VARIETIES, POULTRY MANURE AND FERTILIZER INFLUENCE ON THE GROWTH AND FIBRE QUALITY OF KENAF (*Hibiscus cannabinus* L.) †

[VARIEDADES, ESTIÉRCOL DE AVES DE CORRAL Y FERTILIZANTES INFLUYEN EN EL CRECIMIENTO Y LA CALIDAD DE LAS FIBRAS DE KENAF (*Hibiscus cannabinus* L.)]

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SUMMARY

Background: The quality of fibre in kenaf is variety and soil fertility dependent. **Objective:** The study was conducted at the Teaching and Research Farm, University of Ilorin, Ilorin, Nigeria, during the 2018 and 2019 cropping seasons to determine the effects of poultry manure and NPK fertilizer on soil properties and fibre quality of four varieties of kenaf *(Hibiscus cannabinus* L.). **Methodology**: The experiment was laid out as a split-split plot design and replicated four times. The main plot was the years, and the subplots were the four varieties of kenaf (Cuba-108, Ifeken-100, Ifeken-400, and Tainuug 2), and the sub-sub plot was the four rates of poultry manure (0, 5, 10, 15 t/ha) and NPK fertilizer (300 kg/ha). Data were collected on plant height, the number of leaves, stalk girth, stalk weight per net plot and per hectare, fibre weight per hectare and fibre quality (ultimate strength, fibre elongation, and fibre strain). Data were analyzed using the analysis of variance (ANOVA) Genstat software package, and significant means were separated using the New Duncan Multiple Range test at a 5% probability level. **Result**: The 2018 sowing showed no superior growth, yield and fibre attributes compared to the 2019 sowing. Cuba-108 had the best growth, fibre yield, and quality with poultry manure at 15t/ha compared to NPK fertilizer at 300kg/ha. **Implications**: The variability in climatic elements during the study period was of no concern compared to soil factors which was the primary determinant of fibre quality irrespective of variety. **Conclusion**: The use of Cuba-108 cultivar and poultry manure at the rate of 15t/ha improved the growth and fibre quality of kenaf in this locality, thus saving foreign exchange, which could have been used in the importation of fibre.

Keywords: Varieties; Fibre Strength; Poultry Manure; Kenaf

RESUMEN

Antecedentes: La calidad de la fibra en el kenaf depende de la variedad y la fertilidad del suelo. **Objetivo:**. El estudio se llevó a cabo en la Granja de Enseñanza e Investigación de la Universidad de Ilorin, Ilorin, Nigeria durante las temporadas agrícolas de 2018 y 2019 para determinar los efectos del estiércol de aves de corral y el fertilizante NPK en las propiedades del suelo y la calidad de la fibra de cuatro variedades de kenaf (*Hibiscus cannabinus* L .). **Metodología:** El experimento se presentó como un diseño de parcela dividida y se replicó cuatro veces. La parcela principal fueron los años y las subparcelas fueron las cuatro variedades de kenaf (Cuba-108, Ifeken-100, Ifeken-400 y Tainuug 2), y la subparcela fueron las cuatro tasas de estiércol de aves de corral (0, 5, 10, 15 t / ha) y fertilizante NPK (300 kg / ha). Se recolectaron datos sobre la altura de la planta, número de hojas; circunferencia del tallo, peso del tallo por parcela neta y por hectárea, peso de la fibra por hectárea y calidad de la fibra (resistencia máxima, alargamiento de la fibra y deformación de la fibra). Los datos se analizaron mediante el análisis de varianza (ANOVA) del paquete Genstat y las medias significativas se separaron mediante la prueba New Duncan Multiple Range con un nivel de probabilidad del 5%. **Resultado:** La siembra de 2018 mostró un crecimiento, rendimiento y atributos de fibra superiores en comparación con la siembra de 2019, Cuba-108 tuvo el mejor crecimiento y rendimiento y calidad de fibra con estiércol de aves de corral a 15 t/ha en comparación con fertilizante NPK a 300 kg/ha. **Implicaciones:** La variabilidad en los elementos climáticos durante el período del estudio no fue motivo de preocupación en comparación con los factores del suelo, que fue el principal determinante de la calidad de la fibra

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independientemente de la variedad. **Conclusión:** El uso de cultivo Cuba-108 y estiércol de aves de corral a razón de 15 t/ha mejorará el crecimiento y la calidad de la fibra del kenaf en esta localidad, ahorrando divisas que podrían haber sido utilizadas en la importación de fibra.
Palabras clave: Variedades; Resistencia de la fibra; Estiércol de aves de corral; Kenaf

INTRODUCTION

The savannah zone of Nigeria is renowned for the cultivation of cereal crops like rice (*Oryza sativa*), maize (*Zea mays*), sorghum (Sorghum *spp*.), root and tubers; cassava (*Manihot esculenta* Crantz), yam (*Dioscorea* spp.), sweet potato (*Ipomea batatas*) and several vegetable crops. It is also an area endowed with the rearing of animals due to the abundance of forage crops and low incidence of the tsetse fly (*Glossina* spp.). Apart from food crops, the land is also suitable for the cultivation of fibre crops (cotton (*Gossypium* spp.), sisal (*Agave sisalana*), jute (*Corchorus* spp.) and kenaf *Hibiscus cannabinus* L.) which are used in the manufacturing of paper and cord for many years. Of these crops, kenaf, a member of the Malvaceae family, is a multipurpose crop that is fast-growing and can produce a large quantity of biomass in less than eight months; thus, it can sequester carbon (Dauda *et al*., 2013). Besides, materials made from natural fibres are biodegradable, cause no harm to the environment, renewable and cheap (Huda et al., 2006) compared to synthetic products.

Despite its importance, Africa produces a tiny percentage of the global production output, with Bangladesh, India and China accounting for over 90 % of world exports (AAE, 2020) which is grossly inadequate for the packaging of agricultural produce in the continent; hence the agro-based industries in Nigeria rely on the importation of fibre products. In 2019, the country spent about twenty million dollars on the importation of sacks. Another alternative is the use of synthetic sacks made from hydrocarbons which are non-biodegradable, non-renewable, and less durable due to the vagaries of weather in the packaging of products such as cocoa, palm kernel, rice, groundnut, maize, soybean, coffee, millet, sorghum and cashew nuts for export. The use of synthetic sacks for packaging has caused the rejection of some farm produce at the international market because of condensation of moisture, which often leads to the proliferation of fungi and bacteria. Consequently, rejection leads to a shortfall in foreign exchange accruable to exporting countries. On the other hand, using sacks made from plant materials for packaging and storage of agro products promotes aeration, prevents accumulation of heat, improves shelf-life and prevents the death of the seed's embryo.

Recently, there has been an interest in the growth of kenaf worldwide for its high fibre content and tensile strength (Salih *et al*., 2014). About one million hectares of land is suitable for cultivating kenaf in Nigeria, which can generate a projected two million jobs for teeming unemployed youths. However, soil fertility in the areas that are suitable for its cultivation is low. Cultivating the crop on poor soils will result in low yield and poor fibre quality. Kayembe (2015) reported that the chemical characteristics of kenaf bark fibre showed inconsistent responses to all agronomic practices. Still, fibre properties improved with increasing nitrogen levels. At the same time, Girma et al. (2007) stated that inorganic fertilizer improved the quantity of cotton fibre but reduced its quality, especially N applied over 90 kg. We hypothesize that poultry manure, a readily available input for smallholder farmers, will improve both the quantity and quality of kenaf fibre. The present study was thus conducted to determine the effects of poultry manure on the growth, fibre yield and quality of four varieties of kenaf.

MATERIALS AND METHODS

Site description and treatments

A field experiment was conducted at the Teaching and Research Farm, University of Ilorin, Ilorin, Nigeria (8^{o} 29^{1}N $04^{o}35^{1}$E, 307 m above sea level), during 2018 and 2019 cropping seasons. The site is located in Nigeria's southern Guinea savannah zone on an Alfisol belonging to the Bolodunro Series (Ogunwale *et al.,* 2002). The soil depth of the area ranges from shallow to deep, with granite outcrops doting the landscape. The surface soils are coarsely textured, low in organic matter content. The soils are highly degraded in some locations, and topsoil erosion is common, leading to low soil fertility. The rainfall pattern of the location is bimodal, starting in late March to July, with the first peak in late July followed by a break in August. The second part of the rainy season usually begins in late August, peaks in late September, and ends in late October. The annual rainfall for the location was 991 mm in 2018 and 1432.92 mm in 2019. The yearly mean temperature of the study area is 29^{o}C while the average annual relative humidity is about 85%. The study was conducted under rain-fed conditions without supplemental irrigation.

Experimental layout and sowing

The land was ploughed and harrowed before marking out into plots. The size of each plot was 3 m × 4 m with a 0.50 m avenue between the plots. The kenaf seeds were obtained from the Institute of Agriculture, Research and Training (I A R&T) Ibadan - Nigeria. The seeds were sown on the 4th of July, 2018, and repeated on July 3, 2019. Two seeds were sown at a depth of 2.5 cm and covered lightly with soil to prevent desiccation by sunlight. The seedlings were later thinned at two weeks after sowing to one plant per stand at a spacing of 30 × 50 cm between and within rows (the total plants in the net plots were 44 while the border rows were 36 plants) to give a plant population of 66,667 plants per hectare.

Experimental design

The experiment was laid out as a split-split-plot design. The main plot was the years (2018 and 2019), the subplot was the kenaf varieties (Cuba-108, Ifeken-100, Ifeken-400 and Tianung-2), while the sub subplot was the poultry manure rates (0, 5, 10, 15 tonnes/ha and NPK 15:15:15 fertilizer at 300kg/ha). These treatments were replicated four times. The poultry manure was incorporated into the soil using a hand-held hoe two weeks before sowing (WAS), and the NPK fertilizer was applied at 3 (WAS).

Soil and poultry analyses

Soil samples from the experimental plot were collected at a depth of 0 – 30 cm from a 2.5 x 2.5 m grid, bulked. A composite was taken for physical and chemical analyses before sowing and poultry manure incorporation. At the end of the cropping season, soil samples were collected from individual plots. The soil samples collected were air-dried ground and passed through a 2 mm sieve. The sieved soil samples and poultry manure were analyzed as described by Carter and Gregorich (2007). Soil pH was measured (soil: water ratio, 1:2) using a glass electrode; Particle-size analysis was done using the hydrometer method (Gee and Or, 2002). Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996).

Organic matter was estimated by multiplying carbon (C) by 1.724. Total nitrogen was determined by Micro-Kjeldahl digestion and distillation techniques. Available phosphorus was determined following Bray No 1 (1N NH4F + 0.5N HCl) extractant by vanadomolybdophosphoric acid method (Kuo, 1996), Textural class was determined using a textural triangle (USDA, 2017) and extraction of exchangeable bases was done by using IN ammonium acetate, exchangeable potassium and sodium were determined by using flame photometry while calcium and magnesium were analyzed by atomic absorption spectrophotometry.

Data Collection

Data were collected on plant height, the number of leaves, yield components (stalk girth, stalk weight per net plot and fibre weight per hectare) and fibre quality (ultimate strength, fibre elongation, and fibre strain). The plant height of ten tagged plants from the net plot (10 plants) was measured by using a metre rule from the base of the plant to the terminal point of the plant at 4, 6, 8, and 10 (WAS). The mean was calculated and recorded as height per plant. The number of leaves of the tagged plants was visually counted at 4, 6, 8, and 10 WAS. The stalk girth of the ten tagged plants was measured at 10 cm above the ground using a digital vernier calliper (Model Mitutoyo 200 mm). Two plants from the gross plot were sampled using the destructive method at each sampling date of 4, 6,8, and 10 WAS to obtain the dry weight which was used to determine crop growth rate and net assimilation rate per plant as suggested by Radford (1967).

Yield parameters

Kenaf stalks from the net plots were harvested close to the ground (2 cm) manually using a cutlass. The harvested stalks were left on the plots for five days for the leaves to fall off. Then the weight of the stalks was weighed using a weighing balance. This was extrapolated to a hectare basis.

Retting and Fibre Extraction

The defoliated stalks from each net plot (ten tagged plants) were tied in bundles and labelled. Retting was carried out by soaking the bundled stalks in a flowing stream for fifteen days. This was important to separate the bast fibre from the core. Then, the bast fibres were extracted by hand, washed, and hung to dry (Donaphy *et al*., 1990).

Determination of tensile strength of kenaf fibre

The kenaf fibre bundles were cut to approximately 190 mm, a diameter of about 3.00 mm, weighed, and finally mounted on Universal Testing Machine. The tensile test was conducted by tying the fibre on the machine's upper and lower tool posts. It was screwed properly to a fixed point, and the kind of material to be tested (Fabric/ rope) was selected on the computer system. Then, the machine was set at a crosshead speed of 50mm/min. The specimens were analyzed for ultimate strength, elongation, and strain of kenaf fibre (Ribot *et al.*, 2011).

Data analysis

Data were subjected to analysis of variance (ANOVA) using Genstat software package (Genstat, 2005), and mean separation was done using the new Duncan Multiple Range test at p<0.05, where significant differences were observed.

RESULTS

Soil and Poultry Manure physical and chemical Properties

The results of the physical and chemical properties of the soil of the experimental site and the poultry manure are presented in Table 1. It showed that the soil was slightly acidic, sandy loam in texture, low in organic carbon, available phosphorus, potassium, effective cation exchange capacity, and nitrogen content at the start of the experiment. The organic carbon, nitrogen, available phosphorus, potassium, calcium and magnesium contents of the poultry manure were very high.

Change in physical and chemical properties after the first growing season

Results of the soil physical properties analyses carried out at the end of the first growing season are presented in Annex 1. The highest bulk density was recorded in the control plot and was about 29% higher than that obtained in the plot treated with poultry manure at the rate of 15 t ha^{-1}. The highest total porosity value was also recorded under the poultry manure treated plot (15 t ha^{-1}). The total porosity value was about 23 % higher than that recorded under the control plot. Soil water holding capacity was also about 84% higher in the poultry manure-treated plots than the control. The chemical properties of soils of the experimental site after the first cropping season are presented in Annex 2. Poultry manure application at 15 t ha^{-1} resulted in a slight increase in soil pH, resulting in a neutral soil reaction. Control and the NPK treated plots however remained slightly acidic.

Table 1. Physical and Chemical Properties of Soil of the Experimental Site and Poultry Manure.

Properties	Soil	Poultry Manure
Clay (g/kg)	6.60	-
Silt (g/kg)	8.08	-
Sand (g/kg)	85.22	-
Textural Class	Sandy loam	-
pH (H_2O)	6.26	-
pH (KCl)	5.30	-
Organic Carbon ($^0/_0$)	0.77	12.2
Total Nitrogen ($^0/_0$)	0.28	5.32
Available Phosphorus (mg/kg)	2.20	4.60
Potassium (cmol/kg)	3.30	4.80
Exchangeable Cation		
Calcium (cmol/kg)	7.30	3.50
Magnesium (cmol/kg)	3.42	3.63
Exch. acidity (cmol/kg)	0.31	-

Table 2. Effect of year, cultivars and rate of poultry manure application on plant height (cm) of kenaf at 4, 6, 8 and 10 WAS in the two seasons.

Year	4 WAS	6 WAS	8 WAS	10 WAS
2018	57.84	84.45	134.98	151.92
2019	56.67	84.04	134.72	150.83
SE (p<0.05)	NS	NS	NS	NS
Varieties				
Cuba 108	59.48	85.31	136.67a	152.81
Ifeken-100	58.88	85.87	138.17a	152.61
Ifeken -400	56.79	84.31	132.33b	152.72
Tainung2	53.88	81.50	132.25b	147.35
SE (p<0.05)	NS	NS	1.958	NS
Rates (tha^{-1})				
0	43.89e	63.30e	109.67e	122.85e
5	60.77c	85.90c	135.99c	150.50c
10	66.26b	92.96b	147.54b	165.86b
15	69.91a	103.47a	154.38a	179.45a
NPK	45.46d	70.59d	126.63d	138.21d
SE (p<0.05)	1.819	2.086	2.950	3.059
Interactions				
Yr x Var.	NS	NS	NS	NS
Var. x Rates	NS	NS	NS	NS
Yr x Var x Rates	NS	NS	NS	NS

Effect of experimental treatments on plant height

The mean plant height of kenaf under experimental treatments is presented in Table 2. Higher plant height values were generally recorded in the first growing season (2018), and values were on average about 2% higher than those recorded in 2019. This difference was however not significant at $p \leq 0.05$. At 4 WAS, Cuba 108 variety produced the tallest plants than the other varieties, but the difference was insignificant ($p \leq 0.05$). At 6 and 8 WAS however, Ifeneken-100 had taller plants, and the difference between its value and those of the other cultivars except Cuba 108 at 8 WAS was significant ($p \leq 0.05$). The application of poultry manure and NPK fertilizer resulted in significantly different ($p \leq 0.05$) plant heights for all the measurement times. Poultry manure application at 15 tha^{-1} resulted in the highest plant heights in the four sampling periods, and the least values were recorded under control treatment across the same period. No significant interactions between experimental factors were recorded.

Effect of experimental treatments on the number of leaves

The measured mean number of plant leaves under experimental treatments is presented in Table 3. A slightly higher number of leaves was recorded in the first year, but the differences recorded were not significant ($p \leq 0.05$). The highest number of leaves was recorded in Cuba 108 at 4 WAS, Ifeneken-100 had the highest leaf numbers at 6 and 8 WAS, and the highest number of leaves at 10 WAS were recorded in the Tainung2 variety. These differences were not significant at $p \leq 0.05$. Also, there were no significant interactions between experimental factors.

Effect of experimental treatments on plant stem girth

Values of mean stem girth of kenaf measured in this study are presented in Table 3. As with other vegetative indices, stem girth values were slightly but insignificantly ($p \leq 0.05$) higher in the first growing season. The differences in kenaf stem girth between evaluated cultivars were also largely insignificant ($p \leq 0.05$) except at 10 WAS when Cuba-108 had the highest girth values, significantly different from those of the other varieties. Poultry manure and NPK fertilizer application also brought about significant differences in kenaf stem girth. The highest values were consistently recorded under poultry manure application at 15 tha^{-1}, and this was significantly ($p \leq 0.05$) different from values recorded under other amendments. No significant experimental factors interactions were recorded.

Table 3. Effect of year, cultivars and rate of poultry manure application on the number of leaves of kenaf at 4, 6, 8 and 10 WAS in the two seasons.

Year	**4 WAS**	**6 WAS**	**8 WAS**	**10 WAS**
2018	31.61	46.48	66.48	95.20
2019	31.07	46.43	65.57	94.48
SE ($p<0.05$)	NS	NS	NS	NS
Varieties				
Cuba 108	35.23	48.57	62.93	93.20
Ifeken-100	31.30	48.63	68.63	96.20
Ifeken -400	29.00	44.10	64.80	90.70
Tainung2	29.80	44.53	67.73	99.27
SE ($p<0.05$)	NS	NS	NS	NS
Rates (tha^{-1})				
0	21.50	33.79	54.42	79.79
5	34.08	48.17	67.62	90.71
10	38.38	53.96	70.92	103.12
15	41.17	61.12	80.58	1120.83
NPK	21.54	35.25	56.58	79.75
SE ($p<0.05$)	1.991	2.285	2.574	3.018
Interaction				
Yr x Var.	NS	NS	NS	NS
Var. x Rates	NS	NS	NS	NS
Yr x Var x Rates	NS	NS	NS	NS

Yield and fibre quality of kenaf under experimental treatments

The mean yield and fibre quality of kenaf recorded under experimental treatments are presented in Table 4. The stalk weight per hectare in 2018 was about 4% higher than that recorded in the 2019 growing season. This was, however, not statistically significant ($p \leq 0.05$). Cuba 108 variety produced slightly higher stalk weight than the other cultivars, but the difference was only significant at 10 WAS evaluation. Poultry manure application at 15 tha^{-1}however has significantly ($p \leq 0.05$) higher stalk weight values than the other amendments, with a mean value of 11.63, 16.50, 23.63, and 27.82 mm recorded for evaluation at 4, 6, 8, and 10 WAS, respectively. There were no significant interactions between experimental factors.

Results of evaluated yield parameters of kenaf in the two-year study are presented in Table 5. All kenaf yield parameters evaluated had higher values in the first experimental year, except ultimate fibre strength (N/mm) and elongation at peak (mm). The differences recorded between the two years were, however, not significant ($p \leq 0.05$). Differences in these parameters recorded between cultivars were marginal and not statistically significant at $p \leq 0.05$. Poultry manure application at 15 tha$^{-1,}$ however, brought about significantly ($p \leq 0.05$) higher stalk weight/net plot (86.9 kg), stalk weight (9.47 tha^{-1}), and ultimate fibre strength (1.82 N/mm) than the other amendments.

DISCUSSION

Response of soil properties

Kenaf can be utilized for many purposes but has never been given due attention in Nigeria, probably due to the neglect of some crops by the government and over-dependence on petroleum which is the mainstay of the economy. Soil parameters evaluated before cropping indicated that soil was slightly acidic, low in plant nutrients, and exchangeable bases (K, Ca, Mg). The low exchangeable bases could be attributed to the sandy nature of the soils. Previous studies conducted by Toriman *et al.* (2009) reported that due to the sandy nature of the soil, the content of bases in sandy loam is relatively low. This is typical of Nigerian savanna soils (Raji and Mohammed, 2000). This status is also indicative of the low OM content of the soil. This study showed that soil physical properties were influenced by the application of poultry manure, which reduced the soil bulk density, higher water holding capacity and porosity. This improvement in the composition of soil nutrients must have contributed to the improvement in the growth and yield attributes of kenaf experienced in the two years of study against the control.

Table 4. Effect of year, cultivars and rate of poultry manure application on the stalk girth (mm) of kenaf at 4, 6, 8 and 10 WAS in the two seasons.

Year	4 WAS	6 WAS	8 WAS	10 WAS
2018	9.52	13.65	19.64	23.25
2019	9.13	13.87	19.07	22.24
SE ($p<0.05$)	NS	NS	NS	NS
Variety				
Cuba 108	9.59	14.42	20.59	24.46a
Ifeken-100	9.59	13.73	19.57	22.33b
Ifeken -400	9.15	13.26	18.56	21.94b
Tainung 2	8.97	13.64	18.71	22.24b
SE ($p<0.05$)	NS	NS	NS	0.534
Rates (tha^{-1})				
0	7.13d	12.94e	14.58e	17.81e
5	9.91c	13.55d	19.16c	22.08c
10	10.87b	15.39b	21.81b	25.43b
15	11.63a	16.50a	23.63a	27.82a
NPK	7.08d	14.58c	17.61d	20.59d
SE ($p<0.05$)	0.240	0.295	0.532	0.797
Interactions				
Yr x Var.	NS	NS	NS	NS
Var. x Rates	NS	NS	NS	NS
Yr x Var x Rates	NS	NS	NS	NS

Table 5. Effect of year, cultivars and rate of poultry manure application on the fibre quality of kenaf in the two seasons.

Year	Stalk wt/ netplot (kg)	Stalk wt (tha^{-1})	Ultimate Strength (N/mm)	Strain at peak (%)	Elongation at peak (mm)
2018	58.1	5.97	13.12	3.26	6.28
2019	52.4	5.76	14.98	3.24	6.49
SE (ρ<0.05)	NS	NS	NS	NS	NS
Varieties					
Cuba 108	58.2	6.49	16.42	3.22	6.26
Ifeken 100	55.9	5.69	14.53	3.33	6.23
Ifeken 400	54.3	5.67	13.04	3.27	5.98
Tainung 2	52.7	5.61	12.19	3.18	4.06
SE (ρ<0.05)	NS	NS	NS	NS	NS
Rates (tha^{-1})					
0	29.2e	2.82e	10.15e	3.11	6.05
5	49.9d	5.28d	12.07d	3.27	6.32
10	59.2b	6.54b	15.30b	3.28	6.34
15	86.9a	9.47a	18.92a	3.42	7.11
NPK	51.2c	5.22c	13.80c	3.16	6.09
SE (ρ<0.05)	4.30	0.479	1.822	Ns	Ns
Interactions					
Yr x Var.	NS	NS	NS	NS	NS
Var. x Rates	NS	NS	NS	NS	NS
Yr x Var x Rates	NS	NS	NS	NS	NS

An improvement in soil reaction using the different poultry manure application rates also improved plant nutrient uptake, which can be attributed to the better kenaf performance recorded under these treatments. These findings are also similar to those of Habibu et al. (2021), who reported positive responses of three kenaf varieties and growth components such as plant height, number of leaves and shoot dry weight to poultry manure application from 2 to 6 t ha^{-1} in northern Guinea and Sudan savanna of Nigeria in two years. They attributed the observation to the beneficial role of manure in providing essential soil nutrients such as N, P, and K. The supply of these crucial nutrients was responsible for improving the growth and yield of the crop.

Growth and yield attributes of kenaf

Results showed that the influence of the two growing seasons on the growth, yield and fibre quality of kenaf was negligible. Responses of the crop in the two years evaluated were similar. Hence no significant differences were observed. This could be due to similar rainfall, temperature, and humidity experienced during the two growing seasons. Besides, the evaluated kenaf varieties generally did not exert significant influence on crop performance, except in terms of plant height and stalk girth, in which Cuba 108 and Ifeneken-100 performed better than the others, especially at 8 and 10 WAS. This could be attributed to these varieties' similar growth characteristics and their response to the absorption of growth resources. Habibu et al. (2021) reported a slightly different observation in their study, where the interaction between Ifeken 400, Ifeken D1 400, and Girindanani varieties of kenaf and poultry manure at 9 and 12 WAS was significant on shoot dry weight. The application of 2 t ha^{-1} poultry manure to Ifeken 400 produced higher shoot dry weight in Samaru, Nigeria, higher than 4 and 6 t/ha^{-1} amendment rates. They attributed this finding to the probable ability of Ifeken 400 to better utilize nutrients supplied by the poultry manure for rapid growth and development due to the morphology of the variety.

Biomass production and plant girth are essential attributes in the kenaf crop, as these are important factors in bast fibre production. In this study, the varieties produced similar heights of between 147.35 – 152.81 cm in both seasons, with the highest recorded in Cuba-108 and the least in Tainung2. These values are lower than what was reported by Anfinrud et al. (2013) in Great Plains, United States, but higher than what Ansa (2015) reported in a lateritic soil in Port Harcourt, Nigeria. Plant height, number of leaves and leaf area are among the growth parameters directly linked with the potential productivity of plants (Raju and Mitra (2019). The plant height, number of leaves, stalk girth, leaf area, crop growth rate, and net assimilation rate of kenaf were found to increase with increasing application of poultry manure, with the best performance recorded at 15 t/ha. This further illustrates the importance of plant nutrients in crop growth and yield.

These findings agree with the results of Habibu *et al*. (2021), who reported the highest fibre yield ha^{-1} at the highest application rate of 6 ha^{-1}. The performance observed under control treatment and at lower levels of poultry manure application rate could be attributed to the low level of nutrients in the soil, and leaching. This conforms with the findings of Selim (2020), who reported that loss of soil nutrients due to continuous cropping would promote leaching. Habibu et al. (2021) also reported that poultry manure enhanced plant growth in general due to its rich nitrogen status.

The increase in stalk girth due to the high application rate of poultry manure could be due to nutrient availability to the crop to carry out metabolic activities, such as an increase in the leaf area and improved crop growth rate. The relatively lower kenaf yield under NPK-treated plots could be attributed to the leaching of the fertilizer nutrients by rain and the continuous application of NPK on the farmland for a long time which could have had a depressing effect on yield. This further illustrates the importance of using organic manure in farmland after several years of applying inorganic fertilizer in combination or as sole application. The increase in the fibre yield of plots treated with poultry manure and NPK fertilizer application, especially in the fibre weight, ultimate strength, elongation, and strain, was in consonance with the findings of Kayembe (2015), who reported that fibre quality or characteristics did not improve in cotton by an increase in the rates of nitrogen fertilizer rates unless there is a severe N deficiency. Raju and Mitra (2019) reported that combined fertilizer doses resulted in a significant positive effect on the yield contributing parameters like base diameter, plant height, and fibre yield of four kenaf varieties.

An increase in the poultry manure and NPK fertilizer rates also increased the fibre weight per hectare and ultimate fibre strength. This agrees with the report of Kayembe (2015). Fibre ultimate strength determines the toughness of fibre, which directly affects the quality of any agro sacks and their ability to absorb the pressure of heavy agro-product and their durability. Kenaf fibre elongation and strain, which is a function of residual gum content (the amount of gum left after processing), affects the fineness of fibre, were also improved through poultry manure and NPK application.

CONCLUSION

From the present study results, farmers in the study area are encouraged to sow Cuba-108 variety and apply poultry manure at the rate of 15 t/ha. Kenaf can be cultivated in this region due to its adaptation to a wide range of environments. In doing so, the Nigerian government can save millions of dollars and create jobs for millions of youths. Cultivating the crop in this zone will also reduce the dependence on the importation of sacks for the packaging of agricultural produce. Besides, the cultivation of the crop will help in the purification of air and mitigation of climate change because of the crop's ability to sequester carbon.

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Annex 1. Physical Properties of Soil of the Experimental Site at first Harvest in 2018.

Treatment Levels	Bulk density (g/cm^3)	Total porosity ($^0/_0$)	Water Holding Capacity ($^0/_0$)
Control	1.45a	45.7c	10.1d
PM 5 t/ha	1.32b	50.1b	13.8c
PM 10t/ha	1.29b	53.7ab	15.7b
PM 15t/ha	1.03c	56.3a	18.6a
NPK 300kg/ha	1.42a	46.2b	10.5d
SE (0.05)	0.07	3.89	1.28

Annex 2. Chemical Properties of Soil of the Experimental Site at Harvest in the first season.

Treatments	pH (H_2O)	OM $^o/_o$	N$^o/_o$	P (mg/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)
Control	6.30	1.32c	0.26c	2.29d	3.28c	2.12b	0.41
PM 5 t/ha	6.32	1.79b	0.37b	3.93c	3.49b	2.36a	1.43
PM 10t/ha	6.47	2.01a	0.43b	6.14b	3.52b	2.41a	1.47
PM 15t/ha	6.83	2.09a	0.78a	8.20a	3.73a	2.47a	1.53
NPK 300kg/ha	6.27	1.33c	0.69a	3.87c	3.29c	2.32a	1.43
SE (0.05)	ns	0.10	0.10	0.19	0.24	0.20	ns