Published July, 1973

A Study of Reciprocal Hybrids Between Upland Cotton (*Gossypium hirsutum* L.) and Experimental Lines with Cytoplasms from Seven Other Species[1]

Vesta G. Meyer[2]

ABSTRACT

Genetically or cytoplasmically uniform crops may be vulnerable to disastrous pest infestations. Upland cotton (*Gossypium hirsutum* L.) cytoplasm is present in most of the cotton cultivars grown commercially in the U.S. However, experimental breeding material has been developed from Upland cotton hybrids with cytoplasms from seven other species of *Gossypium*. The most uniform and productive progenies within each of these seven cytoplasms were selected for making reciprocal backcrosses to Upland cotton cultivars. Backcrosses with cytoplasm from two tetraploid species (*G. barbadense* L. and *G. tomentosum* Nutt.) showed no significant differences from their reciprocal hybrids with Upland cytoplasm, but similar backcrosses with cytoplasm from each of the five diploid species (*G. herbaceum* L., *G. arboreum* L., *G. anomalum* Wawra & Peyr., *G. harknessii* Brandagee, and *G. longicalyx* Hutchinson and Lee) differed significantly from their reciprocal hybrids.

Additional index words: Biological resistance, Cotton germplasm, Interspecific breeding, Genetic diversity.

THE increasing homogeneity of major crop plants has caused widespread concern because of the potential vulnerability of a genetically uniform population to precisely adapted mutant pathogens or insects. The recent epiphytotic of corn (*Zea mays* L.) leaf blight caused by *Helminthosporium maydis* Nisikado & Miyake (perfect stage *Cochliobolus heterostrophus* Drechsler) showed that cytoplasmic diversity may be as important as dissimilar nuclear genes. Many papers have emphasized the need for maintaining cytoplasmic and genetic diversity, among them Harlan's "Genetics of Disaster" (1972), and "Genetic Vulnerability of Major Crops" from the National Research Council (1972). A wide choice of cytoplasms for use in crop improvement exists for only a few crops. Cytoplasmic breeding material is available in experimental agronomic stocks from several different species for wheat (*Triticum aestivum* L.) (Maan and Lucken, 1972), tobacco (*Nicotiana tabacum* L.) (Chaplin and Ford, 1965), and potato (*Solanum tuberosum* L.) (Grun, Aubertin, and Radlow, 1962); only a few species have furnished cytoplasm for corn hybrids, but cytoplasmic effects on agronomic characters have been studied by Fleming and Campbell (1966), Hunter and Gamble (1968), and Garwood et al. (1970), among others. Since 1955 we have been developing and maintaining interspecific hybrids with the Upland cotton (*Gossypium hirsutum* L.) genome being transferred into cytoplasm of other species, as one part of the interspecific transfer program. In

[1] Contribution from the Delta Branch, Mississippi Agricultural and Forestry Experiment Station, Stoneville, Mississippi 38776. MAFES Journal Paper No. 2528, Projects S-77 and MIS-2119. Received Jan. 22, 1973.

[2] Associate Geneticist, Mississippi Agricultural and Forestry Experiment Station.

1971 we were asked to prepare to release germplasm stocks with all of the seven available cytoplasms from other species, so that breeders of American Upland cotton could use them. We selected the most uniform and productive progenies within each cytoplasm, disregarding the number of generations of selfing, backcrossing, or outcrossing. This paper reports the performance of reciprocal backcrosses to the commercial cultivars 'Deltapine 16' and 'Delcot 277' from each of these selected cytoplasmic stocks. The basic genetic assumption is that most or all cytoplasmic differences are maternally inherited. The experiment described below was designed to determine whether or not significant differences in agronomic properties would occur between reciprocal backcrosses involving stocks developed from a wide range of *Gossypium* species.

MATERIALS AND METHODS

In 1971 at Stoneville, Mississippi, reciprocal crosses were made in the field between Upland cotton cultivars and seven experimental lines with cytoplasm from other species of cotton. This hybrid seed was sent to Iguala, Mexico, where pollen from the same commercial varieties was used to produce backcrosses from each of the reciprocal hybrids. These backcrosses were grown in the field at Stoneville during 1972 as part of a randomized split-plot design. Each plot consisted of one row 7.5 m long and 1 m apart, with plants spaced about 30 cm apart. Culture and insecticide applications were the same as for the cotton yield plots on the Delta Branch Experiment Station. Two replications consisted of the commercial variety Delcot 277, the seven parental experimental lines, the 14 backcrosses to Delcot 277 grown as seven pairs of rows (the two members of each pair differing in cytoplasm but otherwise of the same pedigree), and one nonreciprocal backcross from a completely male-sterile stock. The other two replications of 23 entries had Deltapine 16 as the Upland cultivar parent.

The description of the seven experimental lines used as parents is given by genome symbol, name of the species furnishing the cytoplasm, and pedigree or description of the stock used for reciprocal backcrosses with Upland cotton. Five of the original speciees were diploid (*G. herbaceum* L., *G. arboreum* L., *G. anomalum* Wawra & Peyr., *G. harknessii* Brandagee, and *G. longicalyx* Hutchinson and Lee); and the three tetraploid species were *G. hirsutum* L., *G. barbadense* L., and *G. tomentosum* Nutt. Saunders' *The Wild Species of Gossypium* (1961) was authority for the nomenclature.

A_1: *G. herbaceum* — An androgenetic hybrid resulted from pollinating the *G. herbaceum* collection 'A_1-6' with pollen from a (*G. hirsutum* 'M8' × *G. anomalum*) hexaploid. The hybrid did not have either the *G. herbaceum* yellow flower or the B_1 petal spot. The seedling was crossed with 'Stoneville 7A' pollen and selfed for two generations.

A_2: *G. arboreum* — The trispecies hybrid (*G. arboreum* × *G. thurberi* Tod.) × *G. hirsutum* was backcrossed for five generations to *G. hirsutum* M8, and then selfed or crossed with its B-line (Meyer, 1970a) for seven generations. Because this experimental line is highly (sometimes completely) male-sterile, it is maintained either by selfing the occasional partially fertile flowers, or by using pollen from the male-fertile B-line, which carries the same genotype in *G. hirsutum* cytoplasm.

B_1: *G. anomalum* — A trispecies hybrid, (*G. anomalum* × *G. thurberi*) × *G. hirsutum,* was handled exactly as described for the experimental line with *G. arboreum* cytoplasm.

D_{2-2}: *G. harknessii* — A presumably triploid F_1 hybrid, *G. harknessii* × *G. hirsutum* M8, produced two seeds after pollination with *G. hirsutum* 'Rowden.' Some third backcrosses to M8 produced completely male-sterile progenies; these were outcrossed to Deltapine 16 and Delcot 277, and then backcrossed to the same cultivars, for the unpaired male-sterile rows. Other third backcross progeny rows segregated for fertility and sterility. Plants in the completely male-sterile rows were used as female parents for crosses with plants in a segregating row; some of the male-fertile plants produced from this cross were used for reciprocal crosses with Delcot 277 and Deltapine 16 in 1971.

F: *G. longicalyx* — A presumably triploid F_1 hybrid, *G. longicalyx* × *G. hirsutum* M8, produced a single seed after pollination with M8. The seedling was backcrossed to M8; the experimental line was crossed for two generations with Stoneville 7A before it was used for reciprocal crosses in 1971.

AD_2: *G. barbadense* — A relatively vigorous and productive first backcross plant [(*G. barbadense* 'Coastland 401' × *G. hirsutum* M8) × M8] was selected, and selfed for three generations to produce the experimental line used for reciprocal crosses.

AD_3: *G. tomentosum* — Among the several available progenies with *G. tomentosum* cytoplasm, one was selected which had reasonable vigor and lacked recessive characteristics such as virescent or dwarf plants. This particular progeny was from (*G. tomentosum* × *G. hirsutum* M8), BC_4 to M8, crossed with the B-line for the male sterility controlled by *G. anomalum* cytoplasm. It was selfed for three generations before its selection in 1971 as a parent for reciprocal crosses.

A summary is given in Table 1.

The individual plants were measured on June 30, and the mean height was calculated for each row.

With one exception, boll and fiber data were obtained from composite samples consisting of one open-pollinated boll from each plant in the row. Because the progeny rows with *G. harknessii* cytoplasm had many male-sterile plants and few open-pollinated bolls, their composite lint samples were assembled from one boll from each plant; frequently crossed bolls had to be used. Fiber tests were conducted by the Fiber Laboratory of the Delta Branch, Mississippi Agricultural and Forestry Experiment Station, Stoneville, Mississippi.

The nine single-row and 14 paired-row entries were randomized together within each replication. Data from the experiment were studied by subdividing the analysis of variance into four replications of nine single-row plots and seven pairs of reciprocal hybrids (split plots). The single-row and paired-row plots were analyzed separately within the analysis. Least Significant Difference (LSD) was calculated from the error (c) for the paired-row split plots and used to test differences between means of the reciprocal hybrids from the same cross. The two parent cultivars produced similar hybrids from the various crosses; overall means were different for some properties, but there were no significant cultivar × cross interactions. Replication sums of squares were subdivided (Table 1) only if there were significant differences between replications.

RESULTS AND DISCUSSION

Germplasm stocks were developed to supply breeders with the cytoplasms of seven other species of American Upland cotton. The experiment described in this paper was designed to answer just one question about these stocks: Would reciprocal crosses from all, some, any, or none of them differ significantly in any agronomic characteristic? Tables 2 and 3 indicate that significant differences do occur within some sets of reciprocal backcrosses. Table 2 summarizes the analyses of variance for plant, boll, and fiber proper-

Table 1. Summarized pedigrees of Upland-type parents with cytoplasms of seven other species of *Gossypium.*

Genome symbol	Species furnishing cytoplasm	Total backcrosses to Upland	Total selfs	Expected* % heterozygosity from donor species
A_1	G. herbaceum†	1	2	4.17
A_2	G. arboreum	5	7	0.012
B_1	G. anomalum	5	7	0.012
D_{2-2}	G. harknessii	3	1	2.083
F	G. longicalyx	4	0	2.083
AD_2	G. barbadense	1	3	3.125
AD_3	G. tomentosum	4+	3	0.422

* Assuming regular chromosome distribution and no selection. † From androgenetic seedling with no genetic markers from diploid species.

Table 2. Analyses of variance for agronomic and fiber properties of Upland cotton, seven experimental lines with cytoplasm from other species, and reciprocal backcrosses between Upland cotton and the experimental lines.

Source of variation	df	Mean squares: Stand at 50 days	Height at 50 days, cm	Lint/ha $\times 10^{-3}$, kg	Seed cotton/ boll, g	g/100 seeds	Lint/100 seeds, g	Lint, %	No. of seeds/boll	Fiber length $\times 10^4$	Fiber strength, T_1	Fiber elonga- tion, E_1	Micro- naire
Single rows vs paired rows	1	110.00	27.95	3,731	39.4147	2.04	8.90	49.33	733.88	306	12.2629	13.51	9.8281**
Single row entries													
btw. entries	8	2.38	217.58**	345**	3.7636**	3.78**	1.65**	40.84**	67.67**	47.25**	4.0637*	1.38*	0.4108**
replications	3	19.33*	32.71*	39*	0.6572*	0.32	0.02	0.82	35.09**	1.33	2.3075*	0.15	0.3081
Error a	24	6.21	9.28	11	0.1542	0.52	0.16	0.44	7.40	4.54	0.7783	0.42	0.1135
Paired row entries													
Crosses	6	36.67*	332.03**	129**	1.2192**	2.43**	0.75**	26.02**	16.57**	10.00	2.6755	0.51	0.1089
Replications	3	21.67	39.58		0.1357							0.44	
btw. Delcot 277 & Deltapine 16	(1)			0		31.80**	0.74*	74.98**	52.41**	60.00**	16.2111**		9.8281**
within Delcot 277	(1)			197*		2.89*	1.69**	0.19	23.40**	11.00	6.2323**		0.0309
within Deltapine 16	(1)			9		0.69	0.00	4.73	0.19	47.00**	0.7167		0.1170
Error b	18	9.22	22.70	25	0.1938	0.53	0.11	3.14	3.54	5.67	0.5889	0.54	0.0553
Subplots													
Cytoplasm (AD$_1$ vs "other")	1	45.00*	189.44**	1,078**	4.1474**	2.83*	0.12	7.57*	71.55**	2.00	0.1840	0.98	0.0849
Cross × cytoplasm	6	19.00*	74.76*	165**	1.2932**	2.66**	0.86**	26.26**	13.73**	9.17*	0.2207	0.44	0.0907
Error c	21	6.05	11.20	10	0.1218	0.37	0.10	1.74	2.74	3.38	0.5142	0.26	0.0769

* F value significant at 0.05 probability level. ** F value significant at 0.01 probability level.

ties. Table 3 shows the means for the parents and hybrids.

The one basic genetic assumption underlying this study is that cytoplasm generally is maternally inherited. This assumption is supported by the inheritance of cytoplasmic-genetic male sterility in other crops, as well as in experimental cotton lines related to some of the stocks used in this experiment. However, except for the completely male-sterile stocks from *G. harknessii*, the experimental materials and breeding procedures were chosen to minimize or eliminate male sterility in this experiment. In developing the germplasm lines the objective was to release the stocks least likely to reduce yield or other important agronomic characters if the releases were used in a breeding program.

Up to this time there has been no published information concerning the agronomic properties of Upland cotton breeding stocks with cytoplasms from the diploid species of *Gossypium*. Information about stocks with cytoplasms from the tetraploid species is scant. However, there are reports concerning male sterility and flower development in association with cytoplasms from the various species. Because some of the cytoplasms used in this study had never been evaluated as possible agronomic material, two replications each from crosses with two commercial varieties seemed more desirable than the alternative, four replications from one variety.

Before flowering began, the progeny rows showed some obvious differences in height. The only significant differences detected were between the hybrids with *G. harknessii* and *G. longicalyx* cytoplasm and their taller, more vigorous reciprocal hybrids.

Gossypium herbaceum cytoplasm affects anther number in roughly the same way as cytoplasms from the other African and Asian species studied; anther number is much lower than in reciprocal hybrids with cytoplasm from a tetraploid species (Meyer, 1971; Rhyne, 1965). A partial male sterility was present in some early-generation derivatives of the original androgenetic seedling. Because the sterility was weaker and more variable than those associated with other cytoplasms, it was not isolated as breeding material. In this study the only significant effects of *G. herbaceum* cytoplasm were higher lint index (more lint/seed) and shorter lint.

G. arboreum cytoplasm was one of the first found

Table 3. Means for agronomic and fiber properties of Upland cotton, seven experimental lines with cytoplasm from other species, and reciprocal backcrosses between Upland cotton and the experimental lines.

Parents: Species cyto- plasm tested	Ge- nome sym- bol	Reciprocal crosses cytoplasm of ♀ parent × ♂ parent	Stand at 50 days	Height at 50 days, cm	Lint/ha, kg	Seed cotton/ boll, g	Seed in- dex, g/ 100 seeds	Lint index, g lint/ 100 seeds	Lint, %	No. of seeds/ boll	Fiber: Length, fibrograph, 0.025	Fiber: Strength, T_1	Fiber: Elon- gation, E_1	Fiber: Micro- naire
G. hirsutum	AD$_1$		27.75	46.40	1,080	6.47	12.08	7.90	39.53	32.25	1.17	21.31	8.53	4.86
G. herbaceum	A$_1$		26.75	52.98	643	4.65	10.35	7.00	39.20	25.83	1.10	19.44	7.85	4.85
		AD$_1$ × A$_1$	31.25	53.35	1,131	6.13	11.53	7.38	39.00	32.10	1.16	21.03	8.40	4.81
		A$_1$ × AD$_1$	28.75	50.65	988	6.14	11.85	8.02**	40.38	30.18	1.12**	20.99	8.98	5.00
G. arboreum	A$_2$		26.50	44.00	358	3.53	10.90	6.73	38.15	20.00	1.10	21.07	8.10	4.76
		AD$_1$ × A$_2$	32.75	51.38	1,117	6.26	12.40	7.97	39.13	30.85	1.16	21.68	8.33	4.79
		A$_2$ × AD$_1$	30.00	49.55	917*	6.25	12.40	8.02	39.30	30.28	1.17	21.35	8.70	4.83
G. anomalum	B$_1$		27.50	49.45	426	3.59	12.38	5.76	31.73	19.70	1.11	22.67	7.20	5.17
		AD$_1$ × B$_1$	32.75*	47.20	1,093	6.40	12.25	7.43	37.78	32.18	1.16	21.64	8.53	4.75
		B$_1$ × AD$_1$	28.50	42.92	877**	5.99	12.03	7.70	38.98	30.15	1.16	21.86	8.53	4.80
G. harknessii	D$_{2-2}$		26.25	41.05	177	3.83	11.08	7.02	38.90	20.00	1.11	21.10	7.93	4.57
		AD$_1$ × D$_{2-2}$	29.25	45.58	1,157	6.44	12.58	7.78	38.25	31.48	1.14	22.25	8.30	4.88
		D$_{2-2}$ × AD$_1$	30.50	40.65*	435**	5.32**	12.30	6.34**	33.95**	27.75*	1.15	22.14	7.70	4.76
		♂sterile D$_{2-2}$ × AD$_1$†	27.00	58.90	205	5.17	13.68	6.62	32.63	25.25	1.18	20.48	7.68	5.18
G. longicalyx	F		28.50	39.10	592	4.99	11.18	7.69	40.70	26.05	1.10	20.37	7.30	5.41
		AD$_1$ × F	27.75	46.33	1,084	6.33	12.43	7.70	38.30	31.28	1.14	21.24	8.33	4.88
		F × AD$_1$	22.50**	30.73**	451**	4.21**	9.40**	7.85	46.05**	23.88**	1.15	21.60	9.13*	4.40*
G. barbadense	AD$_2$		27.50	56.95	682	4.74	12.33	7.48	37.75	23.55	1.08	21.93	6.50	4.58
		AD$_1$ × AD$_2$	26.25	50.93	1,032	6.36	12.43	7.92	38.93	30.93	1.16	22.76	7.98	4.69
		AD$_2$ × AD$_1$	29.75	55.55	1,066	6.22	12.38	7.78	38.60	30.55	1.17	22.47	8.55	4.53
G. tomentosum	AD$_3$		26.25	57.32	814	5.55	10.90	7.20	39.73	28.08	1.10	19.84	7.88	5.38
		AD$_1$ × AD$_3$	31.75	57.40	1,117	6.44	12.05	7.92	39.70	31.90	1.15	21.43	8.35	4.65
		AD$_3$ × AD$_1$	29.25	56.35	1,054	6.44	12.15	7.74	38.95	32.10	1.17	20.81	8.48	4.58
Significant differences btw. paired reciprocal crosses		LSD 0.05	3.62	4.92	150	0.51	0.88	0.47	1.93	2.43	0.03	1.05	0.75	0.41
		LSD 0.01	4.93	6.71	204	0.70	1.20	0.64	2.63	3.74	0.04	1.44	1.02	0.56

*, ** Indicates significant difference between reciprocal hybrids. † Crosses with completely male-sterile lines; no reciprocals possible.

to control a male-sterility in cotton (Meyer and Meyer, 1961). Although modifier genes undoubtedly influence it, the male sterility in this material is primarily due to a heat-sensitive gene more affected in *G. arboreum* than in Upland cytoplasm (Meyer, 1969). Some genes from *G. barbadense* are very effective for restoring male fertility to Upland hybrids with *G. arboreum* cytoplasm. Anther numbers are lower in this cytoplasm than in reciprocal hybrids with cytoplasm from tetraploid species (Meyer, 1965). Even though no male-sterile flowers were observed in any reciprocal backcross rows from this cytoplasm in 1972, lint yield was significantly lower when *G. arboreum* cytoplasm was present.

G. anomalum cytoplasm affects anther number and fertility much as does *G. arboreum* cytoplasm. The first cytoplasmically controlled male sterility described in detail for cotton had *G. anomalum* cytoplasm (Meyer and Meyer, 1965; Meyer, 1969, 1970a). This male sterility is very similar to that described for *G. arboreum* cytoplasm in its heat sensitivity and fertility restoration by genes from *G. barbadense*. The two cytoplasms also have similar effects on anther number. In addition to its effects on anther development, *G. anomalum* cytoplasm also permits other unusual aspects of plant development: changes in plant height, associated with unusual fiber strength (Meyer, 1968), and exposed ovules on petal margins and staminal columns (Meyer and Buffet, 1962; Meyer, 1970b). When the *G. arboreum* '$A_2$47' genome is transferred into *G. anomalum* cytoplasm, the anthers of the staminal column are replaced by petaloids (Meyer and Meyer, 1961). This indicates that A_2 and B_1 cytoplasms are dissimilar in some ways. Also, development of exposed ovules is suppressed or reduced when the "carpelloid petal" or "External Ovule" genes are transferred from *G. anomalum* to *G. arboreum* cytoplasms (Meyer, 1966 and unpublished data). The backcross rows in the 1972 experiment had significantly poorer stands associated with *G. anomalum* cytoplasm. Yield/plant was also lower, although the difference was not significant. Probably these two factors are primarily responsible for the highly significant decrease in yield associated with *G. anomalum* cytoplasm.

G. harknessii cytoplasm is the first from a wild American diploid species to be transferred into an Upland background. Unlike results with the African and Asian species, cytoplasm from this species produced anther numbers far higher than those developed in reciprocal hybrids with cytoplasm from the tetraploid species (Meyer, 1971). The first complete male sterility of cotton known to be under cytoplasmic control was developed from material with *G. harknessii* cytoplasm. Fertility restoration depends on isolating and maintaining one or more genes from *G. harknessii*. Completely male-sterile stocks can be maintained indefinitely by pollination with Upland cotton pollen; no Upland or *G. barbadense* varieties tested so far have fertility-restorer genes effective for the *G. harknessii* cytoplasmic male sterility. Differences in stand, seed index, and fiber properties were not significant, but backcrosses with *G. harknessii* cytoplasm were significantly below their reciprocals in plant height, yield, boll size, lint index, lint percentage, and number of seeds/boll.

G. longicalyx is an unusual species classified by itself in the F genome of *Gossypium* (Phillips and Strickland, 1966). Its cytoplasm affects anther number much as do those from the other three African and Asian species included in this study; anthers are much fewer than in reciprocal hybrids with tetraploid species (Meyer, 1972). Segregating material from this species includes completely male-sterile plants, plants that vary in male sterility from day to day, and productive, completely male-fertile plants; the genetic basis for the male sterility has not yet been determined. The general vigor of unselected populations with *G. longicalyx* cytoplasm is noticeably lower than in reciprocal hybrids; stands are poorer, there is more seedling disease, plants grow more slowly, and seeds are smaller and fewer. There is an interesting effect associated with *G. longicalyx* cytoplasm on lint development. Even though seed index is greatly reduced, lint index is at least as high as for the reciprocal backcross. This produces a very high lint percentage; fiber length and strength are the same, but fibers are finer and fiber elongation is greater. In spite of the reduced general vigor of progenies with *G. longicalyx* cytoplasm, some exceptionally productive individual plants and progenies occur.

The cytoplasms of the three tetraploid species studied, *G. hirsutum, G. barbadense,* and *G. tomentosum,* seem to be very similar. Previous studies (Meyer, 1965, 1971, 1972) showed that anther number is affected similarly by the cytoplasms of all three species; this experiment showed no significant differences between reciprocal hybrids with cytoplasms from tetraploid species for yield, boll characteristics, or fiber properties. In spite of a long history of cultivation over a wide range of environments and in enormous populations, Upland cotton cytoplasm seems to have produced few detectable variants. Kohel and Richmond (1963) found no variation for effects on male fertility by cytoplasms of 22 diverse Upland stocks. Kohel (1967) described a maternally inherited variegation in *G. hirsutum*; apparently a plastid mutation caused the condition. Ali and Lewis (1962) found small but significant differences between reciprocal F_1 populations from the cultivars *G. hirsutum* 'Deltapine 14' and *G. barbadense* 'Pima 32.' No significant differences were found between reciprocal first backcross progenies from this cross.

GENERAL DISCUSSION

Cytoplasmic transfer raises somewhat different problems for research and for practical plant breeding than does the transfer of nuclear genes from one species to another A research worker searching the literature for information about the agronomic characteristics associated with the available cytoplasms of cotton would find very little to help him. At present there are not enough data from this experiment, or any other, to draw more than tentative conclusions about the biological mechanisms responsible for the differences observed. However, examination of such data can suggest some alternative hypotheses, and can perhaps serve as a basis for planning future experiments to test them.

Each of the parent stocks was chosen because, of the material available within the cytoplasm, it had agronomic characteristics closest to Upland cotton. The most interesting question raised by these experimental results is whether the observed significant differences between the reciprocal hybrids are most likely to be due to the effects of cytoplasm or nuclear genes. At this stage of the transfer program neither alternative can be completely ruled out; they are not mutually exclusive. Obtaining other kinds of experimental data might be a more useful activity at this time than speculation based on insufficient information, but these two possibilities are not mutually exclusive either.

If differences in nuclear genes are responsible for the observed differences between reciprocal hybrids, at least three different mechanisms could be involved. (1) Different genes could be transmitted through the pollen rather than through the egg cells if chromosome abnormalities such as aneuploidy or inversions were present. Plants with such chromosome abnormalities characteristically have reduced general vigor and fertility. Selection of parent stocks for uniformity, vigor, and yield of seed cotton would make chromosome abnormalities unlikely, but not impossible, in these stocks. (2) Genetic drift can result if random distribution of segregating genes causes an allele to be present in some populations and absent in others. The chances of random drift depend on the frequency of heterozygous genes in the parents chosen for the reciprocal crosses and on the number of segregating plants used as parents. Estimation of probable heterozygous gene frequencies could be made with more confidence if there had been no selection, and if hybrids between dissimilar species of *Gossypium* were not known to be subject to the following: reduced transmission of genes from the donor species because of preferential gene segregation (Stephens, 1949); deviations from the expected ratios for segregation of genes from the diploid species (Phillips, 1962); spontaneous reduction of chromosome number (Brown, 1947); and production of androgenetic tetraploids when pollen of tetraploid species is used for crosses with Asiatic diploid species (Arutjunova, 1960). At the time that the reciprocal crosses were made, the "expected" genetic heterozygosity of genes from the donor species ranged from 0.012% in the most inbred parent to below 5% in the material with the fewest backcross and selfed generations (Table 1). These figures are probably exceedingly high, both for the reasons given above and because such estimates assume that selection for Upland characteristics did not affect the frequency of genes from other species. If genetic drift is responsible for the differences between the reciprocal hybrids, one would expect some properties for some of the crosses of Deltapine 16 and Delcot 277 to differ in opposite directions. This never happened. There were no significant interactions involving the two cultivars in this experiment. (3) A third possibility is that maternally inherited cytoplasmic differences affect the expression of the nuclear genes present in this material. This seems the most likely of the three alternatives, in view of the known effects of some of these cytoplasms on male fertility and anther development, and the probability that a very low percentage of genes from the donor species remains in some stocks with significant differences for some properties.

Whatever the true explanation for these differences may be, future research with these new germplasm stocks can be planned more efficiently with information than with ignorance about how they may affect agronomic properties. The possibility of differences between reciprocal hybrids from some of these stocks cannot be ignored in designing future experiments in which they will be used.

The obvious reason for developing, studying, and maintaining the widest possible range of germplasms for cotton and other crops is their potential usefulness in: resisting new pests, adapting to new cultural practices, furnishing male sterile stocks for possible use in producing hybrids, and providing chemical or morphological variations needed for future technology. Seven new germplasm stocks of cotton, some with cytoplasms not previously available to breeders of Upland cotton, have been developed. This report tabulates their agronomic properties and shows that some significant differences occurred between reciprocal backcrosses from these germplasm stocks and two commercial cultivars of Upland cotton.

REFERENCES

Ali, Mahbub, and C. F. Lewis. 1962. Effect of reciprocal crossing on cytological and morphological features of interspecific hybrids of *Gossypium hirsutum* L. and *G. barbadense* L. Crop Sci. 2:20-22.

Arutjunova, L. G. 1960. Interspecific hybridization in the genus *Gossypium* L. p. 3-71. *In* Questions of genetics, breeding and seed production in cotton. Uzbek Acad. Agr. Sci., Tashkent. (Plant Breeding Abstr. 1962. 32:895. Abstr. No. 5047).

Brown, Meta S. 1947. A case of spontaneous reduction of chromosome number in somatic tissue of cotton. Amer. J. Bot. 34:384-388.

Chaplin, James F., and Z. T. Ford. 1965. Agronomic and chemical characteristics of male-sterile flue-cured tobacco as influenced by cytoplasms of different *Nicotiana* species. Crop Sci. 5:436-438.

Fleming, A. A., and J. B. Campbell. 1966. Effects of male cytoplasm in a double-cross maize hybrid. Agron. Abstr. p. 6.

Garwood, D. L., Evelyn J. Weber, R. J. Lambert, and D. E. Alexander. 1970. Effect of different cytoplasms on oil, fatty acids, plant height, and ear height in maize (*Zea mays* L.). Crop Sci. 10:39-41.

Grun, Paul, Mary Aubertin, and Anne Radlow. 1962. Multiple differentiation of plasmons in diploid species of Solanum. Genetics 47:1321-1333.

Harlan, Jack R. 1972. Genetics of disaster. J. Environ. Qual. 1:212-215.

Hunter, R. B., and E. E. Gamble. 1968. Effect of cytoplasmic source on the performance of double-cross hybrids in maize, *Zea mays* L. Crop Sci. 8:278-280.

Kohel, R. J. 1967. Variegated mutants in cotton, *Gossypium hirsutum* L. Crop Sci. 7:490-492.

———, and T. R. Richmond. 1963. Tests for cytoplasmic-genetic interaction involving a genetic male-sterile stock of the genotype, ms_2ms_2. Crop Sci. 3:361-362.

Maan, S. S., and K. A. Lucken. 1972. Interacting male sterility-male fertility restoration systems for hybrid wheat research. Crop Sci. 12:360-364.

Meyer, James R., and Vesta G. Meyer. 1961. Cytoplasmic male sterility in cotton. Genetics 46:883. (Abstr.)

Meyer, Vesta G. 1965. Cytoplasmic effects on anther numbers in interspecific hybrids of cotton. J. Hered. 56:292-294.

———. 1966. The effect of *Gossypium arboreum* cytoplasm on expression of the gene for external ovules. J. Hered. 57:72.

———. 1968. An association between male sterility and fiber strength in hybrids of Upland cotton, *Gossypium hirsutum* L. Crop Sci. 8:117-118.

———. 1969. Some effects of genes, cytoplasm, and environment on male sterility of cotton (*Gossypium*). Crop Sci. 9: 237-242.

——— 1970a. Development of B-lines for two cytoplasmically controlled male sterilities of cotton. Crop Sci. 10:720-721.

———. 1970b. A facultative gymnosperm from an interspecific cotton hybrid. Science 169:886-888.

———. 1971. Cytoplasmic effects on anther numbers in interspecific hybrids of cotton. II. *Gossypium herbaceum* and *G. harknessii*. J. Hered. 62:77-78.

———. 1972. Cytoplasmic effects on anther numbers in interspecific hybrids of cotton. III. *Gossypium longicalyx*. J. Hered. 63:33-34.

———, and M. Buffet. 1962. Cytoplasmic effects on external-ovule production in cotton. J. Hered. 53:251-253.

———, and James R. Meyer. 1965. Cytoplasmically controlled male sterility in cotton. Crop Sci. 5:444-448.

National Research Council, Committee on Genetic Vulnerability of Major Crops. 1972. Genetic vulnerability of major crops. National Academy of Sciences, Washington, D.C.

Phillips, Lyle L. 1962. Segregation in new allopolyploids of *Gossypium*. IV. Segregation in New World × Asiatic and New World × Wild American hexaploids. Amer. J. Bot. 49: 51-57.

———, and M. A. Strickland. 1966. The cytology of a hybrid between *Gossypium hirsutum* and *G. longicalyx*. Can. J. Genet. Cytol. 8:91-95.

Rhyne, Claude L., Jr. 1965. Cytoplasmic inheritance of reduced androecium in cotton. J. Hered. 56.67-70.

Saunders, J. H. 1961. The wild species of *Gossypium* and their evolutionary history. Oxford University Press, London.

Stephens, S. G. 1949. The cytogenetics of speciation in *Gossypium*. I. Selective elimination of the donor parent genotype in interspecific backcrosses. Genetics 34:627-637.