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GROWTH, YIELD, AND FIBER MORPHOLOGY OF KENAF (*Hibiscus cannabinus* L.) VARIETIES INFLUENCED BY DIFFERENT LEVELS OF NPK FERTILIZERS

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Abstract. *Different levels of NPK fertilizer were used to improve the growth, yield, and fiber morphology of two kenaf varieties. Therefore, a field experiment was conducted in the summer season of 2021 at the Grdarasha Field, College of Agricultural Engineering Sciences, Salahaddin University-Erbil. The results revealed that adding NPK at the rate of 100 kg/ha caused improved growth and yield characteristics includes; plant height, stem diameter, leaf number, and total fresh stem yield by almost (3.35 m, 25.88 mm, 250.10, and 246.93 t/ha), respectively. While, the best values of fresh and dry matter of core and bast fibers were recorded when NPK was applied at the proportion of 150 kg/ha which were (98.40, 57.80, 39.73, and 15.13 t/ha), respectively. Morphological properties of the kenaf bast fiber were also improved by adding NPK fertilizer. Both levels of NPK 100 and 150 kg/ha were noted to be the best for enhancing kenaf bast fiber compared to the control treatment. Finally, based on the results could recommend the farmers to use NPK fertilizer as a factor to increase fiber yield and improve its quality.*
Keywords: *growth; kenaf; plant nutrition; quality; quantity*

1. Introduction

Kenaf (*Hibiscus cannabinus* L.) is mostly important as one of the natural plant fibers goes to the family Malvaceae. Kenaf is a tropical plant, while nowadays it is growing in a wide range of geographical regions and climates (Lee *et al*., 2018). Every component of the kenaf plant; stem (bast and core fibers), leaves, and seeds are of numerous industrial importance. Traditionally, its fiber is useful in the making of rope, twine, and sackcloth, currently which is used in paper products, building materials, and also in automotive industries. In addition, non-toxic to the healthy (NIH3T3) cells was found from extracts of kenaf leaves and seeds, except *n*-hexane extracts, which were stated to be toxic slightly which was in vitro cytotoxic activity (Adnan *et al*., 2020). Kenaf leaves are rich sources of the bioactive compound such as chlorogenic acid, caffeic aid, kaempferol, and catechin hydrate as proven (Kho *et al*., 2019; Sim & Nyam 2019; Haw *et al*., 2020). High antioxidant activities were found in the kenaf leaves when the age of the plants at the fourth month after planting, which was suggested for tea preparation (Kho *et al*., 2019). Moreover, a high amount of protein exists in the kenaf leaf which is factitious of amino acids necessary for animal growth and milks production (Noori *et al*., 2016).

For improving the growth, fiber yield, and fiber quality of the kenaf plant many ways were applied, one of them is using fertilizers. So, during this present study NPK fertilizer was used. It

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is hypothesized that NPK fertilizer could promote growth of kenaf and then caused to increase in fiber yield with better fiber quality. Ansa (2015) reported that different doses of NPK enhance the growth and yield of the kenaf plant. Eifediyi *et al.* (2022) reported that adding poultry manure and NPK fertilizer caused to increase in fiber weight and fiber strength.

The present study was thus conducted to determine the influences of NPK fertilizer 13:2:44 on the growth, fiber yield, and morphological characteristics of the bast fiber of two kenaf varieties (4383 and 4202 Bangladesh *Var.*).

2. Methods

2.1. Materials

4383 and 4202 were the kenaf varieties selected as plant materials in this current study; the first variety originated from BJRI (Bangladesh Jute Research Institute) code for origin from Sudan, and the second variety was from BJRI (Bangladesh Jute Research Institute) code for the origin from Tanzania which was gotten on both varieties from Malaysia, at Institute of Tropical Forestry and Forest Production (INTROP), Universiti Putra Malaysia (UPM). Additionally, different levels of NPK 13:2:44, as a factor were added to the plants.

2.2. Methods

2.2.1 Study site

Grdarasha Field was the study site at the College of Agricultural Engineering Sciences, Salahaddin University-Erbil, which is located at (Latitude 36°00'16"N and Longitude 44°01'24"E), an elevation of 398 meters above sea level. Figure 1 shows the geographic location of the experiment.

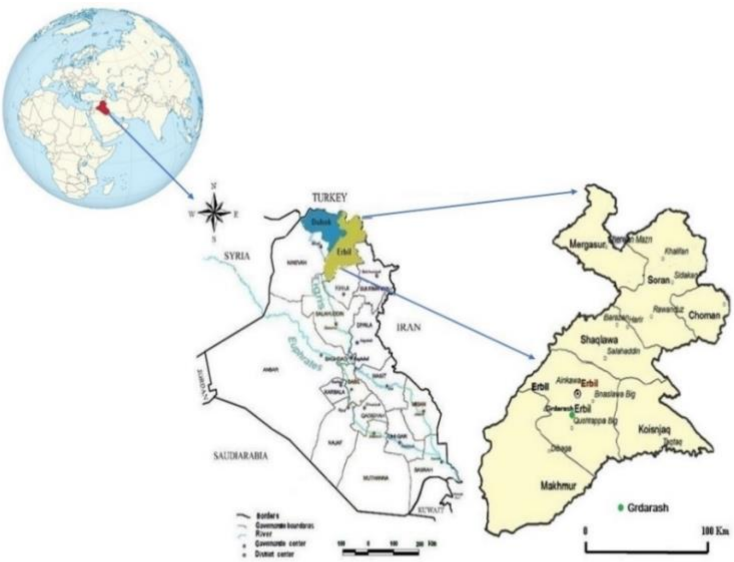

Figure 1. Geographic location of the studied site.

2.2.2 Experimental design

Randomized Complete Block Design (RCBD) was applied as an experimental design with three replications. Seeds of both kenaf varieties 4383 and 4202 were symbolled by (V1 and V2) sowed on 14 Jun 2021, in the depth of (2-3 cm) as a first factor. 1m2 was the plot size, 10 cm was the distance between plants, while the distance between row to row was just 30 cm, which was plant density 400000 plants/ha. The second factor was different levels of NPK fertilizer were added to each plot (0, 100, and 150 kg/ha), two months after planting on 14 August 2021, which were symbolled by (F0, F1, and F2). The experiment was involving 18 treatment units.

2.2.3 Soil sampling

Random soil samples were taken at depths of 0 to 15 cm from several places on the land which was before divided into plots. Then, the sample was transported to the laboratory. Later, the soil was air dried and sieved through a 2 mm pore size sieve. Table 1 shows the physical and chemical properties of the soil of the experimental site in Grdarasha Field.

Table 1. Physical and chemical properties of the soil of Grdarasha filed.

Soil properties	Grdarasha Field	
Physical properties	Sand %	31.0
	Silt %	37.3
	Clay %	31.7
	Soil texture	Clay loam
Chemical properties		
	EC(Ds/m)	0.50
	PH	7.83
	N %	0.07
	P(PPM)	12.5
	K(PPM)	338
	O.M %	1.14

2.2.4 Sampling method

In each treatment plot, five plants were randomly selected, which were to determine the growth, fiber yield, and also morphological properties of bast fiber. Plants were harvested manually on 22 November 2021. Field stick measuring devices were used to measure plant height at the end stage of plant growth, and stem diameter was measured by using a digital caliper from 10 cm above the ground surface. Stalk kenaf fibers (bast and core fibers) were sun-dried indirectly (Figure 2).

Maceration process was also done to determine morphological properties. From the bast fibers achieved, samples were taken and macerated. For that purpose, the kenaf bast was cut into (2×20mm) in width and length and then placed in a mixture of equal volume of 30% hydrogen peroxide and 10% glacial acetic acid in a clear glass test tube bottle and then put in an oven for 24h at 80 °C until soft and bleached white. Then, the slivers washed by distilled water, and dispersed in a 30 mL test tube containing 20 mL of distilled water. One to two drops of methyl red were added into the fiber and was stained for 15 min. The macerated fibers were later mounted on a slide and projected using a digital camera (MICROSCOPE EYEPIECE CAMERA 5.1MP APTINA COLOR CMOS).

Figure 2. Stem, bast and core fibers were sun dried.

2.3. Data analysis

Data on plant growth (plant height, stem diameter, and leaf number), yield parameters such as; total fresh and dry stem yield, fresh and dry core fiber yield, and fresh and dry bast fiber yield, with the bast fiber morphological properties (single fiber length, fiber width, lumen width, and cell wall thickness), were subjected to Analysis of Variance (ANOVA) by using SPSS Statistics (IBM SPSS Statistics 21). Least Significant Difference (LSD) at $P \leq 0.05$ was used to perform the mean comparison according to Duncan's multiple range test.

3. Results and Discuss

3.1. Growth and yield characteristics

Any significant differences could not find among both varieties were studied in this current research of all growth and yield characteristics (Table 2).

Table 2. Effect of varieties on growth and yield characteristics

Varity	Plant height (m)	Steam diameter (mm)	Leaf number (plant)	Total stem yield		Core yield		Bast yield	
				Fresh	Dry	Fresh	Dry	Fresh	Dry
				t. ha^{-1}					
4383	3.15^a	22.99^a	223.07^a	218.44^a	49.24^a	89.97^a	35.51^a	51.38^a	13.73^a
4202	3.09^a	23.42^a	171.11^a	233.82^a	54.58^a	93.78^a	38.89^a	55.95^a	15.51^a

Values with different letters within columns indicate significant differences at 5%.

Table 3 shows the significant differences between levels of NPK that were added during this study on growth characteristics, total fresh stem, and fresh best yields. Generally, adding 100 kg/ha of NPK caused to increase in both study characteristics. The highest plant high, biggest stem diameter, and the highest value of the leaf number were (3.35m, 25.88mm, and 250.10), respectively. Therefore, 100 kg/ha of NPK was also caused to improve total fresh stem yield from (188.47 to 246.93 t. ha-1). While, non-significant differences were found for all dry matter parameters (stem, bast, and core fibers).

Table 3. Effect of NPK on growth and yield characteristics

NPK (kg ha^{-1})	Plant height (m)	Steam diameter (mm)	Leaf number (plant)	Total stem yield		Core yield		Bast yield	
				Fresh	Dry	Fresh	Dry	Fresh	Dry
						t. ha^{-1}			
0	3.23^{b}	21.27^{b}	157.83^{b}	188.47^{b}	47.67^{a}	81.47^{a}	34.40^{a}	47.13^{b}	13.80^{a}
100	3.35^{a}	25.88^{a}	250.10^{a}	246.93^{a}	53.00^{a}	95.47^{a}	37.47^{a}	56.05^{a}	14.93^{a}
150	2.79^{c}	22.46^{b}	183.33^{ab}	243.00^{a}	55.07^{a}	98.40^{a}	39.73^{a}	57.80^{a}	15.13^{a}

Values with different letters within columns indicate significant differences at 5%.

From the interaction treatments the significant differences were found for growth and yield characteristics (Figures 3 and 4). The highest plant high, biggest stem diameter, and leaf numbers were recorded in the interaction treatments 4383 variety with 100 kg/ha of NPK (V1F1) and 4202 variety with the same amount of fertilizer 100 kg/ha of NPK (V2F1) by almost (3.39m, 25.89mm and 269.20 leaf/plant), respectively (Figure 3). Despite that, the smallest values for all characteristics were recorded by 4202 variety with 150 kg/ha of NPK (V2F2), 4383 variety without NPK (V1F0), and 4202 variety again without fertilizer "control treatment" (V2F0), which were (2.76m, 20.86mm and 127.33 leaf/plant), respectively.

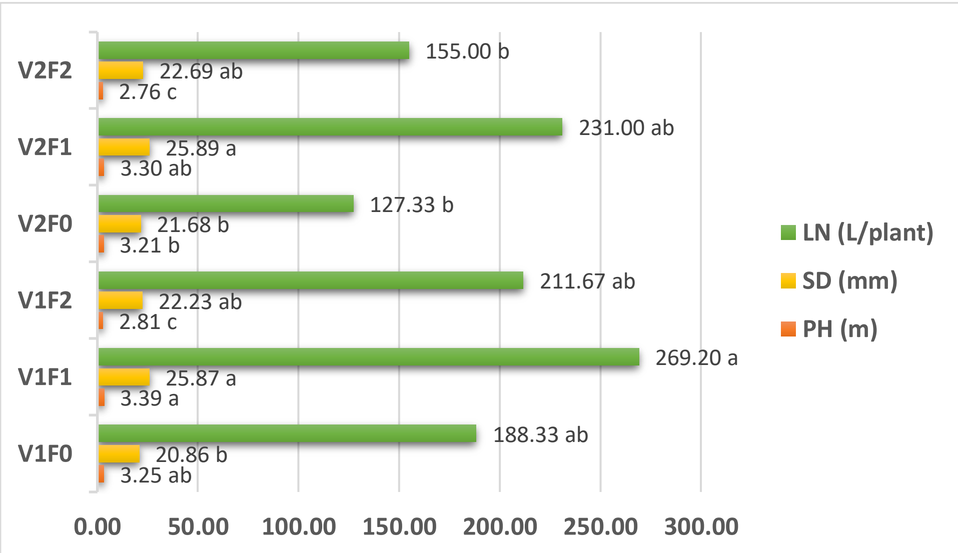

Figure 3. Interaction effect of varieties and NPK on growth characteristics.

V1F0= 4383 variety without fertilizer (control treatment), V1F1= 4383 variety with 100 kg/ha of NPK, V1F2= 4383 variety with 150 kg/ha of NPK, V2F0= 4202 variety without fertilizer (control treatment), V2F1= 4202 variety with 100 kg/ha of NPK, and V2F2= 4202 variety with 150 kg/ha of NPK. LN= Leaf number, SD= Stem diameter, and PH= Plant height.

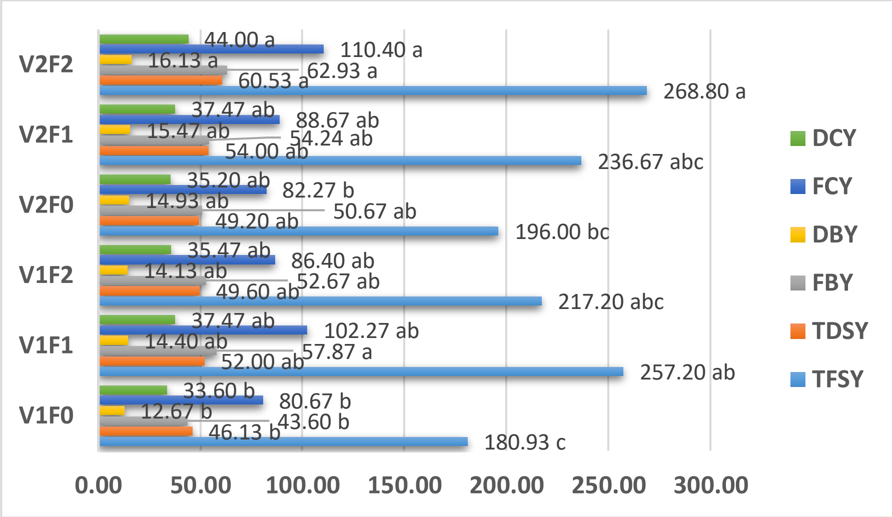

Figure 4. Interaction effect of varieties and NPK on yield characteristics (t. ha^{-1}).

V1F0= 4383 variety without fertilizer (control treatment), V1F1= 4383 variety with 100 kg/ha of NPK, V1F2= 4383 variety with 150 kg/ha of NPK, V2F0= 4202 variety without fertilizer (control treatment), V2F1= 4202 variety with 100 kg/ha of NPK, and V2F2= 4202 variety with 150 kg/ha of NPK. DCY= Dry core yield, FCY= Fresh core yield, DBY= Dry bast yield, FBY= Fresh bast yield, TDSY= Total dry stem yield, and TFSY= Total fresh stem yield

The highest values of totally fresh and dry stem yield, fresh and dry core, and bast fiber yields were found with the interaction treatment V2F2 by almost (268.80, 60.53, 110.40, 44.00, 62.93, and 16.13 t. ha-1), respectively (Figure 4). Consequently, the smallest values for the same characteristics were recorded from the interaction treatment V1F0 by (180.93, 46.13, 80.67, 33.60, 43.60 and 12.67 t. ha-1), respectively.

3.2. Fiber morphology characteristics

All morphological characteristics of bast fiber were studied during this current study significantly changed according to the application of the fertilizer, while by affecting varieties only single fiber length and fiber width (SFL and FW), were found (Table 4).

Table 4. Effect of varieties and NPK on fiber morphology characteristics

Variety	SFL (mm)	FW (µm)	LW (µm)	CWT (µm)
4383	2.49^{b}	15.85^{b}	13.13^{a}	1.57^{a}
4202	3.32^{a}	17.56^{a}	14.13^{a}	1.57^{a}
NPK (kg ha^{-1})				
0	2.39^{c}	17.26^{a}	14.51^{a}	1.35^{b}
100	3.47^{a}	14.84^{b}	11.98^{b}	1.62^{ab}
150	2.87^{b}	18.02^{a}	14.42^{a}	1.75^{a}

Values with different letters within columns indicate significant differences at 5%.

Importance of interaction effects between varieties and fertilizers NPK on fiber morphology were showed in the (Figure 5). The longest single fiber length and the biggest fiber width, lumen width, and cell wall thickness were found in the interaction treatments V2F1 and others of V1F2 and V2F2 by almost (3.91 mm, 18.64, 15.13, and 1.83 µm), respectively. Despite that, the smallest values of all the above characteristics were noted by the interaction treatments V1F0, V1F1, and V2F0 about (2.02 mm, 12.56, 10.37, and 1.30 µm), respectively.

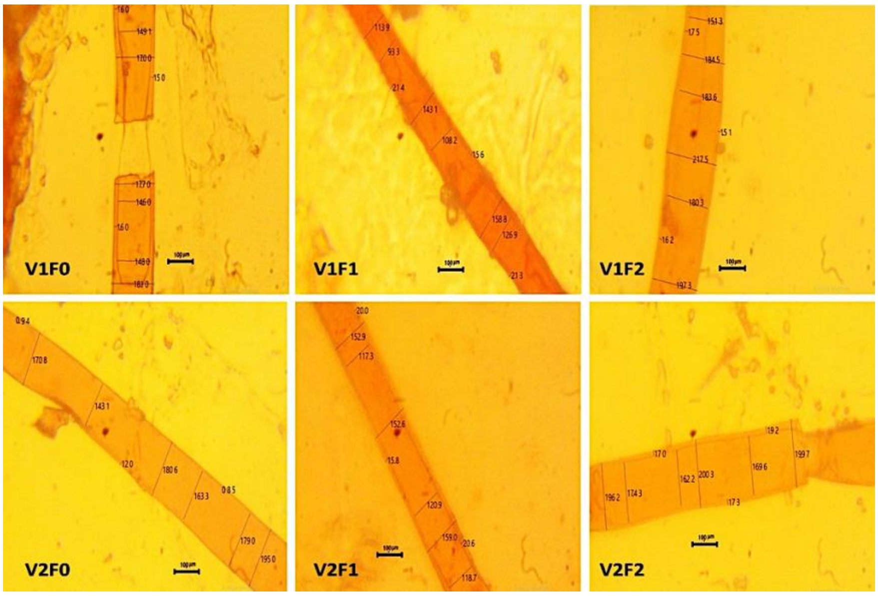

Figure 5. Image microscopy of (fiber width, lumen width and cell wall thickness), of bast fiber of two kenaf varieties 4383 (V1), and 4202 (V2), effected by different levels of NPK, which was at magnification 100X.

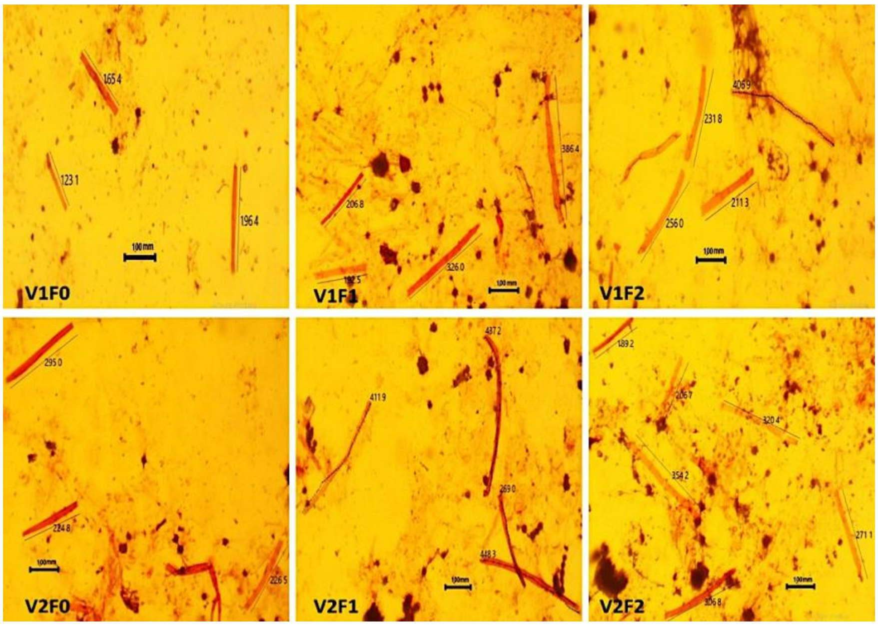

Figure 6. Image microscopy of single fiber length of bast fiber of two kenaf varieties 4383 (V1), and 4202 (V2), effected by different levels of NPK, which was at magnification 10X.

Figures 6 and 7 were showed some image microscopy of kenaf bast fiber, which confirms the impact of NPK fertilizers of both kenaf varieties (4383 and 4202) on the morphological characteristics. Focusing on these images could observe some facts about NPK on changing and enhancing fiber quality properties compared to control treatment (without fertilizer). For example, single fiber length was dramatically increased when fertilizer was added to the plants which were for both varieties. Based on the results found in this present study could decide to apply the compound fertilizer NPK to improve the morphological properties of kenaf bast fiber, which may will interesting to use in textile applications as fabric and also in nonwoven processing.

4. Discussion

Growth, yield, and fiber morphology characteristics affected by the factors were studied in this current study. While, variety alone could not affect growth, yield, and dry matter. In contrast, adding NPK caused enhanced growth, quantity, and quality properties of the fiber. Additionally, interaction treatments were found to be significant in all parameters. Ansa (2015), who concluded that increasing NPK rates from 3 to 9 g caused to increase in growth and fiber yield. Positive effects of growth and fiber yield of kenaf were recorded when organic and inorganic fertilizers (NPK) were added to the plants (Olanipekun *et al.*, 2021; Yanto, 2019).

However, results from this present study were confirmed by Ullah *et al.* (2017), whose reported that the application of NPK resulted in greater growth and yield than the application of N, P, K, NP, NK, or PK. The results of growth parameters were also supported by other researchers, who reported that highly significant differences ($p \leq 0.01$) between the environments and the interaction of genotype and environment were observed in kenaf genotypes on mid diameter and plant height traits (Al-Mamun *et al.*, 2022).

On the other hand, having those rates of nitrogen, phosphorus, potassium, and organic matter from this study site may also be other reasons that led to improve growth and yield productivity of both kenaf varieties. Banerjee *et al.* (2016) found that available nitrogen and potassium had significant effect on plant growth, yield, and fiber quality, whereas available phosphorous had strong positive correlation with fineness, strength and length of fiber, which was of six ramie lines (*Boehmeria nivea* L.).

Additionally, Salih *et al.* (2022) reported that providing the appropriate results of growth and yield characteristics of three kenaf varieties FH952, HC2 and V36 could be considered as substitute materials for timber and other biocomposite manufacturers. Due to that fact above, NPK fertilizer was used in this current study as mentioned earlier to improve growth, quantity, and quality parameters. Abd Eldaiem & El-Borhamy (2015) confirmed that yield and quality properties were also improved by adding the suitable level of NPK, which was one of the favorable factors for increasing flax productivity and quality.

Single fiber length and fiber width of kenaf bast was positively affected by variety. Genetic inheritance, management practices, environmental and other inputs influenced the kenaf fiber morphology and quality (Abdul-Hamid *et al.*, 2009; Hossain *et al.*, 2011). In addition, all fiber morphology properties were also significantly improved when fertilizers were added, which was strongly supported by previous study (Salih *et al.*, 2014).

Attention should be paid to the interaction between organic and inorganic elements that residue in the soil from the study site with NPK application, since any increase of the chemical components in the limited point especially nitrogen and potassium caused to improve fiber quality properties by increasing protein and cellulose contents in the cell wall, then division may have occurred, that fact is supported by finding of (Salih, 2015). Generally, noted that adding NPK at the rates of 100 and 150 kg/ha produced superior fiber morphology than the control treatment (without fertilizer).

5. Conclusion

Various advantages were found from the significant impact of applying NPK fertilizer on growth, yield, and fiber morphology of both kenaf varieties, which encourages researchers by opening the gate for doing more research and then advising farmers to choose the best dosage of NPK fertilizer. Healthy growth, increase fiber yield, and improved quality properties of kenaf bast fiber were noted from the results when 100 and 150 kg/ha of NPK were added to the plants.

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