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Effectiveness of Frego Bract as a Boll Weevil Resistance Character in Cotton[1]

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ABSTRACT

In 1970 four farms located in different parts of Mississippi each were planted to 4 to 8 ha of cotton (*Gossypium hirsutum* L.), homozygous for frego bract (*fg fg*), and to an approximately equivalent acreage of a nonfrego commercial variety. Cottons with frego bract have shown resistance to boll weevils (*Anthonomus grandis* Boh.) when grown in small plots. Our 1970 tests were designed to measure the cumulative effects of a frego-bract cotton, designated M-64, on boll weevil populations when this cotton was grown in large acreages and when the resistance was measured over three or four insect generations. Results from these tests will be used to assess the role of cottons resistant to boll weevil in an integrated approach designed to eradicate this insect. A pilot scale boll weevil eradication program is now underway in Mississippi.

In the frego-bract cotton boll weevil oviposition, an indirect measure of population, was suppressed 66, 71, 75, and 94% below that in the nonfrego varieties. The variation in suppression was due to different numbers of overwintering weevils and to various control measures used during the season. On two farms no insecticides were required for boll weevil control in the frego-bract strain. The frego-bract strain suppressed the population 94% on the farm with the smallest number of overwintering weevils. Thus, oviposition suppression was greatest where it can be of the most use in an eradication program.

Fiber properties and yields of the frego strain were adequate for a nonbiased test of the boll weevil resistance attributed to frego bract.

***Additional index words:* *Anthonomus grandis* Boh; Host plant resistance, *Gossypium hirsutum* L.; Breeding.**

SEVERAL research workers have reported reduced boll weevil (*Anthonomus grandis* Boh.) oviposition in small plots of frego-bract cotton (*Gossypium hirsutum* L.), [Jones, Newsom, and Tipton (1964), Hunter et al. (1965), Lincoln and Waddle (1966), and Jenkins et al. (1969)]. The frego bract mutant is controlled by a single recessive gene (Green, 1955) and is characterized by having rolled or twisted and narrow rather than flat and wide involucral bracts (Fig. 1).

At the US Department of Agriculture Boll Weevil Research Laboratory we are studying population suppression measures that are potentially useful individually or in various combinations to control or to even eradicate the boll weevil. A pilot-scale program, designed to eradicate this insect from a relatively large area, is underway in Mississippi.

Cotton varieties carrying resistance factors should be valuable in an integrated eradication program. Since the frego-bract character confers some resistance, and apparently can be moved into an acceptable agronomic background, it seems to be the most promising morphological character to include in such a program.

No data were available from large block plantings of frego-bract cotton to give us any indication of its performance when planted under these conditions. Frego bract, by nature of its peculiar shape, alters the environment around the square (flower bud), which is the principal site of boll weevil feeding, oviposition, and resting. Our observations of boll weevil behavior on frego-bract plants in small plots led us to think that the resistance was caused primarily by a change in behavior of the boll weevil and was not merely a matter of nonpreference that would disappear in large plantings of cotton. Cross and Mitchell (personal communication) have studied the altered behavior of the boll weevil on frego plants. They reported that overwintered and current-season boll weevils oviposited about 50% fewer eggs per female on frego-bract cotton. Marked, released weevils left frego-bract plots about twice as rapidly as they left nonfrego plots. "Unnatural behavior patterns on frego-bract plants are sugggested by the generally smaller captures on pheromone wing traps through the season in frego, smaller average infestations, loss of time spent in the rolled bracts, greater amounts of movement from plant to plant, and the apparent 'nervousness' of the boll weevil on the frego plants."

Our objectives in the research reported in this paper were *(1)* to measure the cumulative suppressive effects of the frego-bract character on boll weevil populations when frego-bract cotton was grown in large fields and exposed to three to four generations of boll weevils, and *(2)* to measure its effectiveness in population suppression when grown in areas with various densities of overwintering boll weevils and various farming practices that may be encountered in a boll weevil eradication program.

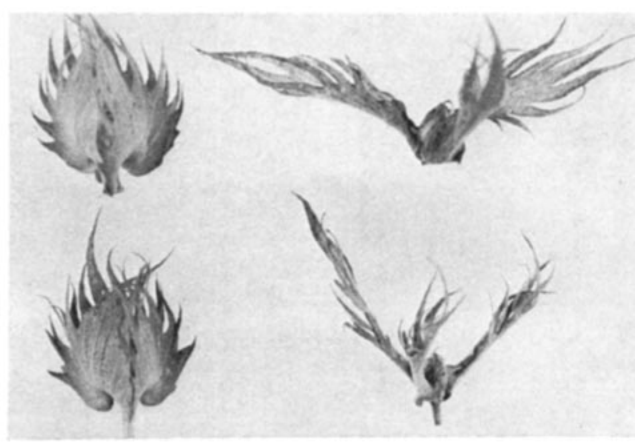

Fig. 1. Normal bract (left); frego bract (right). The bract structure rolls because of a fusion of the veins at the base of the structure.

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MATERIALS AND METHODS

The original mutant frego-bract strain was sent to the US Cotton Field Station, Stoneville, Miss. in 1945 by Mr. Keith J. Bilbrey, County Extension Agent, Blytheville, Ark. (Green, 1955). He obtained it from a gower, Mr. George Frego, who found it as a naturally occurring mutant in a field of 'Stoneville 2B.'

Seeds of the frego-bract strain, M-64, were supplied by Monsanto Chemical Company[3] from cotton grown in Guatemala, Central America. We had no data on fiber properties or agronomic performance of the cotton when grown in the United States. Observations made on plant type during the 1970 growing season indicated that the M-64 frego-bract strain was a heterogeneous plant population; however, only an occasional nonfrego-bract plant was found in the fields.

We conducted four field plot tests (4.0 to 8.0 ha each) with frego-bract and normal-bract cotton during the summer of 1970. All tests were located in Mississippi. Three were on cooperator farms, and one was on a Branch Experiment Station. The operator's customary farming practices generally were followed in each situation.

We tested with four different sets of conditions, as follows. *Farm A* was located in Jefferson Davis County near Prentiss, Miss. A large population of overwintering weevils was present. We planted 4.9 ha of frego bract and 3.1 ha acres of 'Deltapine 16' (DPL-16). Pheromone wing traps were installed around the fields at the rate of 2.47/ha (Lloyd et al., 1971). The cooperator followed acceptable cultural practices. Insecticides were applied for boll weevil control on both the frego-bract strain and DPL-16 based on the boll weevil population in the latter variety.

Farm B also was located in Jefferson Davis County near Prentiss. A large population of overwintering weevils also was present. We planted 4.0 ha of frego bract and 1.2 ha of DPL-16. The cooperator did not follow acceptable cultural practices. Insecticides were recommended when needed; however, the coopator applied tbem only sporadically and was usually 5 to 7 days late with each application. This poor insecticide control program resulted in a build-up of large numbers of weevils during the growing season.

Farm C was located in Monroe County, near Aberdeen, Mississippi. A small population of overwintering weevils was present as a result of a partial diapause control program in the fall of 1969. We planted 5.3 ha of frego bract and 6.5 ha of DPL-16 in fields about 275 m apart. The cooperator followed acceptable cultural practices. Insecticides for boll weevil control were applied as needed in DPL-16. No insecticides were required for control of boll weevil in the frego cotton.

Farm D was located on the Northeast Branch Experiment Station, Verona, Miss. A moderate population of overwintering boll weevils was present. We planted 8.0 ha of frego bract and 4.0 ha of 'Stoneville 213' (St. 213) in adjacent fields. Flooding forced a second planting of both cottons. A subsequent flood delayed the growth of the cotton from the second planting. A late application of herbicides (flometron and disodium methanearsonate) also delayed proper fruiting of the plants. Insecticides for boll weevil control were applied as needed in St. 213. No insecticides were required for control of boll weevil in the frego strain. We attempted to force boll weevils to migrate to the frego-bract cotton by withholding insecticides until the insects had built up to a higher than normal level on the St. 213. The cotton was planted at *Farms A* and *B* on 4/29/70, and at *Farm C* on 5/8/70; the second planting was made at *Farm D* on 5/18/70.

It was necessary to control thrips (*Frankliniella* sp.) on both the frego and nonfrego cotton at all locations. We used dicrotophos or dimethoate at the recommended rate. The insecticides at the rate applied did not kill weevils.

Data were collected once per week on each farm. The frego and nonfrego strains in fields *A, C,* and *D* were each divided into four equal plots for record purposes. Field *B* was divided into four plots of frego cotton and two plots of DPL-16. We determined boll weevil infestations by modifying the point sample method of Lincoln et al. (1963) as follows: We picked a random sample of 100 squares (flower buds) from each plot by walking in two directions diagonally across the plot. The number of feeding and oviposition punctures was recorded for each 100 squares. Oviposition punctures are sealed by the boll weevil, whereas, feeding punctures are open holes. Everett and Ray (1962) obtained a correlation coefficient of 0.92 between sealed punctures and eggs. The number of squares was counted each week on a carefully selected, marked section of row 7.6 m long. We were then able to calculate number of squares per land unit and number of squares with oviposition punctures per land unit (boll weevil eggs per 0.4 ha).

We sampled the frego-bract strain and DPL-16 on *Farm C* with a mechanical insect catcher once per week during July. The pheromone wing traps used around the field in *farm A* were painted solar yellow and were baited once per week with four live, individually caged, 7-day-old male boll weevils that were fed cotton squares or small bolls. The weevils caught on the traps were removed once each week at the time the traps were baited.

We picked a sample of 100 open bolls from each of the plots of frego and nonfrego cotton on each farm. These samples were ginned and lint was submitted to the US Department of Agriculture Spinning Laboratory at Knoxville, Tenn. for fiber and spinning performance data.

Boll weevil damage was estimated by calculating the number of oviposition-punctured squares per acre (0.4 ha) at each date. Calculated values were transformed to square roots since insect counts usually follow the Poisson rather than the binominal distribution. The data from the four farms were analyzed as one split-plot experiment.

[3] The use of trade or proprietary names does not necessarily imply the endorsement of these products by the US Department of Agriculture.

RESULTS AND DISCUSSION

The frego-bract strain had fewer squares with oviposition punctures than the nonfrego. The difference was significant at the 0.01 level. The differences between farms and dates were also significant at the 0.01 and 0.05 levels, respectively. There was no statistical test available to compare the differences between the frego and nonfrego cotton on each farm, since there was only one plot of each type cotton at each farm. However, when the data for the frego and nonfrego-bract strains at each farm were compared with the averages from the four farms, the same trends were present The frego-bract strain was less damaged than the nonfrego strain at each farm and for each date. The data from each farm will be discussed individually, followed by a general discussion.

Farm A

The number of overwintering weevils was very large. By the time the cotton plants were squaring adequately for reliable records (6/22), the pheromone traps had captured 69 weevils/ha (170/acre) (Table 2). The traps were obviously effective in suppressing the number of boll weevils that entered the field. However, an economically damaging infestation developed in the DPL-16 on 6/22; both DPL-16 and the frego-bract plots were sprayed three times with 273 g of methyl parathion/ha. Tables 1 and 3 show the cumulative effects of the resistance of frego bract in suppressing oviposition as it is expressed over three or four generations of boll weevils.

Oviposition is an indirect measure of population. Oviposition was suppressed 66% in frego, i.e., there were only 34% as many boll weevil eggs oviposited in the frego-bract strain as in the DPL-16 during the entire growing season. In fact, during the first 7 weeks oviposition was suppressed 72% in the frego bract plots. The increase in oviposition in the frego-bract strain on 8/10 was correlated with the migration of boll weevils from DPL-16, which had ceased squaring, to the frego-bract cotton. Catches on the pheromone traps (Table 2) also increased on this date; this result verified that the weevils did migrate in response to a cessation of squaring of the DPL-16, Table 4. Boll weevils also were migrating from other nonfrego fields in the area.

Farm B

The boll weevil population was much larger on farm *B* than on farm *A*. The difference in initial infestation probably was caused by the influence of the pheromone traps around *Farm A*, Tables 1 and 2, since 69 weevils/ha were removed (trapped) from *Farm A* by the time the cotton began to square. The differences for the remainder of the season were influenced more, however, by the insect control practices used on the two farms. In spite of the extremely large weevil population during the season, significantly fewer eggs were oviposited in the frego strain than in the DPL-16, Tables 1 and 3. Between 6/29 and 7/20 the operator applied methyl parathion twice at the rate of 273 g/ha, which lowered the infestation temporarily (Table 3). The initial squaring rate and infestation levels were similar for the frego and nonfrego cotton (Tables 1, 3, and 4). The effect of the resistance due to frego bract was cumulative over generations, and oviposition was suppressed 71% below that on DPL-16 over the full season (Table 1).

Farm C

Conditions on this farm closely approximated those expected during a boll weevil eradication program. There were very few boll weevils in the spring, but they slowly built up until control was required in DPL-16 before the season was over. Control in DPL-16 began on 8/1/70. The range in infestation in DPL-16 was 0.5 to 25.3% during the season (Table 3). We were not required to apply insecticide for boll weevil control in the frego cotton. The range in infestation in the frego strain was 0.0 to 2.0% during the season (Table 3). The resistance due to the frego character under these conditions was sufficient to allow a complete season without the need for insecticidal control of the boll weevil. The frego strain was 6 days later than DPL-16 in reaching 100,000 squares/0.4 ha (Table 4); however, there was always a sufficient number of squares in the frego strains to allow a valid test of its resistance potential.

The cumulative number of squares with oviposition punctures is shown in Table 1. The relatively small but important differences in initial infestation and subsequent oviposition due to the differences in the two cotton types are shown in Tables 1 and 3. Also, the cumulative effect of a continuous suppression of oviposition by the frego-bract cotton is shown. The data collected by use of the mechanical insect catcher also confirm this result (Table 5). As shown in Tables 1 and 3 the resistance conferred by the frego-bract strain is the most effective in situations where it can contribute the most to an eradication program, i.e., under extremely low population levels. The differences in number of weevils/0.4 ha (Table 1) and percentage of infestation (Table 3) are not large from

Table 1. Cumulative numbers of oviposition punctured squares/0.4 ha (1 acre) for frego and nonfrego-bract strains on each farm by dates.

Date (1970) Week of	Cumulative numbers, in thousands of oviposition-punctured squares per 0.4 ha: Farm A		Farm B		Farm C		Farm D	
	Frego	DPL-16	Frego	DPL-16	Frego	DPL-16	Frego	St. 213
6/22-26	0.4	10.3						
6/29-7/3	0.8	11.9	12.0	15.7	0.0	0.4		
7/6-10	2.0	15.6	14.1	26.1	0.0	0.9		
7/13-17	6.1	38.2	19.7	45.7	0.0	1.7	0.01	0.1
7/20-24	13.7	60.1	39.1	84.9	0.0	9.6	0.01	0.3
7/27-31	14.2	60.6	52.4	137.3	0.8	40.8	0.2	1.5
7/3-7	14.4	61.8	55.6	192.9	2.6	55.8	0.8	5.2
8/10-14	23.9				4.1	59.0	3.3	17.9
8/17-21					4.4	63.6	8.0	42.5
8/24-28					4.5	75.7	15.3	106.2
8/31-9/2							34.5	205.4
9/7-11							60.5	243.8
$\bar{X}$	3.0(8)	8.8(7)	9.3	32.1	0.5	8.4	6.7	27.9
% reduction	66		71		94		75	

Table 2. Boll weevils caught on 20 wing traps around the 8.0-ha *Farm A*; traps baited weekly with live males.

Date (1970)	No. weevils	% Males	% Females	Date (1970)	No. weevils	% Males	% Females
5/11	897	54	46	7/20	29	17	83
5/18	756	60	40	7/27	20		
5/25	511	46	54	8/3	16		
6/1	424	50	50	8/10	124	33	67
6/8	599	40	60	8/17	664	44	56
6/15	305	51	49	8/24*	1,648	33	67
6/22	93	35	65	8/31	4,625	34	66
6/29	88	48	52	9/7	4,945	40	60
7/6	40	48	52	9/14	4,210	34	66
7/13	23	13	87	Total	19,835	39	61

Table 3. Percentage of squares with oviposition punctures in frego and nonfrego-bract strains on each farm by dates.

Date (1970) Week of	Farm A		Farm B		Farm C		Farm D	
	Frego	DLP-16	Frego	DLP-16	Frego	DLP-16	Frego	St. 213
6/22-26	6.5	15.0						
6/29-7/3	2.7	1.5	17.0	22.5	0.0	0.7		
7/6-10	1.0	1.8	2.0	2.8	0.0	0.5		
7/13-17	1.8	12.0	3.5	6.5	0.0	0.5	0.7	4.0
7/20-24	3.2	18.2	13.2	34.5	0.0	7.3	0.0	1.3
7/27-31	0.3	1.5	10.8	31.0	0.2	25.2	0.8	2.7
8/3-7	0.2	10.5	4.0	17.5	1.0	11.8	1.2	4.3
8/10-14	13.8				2.0	3.7	1.5	8.7
8/17-21					0.8	5.3	2.0	20.5
8/24-28					1.2	21.2	4.8	44.0
8/31-9/2							11.0	63.7
9/7-11							17.0	35.3
$\bar{X}$	3.7	8.6	8.4	19.2	0.6	8.5	4.3	20.5

Table 4. Number of squares/0.4 ha (1 acre) in frego and non-frego cotton on each farm by dates.

Date (1970) Week of	Farm A: Days after planting	Squares per 0.4 ha in thousands		Farm B: Days after planting	Squares per 0.4 ha in thousands		Farm C: Days after planting	Squares per 0.4 ha in thousands		Farm D: Days after planting	Squares per 0.4 ha in thousands	
		Frego	DPL-16		Frego	DPL-16		Frego	DPL-16		Frego	St. 213
6/22-26	57	5.7	61.6									
6/29-7/3	64	15.0	120.9	64	70.3	71.0	55	24.0	45.9			
7/6-10	71	142.0	210.5	71	103.5	143.2	63	70.4	107.5			
7/13-17	78	240.0	188.7	79	170.4	168.6	69	151.4	170.1	60	2.7	1.3
7/20-24	85	229.1	118.8	86	147.4	135.1	77	212.0	127.3	67	15.3	8.7
7/27-31	93	232.2	62.3	93	131.1	96.2	84	291.8	137.5	74	22.7	25.6
8/3-7	99	121.1	14.5	99	65.3	25.9	90	178.6	124.4	80	43.2	76.3
8/10-14	106	86.9	--				97	61.7	111.9	87	160.5	141.8
8/17-21							104	30.0	82.6	94	124.7	117.7
8/24-28							111	5.6	48.2	101	158.5	144.3
8/31-9/2										106	180.6	152.8
9/7-11										113	152.1	101.3

an economic standpoint, but may be sufficient to mean the difference between success and failure in an eradication program. The resistance in the frego strain suppressed oviposition 94% below that in DPL-16, over the full season (Table 1). Only 4,535 eggs were oviposited/0.4 ha in the frego strain, compared to 75,664 in DPL-16, Table 1.

Farm D

A combination of adverse weather and treatment with herbicides delayed the fruiting of the frego cotton and St. 213 2 to 3 weeks later than normal (Table 4). The first time either one had 100,000 squares/0.4 ha was 87 days after planting. High fertilizer rates caused both cottons to square heavily until 113 days after planting. A comparison of the squaring period and dates on *Farm D* with that on other farms is shown in Table 4.

There was a small difference between the two cottons in initial boll weevil infestation. This difference increased during the season as the resistance in the frego strain continued to exert its influence on oviposition (Tables 1 and 3). No insecticides were used to control boll weevils in the frego cotton. However, 546 g/ha of methyl parathion were applied to St. 213 on 8/25 and 9/1. During the 9 weeks the boll weevil population in St. 213 expanded from 76 to 243,805 oviposition-punctured squares/0.4 ha, whereas the population in the frego strain expanded from 13 to 60,526/0.4 ha (Table 1). This difference represents a 75% suppression of oviposition due to the resistance in the frego cotton (Table 1).

Agronomic Properties

Fiber properties and miniature spinning data for the cottons from the various farms are shown in Table 6. DPL-16 and St. 213 are two of the best commercial varieties available for the test areas. The frego strain (M-64) that we used was sufficiently good agronomically to allow us to obtain unbiased data. This fact is emphasized by its adequate squaring rate at all locations during the entire season. A comparison of its fiber properties with those of DPL-16 or St. 213 (Table 6) shows that it may be a useful source strain to use for the development of commercial lines. Yields of lint cotton in kg/ha were as follows: *Farm A*, frego 645, DPL-16 584; *Farm B*, frego 178, DPL-16 166; *Farm C*, frego 458, DPL-16 845; and *Farm D*, frego 200, St. 213 312. Yields were those actually obtained by the cooperator, but they are not intended to represent good estimates of the relative yield potential of the cottons.

Table 5. Boll weevils captured with mechanical insect catcher on *Farm C*.

	No. boll weevils caught per 0.4 ha	
Date	Frego	DPL-16
7/1	0	0
7/7	0	3
7/17	0	22
7/23	5	19
7/31	0	101

We did note some problems with M-64 frego that need to be considered. This frego-bract cotton on *Farm C* was severely attacked by root knot nematodes, [*Heterodera marioni* (Cornu) Goddey]. Drouth stress beginning about Aug. 20 caused severe defoliation and boll shed and is responsible for the major difference in yield between frego and DPL-16 on *Farm C*. On *Farms A* and *C* under conditions of high fertility the frego strain was 7 to 10 days later in reaching 100,000 squares/0.4 ha. This was not true on *Farms B* or *D*. At all locations it was 10 to 14 days later in maturity, as indicated by yield at first picking. The lateness coupled with late planting and adverse weather and cultural practices on *Farm D* caused the frego cotton to be so late that a freeze damaged many small bolls and thus reduced yields. Boll size was smaller than that of DPL-16 and St. 213, but this may not be a detrimental factor.

GENERAL DISCUSSION

The resistance conferred by the frego-bract character was effective in suppressing boll weevil oviposition and thus populations under conditions of varying numbers of overwintering weevils and within a wide range of farming practices. Oviposition suppression ranged from 66 to 94% depending upon the overwintering weevil population, farming practices, and supplemental control measures applied. The amount of oviposition suppression that we found under the varied conditions encountered agrees well with our data from small field plots (Jenkins et al. 1969) and with those of Lincoln and Waddle (1966) and Jones et al. (1964), also from small plots.

These field plots represent the largest acreage of frego cotton ever grown in the United States. These plantings thus afforded us our first opportunity to assess the value of frego bract as a resistance factor against the boll weevil under conditions similar to actual production practices. The agreement between the small and large plot data is significant. We cannot know with certainty how effective the frego-bract character will be in suppressing or in assisting to eradicate boll weevil populations until an acceptable frego

Table 6. Fiber and miniature spinning data of frego and non-frego cotton produced on four farms.

	No. reps	Lint, %	Span length 50%	Span length 2.5%	Uniformity index	Micronaire	Colorimeter RD	Colorimeter B	T_1	E_1	Yarn strength	Boll size†
Farm A - frego	4	38.9	.50	1.08	46	4.9	78	9.0	18.94	7.50	121	6.4
Farm A - DPL-16	4	41.9	.50	1.08	46	5.3	78	8.6	18.15	8.82	113	6.7
Farm B - frego	4	40.3	.46	1.01	46	4.9	77	8.7	17.80	7.54	119	5.9
Farm B - DPL-16	2	43.5	.50	1.06	46	5.5	77	8.7	17.31	9.48	113	6.6
Farm C - frego	4	35.9	.52	1.10	47	4.7	77	9.4	19.21	7.80	132	5.8
Farm C - DPL-16	4	37.3	.56	1.18	47	4.9	80	8.6	18.60	9.46	128	6.7
Farm D - frego	4	33.6	.50	1.14	44	4.5	77	7.8	18.04	7.90	127	5.6
Farm D - St. 213	4	36.4	.52	1.14	46	4.8	77	7.9	17.77	8.13	122	5.9
$\overline{X}$ of 12 frego*	12	38.4	.49	1.06	46	4.8	77	9.0	18.65	7.61	124	6.0
$\overline{X}$ of 10 DPL-16*	10	40.4	.53	1.11	47	5.2	78	8.6	18.16	9.21	119	6.7

* Farm D data not included. † Boll size expressed as grams per boll of seed cotton.

variety is actually grown on an area-wide basis. However, the data obtained thus far indicate that we should expect frego bract to be a valuable character for boll weevil resistance. When varieties with frego bract become available and are grown commercially, the task of boll weevil eradication should be easier and the number of insecticide applications necessary to control the boll weevil until it is eradicated should be reduced. After eradication of the boll weevil in an area, cotton varieties with frego bract should be of value in preventing or suppressing reinfestation. Coupled with all available control and eradication technology, it can make a valuable contribution.

We cannot know how long frego-bract varieties will remain resistant to the boll weevil. The resistance is due to an upsetting of the normal patterns of behavior of the boll weevil. We do not know to what extent the behavior of the boll weevil is under direct genetic control and thus amenable to selection. Frego-bract varieties should remain resistant until or unless populations of boll weevils develop that behave "normally" on frego bract. Adaptation to the frego-bract environment will require several changes in the insect. Probably several years will be required for the boll weevil to adapt to frego-bract cotton, if it can adapt at all. Behavior of boll weevils adapted to frego-bract cotton should be considerably altered from that of those adapted to normal-bract varieties. Thus, a change in plant type back to normal bract cotton should again result in a confused weevil. By monitoring the behavior of the boll weevil population and by selective use of frego and normal-bract cottons, one might be able to keep the boll weevil population in a state of constant "confusion," i.e., abnormal behavior. This strategy should keep the population at subeconomic levels and also should prolong the usefulness of this resistance character for boll weevil control.

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