# NIGERIAN JOURNAL OF GENETICS

VOLUME 28, 2014



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TETFUND-SUPPORTED PRODUCTION

Published By The Genetics Society of Nigeria

# NIGERIAN JOURNAL

OF

GENETICS

VOLUME 28, 2014



PUBLISHED BY THE GENETICS SOCIETY OF NIGERIA

ISSN 0189-9686

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# COMBINING ABILITY AND HETEROSIS FOR FIBRE YIELD TRAITS IN NIGERIA KENAF (*Hibiscus cannabinus* L.) COLLECTIONS

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## ABSTRACT

*Kenaf as a renewable fibre crop is known to yield lower in Nigeria than in other countries of the world. An experiment was conducted at the University of Ibadan, Oyo State, Nigeria, where sixteen (16) crosses were made among four (4) Nigeria kenaf (Hibicuscannabinus) accessions to investigate the combining ability and heterosisforfibre yield traits in the hybrids. The parents and progenies were planted in three replicates in a randomized complete block design. Data were collected on plant height, stem diameter and girth at flowering and at harvest, as well as stalk weight at harvest and means separated at P=0.05. Results showed no significant differences among genotypes at flowering and for stalk weight at harvest. Higher general combining ability (GCA) over specific combining ability (SCA) was recorded for all characters at harvest. Only accession NHC 10(1) had a positive GCA for height at harvest (21.84) and girth at harvest (1.09). The highest SCA effects were recorded in cross NHC 10(1) X NHC 2(2) for all measured traits.In contrast, the highestpositive mid-parentheterosis (28.02%) was obtained in the reciprocal cross NHC 15 X NHC 10(1)followed by NHC 2(2) X NHC 10(1) (25.76%) for HAH. Both crosses had parent NHC 10(1) to be one of their respective parents. Thus, this study identified hybrids NHC 15 X NHC 10(1) and NHC 2(2) X NHC 10(1) as promising for improvement of fibre yield traits. However, performances of these hybrids need to be evaluated in multi-locational and on-farm trials prior to commercial use.*

**Key words:** *Hibiscus cannabinus*, Kenaf, Combining Ability, Heterosis, Fibre yield

## INTRODUCTION

The need to develop a renewable resource that will provide raw materials in a sustainable manner has led to the global acceptance of kenaf as an industrial fibre crop (Balogun*et al.,* 2008). However, in spite of its numerous end uses and being native to Africa (Coetzee, 2004), the region produces only 2.1% of global production while Asia aloneaccounts for 95% (FAO, 2003). Kenaf yields in Japan range from 5.7-13.8 tonnes/ha (Cheng *et al.*, 2002) while in the U.S, dry stalk yields normally range from 11-18 tonnes/ha (Webber and Bledsoe, 2002). In Nigeria,a yield of 2.18-2.49 tonnes/ha was reported in kenaf by Agbaje*et al.*(2008).

To fully explore the benefits of kenaf as a renewable resource for fibre production, an improvement of Nigeria local kenaf varieties is essential. Identification and selection of parental lines followed by hybridization to produce high yielding genotypes are therefore necessary. This experiment was set up to study the combining ability and heterosis of some Nigeria kenaf accessions for fibre yield traits.

## MATERIALS AND METHODS

The field experiments were carried out at the Crop Garden (N 07° 27' 04.9''; E 003° 53' 49.1''; 198m) of the Department of Crop Protection and Environmental Biology, University of Ibadan, Oyo State, Nigeria. Four accessions of kenaf were collected from the kenaf Gene Bank of the Department of Crop Protection and Environmental Biology, University of Ibadan. The kenaf accessions, which had passed through two (2) generations of selfing, comprised NHC 10(1), NHC 13(1), NHC 2(2), and NHC 15, corresponding to an improved line, and collections from Plateau and Niger states, respectively.Kenaf seeds were planted onsingle row plots per accession. A spacing of 10cm × 25cm was used. Two seeds were planted per hole at a depth of 3cm. Weeding, watering, thinning and spraying were carried out as necessary.

Crosses were made among the four kenaf accessions to generate $F_1$ and reciprocal $F_1$ hybrids. Hand emasculation of ready-to-open flower buds was carried out late in the afternoon. Emasculated flowers were bagged to prevent pollination from other flowers. Pollen from freshly dehisced anthers was then used for pollination early the next morning. All pollinations were done before 11:00am in the morning as suggested by Li (2000).$F_1$ pods were harvested at full physiological maturity after 60-80 days, when the color of seeds darkened. Each individual cross was threshed by hand.

The fourparental lines and their $F_1$ seedswere planted in a Randomised Complete Block Design with three replicates in January, 2013 at a spacing of 10cm within and 25cm between rows. Two seeds were planted per hole at a depth of 3cm.Cultural practices were carried out as necessary.

Components of fibre yield such as plant height, stem girth and basal diameter were measured using meter rule, rope and venier calliper at both flowering and at harvest, respectively. Kenaf plants were harvested by cutting each plant from the soil surface 162days after planting. The fresh stalk weight of plants was measured at harvest.

Data collected were analysed using SAS 2002 version for Analysis of Variance. Test of significantdifferences among means was by Duncan's Multiple Range Test (DMRT) at P=0.05. General and specific combining ability (GCA and SCA) effects of crosses were carried out where genotypic differences were significant using the procedures of Singh and Chaudhary (1979).Reciprocal values weresubstituted for values of the missing cross for all characters as proposed by the United States Department of Agriculture (1965). Mid-parent and high-parent heterosiswere calculated for measured characters using the procedures adopted by Hallauer and Miranda (1981). The "t" test was manifested to determine whether $F_1$ hybrids means were statistically different from mid-parent and high-parent means according to the relationship of Wyne*et al.* (1970).

## RESULTS AND DISCUSSION

Table 1 shows that at flowering, no significant difference was recorded among genotypes for characters assessed. In contrast, significant differences were observed among genotypes for all the measured traits at harvestexcept stalk weight (SWH). For all traits considered, GCA was higher than SCA as shown in Table 2. This,according to Adeniji and Kehinde (2007), while working on related family (Okra) shows that additive gene action is more important than non-additive gene action in the inheritance of HAH, DAH and GAH in kenaf. This is however contrary to the findings of Srivastava *et al.*(1978),whoreported a predominance of non-additive gene action for plant height, days-to-flowering and base diameter. Chenget *al.*(2004) reported that plant height was controlled by both additive and dominant gene actions, and stem diameter mainly by dominant genes. This disparity could be adduced to differences in genotypes used and environments.

Negative GCA effects were recorded in all parents except NHC 10(1) for height at harvest. The best general combiner (21.84) was NHC 10(1) while the poorest general combiner (-11.25) was NHC 13(1) for height at harvest (Table 3). There was however no significant difference between the general combining effects of NHC 13(1) and NHC 15. Only NHC 2(2) and NHC 15 showed positive significant GCA effects for diameter at harvest. NHC 2(2) was the best general combiner for this particular trait. NHC 13(1) was the poorest general combiner (-8.92) for diameter at harvest. For girth at harvest, NHC 10(1) was the best general combiner(1.09) amongst the four parents. Alireza (2011) reported that parents possessing high GCA are generally considered for population development and for initiation of pedigree breeding, as it is heritable and can be fixed. Thus, hybrids involving NHC 10(1) have great potentials for the improvement of height and girth at harvest. For diameter at harvest, crosses involving NHC 2(2) possess great potentials for the improvement of this trait.

Hybrid NHC 10(1) × NHC 2(2) also showed the largest positive SCA effects for diameter and girth at harvest (Table 4). SCA is not heritable and therefore cannot be utilized in pure line breeding. According to Alireza(2011),hybrids with high SCA are useful for commercial exploitation. There were no significant differences in the reciprocal effects of hybrids for both diameter and girth at harvest. All attempts made in using NHC 10(1) as the male parent to cross NHC 13(1) was unsuccessful with no pods produced. The largest positive reciprocal effect (35.36) was recorded in NHC 2(2) × NHC 15 while NHC 10(1) × NHC 15 had the largest negative reciprocal effect for height at harvest (Table 5). Significant differences were observed in the reciprocal effects of hybrids NHC 2(2) × NHC 15 (35.36) and NHC 13(1) × NHC 2(2) for HAH. This suggests high influence of maternal effects (Falconer and Mackay, 1996) on height at harvest in hybrids NHC 2(2) × NHC 15, NHC 13(1) × NHC 2(2) and NHC 13(1) × NHC 15.

Table 6 shows the heterotic effects of hybrids over mid- and high-parents. No hybrid showed a positive heteosis over the high parent for DAH, GAH and SWH. However, positive heterosiswas recorded in six (6) hybrids for HAH. A positive heterotic effect shows an increase in the value of measured character over either the mid-parent or high-parent. Heterotic estimate in a hybrid around the mean value of both parents shows an additive gene effect for that particular character.

Pace *et al.*(1998) reported that plant height, basal diameter, dry bark weight, ratio between dry bark weight and woody core weight are major components of fibre yield and quality. Therefore, a positive heterotic effect for these traits is desirable for good fibre yield in kenaf hybrids.

The highest significant (P=0.05) positive effect (28.02%) was recorded in NHC 15 × NHC 10(1).This was followed by 25.76% obtained in NHC 2(2) × NHC 10(1). These results agree with earlier findings of Dempsey (1963), who found the yield of a kenaf $F_1$ generation to be 14-43% higher than that of the parents. This result suggests hybridsNHC 15 × NHC 10(1) and NHC 2(2) × NHC 10(1)as useful inputs in fibre yield improvement programmein Nigeriakenaf collections. The extent of heterotic response of the $F_1$ hybrids largely depends on the breeding value and genetic diversity of the parents included in crosses, and on the environmental conditions under which hybrids are grown (Haullauer and Miranda, 1988). Hence, it is necessary that performances of parental lines and hybrids of Nigeria kenaf need to be evaluated in multi-locations under optimum environmental conditions prior to their commercialization.

## CONCLUSION

Parent NHC 10(1) was the best general combiner for the characters considered. Hybrids derived from this accession also showed good potentials for the improvement of fibre yield traitsHowever, these hybrids must be evaluatedin multi-locational and on-farm trials prior torelease for commercial use.

**Table 1: Mean values of height, diameter, girth at flowering (cm) and harvest (cm) in Nigeria kenaf (*Hibiscus cannabinus*) accessions**

| Crosses | HAF | DAF | GAF | HAH | DAH | GAH | SWH |
|---|---|---|---|---|---|---|---|
| 1 × 1 (P1) | 81.65 | 0.66 | 3.23 | 239.99$^{abc}$ | 2.41$^{a}$ | 8.67$^{a}$ | 474.84 |
| 2 × 2 (P2) | 84.66 | 0.44 | 2.64 | 211.09$^{bcd}$ | 1.52$^{bcde}$ | 6.24$^{abcde}$ | 230.79 |
| 3 × 3 (P3) | 104.22 | 0.49 | 2.86 | 213.94$^{bcd}$ | 1.04$^{e}$ | 4.73$^{e}$ | 114.27 |
| 4 × 4 (P4) | 84.71 | 0.58 | 3.01 | 193.09$^{cd}$ | 1.88$^{abcde}$ | 7.16$^{abcde}$ | 300.27 |
| 1 × 3 (F1) | 92.66 | 0.54 | 3.09 | 258.83$^{ab}$ | 2.15$^{abc}$ | 8.44$^{ab}$ | 376.36 |
| 1 × 4 (F1) | 97.44 | 0.58 | 3.08 | 222.92$^{abcd}$ | 2.08$^{abcd}$ | 7.76$^{abcd}$ | 396.73 |
| 2 × 1 (F1) | 94.35 | 0.75 | 3.25 | 222.93$^{abcd}$ | 1.66$^{abcde}$ | 6.25$^{abcde}$ | 233.82 |
| 2 × 3 (F1) | 84.95 | 0.41 | 2.53 | 229.58$^{abcd}$ | 1.48$^{bcde}$ | 5.98$^{bcde}$ | 224.01 |
| 2 × 4 (F1) | 96.52 | 0.46 | 2.83 | 224.01$^{abcd}$ | 1.6$^{abcde}$ | 6.44$^{abcde}$ | 233.16 |
| 3 × 1 (RF1) | 87.70 | 0.69 | 2.91 | 285.43$^{a}$ | 2.21$^{ab}$ | 7.93$^{abc}$ | 400.42 |
| 3 × 2 (RF1) | 85.53 | 0.44 | 2.70 | 184.61$^{cd}$ | 1.20$^{e}$ | 5.26$^{de}$ | 141.45 |
| 3 × 4 (RF1) | 99.57 | 0.56 | 2.97 | 237.96$^{abc}$ | 1.58$^{bcde}$ | 6.35$^{abcde}$ | 226.09 |
| 4 × 1 (RF1) | 82.43 | 0.59 | 2.95 | 277.23$^{a}$ | 2.16$^{abc}$ | 7.99$^{abc}$ | 423.26 |
| 4 × 2 (RF1) | 82.42 | 0.39 | 2.61 | 199.19$^{bcd}$ | 1.27$^{de}$ | 5.40$^{de}$ | 175.82 |
| 4 × 3 (RF1) | 86.60 | 0.55 | 2.86 | 167.24$^{d}$ | 1.37$^{cde}$ | 5.62$^{cde}$ | 169.02 |

***Means with a common letter superscript in each column are not significantly different at 5% level of significance.**
HAF - Height at Flowering; DAF - Diameter at Flowering
GAF - Girth at Flowering; HAH - Height at harvest
DAH - Diameter at harvest; GAH - Girth at harvest
SWH - Stalk weight at harvest

**Table 2: Mean squares from preliminary analysis of variance and combining ability analysisof variance for height, diameter and girth at harvest in Nigeria kenaf (*Hibiscus cannabinus*) accessions**

| Source | Df | HAH | DAH | GAH | SWH |
|---|---|---|---|---|---|
| Genotype | 15 | 2982.64* | 0.49* | 4.30* | 36015.33 |
| Replicate | 2 | 5032.44* | 0.11 | 2.02 | 26394.69 |
| Error | 30 | 1033.51 | 0.17 | 1.56 | 18033.92 |
| Total | 47 | | | | |
| | ANOVA for Combining Ability | | | | |
| GCA | 3 | 1882.82* | 0.63* | 5.04* | |
| SCA | 6 | 602.80 | 0.07 | 0.86 | |
| Reciprocal | 6 | 941.32* | 0.02 | 0.20 | |
| Error | 28 | 334.50 | 0.06 | 0.52 | |

*: Significant at 5% level of probability
HAH - Height at harvest; DAH - Diameter at harvest
GAH - Girth at harvest; SWH - Stalk weight at harvest
GCA - General combining ability; SCA - Specific combining ability

| Parent | HAH | DAH | GAH |
|---|---|---|---|
| NHC 10(1) | 21.84 | -6.58 | 1.09 |
| NHC 13(1) | -11.25 | -8.92 | -0.65 |
| NHC 2(2) | -0.49 | 8.4 | -0.52 |
| NHC 15 | -10.03 | 7.11 | 0.08 |
| | | | |
| S.E ($g_i$) | 5.68 | 0.07 | 0.22 |
| S.E ($g_i - g_j$) | 9.28 | 0.12 | 0.36 |
| C.D (0.05) | 18.19 | 0.23 | 0.71 |

**Table 3: General combining ability effects for plant height, stem diameter and girth at harvest in Nigeria kenaf (*Hibiscus cannabinus*) accessions**

| Parent | HAH | DAH | GAH |
|---|---|---|---|
| NHC 10(1) | 21.84 | -6.58 | 1.09 |
| NHC 13(1) | -11.25 | -8.92 | -0.65 |
| NHC 2(2) | -0.49 | 8.4 | -0.52 |
| NHC 15 | -10.03 | 7.11 | 0.08 |
| | | | |
| S.E. ($g_i$) | 5.68 | 0.07 | 0.22 |
| S.E. ($g_i - g_j$) | 9.28 | 0.12 | 0.36 |
| C.D. (0.05) | 18.19 | 0.23 | 0.71 |

HAH - Height at harvest; DAH - Diameter at harvest
GAH - Girth at harvest; S.E.-Standard error
*gi*- General combining ability effect of parent *i*
*gj* - General combining ability effect of parent *j*
C.D. - Critical difference

**Table 4: Specific combining ability effects for plant height, diameter and girth at harvest in Nigeria kenaf (*Hibiscus cannabinus*) hybrids**

| Crosses | HAH | DAH | GAH |
|---|---|---|---|
| NHC 10(1) × NHC 13(1) | -12.096 | -0.22 | -0.847 |
| NHC 10(1) × NHC 2(2) | 26.342 | 0.287 | 0.963 |
| NHC 10(1) × NHC 15 | 13.885 | 0.004 | 0.051 |
| NHC 13(1) × NHC 2(2) | -5.588 | 0.046 | 0.135 |
| NHC 13(1) × NHC 15 | 8.516 | -0.075 | -0.168 |
| NHC 2(2) × NHC15 | -11.246 | -0.057 | -0.227 |
| | | | |
| SE ($S_{ij}$) | 10.376 | 0.132 | 0.404 |
| C.D. (0.05) | 20.337 | 0.259 | 0.791 |

HAH - Height at harvest; DAH - Diameter at harvest
GAH - Girth at harvest; S.E.-Standard error
Sij - Specific combining ability effect of parents i and j
C.D. - Critical difference

**Table 5: Reciprocal combining ability effects for plant height, stem diameter and girth at harvest in Nigeria kenaf (Hibiscus cannabinus) hybrids**

| Crosses | HAH | DAH | GAH |
|---|---|---|---|
| NHC 10(1) × NHC 13(1) | 0.00 | 0.00 | 0.00 |
| NHC 10(1) × NHC 2(2) | -13.3 | -0.03 | 0.26 |
| NHC 10(1) × NHC 15 | -27.15 | -0.04 | -0.12 |
| NHC 13(1) × NHC 2(2) | 22.49 | 0.14 | 0.36 |
| NHC 13(1) × NHC 15 | 12.41 | 0.17 | 0.52 |
| NHC 2(2) × NHC15 | 35.36 | 0.10 | 0.37 |
| SE ($r_{ij}$) | 13.12 | 0.17 | 0.51 |
| C.D. (0.05) | 25.72 | 0.33 | 1.00 |

HAH - Height at harvest; DAH - Diameter at harvest
GAH - Girth at harvest; S.E.-Standard error
r*ij* - Reciprocal combining ability effect of parents *i* and *j*
C.D. - Critical difference

**Table 6: Mid-parent and high-parent heterosis estimates (%) of some characters in Nigeria kenaf (*Hibiscus cannabinus*) hybrids at harvest**

| Hybrids | HAH | | DAH | | GAH | | SWH | |
|---|---|---|---|---|---|---|---|---|
| | Mp | Hp | Mp | Hp | Mp | Hp | Mp | Hp |
| 1 × 3 | 14.04 | 7.85 | 25.02 | -10.51 | 25.95 | -2.63 | 27.77 | -20.74 |
| 1 × 4 | 2.94 | -7.11 | -3.13 | -13.81 | -1.95 | -10.48 | 2.37 | -16.45 |
| 2 × 1 | -1.16 | -7.11 | -15.69 | -31.26 | -16.14 | -27.88 | -33.73 | -50.76 |
| 2 × 3 | 8.03 | 7.31 | 15.66 | -2.60 | 8.91 | -4.23 | 29.84 | -2.93 |
| 2 × 4 | 10.85 | 6.12 | -5.67 | -14.67 | -3.88 | -10.05 | -12.19 | -22.35 |
| 3 × 1 | 25.76* | 18.93 | 28.38 | -8.10 | 18.28 | -8.56 | 35.94 | -15.67 |
| 3 × 2 | -13.13 | -13.71 | -6.17 | -20.98 | -4.15 | -15.72 | -18.02 | -38.71 |
| 3 × 4 | 16.92 | 11.23 | 8.13 | -16.00 | 6.75 | -11.33 | 9.08 | -24.71 |
| 4 × 1 | 28.02* | 15.51 | 0.80 | -10.31 | 1.00 | -7.79 | 9.21 | -10.86 |
| 4 × 2 | -1.43 | -5.63 | -25.24 | -32.37 | -19.39 | -24.56 | -33.78 | -41.44 |
| 4 × 3 | -17.82 | -21.83 | -5.82 | -26.84 | -5.54 | -21.54 | -18.45 | -43.71 |

***:Meansfound significant5% level of significance.Percentage increase (+), Percentage decrease (-)**
**Mp-Heterosis over mid-parent; Hp -Heterosis over high-parent**
**HAH - Height at harvest; DAH - Diameter at harvest**
**GAH - Girth at harvest; SWH - Stalk weight at harvest**

## ACKNOWLEDGEMENT

**The authors wish to appreciate** Kenaf Gene Bank of the Department of Crop Protection and Environmental Biology, University of Ibadan for providing the seeds used for this study.

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