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Variability and inheritance of okra leaf- shape of cotton cv. Sudac-k in different genetic backgrounds

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ABSTRACT

Okra leaf- shape is an important trait in cotton. Sudac-k is the only cotton variety with okra leaf type in the Sudan. The objectives of the study were to analyze the inheritance of the okra leaf of Sudac-k and its expression in different genetic backgrounds. The experiment was carried out for two seasons (2004/05 and 2005/06) and one off-season in 2006 at Gezira Research Farm of the Agricultural Research Corporation (ARC), Wad Medani, Sudan. The plant material consisted of Sudac-k and nine different varieties; B-pima, Barakat-90, G.S, Maryoud, Shambat-B, Acala-M, Acala-H, Barac (67) B and Albar (57)12. Eighteen reciprocal F_1s were produced between Sudac-k and respective cultivars. In the second season, F_2 s , backcrosses and F_3 plants were (Sudac-k X Albar (57)12). At maturity, individual plants were visually scored according to the leaf-shape into okra and normal leaf shape. Okra leaf morphology, lobe length, width and angle were measured in fully expanded 5- lobed leaf. It was observed that the okra leaf of Sudac-k had deep sinuses and narrow lobes while in F_1 's, the sinuses were shorter and the lobes were broader. The okra leaf started at seedling stage with three lobes at the 3rd to 4th node and reached a maximum of 5 lobes at node 6 to 8 in Sudac-k, F_1 plants and their progenies. Chi-square test for the segregation of leaf type in F_2 indicated no significant differences among all F_1 's between Sudac-k and the varieties in the distribution of okra and normal which followed the ratio of 1:2:1. This indicates that the okra leaf trait is conditioned by a single partially dominant gene. Significant differences were observed among the F_1 hybrids for the expression of leaf lobing depth, lobe width and angle, indicating the effect of the genetic background on the expression of these parameters. The information will be useful in designing strategy for breeding of cotton varieties with suitable size of okra leaf to maximize its utilization in integrated insect pest management.

INTRODUCTION

Cotton production in the Sudan is faced by many constraints. The most important factors limiting cotton yield are insects, diseases and weeds. The major three diseases that infect cotton are bacterial blight (*Xanthomonas campestris*), leaf curl and fusarium wilt (*Fusarium oxysporum f.sp. Vasinfectum*). The problem of cotton stickiness is one of the many other limiting factors affecting cotton production and marketing in many countries but it is the most serious one compared with other quality factors confronting cotton growers, ginners and spinners (Khalifa and Gameel, 1982). Cotton stickiness is more serious on medium - staple than on long – staple cotton (Khalifa, 1980). Results indicated that heavy stickiness contaminations affect directly or indirectly both yield and quality of cotton (Mound, 1965; Khalifa, 1983). Stickiness of cotton lint was found to be caused by honey-dew excreted by whitefly (*Bemisia tabaci* "Genn") and aphids (*Aphis gossipii*) (Gameel, 1969) and physiological sugars from plant nectaries. Immature fiber and broken seeds are the primary sources of stickiness. The whitefly is one of the most serious pests on cotton. In the Sudan, it is found in all cotton growing areas. It is a leaf-sucking pest and has an adverse effect on cotton yield and quality. It secretes sugary substances known as honey – dew that is the main causative agent of cotton stickiness in the Sudan (Mound, 1965; Gameel, 1969).

Okra-leaf shape line has an open plant canopy, less total area, more sunlight penetration, lower relative humidity and higher temperature. This made unfavorable conditions to the build-up of whitefly, delayed the time for reaching the specified threshold and made of insecticide spraying and penetration more efficient (Khalifa, 1984). Cotton okra-leaf has been associated with production advantages such as early maturity (Andries *et al*., 1969; Heitholt, 1993), reduced leaf area index, higher canopy Co_2–-uptake per unit leaf area (Kerby *et al*., 1980), high light-saturation, high single – leaf photosynthesis per unit leaf area (Pettigrew *et al*., 1993) and increased number of flowers per season (Wells and Meredith, 1986).

Okra-leaf shape is a useful morphological candidate in the Sudan which is not fully utilized in breeding programs. The only released variety with okra leaf, Sudac-k, could not survive for a long time in production because it had low yields compared with commercial cultivars with normal leaf. Okra-leaf has a potential to compete with normal-leaf types in yield and fiber quality. Therefore, the objectives of this study were to provide base line information about the inheritance of the okra leaf- shape of Sudac-k and assess variability of its expression in different genetic backgrounds to facilitate its utilization in breeding programs.

MATERIALS AND METHODS

The experimental material comprised of 9 cotton varieties viz, Barakat90, G.S. (Barakat.S), Maryoud, Shambat-B, Acala-M, Acala-H, Barac (67) B, Albar (57)12 besides Sudac-k. The first 3 were (*Gossypium barbadense* L.), while the remaing were (*Gossypium hirsutum* L.). Field evaluation of the experimental material was carried out for two seasons (2004/05 and 2005/06) at Gezira Research Farm of Agricultural Research Corporation, Wad Medani, Sudan. The hybrid between Sudac-k and cultivars, F_2 ṡ , BC1 and F3 were grown in one or two rows in both seasons. They were planted in 10 m long rows with 0.8 m spacing between rows and 0.5 m within rows. Nitrogen was broadcast as one dose at the rate of 86 kg N ha^{-1} after eight weeks from emergence.

Parameters measured

Five plants from each F1 population were selected randomly for data collection. All individual plants of F2, BC1 and F3 were scored. Data were collected on qualitative classes of leaf shape: okra, superokra, normal and quantitative scoring (Fig.1). Measurements consisted of:

1. Main- lobe length (L1).
2. Main- lobe width (W1).

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3. Second- lobe length (L2).
4. Second- lobe width (W2).
5. Third- lobe length (L3).
6. Third- lobe width (W3).
7. First to second- lobe angle (A1) was measured as the angle between the main lobe and the second lobe.
8. Second to third- lobe angle (A2) indicated the angle between the second and third lobes. For all measurements of second and third lobes, the averages of the two lobes on opposite sides of the leaf were taken.

Statistical analysis

Analysis of Chi-square test was used to measure goodness of fit of observed and theoretical data to known genetic ratio (s) like 1:1 or 1:2:1 *etc*. in the F1 and F2 population.

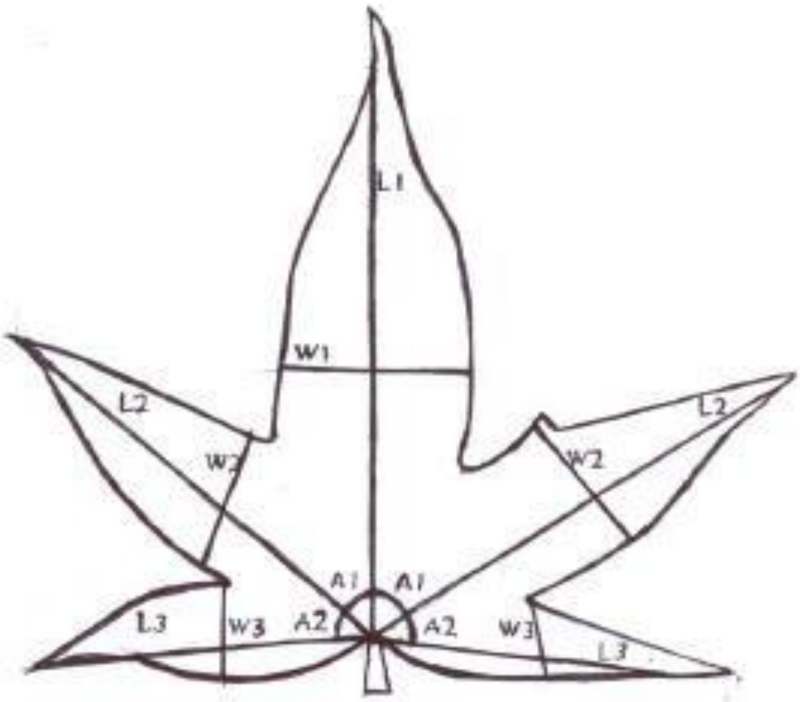

Fig.1. Diagram of 5-lobed okra leaf showing the parameters measured

RESULTS AND DISCUSSION

Differentiation of leaf shape

During development, the differentiation between the leaf shapes was undertaken after germination of genotypes with normal leaf, Sudac-k and F_1. Regardless of the genotypes, the first and the second leaves after the cotyledon were unlobed (Fig. 2). There was a significant difference in the node position at which the 3-lobed and 5-lobed leaf appeared among the tested hybrids and

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Sudac-k (Table 1). This indicated that the process of lobe development started at a similar position at node 3-4 and reached a maximum of 5 lobes at node 6-8. Hammond (194la, b) reported that in the okra and F_1 of the normal x okra cross, the effect of the mutant gene with regard to leaf- shape was not apparent in unlobed first leaf above the cotyledons, which was of similar shape index to unlobed first leaf of the normal type, but manifested itself in the first lobed leaf which appeared at nodes 3 or 4 above cotyledons.

Sinuses were deeper in the okra of Sudac-k compared to the okra of the F1 between Sudac-k and the tested genotypes with normal leaf (Fig. 3). These results agreed with those of Stephens (1945) who stated that super okra, L_2 ʾS, developed a single leaf blade at maturity. Hammond (1941a, b), Stephens (1944) and Dolan and Poethig (1991) reported that the presence of okra (L_2O) mutation in the leaf, altered leaf shape by significantly decreasing the growth of the lamina and increasing the length of leaf lobes early in leaf development. Minute lobing was observed in the normal leaf which became deeper and clearer as leaves grew to the top of the plants.

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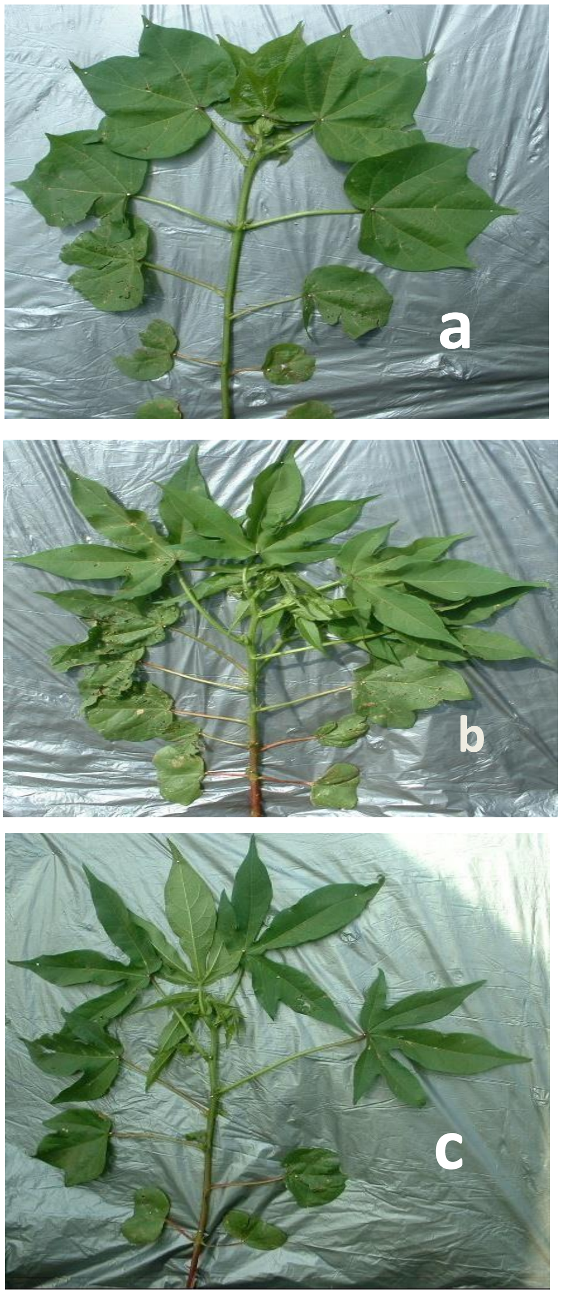

Fig. 2. Succession of Leaf-shape in genotypes with normal leaf (a), Sudac-k (b) and F1 between them (c)

Table 1. Node position of the 3-lobed and 5-lobed okra leaf in F1 hybrids between Sudac-k and six genotypes.

Hybrids	3-lobed	5-lobed

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Su	3.1	7.0
Su x Bp	3.4	7.7
Su x Am	3.1	6.6
Su x Ma	3.3	7.6
Su x Sh	3.2	6.9
Su X Al	3.4	6.4
Su x Br	3.0	6.8
Mean	3.2	7.0
SE±	0.06	0.18

Su: Sudac-k, Bp: B-pima, Ma: Maryoud, Am: Acala-M, Br: Barac (67) Sh: Shambat-B, Al: Albar (57) 12. Data is the average of 5 plants.

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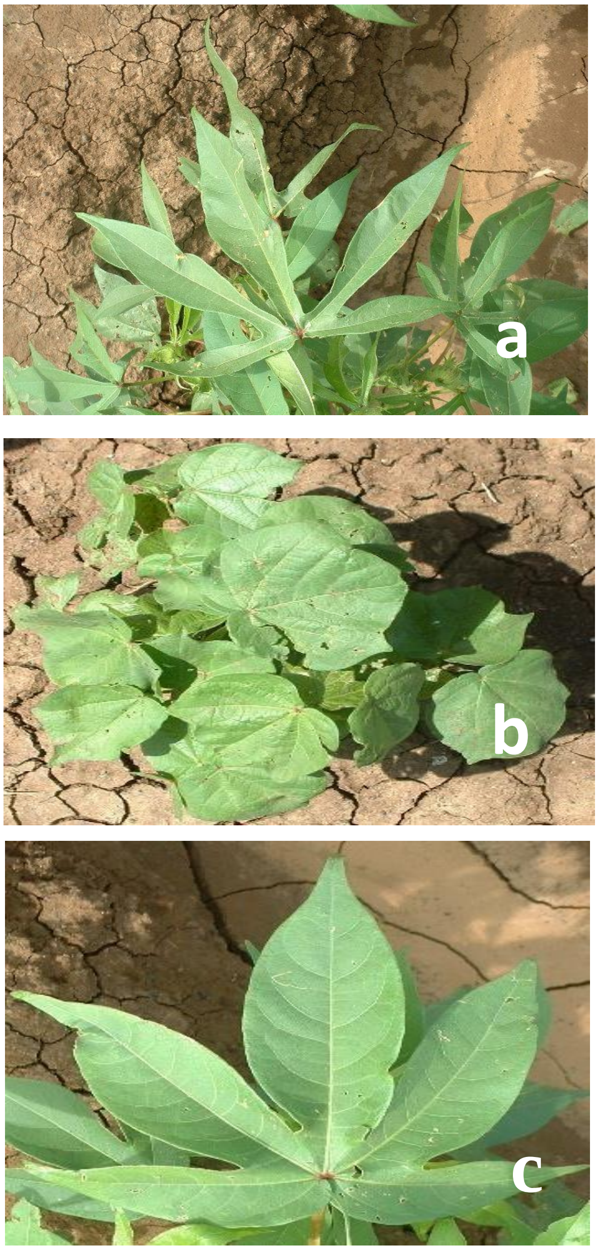

Fig. 3. Three types of leaf- shape observed in this study, Super okra in Sudac-k (a), normal leaf in Barac (67) B (b) and okra- leaf in F1 hybrid between them (c)

Inheritance of the leaf- shape

All F1 hybrids between Sudac-k and nine varieties had okra leaf shape with lesser deep sinus and broader lobes than the okra leaf of Sudac-k. There was no prominent cytoplasm effect as reciprocal F1 did not show difference in type of leaf- shape. Thus the okra leaf can be useful as a morphological marker to score for estimation of out-crossing and recommendation of distance of isolation (Mekki, *et al*., 2005). Table 2 shows the segregation of reciprocal F2 populations between Sudac-k and the nine genotypes with normal leaves. Each of the population segregated into normal (N) and okra (O) leaf type and (S) okra of Sudac-k. The ratio between N: O: S did not deviate significantly from 1:2:1 ratio. The overall χ^2 test fitted to 1:2:1 ratio. This suggests that the okra leaf type is controlled by a single partially dominant gene. Rhaman and Khan (1998) reported that the okra leaf-shape in a similar genotype from Pakistan was determined by a single partially dominant gene. The expression of the gene was not affected by the different varieties and cytoplasm.

F3 progenies from a different type of F2 individual gave normal plants from a normal F2 and gave only okra as that of Sudac-k from F2 in individuals with S-type okra leaf, whereas F2 individuals with O-type okra leaf segregated into N: O: S leaf types with a ratio that did not deviate significantly from 1:2:1.

Backcrossing of F_1 'S to Sudac-k segregated into individuals with okra (O) and others with okra of Sudac-k (S) (Table 3).The ratio of O and S type leaves did not deviate significantly from 1:1 ratio at 1% level of probability.

The reciprocal type of backcrossing to the parent with normal leaf segregated into individuals with normal (N) and okra (O) (Table 4). Also, the ratio between N and O did not deviate significantly from 1:1 ratio at 1% level of probability. There was no significant difference in all tested reciprocal backcross populations (Tables 3 and 4) with respect to the expected 1:1 ratio of leaf type segregation. This further confirms that a single gene is conditioning the leaf type and the expression of the gene is not affected by the genetic background.

Table 2. Segregation of okra leaf- shape in 15 reciprocal F2 hybrids between Sudac-k and varieties with normal leaf

Hybrids	N	O	S	1:2:1
Sudac-k X Shambat-B	8	20	9	0.48
Shambat-B X Sudac-k	5	17	8	1.13
Sudac-k X Acala-M	8	24	4	4.89
Acala-M X Sudac-k	12	25	11	0.13
Sudac-k X Barac (67) B	10	24	11	0.24
Barac (67) B X Sudac-k	10	20	9	0.08
Sudac-k X Acala-H	4	9	5	0.11
Acala-H X Sudac-k	5	9	3	0.53
Sudac-k X Albar (57)12	10	14	6	1.20

Sudac-k X G.S	5	21	4	4.86
Sudac-k X B-pima	6	19	3	4.22
Sudac-k X Barakat-90	7	18	10	0.54
Barakat-90 X Sudac-k	6	18	9	0.82
Sudac-k X Maryoud	2	13	5	2.70
Maryoud X Sudac-k	3	15	2	5.10
Total	103	266	99	27.3

N: Normal, O: Okra, S: Okra of Sudac-k.

Table 3. Chi- square test for fitness to 1:1 ratio in seven backcrosses to Sudac-k.

Backcrosses	Observed value		χ^2 value
	S	O	(1:1)
Su X Bp X Su	17	13	0.30
Su X Ba X Su	19	11	1.64
Su X Ma X Su	10	6	0.56
Su X Ah X Su	24	17	0.88
Su X Am X Su	11	5	1.56
Su X Br X Su	17	10	1.34
Su X Al X Su	7	2	1.78
Total	105	64	8.06

Su: Sudac-k, Bp: B-pima, Ba: Barakat-90, Ma: Maryoud, Am: Acala-M, Br:Barac (67) B, Ah: Acala-H, S: okra of Sudac-k, O: okra leaf- shape.

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Table 4. Chi- square test for fitness to 1:1 ratio in six backcrosses with normal leaf.

Backcrosses	Observed value		χ^2 value
	N	O	(1:1)
Su X Bp X Bp	14	11	0.16
Su X Ba X Ba	10	20	2.70
Su X Ma X Ma	15	13	0.04
Su X Ah X Ah	11	7	0.50
Su X Am X Am	19	29	1.68
Su X Br X Br	20	14	0.74
Total	89	94	5.82

Su: Sudac-k, Bp: B-pima Ba: Barakat-90, Ma: Maryoud, Am: Acala-M, Br: Barac (67) B, Ah: Acala-H, N: Normal, O: Okra.

CONCLUSIONS

- The okra leaf of Sudac-k is conditioned by a single partially dominant gene. The homozygous allele results in super okra while the heterozygous showed okra leaf type with broader lobes. Thus the okra leaf can be a useful marker for estimation of outcrossing.
- Leaf lobing starts at 3-4th node with 3- lobed leaf and proceeds to reach a maximum of 5-lobes at 5-6th nodes.
- There was no difference in the expressing of the leaf type and the appearance at lobing among different genetic backgrounds.
- This information will provide a base for modeling the leaf-shape of cotton varieties for integrated insect pest management.

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الخلاصة

الوحيد الذي تمت إجازته بالسودان ولدية صفة Sudac.k شكل ورقة البامية من الصفات المهمة في القطن. يعتبر الصنف شكل ورقة البامية. أجريت التجربة لدراسة تعبير وتحليل توريث شكل ورقة البامية في القطن في خلفيات وراثية مختلفة في ثلاث بإستخدام صفة شكل (2004/05 and 2005/06)تجارب تحت الظروف الطبيعية في الجزيرة, وادمدني, السودان خلال المواسم من 12، ب. بيما, البار90ورقة البامية (الصنف سودان أكالا) كمعلم وراثي وتسعة أصناف تجارية هي: شمبات. ب، مريود، جي.س, بركات والأصناف Sudac.k ب و أكالا. هـ، أكالا. م. ثمانية عشر من هجن الجيل الأول وعكسها تم إنتاجها من التهجين بين (67) ، وباراك(57) التسعة في الموسم الأول. تمت إضافة نباتات الجيل الثاني, جيل التهجين الرجعي ونباتات الجيل الثالث في الموسم الثاني. تم تقسيم أوراق النباتات في الجيل الأول والجيل الثاني والثالث والرجعي عن طريق الملاحظة، إلي أوراق عادية تشبه الأصناف التجارية، وأوراق تشبه سودان أكالا، وأوراق تشبه شكل ورقة البامية. تمت القياسات علي الشكل الظاهري لورقة البامية: طول و عرض وزاوية أعماق ورقة البامية عند وصول الورقة شكلها النهائي ذو الخمسة فلقات. ظهور شكل ورقة البامية في البادرات يبدأ من الورقة الثالثة أو الرابعة بثلاث فلقات تصل إلي شكلها النهائي ذو الخمسة فلقات في الورقة السادسة أو الثامنة. أوضح اختبار مربع كاي أن شكل ورقة البامية يتحكم فيها موروث واحد ذو سيادة غير كاملة وأن التوزيع يتبع النسبة 1:2:1. عند دراسة انعزال نباتات الجيل الثاني، أتضح أنه لا توجد فروقات معنوية بين الهجن. أظهرت نتائج التحليل الإحصائي وجود فروقات معنوية بين الهجن لصفة طول وعرض وزاوية أعماق ورقة البامية مما يدل علي تأثير الخلفيات الوراثية في تعبير هذه العوامل. عموماً أوضحت الدراسة إمكانية معالجة شكل الورقة عن طريق برنامج التربية والاستفادة منه في إنتاجية القطن بأوراق البامية المختلفة للظروف الفلاحية المختلفة.