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DIALLEL ANALYSIS FOR SOME QUANTITATIVE CHARACTERS IN KENAF (*Hibiscus cannabinus* L.)

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ABSTRACT

This study was conducted with the objective of estimating combining ability and gene action for fiber weight / plant and its related characters in kenaf. This was achieved via evaluating six parents {P_1(S.105/2), P_2(S.158/4/2/5), P_3(S.103/4), P_4(S.40), P_5 (Cuba) and P_6 (New Indian)} and their 15 F_1's progenies which were evaluated in a randomized complete block design with three replications at Ismailia Agric. Res. Station Farm, Ismailia Governorate, Egypt.

The ratio of general to specific combining ability variance for all characters under study, indicated that additive genetic effects were more important than non-additive genetic effects. These results revealed that the inheritance of these traits was mainly controlled by additive effects of genes. Therefore, selection should be possible within the F_2 and subsequent populations for these characters. P_5 (Cuba) exhibited significant positive GCA effects for fiber weight and most of its components as well as P_1 (S.105/2) and P_6 (New Indian) for green weight / plant, indicating that the use of these parents in kenaf breeding programs could increase green weight and consequent increasing fiber weight / plant. Concerning seed weight / plant, results indicated that P_1 (S.105/2) followed by P_3 (S.103/4) showed significant positive $\hat{g}_i$ values. Therefore, it could be concluded that these two parents appeared to be the best combiners for seed weight. Simple correlation between GCA values and parental means for all studied characters were significantly positive. These results indicated that, the parents showing higher mean performance proved to be the highest general combiners for these traits. One cross ($P_5 \times P_6$) showed significant positive SCA effects for fiber weight and most related characters (plant height, technical stem length and green weight / plant) expect for fiber percentage and fiber percentage. In the meantime, the cross $P_1 \times P_5$ revealed significant positive SCA for some important characters *i.e.*, green weight per plant, technical length and fiber weight per plant. These crosses involved high x low general combiners for these traits. Simple correlation between cross means and their SCA values was significant positive for all characters except fiber percentage and stem diameter. Therefore, the choice of promising cross combination would be based on SCA effects or mean performance of the crosses.

Phenotypic (r_p) and genotypic (r_g) correlation coefficients concluded that plant height, technical stem length, fiber percentage and fiber length / plant are the major components contributing to fiber weight / plant in kenaf. Therefore, selection for these traits will improve fiber yield in kenaf.

Keywords: *Combining ability, Gene action, Correlation, Kenaf*

INTRODUCTION

Kenaf is often touted as being a new crop but in fact it is an ancient crop. In Egypt, kenaf is cultivated to produce bast fibers, which are used alone or mixed with jute fibers to manufacture bags, twine, ropes and other products. Moreover, kenaf seeds contain similar oil to that extracted from cotton seeds but free from gossiboll as edible for human. In addition, kenaf is more tolerant to high soil salinity and is more adapted to these soils than most other summer crops.

The success of any breeding program depends upon the presence of sufficient genetic variability among genotypes to permit effective selection. Estimation of type of gene action is very useful for choosing the most efficient breeding program. One of these methods is the diallel cross analysis (Griffing 1956). Diallel crosses have recently been used extensively for studies of quantitative characters. Information on the relative importance of general (GCA) and specific (SCA) combining abilities is essential for this reason. Generally, GCA is associated with additive genes, while SCA is attributed primarily to non-additive (dominance and epistasis).

A knowledge of relative magnitude of additive and non-additive gene effects would be very useful in designing efficient breeding program. Such information in kenaf is limited. Diallel analysis of yield and its components in kenaf was studied by Mourad *et al*.,(1989), who found that the additive type of gene action was relatively greater in importance for fiber yield/plant, technical stem length, stem diameter and fruiting zone length. Whereas, Abo-Kaied (2007) found that the additive effect was more important than non-additive effect for plant height, technical length, fiber weight, fiber percentage and seed weight, but non-additive effect was more important for stem diameter and green stalk weight / plant. On the other hand, many investigators studied the differences between kenaf genotypes *e.g.*,Osman and Momtaz,1982; Xiao *et al*.,1993; Webber,1993 and El-Kady and El-sweify,1995. Many correlation studies indicated that stem diameter, green plant weight, fiber length and plant height were the major components contributing to fiber weight in kenaf (Chaudhury *et al.*,1981; Mourad *et al*.,1987; Padmaja,1989; El-Shimy *et al*.,1990; Subramanyam et al.,1995, El-Farouk and El-Sweify,1998 and Mostafa, 2003).

One of the most important objectives of kenaf breeding program in Egypt is to improve, each of fiber yield, green stalk yield and fiber content / plant. To select high-yielding genotypes in kenaf, an understanding of the combining ability and the type of gene action for yield and its components of the entries of the reference population is of great importance.

Therefore, this study aimed to estimate general (GCA) and specific (SCA) combining ability for six kenaf genotypes and their 15 F_1 crosses for fiber yield and yield components under sandy soil conditions, in addition to estimate the phenotypic and genotypic correlation coefficients between fiber yield and its related characters. It is hoped that the present study could help kenaf breeders for producing new genotypes with high yielding ability under sandy soil conditions.

MATERIALS AND METHODS

The materials used for the present study consisted of 6 kenaf genotypes. Genotype characteristics of the materials is used according to their pedigree, origin, generation and year released are presented in Table 1. These six parents represent a wide genetic variability for yield, yield component and other related characters of kenaf.

Table 1. Identification of six kenaf genotypes used, pedigree, origin and year released.

Genotypes	Pedigree	Origin	Year Released*
1- S.105/2	Selected from H.119 (G.4 x 16/63-2)	Advanced strain	2000
2- S.158/4/2/2/5	S.105/1 x I.29	" " " " " " "	1996
3- S.103/4	Giza 4 x S.77/68-1	" " " " " " "	1995
4- S.40	4/59-28 x 18/64	" " " " " " "	1976
2-Cuba	Selected from I. 4/29-26	Cuba	1959
6-New Indian	Selected from I. New Indian	India	1996

*** Year released, selected or introduced.**

In 2005 season, the six parents were crossed in a diallel mating design excluding reciprocals to obtain 15 F_1 crosses at Giza Res. Station Farm. In 2006 season, the parents and their 15 F_1's seeds were planted in a randomized complete block design with three replications at Ismailia Agric. Res. Station Farm, Ismailia Governorate, Egypt. The soil type was sandy soil with coarse sand 63.17%, fine sand 33.44%, silt 2.02%, clay 0.57%, organic matter 0.061 %, field capacity 7.53%, available nitrogen 6.63 ppm and pH value of 7.29. Seeds of each parent and F_1 were sown in single rows. The rows were 3 m long and 50 cm apart. The distance between hills was 25 cm and planting date was the first week of May.2006. The seedlings were thinned after four weeks from sowing to leave two plants per hill. The recommended cultural practices for kenaf production were applied. Five random guarded plants were chosen from each row, by means that five plants for each parent and for each F_1 from each replication were used for collecting data. The following traits were recorded:
(1) green weight (g) / plant, as weight in grams of kenaf stalk plant during and at most 48 hours from harvesting, (2) plant height (cm), (3) technical stem length in cm, (4) fiber length (cm), (5) fiber weight (g) / plant, as the weight in grams of the air-dried fibers extracted from retted green stalk of kenaf plant, (6) fiber percentage = (fiber weight/plant ÷ green weight/plant) x 100, (7) fruiting zone length in cm, (8) stem diameter in mm and (9) seed yield per plant (g).

Statistical analysis

Plot means were used for statistical analysis. Combining abilities, general (GCA) and specific (SCA) were calculated according to Griffing's method 2 (parents and one set of F_1's are included but not reciprocal F_1's, i.e., (P (P+1)/2) combination, model 1 (fixed effects).

Phenotypic (r_p) and genotypic (r_g) correlation coefficients were calculated according to the formula suggested by Al-Jibouri *et al.*, (1958).

RESULTS AND DISCUSSION

Analysis of variances:

Mean squares due to 21 kenaf entries (6 parents and 15 F_1's crosses), were significant for green weight / plant and its related characters viz., plant height, technical stem length, and stem diameter, fruiting zone length as well as fiber weight, fiber percentage, fiber length and seed weight / plant (Table2). This indicated that those parents and F_1's crosses showed reasonable degree of variability for these characters. Such variability among different kenaf entries in green weight and its components was also reported by Osman and Momtaz, (1982); Xiao *et al*., (1993), Webber (1993) and Abo-Kaied (2007). Concerning mean square due to parents was significant for all characters studied except fiber length. Also, Mean squares of parents *vs.* crosses was significant for all characters, except both of fiber length and fruiting zone length were non-significant. Mean squares due to general (GCA) and specific (SCA) combining ability variances for each of green weight / plant, plant height, technical stem length, fiber weight, fruiting zone length and seed weight / plant were significant, indicating the presence of both additive and non-additive type of genetic variances. On the other hand, mean squares due to GCA were highly significant, but SCA were non-significant for each of fiber length, fiber percentage and stem diameter,. These results revealed that the inheritance of these traits was mainly controlled by additive effects of genes.

The ratio of general to specific combining ability variance for all characters under study was more than unity, indicated that the additive effects were more important than non-additive effects. Therefore, selection should be possible within the F_2 and subsequent populations for these characters. These results are agreed partially with that reported by Mourad *et al*.,(1989) and Abo-Kaied (2007) who found that the additive type of gene action was relatively greater in importance for all traits except, both of stem diameter and green weight / plant.

GCA effects:

Estimates of general combining ability effects ($\hat{g}_i$) for each parent are shown in Table (3). P_1(S.105/2) and P_6 (New Indian) showed highly significant positive $\hat{g}_i$ for green weight / plant. P_3 (S.103/4) and P_5 (Cuba) exhibited significant positive $\hat{g}_i$ for fiber percentage. P_4 (S.40) and P_6 (New Indian) for stem diameter and P_1 (S.105/2) and P_3 (S.103/4) for seed weight / plant. P_5 (Cuba) exhibited significant positive $\hat{g}_i$ for fiber weight / plant and most important components, *i.e*., plant height, technical stem length, fiber length, fiber percentage and fruiting zone length. These results suggest the importance of choosing these parents in kenaf hybridization programs to improve the aforementioned characters.

In general, P_5 (Cuba) exhibited significant positive GCA effects for fiber weight / plant and most its components as well as P_1 (S.105/2) and P_6 (New Indian) for green weight / plant, indicating that the use of these parents in kenaf breeding programs could increase green weight and consequent increasing fiber yield. Concerning seed weight / plant, results indicated that P_1 (S.105/2) followed by P_3 (S.103/4) showed significant positive $\hat{g}_i$ values. Therefore, it could be concluded that these two parents appeared to be best combiners for seed weight / plant.

Simple correlation between GCA values and parental means for all studied characters were significantly positive. These results indicated that, the parents showing higher mean performance (Table 5) proved to be the highest general combiners for these traits. Therefore, high mean performance of the parents could be transferred to hybrids in such cases.

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SCA effects:

Specific combining ability (SCA) effects of 15 F_1's crosses for fiber weight per plant and its related characters are presented in Table (4). Out of the 15 F_1 crosses, two crosses ($P_1 \times P_5$, and $P_5 \times P_6$) exhibited significant positive SCA effects for green weight per plant, technical stem length and fiber weight / plant, $P_3 \times P_5$, and $P_5 \times P_6$ for plant height, $P_3 \times P_4$, $P_3 \times P_5$, and $P_4 \times P_5$ for technical stem length and finally $P_1 \times P_2$, and $P_4 \times P_5$ for fiber weight / plant. Also, $P_5 \times P_6$, showed significant positive SCA effects for stem diameter, $P_1 \times P_2$ for fiber percentage, $P_4 \times P_5$ for fruiting zone length and P_1xP_4 and $P_3 \times P_4$ for seed yield per plant.

Table 4. Estimation of specific combining ability ($\hat{s}_{ij}$) effects for green weight / plant and its components of 15 F_1's crosses in kenaf.

Crosses	Green weight/ plant (g)	Plant height (cm)	Techni-cal length (cm)	Fiber length (cm)	Fiber weight / plant(g)	Fiber percent-age (%)	Fruiting zone length (cm)	Stem diameter (mm)	Seed weight/p lant (g)
$P_1xP_2$$	12.036	-1.903	2.072	8.302	2.266 **	0.684 *	-3.975	0.076	0.183
P_1xP_3	-8.006	9.688	9.759	-34.808 *	0.249	0.208	-0.071	0.195	0.032
P_1xP_4	5.077	-5.952	-2.016	3.883	-0.384	-0.269	-3.936	0.339	0.531 **
P_1xP_5	18.577 *	9.412	14.862 *	19.483	1.796 *	0.038	-5.450	0.462	0.267
P_1xP_6	-3.756	-1.052	-0.652	1.394	-0.130	0.050	-0.400	0.450	0.199
P_2xP_3	2.994	2.547	5.343	10.777	0.231	-0.027	-2.796	0.331	0.068
P_2xP_4	10.744	2.240	2.868	0.379	0.192	-0.217	-0.628	0.709	0.157
P_2xP_5	-10.423	4.271	3.255	1.279	-1.182	-0.164	1.015	0.075	-0.161
P_2xP_6	6.577	1.827	-3.182	-4.733	1.056	0.172	5.009	0.053	0.041
P_3xP_4	7.702	13.831	15.755 *	20.524	1.458	0.321	-1.924	-0.109	0.409 **
P_3xP_5	4.536	21.748 **	13.866 *	19.124	-0.012	-0.103	7.882	-0.010	0.122
P_3xP_6	-3.131	-11.568	-13.115 *	-7.131	0.098	0.073	1.546	0.162	-0.182
P_4xP_5	0.286	7.442	-1.109	-3.608	1.555 *	0.494	8.551 *	0.135	0.097
P_4xP_6	12.619	12.058	15.677 *	13.570	0.469	-0.111	-3.619	-0.150	0.072
P_5xP_6	18.786 *	15.289 *	14.988 *	13.070	1.762 *	0.149	0.301	0.839 *	0.168
LSD(s_{ij}-s_{ii})									
0.05	24.273	21.533	19.045	42.396	2.178	0.808	12.426	1.238	0.406
0.01	32.476	28.810	25.481	56.724	2.914	1.081	16.626	1.657	0.543
r	**0.59 ***	**0.76 ****	**0.68 ****	**0.76 ****	**0.64 ****	**0.40**	**0.80 ****	**0.46**	**0.64 ****

Number refer to parent codes, Table 1.
Significant at 0.05 and 0.01 levels of probability, respectively.
r : Simple correlation coefficients between SCA values and means of crosses.

In general, out of the 15 F_1 crosses, the two crosses ($P_1 \times P_5$) and ($P_5 \times P_6$) showed significant positive SCA effects for fiber weight / plant and most related characters. The cross (P_5xP_6) involved two parents of high x low GCA effects for fiber weight / plant and most related characters, plant height, technical stem length and green weight / plant. The cross ($P_1 \times P_5$) exhibited the best second combiner for green / plant weight and its two important components (technical stem length and fiber weight / plant). Also, this cross ($P_1 \times P_5$) involved high x low general combiner parents for these characters.

From the breeding point of view as suggested by Bhatade and Bhale (1983) for crosses exhibiting significant SCA effects which resulted from high

× low GCA combiners, the presence of both additive and non- additive genetic variance for these character(s). Therefore, the producing *inter-se* mating may be followed among elite selections in later generations, which may help in fixing non- additive effects.

The correlation between cross means (Table 5) and their SCA values (Table 4) was significant positive for all characters except for fiber percentage with green weight / plant and stem diameter with most studied traits, indicating that the crosses showing higher mean performance (Table 5) proved to be the highest specific combiners for these characters. Therefore, the choice of promising cross combination would be based on SCA effects or mean performance of the crosses.

Mean performance:

Mean performance values of parents as well as their F_1 crosses are shown in Table (5). P_1 (S.105/2), P_5 (Cuba) and P_3 (S.103/4) recorded the highest mean values of green weight / plant, fruiting zone length and seed weight / plant, respectively. Also, P_5 (Coba) exhibited high mean performance for all characters studied except the three characters green weight / plant, stem diameter and seed weight / plant. While the cross (P_1 x P_5) gave the highest mean value for green weight / plant, technical length and fiber length and fiber weight / plant. Also the cro0ss (P_4 x P_5) showed the highest mean values for fiber percentage and fruiting zone length. Moreover, the cross (P_4 x P_5) revealed high means for plant height and fiber weight / plant. From these results, it concluded that, P_4 (S.40) and P_5 (Cuba) possess desirable gene for more than one character in the most previous mentioned crosses. Also, most of the crosses which included one at least of these two parents exhibited highly SCA effects for these mentioned traits.

Correlation studies:

Phenotypic (r_p) and genotypic (r_g) correlation coefficients among nine traits of 21 kenaf entries (6 parents and 15 F_1's crosses) are shown in Table (6). These results indicated that fiber weight / plant was highly significantly positive correlated with each of plant height, technical stem length, fiber percentage and fiber length / plant, but was only significant with seed weight / plant. Concerning, seed weight / plant was positive correlated with green weight / plant and fiber weight / plant. Also, plant height was significantly correlated with each of technical stem length, fiber length, fiber weight / plant, fiber percentage and fruiting zone length. These results are in agreement with those obtained by Mourad *et al*.,1987; El-Shimy *et al*.,1990; Subramanuam *et al*.,1995, Mostafa, 2003 and Abo-Kaied (2007).

In general, it can be concluded that plant height, technical stem length, fiber percentage and fiber length / plant are the major components contributing to fiber weight / plant in kenaf. Therefore, selection for these traits will improve fiber yield in kenaf.

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Table 6. Phenotypic (r_p) and genotypic (r_g) correlation coefficients among nine characters for 21 Kenaf genotypes (6 parents and 15 F_1's crosses).

Characters		1	2	3	4	5	6	7	8
1- Green weight/plant(g)	r_p								
	r_g								
2- Plant height (cm)	r_p	**0.028**							
	r_g	0.505							
3- Technical stem length(cm)	r_p	**0.097**	**0.981****						
	r_g	0.445	0.514						
4- Fiber length (cm)	r_p	**0.087**	**0.882****	**0.880****					
	r_g	0.378	0.601	0.737					
5-Fiber weight/plant(g)	r_p	**0.099**	**0.734****	**0.772****	**0.677****				
	r_g	0.607	0.666	0.601	0.547				
6-Fiber percentage (%)	r_p	**-0.509***	**0.595****	**0.586****	**0.518***	**0.801****			
	r_g	0.014	0.487	0.419	0.479	0.667			
7- Fruiting zone length (cm	r_p	**-0.218**	**0.748****	**0.604****	**0.608****	**0.370**	**0.435***		
	r_g	0.204	0.0104	-0.224	0.402	0.248	0.058		
8- Stem diameter (mm)	r_p	**0.403**	**-0.133**	**-0.131**	**-0.087**	**-0.227**	**-0.457***	**-0.095**	
	r_g	0.562	-0.540	0.208	0.233	-0.487	-0.578	-0.443	
9- Seed weight/plant (g)	r_p	**0.407***	**0.196**	**0.294**	**0.112**	**0.499***	**0.172**	**-0.199**	**-0.148**
	r_g	0.011	-0.134	0.309	0.307	0.255	0.228	0.243	0.416

***, ** : Significant at 0.05 and 0.01 level of probability, respectively.**

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تحليل الهجن الدائرية لبعض الصفات الكمية في التيل

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أجريت هذه الدراسة بهدف تقدير القدرة علي الائتلاف والفعل الجيني لمحصول الألياف والصفات المرتبطة به في التيل من خلال تقييم ١٥ هجين ناتجة من التهجين بين ستة تراكيب وراثية من التيل (١= س ٢/١٠٥ ، ٢= س ٥/٤/٤/١٥٨ ، ٣= س ٤/١٠٣ ، ٤=س ٤٠، ٥= كوبا، ٦= هندي جديد). في موسم ٢٠٠٥ تم إجراء كل الهجن الممكنة بين الستة آباء بدون الهجن العكسية بنظام التهجين الدائري وذلك بمحطة البحوث الزراعية بالجيزة. وفي موسم ٢٠٠٦ تم تقييم الـ٦ آباء و١٥ هجين في الجيل الأول في محطة البحوث الزراعية بالإسماعيلية في تجربة قطاعات كاملة العشوائية ذات الثلاثة مكررات .

وتشير نتائج النسبة بين تباين القدرة العامة على الائتلاف إلى القدرة الخاصة على الائتلاف أن تأثير العوامل الوراثية المضيفة أكبر من غير المضيفة لكل الصفات تحت الدراسة لذلك يمكن ممارسة الانتخاب بكفاءة لتلك الصفات بدايةً من أنسال الجيل الثاني لهذه الهجن لمكونات محصول الألياف ظ نبات. كما تشير النتائج إلى أن الأب كوبا اظهر قدرة عالية علي الأئتلاف لصفات وزن الألياف/ نبات ومعظم مكوناته بالإضافة إلى الأبويين س ٢/١٠٥ وهندي جديد أظهرا قدرة عالية علي الائتلاف للوزن الأخضر للساق. لذلك يمكن استخدام هذه الآباء لتحسين وزن الساق الأخضر /نبات ومن ثم زيادة محصول الألياف / نبات. كما تشير النتائج إلى أن الأب س ٢/١٠٥ يليه الأب س٤/١٠٣ أظهرا قدرة عالية علي الائتلاف لمحصول البذور/ نبات. لذلك يمكن استخدام هذين الأبوين لتكوين هجن عالية في محصول البذور.

كان الارتباط بين القدرة العامة علي الائتلاف وسلوك الآباء موجب ومعنوي لكل الصفات تحت الدراسة يشير إلى أن الأباء ذات المتوسطات العالية لها قدرة عالية على الائتلاف للصفات تحت الدراسة. كما تشير النتائج إلى أن هجين واحد فقط (كوبا X هندي جديد) أظهر تفوق في القدرة الخاصة علي الائتلاف لصفة وزن الألياف ومكوناته (الطول الكلي والطول الفعال والوزن الأخضر للساق) ما عدا النسبة المئوية للألياف. كذلك أظهر الهجين (س ٢/١٠٥ X كوبا) قدرة خاصة على الائتلاف موجبة ومعنوية لصفات الوزن الأخضر للنبات، والطول الفعال ووزن الألياف للنبات. وأن هذين الهجينين كانت القدرة العامة علي الائتلاف لآبائها (عالي X منخفض) لتلك الصفات ، كما تشير النتائج أن الارتباط كان موجب ومعني بين القدرة الخاصة علي الائتلاف للهجن ومتوسطاتها لكل الصفات تحت الدراسة ما عدا النسبة المئوية للألياف وسمك الساق مما يدل علي أن الهجن العالية في صفاتها المحصولية أظهرت قدرة خاصة علي الائتلاف عالية ، لذلك يمكن اختيار الهجن الواعدة علي أساس متوسطاتها العالية.

كما تشير النتائج الخاصة بالارتباط الظاهري والوراثي بين الصفات إلى أن الطول الكلي ،والطول الفعال ، والنسبة المئوية للألياف ، وطول الألياف أظهرت ارتباط موجب ومعنوي مع وزن الألياف/نبات لذلك يمكن الانتخاب لتلك الصفات لتحسين محصول الألياف في التيل.

Table 2. Mean Squares for 21 kenaf genotypes (6 parents and 15 F_1's crosses), general (GCA) and specific SCA) combining ability for green weight / plant and its components.

Characters	S.O.V.								GCA/SCA ratio
	Entries (20)	Error (40)	Crosses (c) (14)	Parents (P) (5)	P.*vs*.S (1)	GCA (5)	SCA (15)	Error (40)	
Green weight/plant (g)	1227.95 **	247.29	920.17 **	1555.83 **	3897.60 **	1124.19 **	171.00 *	**82.43**	**6.57**
Plant height (cm)	2343.10 **	194.60	2193.41 **	2337.62 **	4466.20 **	2524.85 **	199.76 **	**64.87**	**12.64**
Technical stem length (cm)	1625.72 **	152.23	1419.72 **	1667.80 **	4299.35 **	1626.99 **	180.21 **	**50.74**	**9.03**
Fiber length (cm)	2054.83 **	754.40	2142.04 **	1692.02	2648.07	1923.34 **	272.15	**251.47**	**7.07**
Fiber weight / plant (g)	11.61 **	1.99	7.72 **	12.39 **	62.17 **	8.57 **	2.30 **	**0.66**	**3.72**
Fiber percentage (%)	1.62 **	0.27	1.19 **	2.90 **	1.18 *	1.88 **	0.09	**0.09**	**20.08**
Fruiting zone length (cm)	140.35 *	64.81	154.56 *	128.33 *	1.59	118.31 **	22.94 *	**21.60**	**5.16**
Stem diameter (mm)	1.88 **	0.64	1.12	2.60 **	8.84 **	1.65 **	0.28	**0.21**	**5.83**
Seed weight / plant (g)	0.60 **	0.07	0.41 **	0.69 **	2.82 **	0.47 **	0.11 **	**0.02**	**4.20**

 # : The degrees of freedom are indicated in parentheses.
***, ** : Non-significant, significant at 0.05 and 0.01 levels of probability, respectively.**

Table 3. Estimation of general combining ability effects ($\hat{g}_i$) for green weight / plant and its components of six kenaf parents.

CHARACTERS	Parents						r	L.S.D (gi-gi)	
	P1=S.105/2	P2=S.158/4/2/5	P3=S.103/4	P4=S.40	P5=Coba	P6=New indian		0.05	0.01
GREEN WEIGHT/PLANT (G)	18.514 **	-2.819	-12.778 **	-8.194 **	-4.694	9.972 **	**0.97 ****	9.174	12.28
Plant height (cm)	-4.894	-13.086 **	-7.177 **	-3.037	35.599 **	-7.405 **	**0.98 ****	8.139	10.89
Technical stem length (cm)	-3.403	-10.153 **	-4.507	-5.232 *	28.724 **	-5.429 *	**0.99 ****	7.198	9.631
Fiber length (cm)	-8.504	-7.833	-8.979	-2.580	31.153 **	-3.258	**0.98 ****	16.02	21.44
Fiber weight / plant (g)	-0.268	0.073	0.227	-0.744 **	1.843 **	-1.131 **	**0.98 ****	0.823	1.101
Fiber percentage (%)	-0.466 **	0.099	0.341 **	-0.062	0.685 **	-0.597 **	**0.99 ****	0.305	0.408
Fruiting zone length (cm)	-1.491	-2.933	-2.670	2.195	6.875 **	-1.975	**0.83 ***	4.695	6.284
Stem diameter (mm)	-0.079	-0.249	-0.368 *	0.588 **	-0.435 **	0.543 **	**0.98 ****	0.468	0.626
Seed weight / plant (g)	0.361 **	-0.092	0.193 **	-0.236 **	0.018	-0.244 **	**0.98 ****	0.153	0.205

***, **: Significant at 0.05 and 0.01 levels of probability, respectively.**

r : Simple correlation coefficients between GCA values and means of parents.

Table 5. Mean performances of 21 kenaf genotypes (6 parents and 15 F_1's crosses) for green weight / plant and its components.

Genotypes	Green weight/ plant (g)	Plant height (cm)	Technical stem length (cm)	Fiber length (cm)	Fiber weight / plant (g)	Fiber percentage (%)	Fruiting zone length (cm)	Stem diameter (mm)	Seed weight / plant (g)
Parents									
P_1 $	340.67a	206.67b	171.33b	167.07b	19.89bc	5.84cd	35.33a	12.00a-c	3.66a
P_2	299.00b-d	190.89b	164.67b	159.53b	21.19a	7.10b	26.22a	11.80bc	3.22ab
P_3	288.00cd	189.07b	165.33b	161.00b	21.77ab	7.57ab	23.74a	11.90bc	3.71a
P_4	281.00d	200.67b	164.10b	160.67ab	19.20bc	6.89bc	36.57a	13.63a	2.44c
P_5	290.33b	263.67a	224.67a	220.83a	24.06a	8.29a	39.00a	11.30c	3.34ab
P_6	320.00a-c	198.46b	172.43b	168.60ab	18.44c	5.77d	26.03a	13.33ab	2.91bc
Crosses									
P_1xP_2	343.33ab	201.67cd	178.67cd	175.17a-d	24.40a	7.44a-c	23.00c	12.67ab	4.00ab
P_1xP_3	313.33b-e	219.17cd	192.00b-d	130.91d	22.54b-d	7.21a-d	27.17bc	12.67ab	4.13a
P_1xP_4	331.00b-d	207.67cd	179.50cd	176.00a-d	20.93d	6.33de	28.17bc	13.77ab	4.20a
P_1xP_5	348.00a	261.67a	230.33a	225.33a	25.70a	7.38a-d	31.33bc	12.87ab	4.19a
P_1xP_6	340.33a	208.20cd	180.67cd	172.83a-d	20.80d	6.11e	27.53bc	13.83a	3.86a-d
P_2xP_3	303.00d-e	203.83cd	180.83cd	177.17a-d	22.86a-d	7.54ab	23.00c	12.63ab	3.72a-e
P_2xP_4	315.33a-e	207.67cd	177.63cd	173.17a-d	21.85cd	6.95b-e	30.03bc	13.97a	3.38c-f
P_2xP_5	297.67e	248.33ab	211.98ab	207.80a-c	23.06a-d	7.75ab	36.36a-c	12.31ab	3.31ef
P_2xP_6	329.33a-e	202.89cd	171.39cd	167.38b-d	22.33b-d	6.80b-e	31.50bc	13.27ab	3.25ef
P_3xP_4	302.33d-e	225.17bc	196.17bc	192.17a-c	23.27a-d	7.73ab	29.00bc	13.03ab	3.91a-c
P_3xP_5	302.67de	271.72a	228.23a	224.50ab	24.39a-c	8.05a	43.49ab	12.11b	3.88a-c
P_3xP_6	309.67c-e	195.40d	167.10d	163.83cd	21.52cd	6.94b-e	28.30bc	13.26ab	3.32d-f
P_4xP_5	303.00de	261.55a	212.53ab	208.17a-c	24.98ab	8.24a	49.02a	13.21ab	3.43c-f
P_4xP_6	330.00a-e	223.17b-d	195.17bc	190.93a-c	20.92d	6.36c-e	28.00bc	13.90a	3.14f
P_5xP_6	339.67a-c	265.03a	228.43a	224.17ab	24.80ab	7.36a-d	36.60a-c	13.87a	3.49b-f
Means	**315.60**	**221.55**	**190.15**	**183.20**	**22.33**	**7.13**	**31.40**	**12.92**	**3.55**

$:Number refer to parent codes, Table 1.

The values identified by the same letter are not significantly different at 0.05 level of probability.