Published September, 1979

Influence of Five *Gossypium* Species Cytoplasms on Yield, Yield Components, Fiber Properties, and Insect Resistance in Upland Cotton[1]

W. R. Meredith, Jr., Vesta Meyer, B. W. Hanny, and J. C. Bailey[2]

ABSTRACT

The influence of five exotic cotton (*Gossypium* spp.) cytoplasms on yield, yield components, fiber properties, and insect populations was determined at Stoneville, Miss. The five cytoplasms were *G. herbaceum* L., *G. arboreum* L., *G. anomalum* Wawra ex Wawra & Peyr., *G. barbadense* L., and *G. tomentosum* Nutt. ex Seem. The five cytoplasms were combined by repeated backcrossing into the following upland cotton (*G. hirsutum* L.) cultivars: 'B3080', 'Coker 201', 'Delcot 277', 'Deltapine 16', and 'Stoneville 213'. The average number of backcrosses into *G. hirsutum* was 10.1 and into the specific cultivars, 6.5.

The characteristic most influenced by exotic cytoplasms was yield. Cytoplasm from *G. arboreum* decreased yield 18%, averaged for all cultivars. Exotic cytoplasms in general decreased yields, but this trend was not consistent for all cultivars. The average 1977 decrease in yield was 80, 61, 41, 17, and −5 kg/ha for Deltapine 16, Coker 201, Stoneville 213, B3080 and Delcot 277, respectively. The foreign cytoplasms had no strong deleterious effects on yield components and fiber properties.

No evidence of variations in tolerance to tarnished plant bugs (*Lygus lineolaris* Palisot de Beauvois) was detected in the 1977 study. In 1978 no differences due to cytoplasms were detected in numbers of tarnished plant bugs and white flies (*Trialeurodes abutilonea* Haldeman). However, the AD_3 (*G. tomentosum*) cytoplasm resulted in a 70% increase in numbers of leafhoppers (primarily *Empoasca* spp.) and a 35% decrease in weights of 7-day old larvae of tobacco budworm (*Heliothis virescens* F.).

The interaction of some nuclear genes and exotic cytoplasms was compatible for yield and significant for some pest damage. This result suggests that a back-up cytoplasmic system could be developed to help reduce the danger of major ephiphytotics or damage by insects.

Additional index words: Genetic vulnerability, *Gossypium hirsutum* L., Host-plant resistance.

THE need for increased genetic diversity in major crops is widely recognized. The importance of incorporating different cytoplasms in crop cultivars has been adequately shown by the epiphytotic in hybrid corn (*Zea mays* L.) cultivars with Texas (T) cytoplasm caused by *Helminthosporium maydis* Nisikado (perfect stage *Cochliobolus heterostrophus* Drechs.). Mahill and Davis (1) demonstrated that a cytoplasm can affect the virulence of a pest in cotton (*Gossypium hirsutum* L.). Cytoplasm of *G. harknessii* Brandegee enhanced resistance to bacterial blight [*Xanthomonas malvacearum* (E. F. Sm.) Dowson], accounting for about 12% of the observed genetic resistance. Meyer (2) showed that agronomic properties can also be altered by cytoplasms. Lint yields were generally lower in two cultivars with exotic cytoplasms than with upland cytoplasm.

Present information suggests that all upland cottons (*Gossypium hirsutum* L.) grown in the United States have one common cytoplasm. Stephens et al. (3), in their review of the genetic vulnerability of cotton, indicated that it is entirely possible that no significant cytoplasmic differences exist in upland cotton. In general, cytoplasmic effects of cotton have only been studied in connection with male sterility and hybrid cotton. The widespread similarity of cytoplasms and nuclear germplasm may be in part responsible for the leveling off of yield in cottons.

The uniformity of upland cytoplasm suggests that cotton researchers should expand the study and development of exotic cytoplasm. The objective of the study reported in this paper was to investigate the effects of five exotic cytoplasms on yield, yield components, fiber properties, and resistance or tolerance to the following pests: tarnished plant bug (*Lygus lineolaris* Palisot de Beauvois); whitefly (*Trialeurodes abutilonea* Haldeman); leafhopper (*Empoasca* spp.); tobacco budworm (*Heliothis virescens* F.).

MATERIALS AND METHODS

An interspecific *Gossypium* hybridization program was started at Stoneville, Miss. in 1955. Whenever possible, the exotic species was used as the female parent and *G. hirsutum* was used as the male. We maintained five species as maternal parents in a backcross program with *G. hirsutum* males. The five species were *G. herbaceum* L., *G. arboreum* L., *G. anomalum* Wawra ex Wawra & Peyr., *G. barbadense* L., and *G. tomentosum* Nutt. ex Seem. In this paper the five species are referred to by their respective genome designations, A_1, A_2, B_1, AD_2, and AD_3.

Originally, backcrosses with *G. hirsutum* were made with various cultivars and with breeding stock M8. After an average of 3.5 backcrosses to various cultivars, a more specific backcross program was started involving five cultivars. Table 1 gives the average and total number of backcrosses to cultivars of *G. hirsutum*. From 20 to 40 plants were grown in each cycle of the backcross program. Plants were selected for productivity and cultivar type in each cycle. We maintained our own cultivar strain for backcross purposes until the last backcross. Then breeders' seeds of each cultivar were reintroduced into the backcross program.

Table 1. Average and total number of backcrosses to each cultivar and total number to *G. hirsutum*.†

	Genome				
Cultivar	A_1	A_2	B_1	AD_2	AD_3
B 3080	5(6)	7(13)	6(12)	5(7)	5(11)
Coker 201	4(7)	4(10)	4(13)	4(8)	4(7)
Delcot 277	6(7)	7(9)	7(13)	6(8)	6(7)
Stoneville 213	5(6)	5(11)	6(12)	5(7)	5(5)
Deltapine 16	6(7)	8(14)	6(12)	6(8)	7(7)

† Total number of backcrosses to *G. hirsutum* indicated in parentheses.

[1] Contribution from USDA-SEA-AR, Delta States Agric. Res. Ctr., and Delta Branch Exp. Stn., Stoneville, MS 38776. Mississippi Agric. and For. Exp. Stn. Journal Paper No. 4050. Received 29 Jan. 1979.

[2] Research geneticist, Cotton Physiology and Genetics Laboratory; geneticist, Delta Branch Exp. Stn.; plant physiologist and entomologist, Cotton Physiology and Genetics Laboratory, Stoneville, MS 38776, respectively.

Table 2. Mean squares for lint yield, yield components, and fiber properties for five cultivar types as influenced by cytoplasms for six *Gossypium* spp.

Source	df†	Lint yield	Lint‡	Boll size‡	Seed index‡	Span length‡ 50%	Span length‡ 2.5%	Strength	Elongation‡	Micronaire§
		kg/ha	%	g		mm		mN/tex	%	
Insects = I	1	5,800	566	535**	1,228**	2,787**	4,182**	550**	0	1,774**
Repetitions	4	119,773**	800*	29	215*	188	354**	474**	106**	168
Cultivars = V	4	424,917**	6,765**	542**	4,677**	600**	2,052**	20,079**	6,938**	6,410**
IV	4	27,467	465*	8	47	26	86	128	22	134
Error a	16	12,915	154	18	33	25	111	64	16	126
¶AD, vs. Exotic = C	1	189,148**	273*	20	44	1	2	1	65*	333**
Genomes = G	4	89,910**	55	19	37	10	83*	84	23	94**
CG	4	53,502**	165	6	101**	25	137**	41	29	87**
IC	1	1,731	5	15	2	1	4	15	21	2
IG	4	6,324	17	8	18	7	17	25	5	40
ICG	4	1,890	40	14	25	7	4	44	12	35
VC	4	29,231**	86	54**	71*	19	12	40	7	11
VG	16	18,710**	237**	23*	59**	34**	45	34	15	31
VCG	16	8,155*	250**	27**	78**	16	48*	82**	18	51*
IVC	4	7,581	143	5	21	10	14	46	4	4
IVG	16	6,774	62	14	46*	21	23	37	10	27
IVCG	16	2,719	100	12	13	15	35	42	15	41
Error b	180	4,558	84	11	22	14	28	36	16	25

* and ** indicate statistical significance at the 0.05 and 0.01 levels of probability, respectively. † Degrees of freedom for lint yield sources are: Repetitions = 8; error a = 32; and error b = 360. ‡ Mean squares × 100. § Mean squares × 1,000. ¶ Nine df for treatments partitioned into: 1 for AD_1 used as female vs. male parent; 4 df for genomes and 4 df for interaction.

The last backcrosses were made in 1976 with a minimum of 20 plants crossed with each of the five cultivars. Reciprocal crosses were also made with the same plants. Plants of the 50 crosses and five recurrent parents were grown in Iguala, Mexico in 1976-77. Selfed seeds from Iguala were used for the 1977 research.

We grew the 50 hybrid populations and five cultivars at Stoneville, Miss. in 1977. For each cultivar, the five cytoplasms, their five reciprocal crosses, and two entries of the cultivar itself were grown in a block of 12 subplots. The experimental design was a split-plot with cultivars being whole plots. We did not use the performance of the commercial cultivars in the analyses of variance (Table 2).

The 55 entries were grown in two insect environments. The "with" plant-bug environment consisted of four rows of mustard [*Brassica juncea* (L.) Czern. & Coss.] interplanted with 20 rows of cotton. Data were taken from the middle 12 rows and the remaining eight rows were used as border. Large numbers of tarnished plant bugs were attracted to and increased on the mustard. Plant bugs migrated from the mustard to the cotton, thus providing large numbers of plant bugs on the cotton. The treatment "without" tarnished plant bug environment was achieved by five weekly applications of dicrotophos (dimethyl phosphate ester with (E)-3-hydroxy-N, N dimethylcrotonomide)[a] at 115 g/ha beginning about 15 June. These plots were located 25 m from the "with" plots. Mustard was planted 11 April and the cotton was planted 29 April. Five replications of the 50 crosses and five recurrent parents were grown in both the "with" and "without" environments.

Individual plot size for subplots was one row 1 × 6.9 m. Yield components were determined from 50-boll samples taken from three replications of both insect environments. Tarnished plant bug numbers were estimated from the "with" and "without" treatments by use of a De Vac[a] sampler. Each treatment was sampled seven times beginning on 7 June and ending on 21 July 1977. One each date samples from 3.4-m^2 areas were taken from 11 random spots within both the "with" and "without" treatments. No attempt was made to distinguish possible differences among cultivars or cytoplasms. Fiber properties from the ginned lint of these samples were determined at the Cotton Fiber Laboratory, SEA, USDA, at Knoxville, Tenn. The plots were hand picked for yield determinations.

Seeds from the 10 1977 Deltapine 16 cytoplasmic populations and the two entries of the cultivar, Deltapine 16, were used for 1978 plantings. Twelve plots were replicated six times at each of two Stoneville locations. Plot size was two 1-m rows, 15.2 m long. The plots were hand harvested for yield determinations. From one location, De Vac[a] samples from 7.9 m of row length were taken three times from six replications. From these samples, population numbers of tarnished plant bug, white fly, and leafhopper were estimated.

Tobacco budworm larvae were fed squares (young flowerbuds) obtained from the 12 entries grown at the second location. About 1 to 3 days before anthesis, squares from the field plots were harvested and brought to the laboratory. For each entry, individual squares were placed in 20 cups. Three first instar larvae were placed in each cup. The cups were placed in a growth chamber in the dark at 27 C and the larvae were allowed to feed for 3 days. After 3 days the larvae were thinned to one per cup, fresh squares were added, and the cups were returned to the growth chamber. Larvae were transferred to fresh squares again on the 5th day. After 7 days, the larval weights were determined. Three separate tests were conducted at weekly intervals in August 1978. An average of 48 larvae were weighed per entry over the three test periods. In a fourth test on the AD_3 × Deltapine 16 and its reciprocal, 53 and 55 larvae, respectively, were weighed at the end of 7 days.

RESULTS AND DISCUSSION

The basic assumption underlying this study is that reciprocal differences primarily reflect cytoplasmic effects. Although non-cytoplasmic effects can result in reciprocal differences, many of the noncytoplasmic effects should have been lost after an average of 10 backcrosses into upland backgrounds. The selection for fertility and productivity during the backcross program may also have prevented the various populations from being truly isogenic with the cultivars used as reference populations. However, this factor should not have affected reciprocal crosses, because the same plants were used as both male and female. Repeated backcrossing to specific cultivars merely assures the researcher of the predominant genetic background into which cytoplasms are transferred.

The "with" and "without" insect enhanced environments, respectively, averaged 7,045 and 1,972 tarnished plant bugs/ha/date of sampling. Large mean squares (Table 2) attributable to insect environments were de-

[a] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the USDA, and does not imply its approval to the exclusion of other products that may also be suitable.

Table 3. Lint yield of five cultivars as influenced by cytoplasms from six *Gossypium* spp.

Cross	1977 B 3080	Coker 201	Delcot 277	DPL 16	Stoneville 213	Avg.	1978 DPL 16
Female × Male	kg/ha						
$A_1 \times AD_1$	601	683	606	680	689	652	527
$AD_1 \times A_1$	592	683	565	755*	713	662	759**
$A_2 \times AD_1$	498	468	528	492	659	529	565
$AD_1 \times A_2$	559*	669**	574	712**	706	644	788**
$B_1 \times AD_1$	578	602	615	730	650	635	545
$AD_1 \times B_1$	585	688**	604	748	706	666	795**
$AD_2 \times AD_1$	569	665	608	734	706	656	742
$AD_1 \times AD_2$	567	666	560	748	719	652	749
$AD_3 \times AD_1$	571	626	552	752	648	630	789
$AD_1 \times AD_3$	597	645	582	829*	713*	673	803
Cross avg.	572	640	579	718	691	640	706
Cultivar (check)	333	704	586	692	691	601	785
Exotic cytoplasm	563	609	582	678	670	620	634
AD_1 cytoplasm	580	670	577	758	711	659	779

L.S.D. = 59 and 78, respectively, at 0.05 and 0.01 probability level for any two 1977 specific cross means within a column and 77 and 102, respectively, for 1978 means. * and ** indicate significantly higher yield of a given hybrid than its reciprocal at the 0.05 and 0.01 probability levels, respectively.

Table 4. Insect numbers and *H. virescens* larval weights as influenced by cytoplasms from six *Gossypium* spp.

Genetic type	Plant bug	White fly	Leaf-hopper	Larval wt. 26 July	2 Aug.	9 Aug.	Avg.†
	No./ha			mg/7 days			
$A_1 \times$ DPL 16	383	8,975	2,058	50.3	50.6	42.8	47.7(53)
DPL 16 × A_1	359	9,693	2,752	56.3	40.4	44.0	46.9(50)
A_2 DPL 16	311	9,215	3,135*	43.6	46.0	59.0	51.3(39)
DPL 16 × A_2	335	11,249	4,859	44.0	55.3	43.4	47.7(52)
$B_1 \times$ DPL 16	287	7,779	3,806	65.8	52.9	47.0	55.4(47)
DPL 16 × B_1	263	9,683	3,279	54.0	48.5	30.8	45.1(41)
$AD_2 \times$ DPL 16	279	9,693	3,087	64.2	55.1	58.6	59.4(52)
DPL 16 × AD_2	311	11,369	3,542	33.5	59.5	58.4	51.0(51)
$AD_3 \times$ DPL 16	383	6,821	5,050	45.6	37.9	38.5	40.4(46)*
DPL 16 × AD_3	311	10,651	2,968*	52.5	53.4	78.2	61.1(49)
DPL 16 cultivar	419	8,199	3,136	50.4	56.1	55.1	53.8(104)
L.S.D. 0.05	N.S.	N.S.	1,627				14.2

* Indicates significantly lower than its reciprocal cross at the 0.05 level of probability.
† Total number of larvae weighed per treatment indicated in parentheses.

tected for boll size, seed index, 50 and 2.5% span length, strength, and micronaire. The only interaction detected with insect levels of any possible importance was the cultivar × insect interaction for lint percentage (Table 2). The interaction is primarily related to Stoneville 213 populations having a higher lint percentage in the "with" than in the "without" environments; 37.0 vs. 36.0%, respectively. For the other cultivars, the average lint percentage was 34.65 vs. 34.68%, respectively. A significant ($P<0.10$) cultivar × insect environment interaction for lint yield is suggested and is primarily related to the greater sensitivity of the Coker 201 populations to plant bugs. The average yield of the Coker 201 population was 46 kg/ha lower in the "with" than in the "without" environments. Average yield of the four other cultivars was 642 and 638 kg/ha in the "with" and "without" environments, respectively. No significant insect environment × cytoplasm (C) interactions (IC, ICG, IVG, and IVCG in Table 2) were detected.

Highly significant cultivar mean squares were detected for all nine characteristics measured, indicating the five cultivars studied represent a broad genetic background. Statistical significance due to cytoplasms or interactions with cytoplasms were detected for all yield components and four of the five fiber properties. However, the magnitudes of these sources of variability were small relative to that of cultivars. For example, significant "F" values for cultivars ranged from 18 for 2.5% span length to 434 for elongation. For cytoplasms or interactions with cytoplasms, F values ranged from 2.2 for strength to 13.3 for micronaire. Micronaire averages of 3.98 and 4.05 for the exotic and AD_1 cytoplasms, respectively, are significantly different using "Error b" for L.S.D. computations. For yield components and fiber properties, the detectable significant differences due to cytoplasms or interactions with cytoplasms were generally less than 2% of the characteristic's mean. While small values such as these may be important in an applied breeding program, the values do not suggest any major breeding problems.

Yield was the characteristic most influenced by cytoplasm. The degree of cytoplasmic expression varied with cultivar background (Table 3). The A_2 cytoplasm had the greatest effect, decreasing average 1977 yield 18% or 115 kg/ha. Hybrids from all five cultivars with A_2 cytoplasm had lower yields than their reciprocals. Yield decreases were statistically significant for three cultivars, B3080, Coker 201, and Deltapine 16. High temperature will cause some male sterility in A_2 cytoplasm populations. Thus, A_2 cytoplasm influ-

ences yield to a great degree. Four other significant differences between reciprocal populations were observed in 1977. The lines derived from *G. hirsutum* cytoplasm were significantly higher in yield than those from the reciprocal crosses of A_1 × Deltapine 16, B_1 × Coker 201, AD_3 × Deltapine 16, and AD_3 × Stoneville 213.

Although exotic cytoplasms in general tended to decrease lint yield, the decrease was not consistent for all cultivars. The average decrease in yield in 1977 was 80, 61, 41, 17, and −5 kg/ha for Deltapine 16, Coker 201, Stoneville 213, B3080, and Delcot 277, respectively. In 1978 the decrease in yield was 145 kg/ha for Deltapine 16. Compatible interactions of exotic cytoplasms and nuclear genes apparently are possible with AD_1. These results suggest that a black-up cytoplasm could be developed in cotton.

In 1977 the yield of Deltapine 16, AD_1 × AD_3, was 829 kg/ha. This value was significantly higher than that for any other Deltapine 16 population, including the commercial cultivar at 692 kg/ha. In 1978, AD_1 × AD_3 was also the highest yielding entry but it did not yield significantly more lint than the Deltapine 16 check. In appearance, yield components, and fiber properties, the AD_1 × AD_3 Deltapine 16 population did not differ from Deltapine 16. We can only speculate on the cause of the favorable yield response. Apparently, selection of individual plants during the backcross process was effective for increased yield. These results also suggest that the nuclear genes, transferred either from *G. tomentosum* or from some upland strain, are very compatible with the Deltapine 16 cytoplasm and nuclear genes.

The cytoplasm populations of B3080 outyielded the B3080 cultivar. B3080 is an Acala type developed in New Mexico that is late in maturity under Stoneville conditions. During the first backcrosses an early matupring selection of B3080 was used. The last backcross was made with B3080 Breeders' seed.

The results of the 1978 insect sampling study of Deltapine 16 populations are given in Table 4. No significant differences in numbers of plant bugs and white flies were detected. The A_2 cytoplasm had significantly fewer leafhoppers than its AD_1 isoline. However, the average number of leafhoppers for the A_2 cytoplasm was not different from that of the cultivar Deltapine 16. Therefore the cytoplasmic difference was apparently of no practical value. Significantly more leafhoppers were detected on the AD_3 cytoplasm plants than on those of its AD_1 isoline or of Deltapine 16.

Average larval weights after 7 days are given in Table 4. The average larval weight on the AD_3 cytoplasm was significantly lower than that for its AD_1 isoline reciprocal and for the Deltapine 16 check (the L.S.D. for comparing the AD_3 cytoplasm and Deltapine 16 was 12.9 mg). A second larval feeding study involving only AD_3 and its AD_1 isoline resulted in larval weights of 60.4 and 92.5 mg, respectively. Thus, an average weight reduction of 35%, attributable to the AD_3 cytoplasm in these studies represents a major potential for breeding improved resistance to tobacco budworm in cotton.

These results are the first in cotton to indicate that cytoplasm may have a major influence on at least two insect pests, leafhopper and tobacco budworm. The AD_3 cytoplasm resulted in increased numbers of leafhoppers and decreased weights of tobacco budworm larvae. Other characteristics in cotton that have a positive effect on control of one insect pest but a negative effect on another are smooth leaf, frego bract, and high gossypol.

REFERENCES

1. Mahill, J. F., and D. D. Davis. 1978. Influence of male sterile and normal cytoplasms on the expression of bacterial blight in cotton hybrids. Crop Sci. 18:440-443.
2. Meyer, V. G. 1973. A study of reciprocal hybrids between upland cotton (*Gossypium hirsutum* L.) and experimental lines with cytoplasms from seven other species. Crop Sci. 13:439-444.
3. Stephens, S. G., C. F. Lewis, and T. R. Richmond. 1972. Cotton. p. 270-281. *In* Genetic vulnerability of major crops. NAS, Washington, D. C.