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Inheritance and Linkage Relationship of Strap Leaf Mutant in Cotton[1]

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ABSTRACT

A new mutant in Upland cotton (*Gossypium hirsutum* L.) is described. The inheritance and linkage data show that the mutant expression is controlled by homozygous recessive alleles at a new locus. The mutant was designated "strap leaf" and assigned the gene symbols *ss* for the homozygous recessive character. Strap leaf is linked to veins-fused (*vf*) and Green lint (*Lg*) by 3.7 and 11.1 crossover units, respectively.

Additional index words: **Linkage group, 2,4-D phenocopy.**

A SINGLE abnormal plant was found by B. A. Waddle and N. D. Fulton (University of Arkansas, Departments of Agronomy and Plant Pathology, respectively) in 1962 in a field of American Upland cotton (*Gossypium hirsutum* L.) near Paragould, Arkansas. The phenotype of the aberrant plant was similar to cotton plants that have been exposed to low concentrations of 2,4-D (2,4-dichlorophenoxy acetic acid.) The leaves were strapped, the leaf veins were parallel to the midrib causing the leaves to roll to the dorsal side, the bracts were twisted or rolled at the base, the stigma protruded through the top of the young squares where the petals normally come to a rounded apex, and the entire plant was glabrous

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Fig. 1. Phenotype of the aberrant strap leaf plant.

with short fruiting branches (Fig. 1). The abnormal plant was referred to as "strap leaf" because of the unusual phenotype of the leaf.

Mutations with phenotypes that are mimicked by physiological or hormonal types of departures from normality have been found previously in cotton (3, 4, 7, 9). For example, frego bract (*fg*), veins-fused (*vf*), and crinkle leaf (*cr*) are all monogenic recessive mutants that resemble some features of a plant's response to a very low dosage of 2,4-D. McNamara and Porter (9) also collected seven heritable abnormalities which possess similar phenotypes (HA-1 through HA-7). It is significant that several of these mutations are either closely linked to or members of a multiple allelic series (8, 10). If these mutants ultimately can be shown to reflect closely linked adjacent loci, then a specific segment of a chromosome that controls leaf development would be mimicking the action of 2,4-D.

The objectives of the present study were: 1) to determine whether the strap leaf character was due to a new mutation, and 2) if so, to determine its inheritance and linkage relationship to other characters for which the mode of inheritance is known.

Table 1. Name and gene symbol of mutants in linkage test (references in parentheses).

Name	Symbol	Linkage group
Brown lint	Lc_1 (5)	I
Red plant	R_1 (8)	III
Pilose	H_2 (10)	IV
virescent yellow	v_1 (6)	?
round leaf	rl (2)	?
Okra leaf	L^0 (5)	II
Green lint	Lg (5)	II
veins-fused	vf (7)	II

MATERIALS AND METHODS

The original strap leaf plant produced one open-pollinated boll containing three seeds in the field in 1962. These seeds were planted in the greenhouse at the Agricultural Experiment Station, Fayetteville, Arkansas, in the fall of that year. The seeds germinated and the plants appeared to be normal throughout the growing season. Self-pollinated seed were obtained from the three plants and individual progeny rows were planted in the field at Fayetteville in the spring of 1963. These plants were self-pollinated and classified as either possessing a normal or strap leaf type. Several of these individual plants were selected at random and their seed planted in progeny rows in the field in 1964.

It became apparent during the 1964 growing season that the plants could be separated into at least three classes. In midsummer, the plants were classified as strap leaf, normal, or intermediate strap leaf. Several strap leaf plants were transplanted to the greenhouse in the fall of 1964 and self-pollinated seed were obtained.

In the spring of 1965, seed from aberrant plants, eight genetic markers (Table 1), and two commercial varieties, 'Rex' and 'Paymaster,' were planted at Fayetteville. Cross-pollinations were made between the apparent strap leaf abnormality and the commercial varieties for inheritance information. Linkage data were obtained from progeny of crosses between strap leaf and eight marker stocks. The eight markers represented the four known linkage groups existing in cotton at that time (10).

Backcrosses were made in the greenhouse during the winter of 1965-66. In the spring of 1966, the parent, F_1, F_2, and backcross seeds from each combination were planted. Plants in the F_2 and backcross populations were separated into distinct phenotypic classes after they had reached the 6- to 7-true-leaf stage.

Chi-square values were used to test segregation ratios in each of the F_2 and backcross populations and to detect linkage. Recombination values or the degree of linkages were estimated by the maximum likelihood method (1).

RESULTS AND DISCUSSION

Inheritance of Strap Leaf. Data from the F_2 and BC_1 populations of Paymaster × strap leaf plants and Rex × strap leaf plants supported the hypothesis that the abnormality was controlled by a simply inherited recessive allele (Table 2). The Chi-square tests showed that the observed segregation did not deviate significantly from the expected ratios in both

Table 2. Classification of abnormal parent (S_2, S_3), F_2, and BC_1 plants of the cross normal × aberrant plant.

Population	Number of plants: Normal, SS	Intermediate, Ss	Mutant, ss	Total	Expected ratio	χ^2 analysis: χ^2	P
S_2 (strap leaf	0	0	274	274			
S_3 (strap leaf)	0	0	27	27			
F_2 (Paymaster × strap leaf)	92	181	89	362	1:2:1	0.06	0.97
BC_1 (Paymaster × strap leaf) × Paymaster	58	65		123	1:1:0	0.40	0.54
BC_1 (Paymaster × strap leaf) × strap leaf		42	38	80	0:1:1	0.20	0.67
F_2 (Rex × strap leaf)	43	59	37	139	1:2:1	3.69	0.17
BC_1 (Rex × strap leaf) × Rex	141	154		295	1:1:0	0.57	0.44
BC_1 (Rex × strap leaf) × strap leaf		19	25	44	0:1:1	0.82	0.38

Fig. 2. Phenotype of a plant of strap leaf stock *ss* onto which a normal branch *SS* was grafted.

the F_2 and backcross populations. Therefore, the aberrant plant designated "strap leaf" was assigned the symbols *ss* for the homozygous recessive condition in accordance with the rules for symbolizing gene and chromosome aberrations in cotton.

Graft and Cytological Test. The striking similarity of the new strap leaf mutant and 2,4-D-damaged plants stimulated two points of interest. First, a series of splice grafts were made between normal and strap leaf cotton stocks to determine if the abnormal condition could be translocated across a graft junction. A normal branch was successfully grafted to an abnormal stock and the normal branch grew to maturity without exhibiting any of the characteristics of strap leaf (Fig. 2). Second, young buds from the homozygous strap leaf plants were sent to Meta S. Brown at the Texas Agricultural Experiment Station for cytological observations. She observed that the cytological configurations produced by the young buds of the strap leaf material were similar to material that she had previously analyzed which had been exposed to 2,4-D (M. S. Brown, personal communication).

Linkage Test. The linkage and inheritance tests were run simultaneously. After the inheritance analysis established that the abnormality was controlled by one gene, the linkage data from the crosses between strap leaf and the eight genetic marker stocks were tested for independence. Two of these marker genes,

Table 3. Segregation of veins-fused and strap leaf alleles in F_2 and backcross populations.

Genotype	Observed	χ^2	P	Genotype	Observed	χ^2	P
VfVfSS	3	25.67		VfvfSs	13	1.78	
VfvfSS	7	49.54	VfvfSS	VfvfSS	0	9.00	
Vf--Ss	243	15.90		vfvfSS	17	7.11	
vfvfS-	131	14.43		vfvfSs	6	1.00	
Vf--ss	118	6.05					
vfvfss	0	31.38					
Total χ^2		142.97	0.01			18.89	0.01
Regression coefficient		3.7*					

* Linkage calculated from F_2 and BC_1 populations.

Table 4. Segregation of Green lint and strap alleles in F_2 and backcross populations.

F_2				BC_1			
Genotype	Osberved	χ^2	P	Genotype	Observed	χ^2	P
LgLgSS	33	54.82		LglgSs	11	3.61	
LglgSS	10	4.72		LgLgSs	1	4.41	
lglgSS	1	7.91		LgLgSS	10	2.25	
LgLgSs	4	12.44		LglgSs	3	1.69	
LglgSs	69	22.57					
lglgSs	7	0.80					
lglgss*	33	0.99					
Total χ^2		104.25	0.01			11.96	0.01
Regression coefficient		11.1†					

* Lint color could not be classified on homozygous strap leaf plants because no bolls were set. † Linkage calculated from F_2 and BC_1 populations.

veins-fused and Green lint were found to be linked with strap leaf (Tables 3 and 4) by 3.7 and 11.1 crossover units, respectively.

Since veins-fused and strap leaf are phenotypically similar to each other, the possibility existed that they were alleles instead of closely linked loci. However, two independent tests showed that veins-fused and strap leaf are two independent loci which are closely linked. Also, three normal plants were observed in the F_2 population of veins-fused $\times$ strap leaf and for these two mutants to be alleles, the three normal plants would have to be contaminants. If veins-fused and strap leaf were alleles, the expected phenotype of their F_1 progeny would resemble the parents. The F_1 plants of the cross veins-fused $\times$ strap were normal. Therefore, it was concluded that the three normal plants in the F_2 population were recombinants reflecting two different loci. Their linkage was determined by the maximum likelihood method (1).

Previous reports have shown that Green lint and veins-fused are located 13.6 crossover units apart on chromosome 15 of the D subgenome (8). Data obtained in this study places the strap leaf locus on the same chromosome, approximately 11.1 crossover units from Green lint and 3.7 crossover units from veins-fused.

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