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Foliar Application of NPK Improves Growth, Yield and Fiber Morphological Properties of Some Kenaf (Hibiscus cannabunus L.) Varieties

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ABSTRACT

Different concentrations of NPK fertilizer applied to enhance growth, fiber yield and bast morphological properties of three kenaf varieties. The research was done at Grdarasha Field/ Erbil, Kurdistan in summer season 2021. Randomized Complete Block Design (RCBD) with three replications by two factors (three varieties and two NPK concentrations with a control) which was applied as experimental design. Results showed the significance differences among all growth, quantity and quality properties except of few situations. The highest plant height was noted from FH952 (V1), while the biggest stem diameter recorded from 4202 (V3), and the highest value of the leaves number were by 4383 (V2), which were (3.70 m, 23.77 mm and 214.67 leaf plant^{-1}), respectively. Foliar application of NPK caused to increase fresh and dry matter of total stem, bast and core fiber yields when 2000 mg L^{-1} applied to plants. Interaction between factors was also significantly affected all studied parameters. The biggest total fresh and dry stalk yield were noted of FH952 *var*. when 4000 mg L^{-1} NPK was added (V1NPK2), which were by (284.93 and 72.80 t ha^{-1}), respectively. While, the longest single fiber length was recorded from interaction treatment of (V3NPK2), 4202 *var.* with 4000 mg L^{-1} NPK by almost (6 mm). Despite that, other bast fiber morphology properties changed dramatically in the other states of interaction between factors. Both concentrations of foliar application of NPK 2000 and 4000 mg L^{-1} were suggested to use as a nutrient supplement to the kenaf plants, since it caused to improve not just growth parameters but also quantity and quality properties of the stalk and fiber yields.

Keywords: Kenaf, NPK, Quantity, Quality, Bast, Core, maceration process.

1. Introduction

Hibiscus cannabinus L. is botanical name of kenaf plant, which belongs to the family Malvaceae. It is also, one of the importance natural crops growing fastly. Kenaf is industrial crop could growing perfectly in any soil types additionally has high potential for cultivation in a tropical climate. During manufacture applications choosing of the raw materials are really important. Kenaf fibers are not just a part of plant useful as raw material, but also there are many other benefits of the seeds and leaves that can be used in medicine and food[1].

On the other hand, the previous studies indicated that fibers of kenaf are a source for using as forage and feedstock that leads to cultivate it in large areas globaly[2]. However, mechanical characteristics of kenaf fibers are suitable to use in composite manufacturing, which can be used as alternative material for making automotive parts as dashboard and door panel[3]. Besides of using kenaf fibers in industrial sectors, cultivation of this kind crop has many environmental advantages, since it is one of the ecofriendly crops. High amount of CO_2 absorption was noted by kenaf plant, which is more when compared to other crops. Kenaf plants can absorb 1.5 times CO_2 by its weight [4]. Likewise, concrete made of kenaf fibers caused to reduce the quantity of CO_2 in the atmosphere. Morevere, applying natural fibers as an alternative for concrete is of interest not because increasing ductility and versatility of the material but also from an environmental viewpoint[5].

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During this present study, different concentrations of NPK fertilizer were foliar applied which were to investigate its impact on growth, yield productivity and bast fiber morphology. Kenaf growth and yield could be improved through the use of external input such as fertilizers[6].

Adding different rates of NPK caused to increase Plant height. Leaf area and leaf area index were significantly affected by NPK doses; 9 g NPK rate produced kenaf plants that were 40% taller, 2 times wider girth, and a ratio 10:1 leaf area index over the control plants. Stalk, core and bark dry weights were also changed due to NPK affects[7]. In Southwest Nigeria NPK fertilizer was combined to organic manuer by the rate of 50:50, which was for cultivation kenaf plant[8]. Additionally, other researchers were also mixed different rates of NPK fertilizer to poultry manure, so from their results was found that adding poultry manure with different rates of NPK fertilizer leads to increase the fiber weight ha^{-1} and improve fiber strength[9].

The present study was imagined that foliar application of different concentrations of NPK fertilizer may cause to develop growth, fiber yield and morphological properties of the outer part of the stem of several varieties of the kenaf plant.

2. Methods and Materials

2.1 Study Site

Grdarasha Field, College of Agricultural Engineering Sciences, Salahaddin University-Erbil was the study location for this present research (Latitude 36. 10116 N and Longitude 44.00925 E), and elevation of 415 meters above sea level. Figure 1 displays the geographic location of the experimental site. While, different kenaf varieties in the farm from the study site were showed in the (Figure 2). Actually, kenaf can be recognized and separated by its leaves as shown in the figure 3, but in some case make the differences between them is so difficult look to the images (a and b).

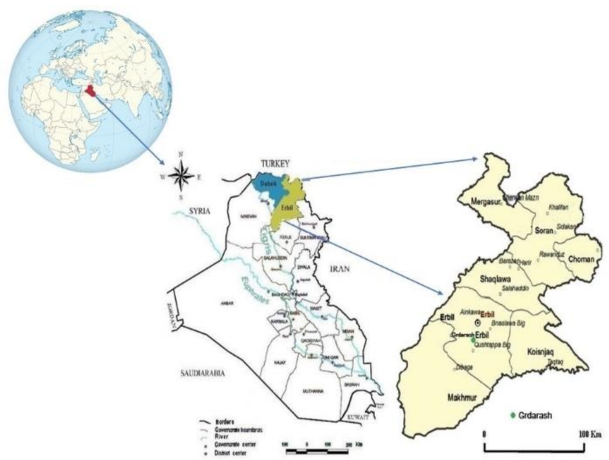

Figure 1: Geographic location of the study site.

Figure 2: Different kenaf varieties in the farm from the study site.

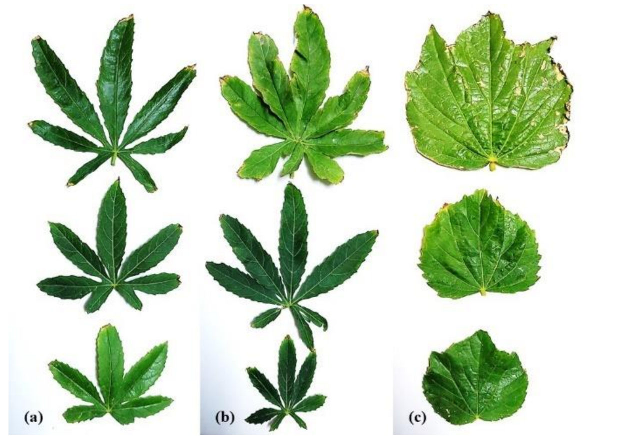

Figure 3: Kenaf leaves; (a) leaf of FH952 var. (B) leaf of 4202 var. (c) leaf of 4383 var.

2.2 Experimental Design

The experiment carried on 14 June 2021 has an organization based on to two factors with three replications, which was by Randomized Complete Block Design (RCBD). The first factor was selected three kenaf varieties; Fuhong-952 (FH952) variety originated in Fujian Fuzhou, China, 4383 originated from BJRI (Bangladesh Jute Research Institute) code for origin from Sudan, and 4202 was from BJRI (Bangladesh Jute Research Institute) code for origin from Tanzania, which were represented by (V1, V2 and V3), respectively. 2-3 cm was the depth of seeding for all kenaf seeds. $1m^2$ was the plot area, (10 and 30) cm were the distance between plants row to rows, respectively thus the plant density was 400000 plants ha^{-1}. The second factor was foliar applied of different concentrations of NPK (13:2:44) fertilizer (0, 2000 and 4000 mg L^{-1}), which were represented to (NPK0, NPK1 and NPK2) with 1.5 g of humic acid $2L^{-1}$ of water as basal fertilizer were added to the plants on August 3, 2021.

2.3 Sampling Method

Plant height, stem diameter and leaves number were calculated on November 6, 2021. In each treatment plot five plants were randomly selected. Plant height at the end stage of plant growth was measured by using field stick measuring devices. Also, digital caliper was used to measure stem diameter from 10 cm above of the ground surface. Then, plants were harvested manually on November 20, 2021 which were for determination fresh stem and fiber yields. On December 6, 2021 dry matter of stem, bast and core fibers were also calculated, which were dried under sun indirectly.

Maceration process was also done to determine kenaf bast morphology properties. Bast fiber samples were taken for maceration process. For that purpose, the kenaf bast was cut into (2×20mm) in width and length and then put in a mixture of identical 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[10]. The macerated fibers were later mounted on a slide and projected using a digital camera (MICROSCOPE EYEPIECE CAMERA

5.1MP APTINA COLOR CMOS). Figure 4 displays the chemical and equipments used through maceration processing for making slides. Chemical and equipment requested during maceration process:

1. 30% hydrogen peroxide
2. 10% glacial acetic acid
3. Methyl red
4. Distilled water
5. Clear test tube bottle
6. Laboratory oven
7. Scissors
8. Slides and cover slips
9. Glue/ clear nail polish
10. Plastic pipette
11. Microscope digital camera

Figure 4: Chemical and equipments used during maceration processing for making slides.

2.4 Soil Sampling

At depth of 0 to 30 cm soil samples were randomly taken from several places on the land before it was divided into plots. The samples were then transported to the laboratory. Next, physicochemical characteristics of the soil were determined (Table 1).

Table 1: The initial physical and chemical properties of the soil used in the experiment.

Physical properties					
Sand%		Silt%		Clay%	
31.0		37.3		31.7	
Soil texture	Clay loam				
Chemical properties					
N %	P ppm	K ppm	O.M. %	pH	EC dS m^{-1}
0.07	12.5	338	1.14	7.83	0.5

2.5 Data Analysis

Data on plant growth, yield and bast fiber morphological properties were subjected to Analysis of Variance (ANOVA) by using SPSS Statistics (IBM SPSS Statistics 21). Duncan's multiple range test at $P \leq 0.05$ was used to perform the mean comparison.

3. Results and Discussions

When plants pass their growth stages well, which cause to have better productivity. Table 2 displays growth and yield parameters, which were affected by varieties. The longest plant height was recorded by the FH952 *var.* (3.70m), while the biggest stem diameter was noted from 4202 (23.77mm), and greater value of leaf number was recorded by 4383 (214.67 leaf $plant^{-1}$), compared to other varieties. Results in agreement with statement by[11], stated that variety significantly influences on all the measured characteristics (plant height, stem diameter and leaves number). FH952 *var.* noted to have the highest values for the characteristics except for leaves number. While, 4383 *var.* different from others by having more leaves number. In addition, in this current study fresh and dry matter of stem, core and bast fiber yields were noted of FH952 *var.* by almost (232.18, 60.89, 98.71, 42.67, 64.18 and 18.00 t ha^{-1}), respectively.

Table 2: Effect of varieties on growth and yield characteristics.

Varity	Plant height (m)	Stem diameter (mm)	Leaves number (plant)	Total stem yield		Core yield		Bast yield	
				Fresh	Dry	Fresh	Dry	Fresh	Dry
				t. ha^{-1}					
FH952	3.70^a	21.55^b	133.96^c	232.18^a	60.89^a	98.71^a	42.67^a	64.18^a	18.00^a
4383	3.52^a	23.12^a	214.67^a	216.80^{ab}	53.91^b	94.88^a	38.09^{ab}	57.69^{ab}	15.73^b
4202	3.20^b	23.77^a	176.18^b	198.44^b	47.91^b	80.04^b	33.38^b	52.84^b	14.31^b

Values with different letters within columns indicate significant differences at 5% of probability according to Duncan's multiple range test.

Foliar application of 2000 mg L^{-1} NPK was also significantly affected growth and yield characteristics as can be seen in the (Table 3). Despite that, only plant height was not affected by adding NPK. The biggest stem diameter of the plants was found when 2000 mg L^{-1} NPK was added (24.89mm), which was caused to provide the greater fresh and dry matter productivity. These results strongly supported by[12], whose stated that applying NPK doses in the right way caused to increases growth biomass parameters of kenaf plant. This finding was also in line with the report by[13] whose said that stem diameter, plant height and leaf number significantly affected by nitrogen, phosphor and potassium, which when added at the rates of 200, 100 and 100 mg l^{-1}, respectively. Adding NPK was also at the rate of 100 kg ha^{-1} leads to improve plant height, stem diameter, leaf number, and total fresh stem yield. While, fresh and dry matter of core and bast fibers were increased by applying NPK at the proportion of 150 kg ha^{-1}[10].

Table 3: Effect of NPK on growth and yield characteristics.

NPK (mg L^{-1})	Plant height (m)	Stem diameter (mm)	Leaves number (plant)	Total stem yield		Core yield		Bast yield	
				Fresh	Dry	Fresh	Dry	Fresh	Dry
				t ha^{-1}					
0	3.47^{a}	21.85^{b}	167.20^{b}	197.20^{b}	50.62^{b}	84.49^{b}	35.42^{b}	54.89^{b}	15.02^{b}
2000	3.53^{a}	24.89^{a}	201.20^{a}	253.33^{a}	62.67^{a}	105.87^{a}	43.91^{a}	65.87^{a}	18.67^{a}
4000	3.42^{a}	21.70^{b}	156.40^{b}	196.89^{b}	49.42^{b}	83.29^{b}	34.80^{b}	53.96^{b}	14.36^{b}

Interaction between varieties and NPK concentrations significantly affected growth and yield characteristics (Table 4). The highest plant height was noted when 2000 mg L^{-1} of NPK added to the variety FH952 (3.80m), in the treatment (V1NPK1), followed by the treatment (V1NPK2), when was the concentration of NPK increased to 4000 mg L^{-1} (3.78). Stem diameter was dramatically improved when 4000 mg L^{-1} NPK was added to the 4202 *var.* (V3NPK2), this fact of affecting NPK was noted when compared to the control treatment (V3NPK0), so the values of stem diameter were (20.70mm) in the control treatment, while increased to (28.91mm), in the situation of (V3NPK2). Leaves number was also other growth parameters significantly changed according to the different situations of the treatments. The results in line with the report by[14], at a definite dose range NPK (15:15:15) significantly increased the number of leaves, plant height, and leaf area of the *Punica granatum* plant.

On the other hand, believed that not just fertilizer and genetic factors affected leaves number per plants but also shape of leaves to be affected. The leaf shape of the 4383 *var*. has complete, while both other varieties FH952 and 4202 have the divided shape leaves (Figure 2). So, the greater leaves number was found in situation (V2NPK2), by (269.80 leaf plant^{-1}). However, the best values of the fresh and dry matter productivity of total stem, core and bast fiber yields were noted with the situation of (V1NPK2), when 4000 mg L^{-1} NPK added to FH952 *var*. which were by (284.93, 72.80, 118.80, 50.93, 74.13 and 21.73 t ha^{-1}), respectively. While, in the control treatment these values of fresh and dry matter were too smaller in the same variety, this comparison is also true about other varieties. The changed of the fiber productivity showed the impact of applying NPK fertilizer especially by foliar application. As mentioned in the previous researching the NPK macro nutrients become the main component to determine the growth, yield, and quality of crop yields. Balancing NPK is a key strategy in cultivation to increase crop productivity or fresh crop yields[15,16]. Different concentrations of Nano NPK and mineral fertilizer were spraying to investigate its effect on some growth characteristics of *Pinus brutia* seedlings. The interaction between Nano NPK (20:20:20) and mineral NPK (20:20:20) was significantly superior by giving the highest average growth of all studied characteristics[17].

Table 4: Effect of interaction between variety and NPK on growth and yield characteristics.

V. × NPK	Plant height (m)	Stem diameter (mm)	Leaves number (plant)	Total stem yield		Core yield		Bast yield	
				Fresh	Dry	Fresh	Dry	Fresh	Dry
				t ha^{-1}					
V1NPK0	3.51^{abc}	21.93^{bc}	131.13^{de}	212.80^{b}	55.07^{bc}	87.60^{c}	38.93^{bc}	58.93^{bc}	15.73^{bcd}
V1NPK1	3.80^{a}	20.64^{c}	114.20^{e}	198.80^{b}	54.80^{bc}	89.73^{c}	38.13^{bc}	59.47^{bc}	16.53^{bc}
V1NPK2	3.78^{a}	22.07^{bc}	156.53^{cd}	284.93^{a}	72.80^{a}	118.80^{a}	50.93^{a}	74.13^{a}	21.73^{a}
V2NPK0	3.51^{abc}	22.46^{bc}	159.53^{cd}	171.73^{b}	44.53^{c}	80.67^{c}	31.47^{c}	48.67^{c}	12.80^{d}
V2NPK1	3.42^{abc}	23.22^{bc}	214.67^{b}	214.00^{b}	54.80^{bc}	92.40^{bc}	38.80^{bc}	58.13^{bc}	16.00^{bcd}
V2NPK2	3.64^{ab}	23.68^{b}	269.80^{a}	264.67^{a}	62.40^{ab}	111.60^{ab}	44.00^{ab}	66.27^{ab}	18.40^{b}
V3NPK0	3.24^{bc}	20.70^{c}	178.53^{bc}	206.13^{b}	48.67^{c}	81.60^{c}	34.00^{c}	54.27^{bc}	14.53^{cd}
V3NPK1	3.17^{c}	21.70^{bc}	172.73^{bcd}	178.80^{b}	42.27^{c}	71.33^{c}	29.33^{c}	47.07^{c}	12.53^{d}
V3NPK2	3.17^{c}	28.91^{a}	177.27^{bc}	210.40^{b}	52.80b^{c}	87.20^{c}	36.80^{bc}	57.20^{bc}	15.87^{bcd}

Improving of fiber quality is requested since based on the quality properties fibers will have multipurpose uses in the industrial sections; textile, nonwoven, biocomposites, medium-density fibreboard (MDF) products, building blocks…etc. Table 5 shows the results of fiber morphology characteristics were affected by varieties and NPK fertilizer. 4202 was recorded the longest single fiber length (SFL) by almost (3.60mm), while by adding 2000 mg L^{-1} of NPK just about (3.56mm), however in the control treatment was by (2.98mm). The biggest fiber width (FW), and lumen width (LW), were about (18.60 and 15.64 µm), respectively when 4000 mg L^{-1} NPK was added. While, the biggest value of cell wall thickness (CWT) noted in the control treatment and when 2000 mg L^{-1} NPK was applied which was by almost (1.70 µm). These results are confirmation to the impact of single effect of variety and NPK on the fiber morphology properties. The appropriate rate of residue potassium (K) in the study site with its amount of the applied fertilizers may cause to improve quality properties of the kenaf plants. The optimal fertilizer dosage also determines the yield and quality. Report of[18], stated that the optimal potassium dose increases leaf physiology, fiber yield and cotton fiber length.

Table 5: Effect of varieties and NPK on fiber morphology characteristics.

Variety	SFL (mm)	FW (µm)	LW (µm)	CWT (µm)
FH952	2.42^{b}	15.65^{a}	12.56^{b}	1.36^{b}
4383	2.58^{b}	17.64^{a}	14.38^{a}	1.58^{ab}
4202	3.60^{a}	16.96^{a}	12.56^{ab}	1.76^{a}
NPK (mg L^{-1})				
0	2.98^{a}	15.27^{b}	12.16^{b}	1.69^{a}
2000	3.56^{a}	16.39^{b}	13.05^{b}	1.70^{a}
4000	2.06^{b}	18.60^{a}	15.64^{a}	1.30^{b}

Values with different letters within columns indicate significant differences at 5% of probability according to Duncan's multiple range test. SFL= single fiber length, FW= fiber with, LW= lumen with, and CWT= cell wall thickness.

Figures 5 and 6 show the interaction effects on bast fiber morphological properties, which were dramatically changed based on the different situations. Single fiber length was increased and improved when 4000 mg L^{-1} NPK added to the 4202 *var*. which was by more than (5mm), while in the control treatment just about (1.5mm), due to that fact using of NPK is more necessary especially through foliar application method.[19], confirmed the impact of applying GA3 with NPK fertilizer. They stated that, fiber diameter, fiber elongation and breaking strength were dramatically improved by adding GA3 with low NPK treatment, which was compared to both treatments; NPK alone and control[10] was also reported that the longest single fiber length and the biggest fiber width were found in the interaction treatment 4202 × 100 kg ha^{-1} NPK (V2F1), by almost (3.91 mm, 18.64 µm), respectively while the biggest lumen width and cell wall thickness were noted of 4383 × 150 kg ha^{-1} NPK (V1F2) and 4202 × 150 kg ha^{-1} NPK (V2F2) by almost (15.13, and 1.83 µm), respectively. Despite that, the smallest values of all mentioned characteristics were noted by the interaction treatments 4383 × 0 NPK (V1F0), 4383 × 100 kg ha^{-1} NPK (V1F1), and 4202 × 0 NPK (V2F0) were about (2.02 mm, 12.56, 10.37, and 1.30 µm), respectively.

Fiber width, lumen width and cell wall thickness were also significantly changed according to the interaction treatments. Despite that, in some situations not significant was found between treatments (Figure 6).

Figure 7 was some images microscopy which are the best evidence to confirm the improvement of single fiber length with different situations. Generally, the longest single fiber length was found in the image microscopy in the treatment (V3NPK2) as stated earlier. As the same time, the shortest single fiber length was noted in all control treatments for all other varieties in the images microscopy (V1NPK0, V2NPK0 and V3NPK0).

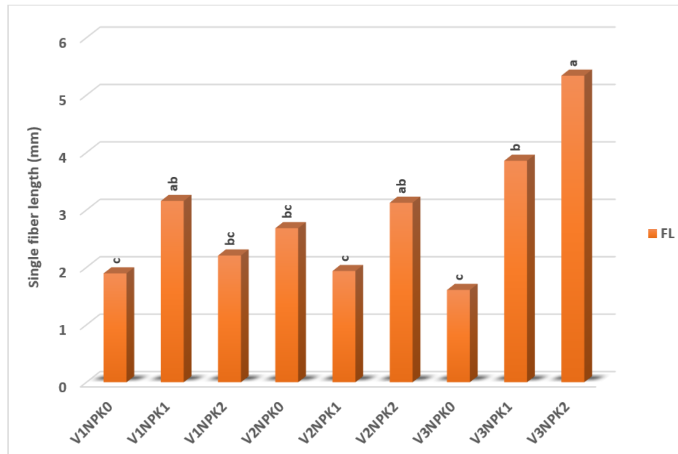

Figure 5: Effect of interaction between factors on single fiber length (mm).

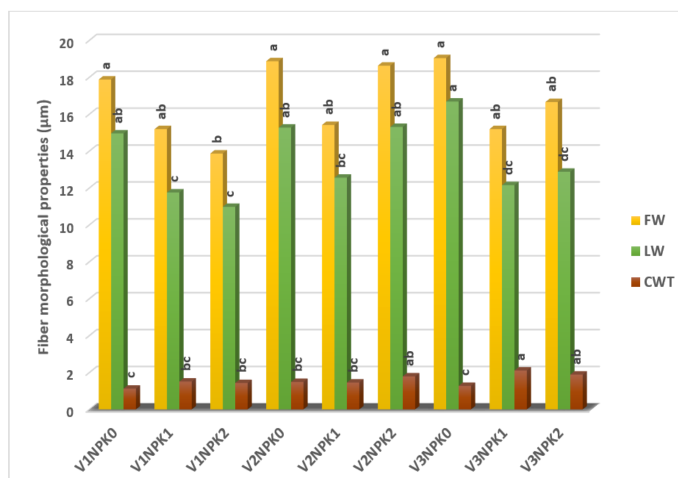

Figure 6: Effect of interaction between factors on kenaf bast fiber morphology properties (µm).

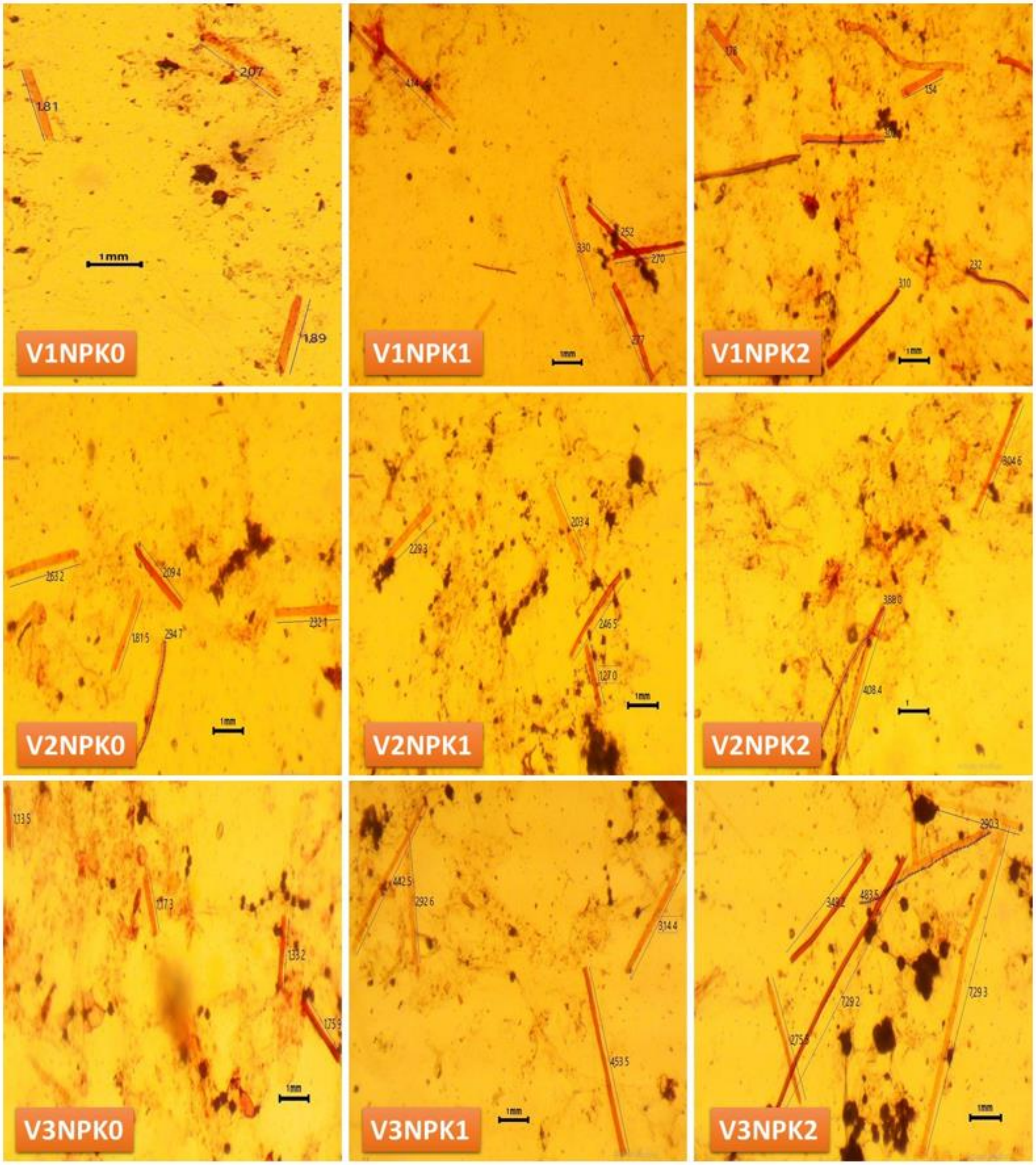

Figure 7: Image microscopy of single fiber length of kenaf bast fiber at magnification 10X. Which was effected by interaction between factors.

Besides of image microscopy of single fiber length figures 8, 9 and 10 were also showed some other images about of fiber width, lumen width and cell wall thickness which were to confirmation of impact foliar application of NPK fertilizer on different kenaf varieties[10] found that bast kenaf fiber morphology was improved, when NPK fertilizer was added. 100 and 150 kg ha^{-1} of NPK were noted to be the best for enhancing kenaf bast fiber compared to the control treatment. Increasing and decreasing of fiber diameter cause to decide of using fibers for different industrial applications. Additionally, when fiber has the big cell wall thickness, it leads to a reduction of the lumen width. Eventually, it causes to reduce fiber length and flexibility. Since, fiber flexibility strongly relative to the values of lumen width and fiber width or diameter as expressed in the following equation.

$$\boldsymbol{Flexibility} = \frac{100 \times \ Lumen\ diameter\ (\mu m)}{Fiber\ diameter\ (\mu m)}$$

These results strongly supported by the findings of[20]. Who, found that flexibility of fiber was improving with improving of fiber morphology properties. However,[21] stated that, cell wall thickness was increased with changing of nitrogen content, so the biggest result of this fiber morphology properties was noted with adding potassium at the rate of 150 kg ha^{-1}, which was by (7.73 μm) of FH952 variety.

On the other hand, the values of fiber width, lumen width and cell wall thickness were changed with changing of chemical compositions in cell layers, such as; cellulose, hemicellulose, lignin, pectin, protein, wax…etc. which were due to NPK effects.

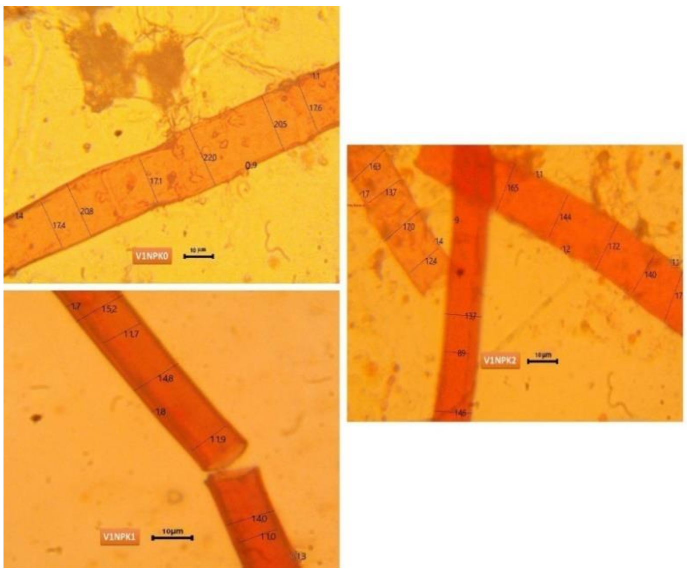

Figure 9: Image microscopy of kenaf bast fiber at magnification 100X. Fiber width, lumen width and cell wall thickness of FH952 variety response to different concentration of NPK fertilizer.

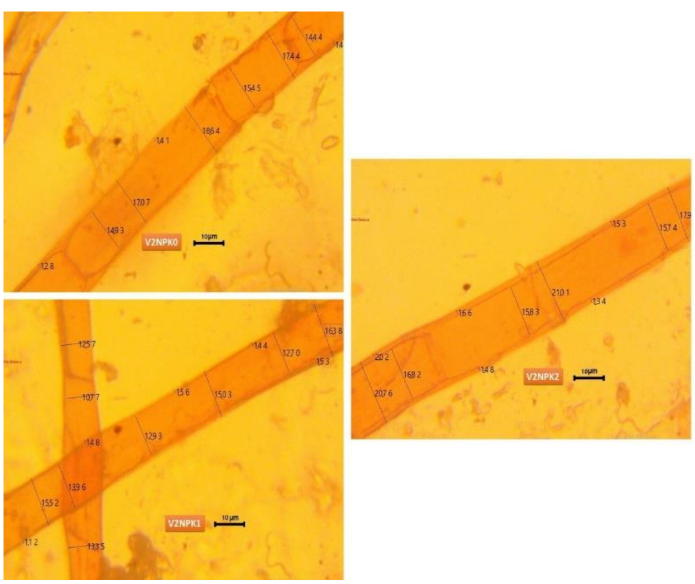

Figure 10: Image microscopy of kenaf bast fiber at magnification 100X. Fiber width, lumen width and cell wall thickness of 4383 variety response to different concentration of NPK fertilizer.

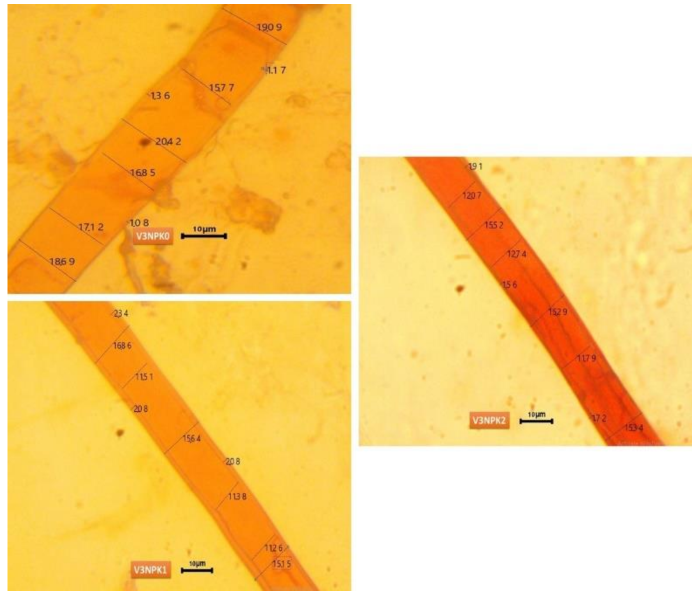

Figure 8: Image microscopy of kenaf bast fiber at magnification 100X. Fiber width, lumen width and cell wall thickness of 4202 variety response to different concentration of NPK fertilizer.

Conclusion

As known NPK fertilizer is necessary to enhance the growth, yield, and quality of crop yields, but method of its application is more important. From this present study foliar application of different concentrations of NPK was investigated. Generally, could concluded that every characteristic studied was significantly changed except of few situations, additionally foliar application of NPK have been a good response to obtain the objectives of the study. Based on the results, could recommended to apply both levels on NPK 2000 and 4000 mg L^{-1} for kenaf plants.

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Conflict of interests

The authors declare no conflict of interest.

Author contributions

Authors attest that the submitted manuscript is original and they confirmed that it has not been published or is not under consideration for publication elsewhere.

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