larger than those under surface-broadcasting. Large leaves mean high exposure to sunlight, high photosynthesis, high assimilate partitioning, and possibly high fruit yield (Pallardy, 2008).

The matching of crop demand and nutrient supply leads to efficient use and vigorous growth of plants (Cassman *et al*., 2002). In this study, it could be that there was a good match and synchrony between nutrient release and nutrient demand in the plow-incorporation treatments at 0-DOP, but not in the case of 4-WAP treatments. Therefore, the application of manure after four weeks of growth may not be necessary because okra is a short-duration crop. The okra plant may not have the capacity to use the nutrients in significant amounts at this stage of its growth.

Conclusion

Okra production was highest under the plow incorporation of poultry manure on the day of planting. The enhanced morphological growth and increased yield indicated that this method and time of application may be the most suitable for poultry manure use. There was a good match between crop demand and nutrient supply for enhanced productivity of okra in the plow-incorporation treatments. This is critical for okra yield improvement, especially for smallholder and resource-limited farmers.

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