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Effect of Environments and Genetic Backgrounds on Evaluation of Cotton Isolines[1]

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ABSTRACT

This study was conducted to measure the influence of genetic backgrounds in cotton (*Gossypium hirsutum* L.) and of environments on the effects that two traits, Okra leaf (*L*$^o_2$) and frego bract (*fg*), exert on lint yield and its components. The genetic backgrounds used were DES 24-8ne, a normal leaf and bract strain; ORH 55, an Okra leaf and frego bract strain; and two F_5 plant selections derived from the cross of DES 24-8ne X ORH 55. For each of the four genetic backgrounds, four near-isogenic lines were produced among all homozygous combinations of normal vs. Okra leaf and normal vs. frego bract. The 16 genotypes were evaluated for lint yield in 1979 and 1980 under two insect-control regimes (for a total of four environments). One regime was produced by applying early-season insecticides; the other was produced by applying no early-season insecticides and by growing plants of mustard [*Brassica juncea* (L.) Czern. & Coss.] near the plots to enhance early-season insect infestations. Lint yield varied greatly among years, averaging 742 and 479 kg/ha for 1979 and 1980, respectively. Cotton grown with and without early-season insect control yielded 667 and 554 kg/ha, respectively. The effect of Okra leaf on lint yield and its components was influenced greatly by environments but relatively little by genetic backgrounds. Average yield of Okra and normal leaf types was 597 and 625 kg/ha, respectively. Bract types were more sensitive than leaf types to environments and genetic backgrounds. Normal-bract isolines, however, yielded more lint in all environments than did their frego-bract counterparts. The average yield for normal and frego-bract types grown under the insect control regime was 751 and 582 kg/ha; and under the no control regime was 674 and 435 kg/ha, respectively. Varying environments were more important in the evaluation of these traits than varying genetic backgrounds.

Additional index words: Gossypium hirsutum L., Host-plant resistance, Frego bract, Okra leaf, Genotype × environment interaction.

MOST mutants in nature are initially deleterious because they are less fit than the wild or "normal" genotype. With a changing environment or gene pool, however, some mutants do become established, even to the point of being identified eventually as "the norm". Other mutants do not find their niche and remain in the gene pool at a very low frequency, about equal to their mutation rate. In cotton (*Gossypium hirsutum* L.) a great diversity is available to simply inherited morphological traits. The breeding value for commercial production of those traits is usually evaluated by use of the backcross procedure to produce near-isogenic lines for comparisons with the normal type. In general, these traits are deleterious in that they result in lower lint yield or quality. One can ask the question, "Are these traits deleterious because their breeding value is determined by backcrossing them into an already well integrated 'normal' genetic background or because they universally cause physiologies that are inefficient in the production of lint?" In this study the effect of genetic and environmental backgrounds on the genetic analyses of two traits was investigated.

Frego bract is a trait frequently researched by geneticists and breeders interested in host-plant resistance. Green (2) described the trait and determined that it is conditioned by a single recessive gene, later designated *fg*. Percival and Kohel (11) developed near-isogenic frego and normal isolines by backcrossing the trait into a Texas Marker-1 (TM-1) background. They reported that frego-bract lines reduced boll size, lint percentage, lint index, and delayed the date of first flower (implying lateness). Delayed fruiting of frego-bract strains and subsequently lower yields have been frequently observed; and at least in some cases, those effects were attributed to greater sensitivity of frego-bract strains to tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois) (9). An advantage of the trait is that it produces less trash in mechanically harvested lint (13). It also exhibits resistance to the boll weevil, *Anthonomus grandis* Boheman, as reported by Jenkins and Parrott (4). Pieters and Bird (12) reported that the combination of Okra leaf and frego bract reduced boll weevil oviposition punctures by 60%.

Okra leaf is also a trait frequently researched in host-plant resistance work. It was described by Hutchinson and Silow (3) to be controlled by a single dominant gene, L^0. Kohel (7) reported the correct identification of this gene was L^o_2. Andries et al. (1) produced near-isogenic Okra- and normal-leaf lines in three cultivar backgrounds and compared them at three locations. They reported that Okra leaf had only 59% as much leaf area as the normal leaf types. The openness of the plant canopy allowed better air exchange and, in their studies, significantly reduced boll rot. When boll rot was a serious problem, Okra-leaf cotton displayed higher yields than corresponding normal leaf types. Okra leaf also resulted in increased earliness, lint percentage, and micronaire. Kohel and Richmond (8) also reported that an Okra leaf isoline was markedly earlier and had shorter lint, lower seed index, lint index, and boll size than its normal leaf counterpart. Jones et al. (5) found that Okra leaf was associated with a high degree of resistance to the banded-wing whitefly, *Trialeurodes abutilonea* (Haldeman). Its reduction of boll weevil damage when in combination with frego bract has already been noted (12). The Okra-leaf trait also has been reported to have some potential in resisting moisture stress (6).

MATERIALS AND METHODS

The isolines used in this study were developed from DES 24-8ne and ORH 55 or from their cross. DES 24-8ne, a germplasm release (10), is in a predominately 'Deltapine 16' background and is characterized as having normal leaves and bracts. It is also nectariless (ne_1, ne_2) which gives it some insect suppression characteristics. ORH 55 was developed by L.S. Bird, Texas Agric. Exp. Stn., College Station, in his multi-adversity resistance (MAR) breeding program. It has Okra leaf and frego bract. Backcross programs at Stoneville, Miss. and Iguala, Mexico were carried out from 1974 to 1978. Near-isogenic lines (backcross five) were developed in both DES 24-8ne and ORH 55 backgrounds of normal leaf, normal bract (NN); normal leaf, frego bract (NF); Okra leaf, normal bract (ON); and Okra leaf, frego bract (OF).

Two other groups of four isolines were produced from the F_4 segregating population of DES 24-8ne × ORH 55. In 1976, the F_3 population was grown on four rows; each row was 1.0 × 152

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m. In June, plants were thinned to about 500 heterozygous Okra leaf plants, from which 129 were selected for progeny row observations in 1977. In that year, each progeny row was 1.0 × 13 m with two to three replications/progeny. The progenies were planted 26 April in an environment which encouraged early-season insects; the primary pest was the tarnished plant bug. Two rows of mustard, *Brasica juncea* (L.) Czern. & Coss. 'Florida Broadleaf', were grown adjacent to 32 rows of cotton to encourage early-season insect infestation. The middle 24 rows of the 32 were used for progeny evaluation. Progeny rows were thinned to one plant/ 32 cm of row.

Eighty-seven F_4 plants from 62 progenies which showed good productivity and were $L_2^{\ell}1$ were selected for further evaluation in 1978. Two replications of each progeny were planted in plots 1.0 × 15 m and again planted in an environment which encouraged early-season insects. Heterozygous Okra-leaf plants were removed from the plots. Two progeny rows in the F_5 were selected, and the four near-isogenic types NN, NF, ON, and OF were visually identified within those rows. From 10 to 20 plants of each near-isogenic type were harvested, and those furnished seed for the 1979 plantings. The two selected F_5 progeny rows were designated selection "A" and "B."

Table 1. Expected mean squares for the sources of variation assuming a random model for all effects except leaf, bract, and leaf × bract.

Source	Expected mean squares
Environ. (E)	$\sigma^2_{r} + rlbg\,\sigma^2_{E}$
Reps/E	σ^2_{r}
Genet. background (G)	$\sigma^2_{a} + rlb\,\sigma^2_{GE} + rlbe\,\sigma^2_{G}$
G × E	$\sigma^2_{a} + rlb\,\sigma^2_{GE}$
Error a	σ^2_{a}
Leaf (L)	$\sigma^2_{b} + rb\,\sigma^2_{LGE} + rbg\,\sigma^2_{LE} + rbe\,\sigma^2_{LG} + rbge\Sigma l$
L × G	$\sigma^2_{b} + rb\,\sigma^2_{LGE} + rbe\,\sigma^2_{LG}$
L × E	$\sigma^2_{b} + rb\,\sigma^2_{LGE} + rbg\,\sigma^2_{LE}$
L × G × E	$\sigma^2_{b} + rb\,\sigma^2_{LGE}$
Bract (B)	$\sigma^2_{b} + rl\,\sigma^2_{BGE} + rlg\,\sigma^2_{BE} + rle\,\sigma^2_{BG} + rlge\Sigma b$
B × G	$\sigma^2_{b} + rl\,\sigma^2_{BGE} + rle\,\sigma^2_{BG}$
B × E	$\sigma^2_{b} + rl\,\sigma^2_{BGE} + rlg\,\sigma^2_{BE}$
B × G × E	$\sigma^2_{b} + rl\,\sigma^2_{BGE}$
L × B	$\sigma^2_{b} + r\,\sigma^2_{LBGE} + rg\,\sigma^2_{LBE} + re\,\sigma^2_{LBG} + rge\Sigma lb$
L × B × G	$\sigma^2_{b} + r\,\sigma^2_{LBGE} + re\,\sigma^2_{LBG}$
L × B × E	$\sigma^2_{b} + r\,\sigma^2_{LBGE} + rg\,\sigma^2_{LBE}$
L × B × G × E	$\sigma^2_{b} + r\,\sigma^2_{LBGE}$
Error b	σ^2_{b}

The 16 genotypes were grown in two insect environments each year. The "with" early-season insecticide regime was achieved by sidedressing aldicarb [2-methyl-2-(methylthio)-propionaldehyde *O*-(methylcarbamoyl) oxime] at the rate of 1.12 kg/ha when plants were in the fourth true-leaf stage. This initial treatment was followed with three applications of dicrotophos [dimethyl phosphate ester with (*E*)-3-hydroxy-*N*,*N*-dimethylcrotonamide] at 115 g/ha beginning about 15 June and ending 15 July. The "without" early-season insecticide environment consisted of two rows of mustard planted adjacent to 20 rows of cotton. Data were taken from the middle 18 of the 20 rows. Mustard was planted 13 and 22 April in 1979 and 1980, respectively; and cotton was planted 8 and 14 May in 1979 and 1980, respectively. The soil type used for all plantings was a Beulah fine sandy loam, a member of the coarse-loamy, mixed, thermic Typic Dystrochrepts.

Plot size for all studies in 1979 and 1980 was three rows 6.0 m long with a distance between rows of 1.0 m. The experimental design was a split-plot with genetic background and isolines used as whole and subplots, respectively, with six replications. Lint yield and yield components were determined from the center row. Fifty-boll samples from three replications in each test were used to determine yield components. Plots were hand picked twice to determine yield.

The expected mean squares for the analyses of these experiments are given in Table 1. It was assumed that leaf and bract effects and the leaf × bract interaction were fixed and that all other effects were random.

Table 2. Yield and yield components mean squares as influenced by years, insect control regimes, genetic backgrounds, and leaf and bract isolines.

		Mean squares						
		Lint yield†						
Source	df§	Total	1st harvest	Lint %‡	Boll size‡	Seed index‡	Lint index‡	Seed/boll
Environ. (E)	3	2,775**	754**	10,863**	5,811**	4,402**	1,163**	1,010.6**
Year (Y)	1	6,724	2,060**	686	16,024	7,651**	3,142	2,300.2
Insect (I)	1	1,228	157*	31,289**	2	5,355**	80	100.4
Y × I	1	373**	44	613	1,408**	200	266**	631.2**
Reps/E	20	33	34	689	33	113	20	12.6
Genet. backgrounds (G)	3	813**	377**	34,177**	184	3,462**	1,190**	162.2**
G × E	9	70*	33	365**	56**	86**	12	14.3**
G × Y	3	89*	20	175	58	30	14	4.8
G × I	3	60	24	429	46	169**	9	20.2
G × Y × I	3	60	54*	490**	63*	60	12	18.0*
Error a	60	30	17	77	17	23	14	4.4
Leaf (L)	1	77	12	0	97	161	34	8.3
L × G	3	9	7	100	2	58	6	0.7
L × E	3	150**	252**	933**	62**	20	112**	14.4*
L × G × E	9	19	13	68	4	41*	8	2.1
Bract (B)	1	4,051	3,878	2,100	670*	70	324*	109.5*
B × G	3	58	38	146	40	156**	28*	10.0*
B × E	3	670**	594**	520**	21	40	8	8.8
B × G × E	9	51**	50**	102	5	24	11	2.1
L × B	1	281*	77**	679	8	347*	6	18.0
L × B × G	3	4	6	238	42	56	30	17.0
L × B × E	3	29	9	108	28	45	5	10.5
L × B × G × E	9	27	16	173*	54**	59**	6	20.7**
Error b	240	16	11	73	16	17	8	4.4

*,** Significant at the 0.05 and 0.01 levels of probability, respectively.
† Mean square × 10^{-3}.
‡ Mean square × 10^{2}.
§ df for reps/E, error a, and error b are 8, 24, and 96, respectively, for the five yield components.

RESULTS AND DISCUSSION

Of major interest in this study were the effects of leaf and bract types and their interactions when evaluated in various genetic backgrounds and environments. Genetic analyses were partitioned into one degree of freedom comparisons for leaf and bract effects and their interactions. Those comparisons also, by historical definition, measure the additive effects of leaf and bract types and leaf additive × bract additive epistasis. Large mean squares for the interactions of genetic backgrounds with leaf and bract types also indicate epistasis.

Mean squares from the analyses of variance for yield and its components are given in Table 2. Large mean squares for years (Y), insecticide control regimes (I), and genetic backgrounds (G) were evident for most characteristics which indicates that the study was conducted over a range of environments and genetic types. For example, mean lint yields were 742 and 479 kg/ha for the 1979 and 1980 seasons, respectively; and the mean yields for the with and without early-season insect control regimes were 667 and 554 kg/ha, respectively. For summarization purposes, the interactions of environmental variables, Y, I, and Y × I were combined in the sub-subplot analyses into one source of variation, interactions involving environments (E).

Table 2 indicates that leaf type (L) comparisons were not significantly influenced by genetic backgrounds but for six of seven characters were affected by environments. Bract type (B) and bract interaction mean squares were generally larger than those for leaf type and its interactions. For bract types, small but significant genetic background influences were detected for seed index, lint index, and seed/boll. The B × E and B × G × E interactions were highly significant for total and first harvest yield, and B × E was highly significant for lint percentage. Significant L × B epistasis for total lint yield, first harvest lint yield, and seed index was detected. No significant L × B × G or L × B × E interactions were detected; however, L × B × G × E interactions were detected for several yield components.

Mean performances for various isoline combinations are given in Table 3. The performances of normal- and Okra-leaf isolines was similar for all characteristics. Normal bract isolines usually produced more total and first harvest yield, larger bolls, higher seed and lint index, and more seed/boll than the frego bract isolines. The interactions detected with bract types were usually a matter of degree of superiority of normal over frego and not reversals in direction of response.

Epistatic interactions of leaf and bract types for lint yield are of considerable interest. Mean yield superiority of normal over frego bract was 257 and 150 kg/ha, in normal (753 - 496) and Okra leaf (672 - 522) backgrounds, respectively. Normal minus Okra leaf yields averaged 81 and −26 kg/ha in normal (753 - 672) and frego bract (496 - 522) backgrounds, respectively. The double deviate type, Okra leaf and frego bract, therefore yielded more lint than expected on the basis of individual performance of the two traits. Since in this study the two mutants combined to produce a favorable synergistic effect, it suggests that mutants may produce their best lint yields in combination with other mutants or exotic physiological backgrounds. The genetic background in which isolines were produced had only a small influence on isoline yield expression. There was a tendency for the Okra leaf and frego bract isolines to yield more lint in the DES 24-8ne background than in the ORH 55 background.

Because environment interacted significantly with leaf and bract types for lint yield, the interactions of those types with years and insect-control regimes are shown in Table 4. Okra-leaf isolines averaged significantly higher first harvest and slightly higher total yields than normal leaf in 1979, but in 1980 normal leaf isolines yielded significantly more lint at both harvests. The 1979 season was characterized as having significantly more rainfall than normal and below average temperatures and light intensity. The 1980 season can be described as having the opposite. Normal leaf isolines averaged 45 kg/ha more and 11 kg/ha more than Okra leaf isolines when grown in the without and with early-season insect control regimes, respectively.

Table 3. Mean performance for Okra-leaf and frego-bract combinations over environments.

Strain-isoline†		Lint yield Total	Lint yield 1st harvest	Lint %	Boll size	Seed index	Lint index	Seed/boll
		kg/ha	kg/ha	%	g	g	g	no.
DES 24-8ne	NN	888	650	38.7	5.14	10.42	6.49	33.3
	NF	571	395	37.5	4.87	10.17	6.06	32.0
	ON	803	651	38.5	4.99	10.23	6.74	32.9
	OF	604	421	37.9	4.79	9.94	6.43	33.0
ORH 55	NN	616	476	32.4	4.99	11.62	6.90	32.5
	NF	432	296	31.0	4.87	12.28	6.72	30.8
	ON	576	492	32.1	4.93	11.67	6.93	31.1
	OF	460	349	32.1	4.55	11.29	6.63	28.1
Sel. A	NN	689	512	35.2	5.40	12.32	6.04	24.3
	NF	454	300	35.3	4.46	12.13	5.87	20.5
	ON	587	468	35.1	4.92	12.59	5.92	22.4
	OF	468	335	34.7	4.59	11.67	5.59	21.9
Sel. B	NN	820	622	37.4	5.47	11.05	6.01	28.0
	NF	528	351	35.8	5.13	11.43	5.90	26.3
	ON	719	579	36.6	5.41	11.28	5.66	27.6
	OF	554	395	36.5	5.00	11.31	5.42	27.3
LSD 0.05‡		71	59	NS	NS	NS	0.23	NS
Mean	NN	753	565	35.9	5.25	11.36	6.36	29.5
	NF	496	430	34.9	4.83	11.50	6.14	27.4
	ON	672	548	35.6	5.06	11.44	6.31	28.5
	OF	522	378	35.3	4.73	11.07	6.02	27.6
LSD 0.05‡		35	30	NS	NS	0.17	NS	NS
Mean	Normal	625	450	35.4	5.04	11.43	6.25	28.5
	Okra	597	461	35.4	4.90	11.24	6.17	28.0
Mean	Normal	712	556	35.8	5.16*	11.40	6.34*	29.0*
	Frego	509	355	35.1	4.78	11.28	6.08	27.5

* Significant difference at the 0.05 level of probability (as indicated by F tests in Table 2).
† Abbreviations: NN = normal leaf, normal bract; OF = Okra leaf, frego bract; etc.
‡ LSD 0.05 given for the four means within a column for a particular strain or for the four means among isolines over strains. Error b used for all comparisons.

Table 4. First harvest and total lint yield means for leaf and bract types grown with and without early-season insect controls for 2 years.

Type	Lint yield 1st harvest 1979	1st harvest 1980	Total 1979	Total 1980	1st harvest With	1st harvest Without	Total With	Total Without
	kg/ha							
Leaf								
Normal	493	408**	726	523**	451	449	672	577
Okra	565**	357	758	436	501**	422	661	532
Bract								
Normal	681**	430**	910**	514**	545**	568**	751**	674**
Frego	375	336	573	444	408	303	582	435

** Indicates significantly higher yield for paired column data at the 0.01 level of probability. LSD 0.05 and 0.01 for first harvest yields = 29 and 39 kg/ha, respectively, and for total yields = 35 and 47 kg/ha, respectively. LSD's for interactions [i.e., 1979 (normal − okra) − 1980 (normal − okra)] are 1.41 × specific LSD's given.

Normal vs. frego bract comparisons were more sensitive to environmental differences than were those for normal vs. Okra leaf. Normal bract isolines averaged 337 and 70 kg/ha more total lint than the frego bract isolines in 1979 and 1980, respectively. Normal types produced 169 and 239 kg/ha more total lint than frego types when grown in the with and without regimes, respectively. Our results suggest that the use of the backcross procedure to produce isogenic normal vs. mutant types is an acceptable method for evaluating new traits. Varying environments were more important than varying genetic backgrounds in evaluating the traits studied.

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