



## Effects of Organic and Inorganic Fertilizers on the Growth and Yield of Kenaf (*Hibiscus cannabinus* L.) Production in South Western Nigeria

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### Authors' contributions

This work was carried out in collaboration among all authors. Author SOO designed the study, managed the literature searches, wrote the protocol and wrote the first draft of the manuscript. Author AOT supervised the entire research work and proof read the manuscript. Author AKA managed the field and collected the data. Author FBA performed the statistical analysis. All authors read and approved the final manuscript.

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### ABSTRACT

Farmers use Inorganic Fertilizers (IF) to improve kenaf yield in Nigeria. However, the detrimental effects of mineral fertilizers and its high cost calls for the use of organic fertilizers that are locally available and environment friendly. Combination of Organic Fertiliser (OF) with IF may reduce the bulkiness of OF while harnessing the benefit of both for higher yields. Field trials were conducted at Ibadan and Ilora in 2013 and 2014 to investigate the effects of combined fertilizers on the growth and yield of kenaf. Organic and IF (NPK 20:10:10) fertilizers as: (i) 160 kg ha<sup>-1</sup> (sole organic), (ii) 100 kg ha<sup>-1</sup> (sole IF), (iii) Organic and IF at 50:50 ratio and (iv) control (no fertilizer). The experiment was laid out in Randomized Complete block design (RCBD) and replicated three times. Results showed that plant height (220.17 cm, 216.80 cm) and stem diameter (2.27 cm, 1.16 cm). Bast fiber (2.27 t/ha, 2.27 t/ha) and seed yield (1.69 t/ha, 1.78 t/ha) in Ibadan and Ilora respectively were significantly higher in plots with combined fertilizer. Combined fertilizers had the highest fiber and seed yield above sole application and control (no fertilizer application). Hence it is recommended for kenaf cultivation in Southwest Nigeria.

**Keywords:** Kenaf; organic; mineral fertilizer; fiber; seed yield.

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## 1. INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.) is an annual herbaceous crop of the Malvaceae family known for both its economic and horticultural importance. It is a fiber plant native to Africa where it has been grown for several thousand years for food and fibre [1]. Kenaf is a fast growing industrial crop and it contains fiber materials with high quality lignocellulosic material [2]. The stalk of the plant is composed of two distinct fiber types. They include the bark of the kenaf stalk which contains the long small bast fibers and the woody core material which is the portion remaining when the bark is removed which contains core fibers.

Kenaf cultivation in Africa has been limited to small plots with attendant low yield (Agbaje et al., 2008) hence as low as 2.91% of the global production is being produced in Africa according to FAO (2003). Agronomic practices such as fertilizer application may improve kenaf productivity and biomass yield [3-5]. However, there are contrasting reports on the impact of fertilizer application on kenaf yields. Manzanares et al. [2], Kipriotis et al. [6], and Patane et al. [7] reported no effect of nitrogen application (range: 0-150 kg N/ha) on kenaf. In contrast, Bhangoo et al. [8], Muschow [9,10], Webber [11] and Kuchindra et al. [12] working under different soil-climatic conditions found a positive effect of nitrogen on kenaf yields, which were maximized with N- dressing in the range 86-224 kg N/ha. Meanwhile, Adekunle et al. [5] reported that the utilization of organic fertilizer which is rich in carbon is very important in improving soil quality in Southwestern Nigeria. Carbon is a key ingredient in soil organic matter (57% by weight), which is crucial for the soil because of its role in soil nutrient holding capacity for soil especially in less fertile sandy soil [13]. Bearing in mind the low nutrient nature of most Nigerian soils and the low nutrient releasing nature of organic fertilizer as well as its bulkiness, it may be necessary to assess the combination of the two sources of the nutrient. Therefore, the objective of this study was to assess the effect of the combined organic and inorganic as well as their sole application on the growth and fiber yield of kenaf in southwest Nigeria.

## 2. MATERIALS AND METHODS

### 2.1 Description of the Study Area

The experiment was conducted in 2013 and 2014 in two agro-ecologies in the Southwest

Nigeria. The experimental sites were located in Ibadan (rainforest savanna transition) (07°38'N, 03°84'E 182M) and Ilora (derived savanna) (07°81'N, 03°82'E 278M).

The field was properly ploughed; harrowed and marked out into 4 m × 3 m at each location to fit into the randomized complete block design (RCBD) with three replicates. Soil samples were taken for pre planting analysis. Compost made from municipal waste and cow dung to form organic fertilizer was sourced from Aleshinloye commercially produced organic fertilizer plant. The compost was applied and thoroughly mixed with the soil 2 weeks before planting (WBP) in the plots that were to receive such while the NPK 20-10-10 was applied to the plots designated for it at 4 weeks after planting (WAP).

### 2.2 Treatments and Plant Materials

One rate each of OF (160 kg ha<sup>-1</sup>) and IF (NPK 20:10:10) (100 kg ha<sup>-1</sup>) which has been established for providing optimum yield and their combination in ratio 50:50 were used as: (i) 160 kg ha<sup>-1</sup> (sole OF), (ii) 100 kg ha<sup>-1</sup> (NPK 20:10:10) (iii) OF and IF combined at ratio 50:50 and (iv) the control plot receiving no fertilizer were used as treatments. The experiment was laid out in a randomized complete block design with three replications.

### 2.3 Field Experiment and Cultural Practices

Planting was done in June 2013 and 2014 after the rain was established. One kenaf variety, Ifeken 400 was used as a test crop. Five seeds were sown per hole at spacing of 50 cm apart and 20 cm within the row and thinned to two plants per stand at three weeks after sowing to give a plant population of 200,000 plants per ha. Weeding was done using hoe at 3 and 6 weeks after sowing (WAS) while the insect pests were controlled using Laraforce (Lamda- cyhalothrin 2.5% E.C) at the rate of 1L /ha with a dilution factor of 2.5 ml/ lit (recommended dose).

### 2.4 Growth Measurements

Plant height, stem diameter, number of leaves and leaf area were determined on five randomly pre-selected and tagged plants in each replicates. Plant heights were measured as the distance from the soil surface to the stem apex using meter rule. Stem diameter was measured at (10 cm above soil surface) the plant base using a digital caliper. Leaf number was

determined by counting while the leaf area was determined using SHY- 150 leaf area meter with accuracy of  $\pm 2\%$  from third fully matured leaf at the top of the plant. All agronomic parameter were measured at 10 weeks after sowing and recorded in cm except for number of leaves.

## 2.5 Fiber Yield Determination

Five plants in each replicates were cut from the base at 10 WAS, leaves were removed and stems were retted in water by total immersion. After 14 days, the retted plant were removed from the water to separate the bast from the core and thoroughly washed with clean water to remove all the dirt. Thereafter, both the bast and core were sundried till constant weight was attained and fibre yield (t/ ha) was determined by weighing.

## 2.6 Statistical Analysis

Data on plant height stem diameter, number of leaf, leaf area and fibre yield were subjected to statistical analysis (ANOVA) using SAS statistical package [14]. Means comparisons were performed by Duncan's multiple range test (DMRT) at  $p \leq 0.05$ .

## 3. RESULTS

### 3.1 Pre Cropped Soil of the Experimental Sites

The physical and chemical properties of the first 15 cm soil depth of the study sites were shown in Table 1. The soil sample of Ibadan experimental site belongs to Iwo series and was classified as Alfisol. It was formed from the igneous rock of the basement complex [15]. This soil sampled from Ilora belongs to Egbeda series. Both soils are sandy loam, though the soil of Ibadan site has higher clay content than Ilora. They are both slightly acidic with pH ( $H_2O$ ) value of 6.09 and 6.24 for Ibadan and Ilora respectively. However, Ilora soil contained higher organic carbon and nitrogen than the soil of Ibadan site. On the contrary, the available Phosphorus of Ibadan site was considerably higher than that of Ilora 5.63 and 3.25 mg.  $Kg^{-1}$  respectively though they are both low (Table 1).

### 3.2 Effect of Fertilizer Application Rates and Types on the Vegetative Performance of Kenaf at Ibadan

Plant height of kenaf was significantly influenced by varying rates and types of fertilizer applied (Table 2). Effect of sole mineral fertilizer (NPK)

applied at 0.60 kg/plot was not significantly different from the control (no fertilizer) 189.19 cm and 174.41 cm respectively. These results were significantly lower than 208.17 cm obtained with the application of 14.55 kg/plot sole organic fertilizer. However, significantly highest plant height (220.17 cm) was obtained under combined organic and NPK fertilizer applied at ratio 50:50.

Similar trend was observed for the stem diameter. The application of NPK (0.60 kg/plot) was not significantly different from control in their response to stem diameter 1.08 cm and 1.04 cm respectively. Stem diameter of 2.00 cm was obtained from the application of 14.55 kg/plot organic fertilizer which though was significantly higher than the mean values obtained from both control (1.04 cm) and NPK (1.08 cm), it was however significantly lower than the values (2.27 cm) obtained from the application of combined fertilizer. The application of combined fertilizer resulted into the highest number of leaves (74.99) which was significantly higher than the results obtained from the sole application of NPK fertilizer (60.02) but not significantly different from the mean value obtained under sole organic (69.12) fertilizer. The least number of leaves 51.84 was from control (no fertilizer). Control (no fertilizer) had the least leaf area value of 111.24  $cm^2$ .

Leaf area obtained from sole organic and sole inorganic 150.39  $cm^2$  and 147.86  $cm^2$  respectively were not significantly different from each other but were significantly higher than what was obtained from control. The application of combined fertilizer (50:50) gave the highest leaf area mean value of 216.73  $cm^2$ . While plant height and stem diameter were significantly higher in 2013 than 2014, number of leaves were not significantly different in both years and leaf area was significantly higher in 2014 than 2013.

### 3.3 Effect of Fertilizer Application Rate on the Vegetative Performance of Kenaf at Ilora

Table 3 showed that the lowest mean value for plant height (199.80 cm) from control was not significantly different from (201.30 cm) that was obtained from sole NPK fertilizer. Both values were however significantly lower than 210.70 cm obtained from the application of sole organic. The significantly highest plant height (216.80 cm) was obtained under combined fertilizer. The least stem diameter (0.92 cm) was obtained from control (no fertilizer) and was not significantly

different from (1.00 cm) stem diameter obtained under sole inorganic fertilizer. Next to this was 1.09 cm stem diameter from sole organic and it was significantly higher than the stem diameter obtained from both sole inorganic and control. However, the significantly highest stem diameter 1.16 cm was from the application of combined fertilizer. The significantly highest number of leaves (82.16) was obtained from the application of combined fertilizer, followed by 77.62 from the application of sole organic while 66.02 and 61.84 were from sole NPK and control respectively, both values were not significantly different from each other. Leaf area was not significantly different from the three fertilizer type but least under control. All the parameters assessed were significantly higher in 2013 than 2014 (Table 3).

### **3.4 Effect of Fertilizer Application Rate on the Fibre and Seed Yield of Kenaf at Ibadan**

Table 4 showed that core (2.45 t/ha), bast (2.27 t/ha), number of capsule per plant (56.89), number of seed per capsule (30.33) weight of 100 seed (3.57 g) and seed yield (1.69 t/ha) were all significantly higher under combined fertilizer than those obtained under sole organic or NPK while they were least in control. Core (2.54 t/ha) and bast (2.29 t/ha) yield were significantly higher in 2013 than 2014 while seed yield (1.64 t/ha) was significantly higher in 2014 than the yield (1.18 t/ha) in 2013.

### **3.5 Effect of Fertilizer Application Rate on the Fibre and Seed Yield of Kenaf at Ilora**

Table 5 showed that all the treated plant were significantly higher than the control for the parameters assessed. The application of combined fertilizer resulted into significantly higher core (2.43 t/ha), bast (2.27 t/ha), number of capsule /plant (52.18), number of seed/capsule (33.13), weight of 100 seed (3.26 g) and seed yield (1.78 t/ha) respectively. These parameters were not significantly different under sole organic and NPK but were higher than those obtained from control (no fertilizer). While Core (2.65 t/ha) and bast (2.34 t/ha) fibre yield were significantly higher in 2013, there was no significant different in the seed yield obtained in both years (1.16 and 1.14 t/ha) respectively.

### **3.6 Climatic Description of the Experimental Site**

The experimental fields were located within the rain forest-savanna transition agro-ecological zone of Nigeria. The ecology is characterized with bimodal rainfall distribution with distinct dry and wet seasons. Annual rainfall was between 1269 and 1315 mm for the period of the experiment. The dry season ran through early November to the end of March, while the raining season falls within the month of April to October of each year. Annual maximum temperature was  $30 \pm 5^{\circ}\text{C}$ . Relative humidity was high during the period of the field trials and was between 55 and 90%. Information on rainfall and other weather parameters for the period of the experiment was collected from the Nigerian Meteorological Agency (Table 6).

## **4. DISCUSSION**

The result presented in this study revealed that plant height, stem diameter, number of leaves and leaf area are factors responsible for the growth and yield of kenaf. Organic or NPK fertilizer as well as their combination showed significant effects on all the growth parameters as evident in this study. Plant height and stem diameter which are determinants of fibre yield in kenaf significantly increased under organic and NPK fertilizers combined at 50:50 compared to sole organic or NPK fertilizer while either of the fertilizer type positively affected these important plant growth parameters over control. The least performance of the plants in the control plots was a reflection of soil nutrient deficit. This agree with the findings of [2,16,6,7,17] that kenaf needs fertilizer for optimum growth just like any other crop.

The overall result obtained under combined fertilizer might be attributed to synergy effect of NPK and organic manure. The NPK supply immediate nutrient needed by the plant while organic manure supply additional nutrients through mineralization and improvement in physico-chemical properties of the soil. The organic fertilizer serves as nutrient holding site for NPK hence preventing nutrient being wash off. Similar results of yield increase in groundnut with combined application of NPK and organic manures like farmyard manure, pig manure and poultry manure were also reported by Laxminarayana and Patiram [18].

The difference obtained in two different seasons seems mainly due to the variation in environment during the period of growth and development of the crop. Amount of rain fall in 2013 was about 3.5% more than that of 2014. Fiber yield was significantly higher in year 2013 at both locations

while seed yield was positively influenced in 2014 at Ibadan but no significant increase was recorded at Ilora. This is in line with Danalatos and Archontoulis [19] reported that shortage in amount of precipitation may lead to reduction in kenaf biomass production.

**Table 1. Chemical and physical properties of the soils of the two experimental sites**

Parameters	Location	
	Ibadan	Ilora
pH (H <sub>2</sub> O)	6.09	6.24
Org.C (g/kg)	0.21	0.54
TN (g/kg)	0.02	0.05
Avail.P (mg/kg)	5.63	3.25
Exchangeable Cations (cmol/kg)		
Ca	2.87	2.21
Mg	2.52	0.90
K	0.17	0.22
Na	0.43	0.41
Exchangeable acidity (cmol/kg)	0.10	0.12
ECEC	6.09	3.86
Particle Size (g/kg)		
Sand	828	864
Silt	48	68
Clay	124	68
Textural Class (USDA)	Sandy loam	Sandy loam

**Table 2. Effects of fertilizer on the vegetative performance of kenaf at Ibadan**

Treatments	Plant height (cm)	Stem basal diameter (cm)	Number of leaves	Leaf Area (cm <sup>2</sup> )
<b>Fertilizer Type</b>				
Sole organic	208.17 <sup>b</sup>	2.00 <sup>b</sup>	69.12 <sup>ab</sup>	150.39 <sup>b</sup>
Sole inorganic	189.19 <sup>c</sup>	1.08 <sup>c</sup>	60.02 <sup>bc</sup>	147.86 <sup>b</sup>
Combined	220.17 <sup>a</sup>	2.27 <sup>a</sup>	74.99 <sup>a</sup>	216.73 <sup>a</sup>
Control	174.41 <sup>c</sup>	1.04 <sup>c</sup>	51.84 <sup>c</sup>	111.24 <sup>c</sup>
<b>Year</b>				
2013	217.63 <sup>a</sup>	2.08 <sup>a</sup>	67.98 <sup>a</sup>	118.43 <sup>b</sup>
2014	194.29 <sup>b</sup>	1.95 <sup>b</sup>	64.03 <sup>a</sup>	211.44 <sup>a</sup>
CV (%)				

Control = No fertilizer; Means within the column followed by similar letter (s) are not significantly different at  $p \leq 0.5$  according to DMRT

**Table 3. Effects of fertilizer on the vegetative performance of kenaf at Ilora**

Treatments	Plant height (cm)	Stem basal diameter (cm)	Number of leaves	Leaf Area (cm <sup>2</sup> )
<b>Fertilizer Type</b>				
Sole organic	210.70 <sup>b</sup>	1.09 <sup>b</sup>	77.62 <sup>b</sup>	7669.00 <sup>abc</sup>
Sole inorganic	201.30 <sup>c</sup>	1.00 <sup>c</sup>	66.02 <sup>c</sup>	1083.60 <sup>a</sup>
Combined	216.80 <sup>a</sup>	1.16 <sup>a</sup>	82.16 <sup>a</sup>	9773.00 <sup>ab</sup>
Control	199.80 <sup>c</sup>	0.92 <sup>c</sup>	61.84 <sup>c</sup>	5562.00 <sup>c</sup>
<b>Year</b>				
2013	207.55 <sup>a</sup>	2.10 <sup>a</sup>	74.85 <sup>a</sup>	2248.03 <sup>a</sup>
2014	198.17 <sup>b</sup>	2.01 <sup>b</sup>	68.13 <sup>a</sup>	2214.14 <sup>b</sup>

Control = No fertilizer; Means within the column followed by similar letter (s) are not significantly different at  $p \leq 0.5$  according to DMRT

**Table 4. Effect of fertilizer application on the fibre and seed yield of kenaf at Ibadan**

Treatments	Fibre yield (t/ha)			Seed yield		
	Core	Bast	No of capsule/plant	No of seed/ capsule	Weight of 100 seed(g)	Seed (t /ha)
<b>Fertilizer Type</b>						
Sole organic	1.46 <sup>b</sup>	1.28 <sup>b</sup>	41.39 <sup>b</sup>	24.00 <sup>c</sup>	2.40 <sup>b</sup>	1.34 <sup>b</sup>
Sole inorganic	1.43 <sup>b</sup>	1.26 <sup>b</sup>	42.11 <sup>b</sup>	24.17 <sup>bc</sup>	2.72 <sup>b</sup>	1.35 <sup>b</sup>
Combined	2.45 <sup>a</sup>	2.27 <sup>a</sup>	56.89 <sup>a</sup>	30.33 <sup>a</sup>	3.57 <sup>a</sup>	1.69 <sup>a</sup>
Control	0.91 <sup>c</sup>	0.73 <sup>c</sup>	36.83 <sup>c</sup>	23.72 <sup>c</sup>	2.08 <sup>c</sup>	1.15 <sup>c</sup>
<b>Year</b>						
2013	2.54 <sup>a</sup>	2.29 <sup>a</sup>	25.56 <sup>b</sup>	22.96 <sup>b</sup>	2.93 <sup>a</sup>	1.18 <sup>b</sup>
2014	2.33 <sup>b</sup>	2.23 <sup>b</sup>	63.82 <sup>a</sup>	28.91 <sup>a</sup>	3.75 <sup>a</sup>	1.64 <sup>a</sup>

*Sole organic = 14.55 kg/plot, NPK = 0.60kg /plot, Combined = 50:50 organic: NPK, Control = No fertilizer; Means within the column followed by similar letter (s) are not significantly different at  $p \leq 0.5$  according to DMRT*

**Table 5. Effects of fertilizer application rate on fibre and seed yield of kenaf at Ilora**

Treatments	Fibre yield (t/ha)			Seed yield		
	Core	Bast	No of capsule/plant	No of seed/ capsule	Weight of 100 seed(g)	Seed (t/ha)
<b>Fertilizer Type</b>						
Sole organic	1.45 <sup>b</sup>	1.26 <sup>b</sup>	41.40 <sup>b</sup>	22.20 <sup>c</sup>	2.20 <sup>b</sup>	1.44 <sup>b</sup>
Sole inorganic	1.39 <sup>b</sup>	1.22 <sup>b</sup>	39.61 <sup>c</sup>	24.23 <sup>bc</sup>	2.12 <sup>b</sup>	1.45 <sup>b</sup>
Combined	2.43 <sup>a</sup>	2.27 <sup>a</sup>	52.18 <sup>a</sup>	33.13 <sup>a</sup>	3.26 <sup>a</sup>	1.78 <sup>a</sup>
Control	0.71 <sup>c</sup>	0.53 <sup>c</sup>	29.89 <sup>d</sup>	20.12 <sup>c</sup>	2.00 <sup>d</sup>	1.12 <sup>c</sup>
<b>Year</b>						
2013	2.65 <sup>a</sup>	2.34 <sup>a</sup>	22.36 <sup>a</sup>	22.00 <sup>a</sup>	2.13 <sup>b</sup>	1.16 <sup>a</sup>
2014	2.42 <sup>b</sup>	2.20 <sup>b</sup>	23.32 <sup>a</sup>	23.01 <sup>a</sup>	3.15 <sup>a</sup>	1.14 <sup>a</sup>

*Control = No fertilizer; Means within the column followed by similar letter (s) are not significantly different at  $p \leq 0.5$  according to DMRT*

**Table 6. Recorded weather parameters at the Ibadan and Ilora experimental site in 2013 and 2014**

	J	F	M	A	M	J	J	A	S	O	N	D	Total rainfall (mm)	Rainy day
<b>2013</b>														
Total rainfall (mm)	4	23	83	150	156	182	173	147	183	179	29	6	1315	228
Max Temp (°C)	33	34	34	33	32	30	28	27	29	30	32	33		
Min Temp (°C)	21	22	23	23	22	22	21	21	22	22	22	21		
Sunshine Hour(hr/day)	5.4	6	5.8	6	6.8	5.8	5.9	5.0	5.2	5.4	6	6		
R. Humidity (%)	65.5	65.5	69.9	69.1	68	80.8	84.3	84	81.2	81	55	67		
<b>2014</b>														
Total rainfall (mm)	3	10	45	145	149	192	175	150	192	182	22	4	1269	260
Max Temp (°C)	32	33	33	34	31	30	29	28	30	32	33	34		
Min Temp (°C)	22	22	22	22	23	21	22	22	22	22	23	19		
Sunshine Hour(hr/day)	6	7	6	7	6	6	6	5.8	5.7	6	7	7		
R. Humidity (%)	66	77	72	55	72	90	82	90	86	77	48	55		

Source: Nigerian Meteorological Agency (2013 – 2014)

## 5. CONCLUSION AND RECOMMENDATION

The combined application of organic and NPK fertilizers may be highly rewarding in nutrient depleted and marginal soils for remediation and immediate nutrients supply especially in continuously cropped soil over years. Organic and NPK fertilizer combined in ratio 50:50 could be adopted for the cultivation of Kenaf in Southwest Nigeria. While sole organic fertilizer may be bulky coupled with its slow releasing nutrient nature, the use of NPK fertilizer with its detrimental effect on soil and environment is not encouraging. The comparative advantage of organic fertilizer on the soil physical and fertility status should be considered over sole application of NPK fertilizer in cropping activities and planting should be done at the appropriate time to maximize its potential. This combination will reduce the adverse effect of mineral fertilizer on the soil while organic fertilizer will improve the soil.

### SUMMARY STATEMENT

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### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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