Response of Some Kenaf (*Hibiscus cannabinus* L.) Accessions from Northern Nigeria to water Stress

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Abstract
Kenaf (*Hibiscus cannabinus*) is mainly cultivated in Northern Nigeria, where desertification is increasing due to climate change, exposing plants to water stress. However, Nigeria's kenaf is yet to be evaluated for drought tolerance. This study determined the drought threshold of Nigeria's kenaf accessions to develop adapted varieties. Six seeds of accessions of kenaf landraces from Northern Nigeria (NHC 3(1), NHC 9(2), NHC 11(1), NHC 1, NHC 13(1), NHC 8(1)) were planted in 5L sterile topsoil in a Complete Randomized Design with three replicates. Water stress was imposed by withdrawing watering from the 30^{th}-40^{th} day, while control plants were watered throughout the experiment (well-watered). The experiment was a 6 (accessions) by 2 (Stress state) factorial arranged in a completely randomized design and replicated three times. After stress imposition, data were collected on growth and yield parameters. All data were analyzed using analysis of variance, and means were separated using least significant differences at 5% significance level. The PH and CLC differed significantly across accessions and ranged from 16.59±1.68 (NHC9(2)) to 27.22±1.68 (NHC11(1)), 8.67±2.01 (NHC9(2)) to 29.44±2.01 (NHC11(1)), and 37.70±5.19 (NHC13(1)) to 50.05±5.19 (NHC3(1)). NHC 11(1) and NHC 9(2) were the most and least tolerant of water stress, respectively, in terms of growth and yield performance. Water stress significantly reduced CLC in non-tolerant genotypes but had no significant effect on drought-tolerant genotypes.

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Introduction

Kenaf (*Hibiscus cannabinus* L.) is a common wild plant found in tropical and subtropical Africa and Asia. It is a fiber plant native to east-central Africa, where it has been grown for several thousand years for its food and fiber. It is a short-day annual herbaceous plant mainly cultivated for the soft bast fiber in its stem (Ayadi *et al*., 2017) [4]. It is an environmentally friendly crop that helps mitigate global warming by absorbing carbon dioxide through its rapid growth rate (Asumani, O. 2021) [3]. Additionally, its cultivation requires minimal input of chemical inputs, making it a low-risk cash crop. Kenaf is a plant in the Malvaceae family, notable for its economic and horticultural importance (Balogun *et al*., 2009; Ogunniyan *et al*., 2017) [5]. *Hibiscus cannabinus* is a member of the genus Hibiscus and is likely native to southern Asia, although the exact origin of the kenaf plant remains unknown. It is a warm-season annual fiber crop closely related to cotton (*Gossypium hirsutum* L., Malvaceae) and okra (*Abelmoschus esculentus* L., Malvaceae) (Jiantang Xu *et al*., 2020). The genus Hibiscus is widespread, comprising approximately 200 annual and perennial species. Kenaf, along with roselle, is classified taxonomically in the Hibiscus section of the Furcaria.

In Nigeria, Kenaf is popularly grown in Sokoto, Borno, Kaduna, Plateau, Niger, Benue, Kwara, and Nasarawa States for food and fiber. Additionally, it performs well in Oyo and Ogun states of southwestern Nigeria (Ogunniyan *et al*., 2024) [11]. Next to cotton, it is the most widely cultivated fiber plant in open country, found from Senegal to Nigeria. The plant in Africa had several non-fiber uses. Kenaf fiber is used to make rope, twine, coarse cloth, and paper (Webber III *et al*., 2024) [14]. Kenaf is also used in the production of engineered wood, insulation, clothing-grade cloth, soilless potting mixes, animal bedding, feed, packaging materials, and materials that absorb oil and other liquids. It is also helpful as a cut-bast fiber for blending with resins in plastic composites, as a drilling-fluid loss-preventative for oil-drilling muds, and as a seeded hydro-mulch for erosion control (Webber III *et al*., 2024) [14]. Kenaf can be used to create various types of environmental mats, including seeded grass mats for instant lawns and moldable mats for manufactured parts and containers. The core of kenaf can be used as an absorbent to clean up oil and chemical spills (Zulkifli & Ahmad, 2025) [18]. It is commonly cultivated for both food and fiber in West Africa (Cheng *et al*., 2016) [6]. In addition, kenaf fibers provide significant employment and constitute a primary source of foreign exchange (Alexopoulou, E. 2023) [1]. Leaves and flowers are used as a vegetable, its seeds are used for oil production, and various plant parts are used in medicines and in certain superstitious rites.

The use of kenaf in paper production offers various environmental advantages over producing paper from trees. It has been rated as the most viable replacement for trees in papermaking, with kenaf newsprint offering stronger, brighter, and cleaner pages than standard pine paper, while causing less environmental harm (Austin, C. C. *et al*., 2024). Up to 76.6% of the world's Kenaf is produced in Asia, while Africa, its center of origin, accounts for about 6.8% of global production. Kenaf was first domesticated and used in northern Africa. India has produced and used kenaf for the last 200 years, while Russia started producing kenaf in 1902 and introduced the crop to China in 1908. In the United States, research and production of kenaf began during World War II to supply cordage for the war effort (Alexopoulou *et al*., 2015; Ayadi *et al*., 2017) [2, 4]. The kenaf plant has a broader range of adaptation to climates and soils than any other fiber plant in commercial production. Kenaf yields have been highest in regions with high temperatures, a long growing season, and abundant soil moisture. It is said that the kenaf plant is quite sensitive to cool temperatures and grows relatively slowly when temperatures are below 50°F. Kenaf, although adaptable to various soils, grows best in well-drained sandy loam and requires a warm, moist, tropical or subtropical climate without excessive rainfall or strong winds (Vayabari, D. A. G. *et al*., 2023) [13].

Kenaf (*Hibiscus cannabinus*) is an economically important industrial fiber crop that suffers severe losses in fiber yield and quality under drought-stress conditions. Drought stress in kenaf plants has been well documented as a significant factor in reducing kenaf crop production (Yuan, S., & Zhang, K., 2018) [16]. A good understanding of the factors limiting yield now provides us with an opportunity to identify and select for physiological traits that increase drought tolerance and yield under rainfed conditions. Applying various agro-morphological tests to identify and evaluate drought tolerance in kenaf plants enables faster selection. Therefore, these characters can serve as indirect selection criteria for screening drought-tolerant kenaf plants. This strategy will lead to new cultivars with high yield potential and stability, which, in turn, will result in superior performance of kenaf plants in drier environments.

Drought is becoming a significant agricultural constraint in Northern Nigeria; therefore, it is necessary to characterize landraces from the region in terms of their responses to water stress and the impact of such stress on yield. However, many of the landraces have not been registered and released as new varieties because they have not been associated with specific attributes. A good understanding of the factors limiting yield now provides us with an opportunity to identify and select for morphological traits that increase drought tolerance and yield under rainfed conditions. Applying various physiological and agro-morphological tests to assess drought tolerance in plants enables faster selection methods (Zhang H. *et al*., 2025) [17]. Developing and releasing kenaf accessions adapted to water-deficient conditions can be a constructive approach to overcoming the environmental constraints that limit kenaf (Dengjie Luo *et al*., 2023). Kenaf is mainly cultivated in Northern Nigeria; however, many landraces have not been registered or released as new varieties because they have not been associated with specific attributes. The climate in Nigeria is changing, especially in Northern Nigeria. Shorter duration of rainfall days, which causes drought, therefore requiring a drought-tolerant kenaf plant. However, they have not been characterized in terms of specific adaptations to different agroecologies (Onwualu, A. P., & Ogunleye, B. M., 2023) [12]. Prolonged drought leads to retarded growth, reduced yield, and may cause death. Information on the water-use efficiency of kenaf accessions from Northern Nigeria has not been explored in detail, and such knowledge can provide a better understanding of kenaf physiology, which ultimately affects its growth, biomass productivity, and the most prominent aspect: fiber quality. To ensure that these kenaf accessions can be cultivated in the Savannah agroecology.

The objectives of the research are to;

1. Determine the accessions of the kenaf seeds obtained from Northern Nigeria that are tolerant to water stress.
2. Determine the effect of water stress on the chlorophyll content of kenaf genotypes as an indicator of their physiological status.

Materials and Methods

Experimental Site

The experiment was conducted in the rooftop garden of the Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan.

Source of Seed

Six accessions of kenaf seeds from Northern Nigeria (Table 1) were collected for this study from the kenaf Gene bank of the Department of Crop Protection and Environmental Biology, University of Ibadan.

Table 1: List of kenaf accessions (Nigeria *Hibiscus cannabinus*) obtained from Northern Nigeria used in the study

Serial number	Accessions	State of collection
1	NHC 3(1)	Niger State
2	NHC 9(2)	Adamawa State
3	NHC 11(1)	Plateau State
4	NHC 1	Niger State
5	NHC 13(1)	Plateau State
6	NHC 8(1)	Adamawa State

NHC: Nigeria *Hibiscus cannabinus*

Determination of Water Holding Capacity

Water holding capacity is the amount of water that a given soil can hold for crop use. The water-holding capacity of a soil is a very important agronomic characteristic. Soils that hold generous amounts of water are less subject to leaching losses of nutrients or soil-applied pesticides. This is true because a soil with a limited water holding capacity (i.e., a sandy loam) reaches the saturation point much sooner than a soil with a higher water holding capacity (i.e., a clay loam). After soil is saturated with water, excess water, along with some nutrients and pesticides in the soil solution, is leached downward through the soil profile. Water-holding capacity in this experiment was calculated as (Volume of water applied–Volume of water drained).

This was done to determine the exact amount of water to use for the plants, preventing excessive water (flooding) or insufficient water (drought). This experiment was conducted in the rooftop garden of the Department of Crop Protection and Environmental Biology. Three pots were filled with 5L of soil each. 2L of water was measured into three cups, then poured into each pot until each pot began to drip from the holes beneath it. The remaining water in the cup was measured and recorded to determine how much water was poured into the soil. The weight of the soil after adding water was then taken. The pots filled with watered soil were then placed in another empty bucket to allow the water to drain into it. It was left for three days to ensure proper drainage; afterward, the water that drained into the empty buckets was measured, and the soil's weight after three days as also recorded. Values are properly displayed in Table 2.

Table 2: Water holding capacity of soil

Initial Weight of Soil (KG)	**Volume of Water Added** (L)	**Weight of Soil After Adding Water** (KG)	**Weight of Soil After 3 Days** (KG)	**Volume of Water Drained** (L)	**Water Holding Capacity** (L)
5.0	1.30	6.35	5.55	0.06	1.24
5.0	1.20	6.40	5.60	0.21	0.99
5.0	1.50	6.40	5.50	0.10	1.40
MEAN	1.33	6.38	5.55	0.12	1.21

Experimental Setup

Top Garden soil was collected from the crop garden of the Department of Crop Protection and Environmental Biology. The soil was steam-sterilized at 95°C for 3 hours (after boiling water). Experimental pots were filled with 5 L of sterilized soil, and 4 seeds were sown per pot. Afterward, the plants were thinned to 1 plant/pot. Plants were watered with 1 liter of water (approximately 90% of their water-holding capacity) twice daily. Water stress was imposed 30 days after germination, with some plants exposed to it and others kept well-watered throughout the experiment. Watering was resumed for the water-stressed plants exactly 10 days after the onset of water stress, and the plants were closely observed thereafter.

Experimental Design

The experiment was a 6 (accessions) by 2 (Stress state) factorial arrangement in a completely randomized design, replicated three times.

Data Collection and Statistical Analysis

The first data collection was taken on the 29th day after germination (before water stress). The second data was taken 6 days after the resumption of watering. Data were collected on the following parameters for morphological traits: number of leaves, stem girth at mid (cm), stem girth at base (cm), plant height (cm), and stem color. After harvesting, data were collected on the following parameters for fiber yield: plant height (cm) at harvest, dry plant mass (kg), dry core mass (kg), dry bast mass (kg), mid-stem diameter (cm), and base-stem diameter (cm). The efficiency of Recovery, i.e., the increase in growth after stress, was also calculated after the imposition of water stress. This was done after taking the readings of the plants under water stress. It was calculated using the formula: Efficiency of Recovery = (after stress - before stress). Chlorophyll content of the plants was evaluated using the Soil Plant Analysis Development (SPAD) method. All data were analyzed using analysis of variance, and means were separated using the least significant difference test at a 5% significance level.

  

Plate 1: A Flowering Kenaf Plant on the rooftop garden, **Plate 2:** Well watered kenaf plant, **Plate 3:** A water-stressed kenaf plant

Results

The result obtained before stress imposition showed that NHC11(1) was the tallest accession (21.17±0.96), significantly taller than the other accessions (Table 3). The number of leaves produced by NHC11(1) was the highest (18.11±0.96) and significantly higher than that of the other accessions. However, NHC11(1) and NHC8(1) produced the mid stem girth (0.28±0.03) which was statistically similar with other accessions, except NHC13(1) (0.20±0.03). Also, NHC3(1) produced the longest basal stem girth (0.29±0.02) which was statistically similar with other accessions except NHC1 (0.21±0.02) and NHC13(1) (0.19±0.02). There were significant differences among the accessions in plant height, number of leaves, and mid-stem girth after stress was imposed. The tallest plant height was observed in NHC11(1) (27.22±1.68) and it was significantly taller than NHC9(2) (16.59±1.68) and NHC13(1) (19.14±1.68). NHC11(1) also produced the highest number of leaves (29.44±2.01), which was significantly higher than the rest of the accessions. NHC8(1) produced the widest stem (0.48±0.03) that was significantly wider than the rest accessions except NHC11(1) (0.40±0.03) and NHC3(1) (0.47±0.03), respectively.

Table 3: Growth performances of six accessions of kenaf grown in potted topsoil

Accessions	PHB	NOLB	MSGB	BSGB	PHA	NOLA	MSGA	BSGA
NHC11(1)	21.17^{a}	18.11^{a}	0.28^{a}	0.26^{ab}	27.22^{a}	29.44^{a}	0.40^{ab}	0.38^{a}
NHC8(1)	18.17^{b}	9.78^{b}	0.28^{a}	0.24^{ab}	24.28^{ab}	14.56^{bc}	0.48^{a}	0.42^{a}
NHC3(1)	17.33^{b}	12.67^{b}	0.27^{ab}	0.29^{a}	26.17^{a}	17.11^{b}	0.47^{a}	0.42^{a}
NHC1	17.25^{b}	12.88^{b}	0.24^{ab}	0.21^{b}	23.38^{ab}	17.13^{b}	0.38^{b}	0.38^{a}
NHC9(2)	15.83^{b}	10.22^{b}	0.27^{ab}	0.27^{ab}	16.59^{c}	8.67^{c}	0.36^{b}	0.35^{a}
NHC13(1)	15.07b	11.14^{b}	0.20^{b}	0.19^{b}	19.14^{bc}	16.43^{b}	0.36^{b}	0.36^{a}
SE	0.96	0.96	0.03	0.02	1.68	2.01	0.03	0.03

Means with the same letter along the column are not significantly different from each other at the 5% level of significance. PHB, NOLB, MSGB, and BSGB represent plant height, number of leaves, middle stem girth, and base stem girth, respectively, before water stress at 29 days after planting. PHA, NOLA, MSGA, and BSGA represent plant height, number of leaves, middle stem girth, and base stem girth, respectively, after imposition of water stress at 40 days after planting. SE = Standard error, NHC = Nigeria *Hibiscus cannabinus.*

The result collected on the efficiency of recovery of the stressed kenaf accessions showed that the height recovery ranged from 2.13 (NHC13(1)) to 6.75 (NHC3(1)), the leaves production recovered from -0.25 (NHC9(2)) to 6.50 (NHC11(1)), the middle stem girth ranged from 0.06 (NHC11(1), and NHC1) to 0.19 (NHC8(1)). In contrast, the basal stem girth recovery ranged from 0.10 (NHC9(2)) to 0.20 (NHC8(1)) (Table 4). Table 5 showed that there were no significant differences among the accessions on the plant heights at harvest, dry plant mass, base stem diameter, mid stem diameter, dry bast mass, and the dry core mass, while the chlorophyll content of NHC3(1) was the highest (50.05±5.19), which was statistically similar with the rest of the accessions except NHC11(1) (33.86±5.19).

Table 4: Efficiency of recovery for water-stressed plants

Accessions	PH	NOL	MSG	BSG
NHC 11(1)	5.38	6.50	0.06	0.15
NHC 3(1)	6.75	2.75	0.16	0.13
NHC 8(1)	5.50	1.50	0.19	0.20
NHC 1	4.50	-0.25	0.06	0.17
NHC 13(1)	2.13	3.00	0.15	0.14
NHC 9(2)	1.88	-2.50	0.10	0.10

PH: Plant height, NOL: Number of leaves, MSG: Mid stem girth, and BSG: Basal stem girth.

Table 5: Plant height, fiber yield components, and chlorophyll contents of kenaf accessions grown in potted soil

Accessions	PH at harvest	DPM	BD	MD	DBM	DCM	Chlorophyll
NHC8(1)	74.22^{a}	8.18^{a}	0.73^{a}	0.54^{a}	2.61^{a}	3.77^{a}	48.20^{ab}
NHC9(2)	71.28^{a}	8.19^{a}	0.76^{a}	0.61^{a}	2.84^{a}	3.43^{a}	48.20^{ab}
NHC1	71.02^{a}	10.55^{a}	0.85^{a}	0.45^{a}	2.97^{a}	4.32^{a}	43.28^{ab}
NHC11(1)	67.80^{a}	9.39^{a}	0.65^{a}	0.45^{a}	2.52^{a}	3.40^{a}	33.86^{b}
NHC3(1)	66.88^{a}	9.30^{a}	0.63^{a}	0.56^{a}	2.00^{a}	3.65^{a}	50.05^{a}
NHC13(1)	60.10^{a}	12.63^{a}	0.62^{a}	0.53^{a}	2.14^{a}	3.26^{a}	37.70^{ab}
SE	27.81	7.53	0.11	0.17	1.2	2.13	5.19

Means with the same alphabet along the column are not significantly different from each other at 5 % level of significance, SE = Standard error, NHC = Nigeria *Hibiscus cannabinus,* PH = Plant Height, DPM = Dry Plant Mass, BD = Base Stem Diameter, MD = Mid Stem Diameter, DBM = Dry Bast Mass, DCM = Dry Core Mass.

There were no significant differences between the stressed plants and well-watered plants in all growth parameters, except for the number of leaves and mid-stem girth after stress imposition (Table 6). The number of leaves (20.26±1.20) and mid stem girth (0.44±0.02) of the well-watered plants were significantly higher than those of the water-stressed plants. Table 7 showed that there were no significant differences between the water-stressed kenaf plants and the well-watered kenaf plants in terms of plant height at harvest, as well as fiber yield parameters and chlorophyll content at harvest.

Table 6: Effect of water stress and unstressed conditions on the growth parameters of kenaf

Stress state	PHB	NOLB	MSGB	BSGB	PHA	NOLA	MSGA	BSGA
WS	17.67^{a}	12.04^{a}	0.26^{a}	0.24^{a}	22.02^{a}	13.88^{b}	0.38^{b}	0.39^{a}
WW	17.48^{a}	12.93^{a}	0.27^{a}	0.25^{a}	23.83^{a}	20.26^{a}	0.44^{a}	0.39^{a}
SE	0.57	0.58	0.01	1.02	1.2	1.2	0.02	0.02
Acc x Stress state	*	*	NS	NS	*	*	NS	NS

Means with the same letter within a column are not significantly different from each other at the 5% level of significance. PHB, NOLB, MSGB, and BSGB represent plant height, number of leaves, middle stem girth, and base stem girth, respectively, before water stress at 29 days after planting. PHA, NOLA, MSGA, and BSGA represent plant height, number of leaves, middle stem girth, and base stem girth, respectively, after imposition of water stress at 40 days after planting. SE = Standard error. WS = Water stressed, WW = Well Watered.

Table 7: Effect of water stress conditions on the height, fiber yield, and chlorophyll contents of kenaf accessions grown in potted soil

Accessions	Plant height at harvest	DPM	BD	MD	DBM	DCM	Chlorophyll
WS	62.10^{a}	8.95^{a}	0.64^{a}	0.46^{a}	2.30^{a}	3.22^{a}	40.30^{a}
WW	70.39^{a}	11.03^{a}	0.74^{a}	0.53^{a}	2.64^{a}	4.27^{a}	42.49^{a}
SE	6.07	1.64	0.06	0.04	0.26	0.47	2.77
Acc x Stress state	NS	NS	NS	*	NS	NS	*

Means with the same alphabet along the column are not significantly different from each other at 5 % level of significance, SE = Standard error, WS = Water Stressed, WW = Well Watered, DPM = Dry Plant Mass, BD = Base Stem Diameter, MD = Mid Stem Diameter, DBM = Dry Bast Mass, DCM = Dry Core Mass. ``

Discussion

The primary objective of the study was to identify kenaf accessions from northern Nigeria that can survive in drought-prone areas without significantly affecting crop productivity and fiber yield. During the study, it was observed that three accessions exhibited excellent growth performance in plant height, leaf number, and stem girth, both before and after drought stress. These three accessions, NHC 11(1), NHC 3(1), and NHC 8(1), also had a relatively fair recovery rate after the imposition of water stress. This may be due to the high growth performances during and after the imposition of drought stress. This indicates that these accessions can be grown or perform well in the country's northern region, which is sometimes affected by drought. The seed quality of the parent seeds of these accessions may also contribute to their good growth performance.

All the accessions continued to grow even after watering was withdrawn for 10 days, and they could tolerate water stress to some extent before wilting set in. Hassan, M. M., & Muhammad, L. A. (2022) [7] also reported varietal differences in kenaf's response to water stress. This would help select kenaf accessions that are drought-resistant and can survive in drought-affected regions. The high drought tolerance and rapid recovery in kenaf are presumed to depend on photorespiration, which dissipates excess energy in leaves, thereby protecting the photosynthetic apparatus (Khalatbari *et al.*, 2016) [8]. The specific feature of kenaf's photosynthetic response is characterized by maintaining a high CO2 exchange rate, thereby serving as a significant CO2 sequestrator under normal growth conditions (Khalatbari *et al.*, 2014; Asumani, O. 2021) [9, 3], and by an increase in the photorespiration rate under drought conditions.

Two accessions exhibited very poor growth performance during and after water stress. These accessions (NHC13(1) and NHC 9(2)) did not perform well before or after the imposition of water stress. Some of the plants wilted and died after water stress was imposed. However, one of the accessions, i.e., NHC 13(1), had a relatively fair recovery efficiency and even recorded the highest recovery efficiency for stem girth at mid, indicating a relatively high response in growth performance after stress. This indicates that the two accessions would perform well only in regions with relatively high rainfall or in areas with a well-established irrigation system, as they require frequent watering to survive. The remaining accession, i.e., NHC 1, did not exhibit any significant difference before and after water stress; it recorded the highest recovery rate for base stem girth and also showed a medium recovery rate across all other traits after the imposition of water stress. This indicates that this accession can be grown in drought-affected areas. However, it is preferably grown in areas with relatively high rainfall, as its productivity and growth performance increase with frequent rainfall or watering.

Comparing fiber yield for the well-watered plants, NHC 1 and, in some cases, NHC 3(1) and NHC 8(1) had the highest fiber yield, i.e., dry plant mass, dry core mass, dry bast mass, stem mid-diameter, and stem base diameter. This shows that these accessions would produce high fiber yields under frequent rainfall or watering. For the stressed plant, NHC 11(1) and, in some cases, NHC 9(2) showed high fiber yield performance, as indicated by dry plant mass, dry core mass, dry bast mass, stem mid-diameter, and stem base diameter. This shows that for fiber production, which is one of the primary purposes of kenaf production, these accessions, i.e., NHC 11(1) and NHC 9(2), can be grown in the Northern region of the country that is sometimes affected by drought, as their fiber yield performance is not really affected by water stress. NHC 13(1) and NHC 8(1) should also be grown in areas with frequent rainfall or irrigation, as they had the lowest fiber yield under water stress.

Conclusion

I recommend that the following kenaf accessions, i.e., NHC 11(1), NHC 3(1), and NHC 8(1), should be moved and grown more in the savannah regions due to their high resistance to water stress, and also their high fiber yield performance in both stressed and well-watered situations. The following kenaf accessions i.e. NHC 13(1), NHC 9(2) would be recommended to be moved down to the southern region of Nigeria (Oyo, Osun and Ogun state) i.e. in the tropical high forest zone, although NHC 9(2) had a high fiber yield after water stress but due to its low growth performance when subjected to water stress it should be grown more in the southern region of Nigeria. For other kenaf accessions that are moderately affected by water stress, I recommend that they can also be grown in the northern region of Nigeria (Adamawa, Sokoto, and Niger state), i.e., in the savannah regions. However, they would perform much better in southern Nigeria (Oyo, Ogun, and Osun states), i.e., in the tropical high forest zone.

According to their various sources of collection, NHC 11(1) which had high resistance to water stress, and also had a high fiber yield during the experiment, was obtained from Plateau state which is the cold region of Nigeria, I recommend that due to its high-water resistance and high fiber yield performance when exposed to water stress that NHC 11(1) is better grown in states like Adamawa state, Niger state, and even Sokoto state which are dry states. Also, NHC 9(2) which had low resistance to water stress but had a good fiber yield during the experiment was obtained from Adamawa state which is a hot and dry region of Nigeria, I recommend that due to its low resistance to water stress irrespective of the good fiber yield that NHC 9(2) is better grown in states like Oyo state, Osun state, and also Ogun state which are known to be the tropical forest zones of Nigeria.

Author Contributions

NZERE N.V: - Conceptualization, methodology, writing – original draft preparation, writing – review and editing of manuscript, data curation.

BALOGUN M.O: - Conceptualization, methodology review, resources, project administration, supervision.

OSSAI C.O: - Data analysis and review.

All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

There is no conflict of interest on the subject matter.

Data Availability Statement

Data will be provided on request (victornzerennanna@gmail.com).

Ethical Approval Statement

There is no ethical approval statement for this article.

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