PROGRESS REPORT ON HYBRID COTTON

R. F. Holland
Plant Breeding Research
College Station, TX
C. G. Cook
United Agri Products
Santa Rosa, TX

Abstract

Hybrid cotton and heterotic response in cotton has been studied for several years. Although hybrid cottons are planted on large acreages in India and China, no significant acreage is devoted to hybrid cotton in other cotton producing areas. In these studies several hand-pollinated cotton hybrids were evaluated for a 3-year period in Weslaco, TX, which is located in the Lower Rio Grande Valley and for a 2-year period at College Station, TX, which is located in the Brazos River Delta. The objectives of these studies were to identify superior yielding hybrids and to study various factors involved in heterotic response. The evaluated hybrids were developed by two independent programs and with the cytoplasmic male sterility system, which utilized the G*ossypium harknessii* Brandegee cytoplasm. Environmental effects on fertility restoration were noted and several proposed ideas for hybrid cotton seed production were evaluated. Results indicated that hybrids made with particular pedigrees produced significant yield advantage and fertility of the hybrids was not influenced significantly by environmental factors at the test locations.

Introduction

Heterosis for yield has been reported in both interspecific and intraspecific crosses of cotton. An excellent summarization of hybrid cotton research was prepared by Davis (5). Subsequent investigations designed to study specific genetic effects of critical yield factors, combining ability or seed production factors have been reported (1,7,8,9,10).

The majority of the research projects on hybrid cotton have utilized *Gossypium harknessii* Brandegee derived cytoplasmic male sterility (11). This male sterile has been extremely reliable under a wide range of growing conditions. The most obvious effect of the male-sterile condition compared to the normal "B" line used for conversion is 4-6 days earlier to bloom and generally more prolific blooming and taller plants if the flowers are not pollinated.

Obtaining a restorer line that gives complete restoration of *G. harknessii* cytoplasmic male sterility has proven to be a challenge for the breeder. Environmental conditions strongly affect expression of complete fertility. High temperatures during the flowering season tend to reduce fertility restoration. The majority of the Cotton Belt in the United States from the Texas Rolling Plains to Mississippi, and lower elevations in Arizona, would be classified as difficult to restore regions. The Texas High Plains and northerly regions of the Cotton Belt would be classified as easy to restore areas. The lower elevations of Arizona are perhaps the most difficult to obtain complete restoration. Although restorer lines have been developed that give complete restoration for all areas, careful evaluation of hybrids in all regions where they might be grown is necessary (7).

Another complication in developing restorer lines is the tendency for test-crosses of males that do not contain a full complement of restorer factors to express variable fertility during the flowering period. Typically, the first one or two blooms in a nursery row of these type of test-crosses will be partial or completely male sterile. Fertility is expressed more completely on subsequent blooms but all plants in the row will not be fully restored on a given day. This type of fertility expression may be overcome by test-crossing several individually identified plants from a population that is being tested for fertility and then selections made of male plants that express full fertility.

Materials and Methods

F_1 hybrids using *G. harkenssii* cytoplasmic male-sterile lines were made in the field and greenhouse with hand-pollinations to produce the entries for the trials contained in this report. One or more popular local varieties were included as check varieties. Single row plots were arranged in three or more replications with irrigation applied as needed at both locations. The soil type at the Weslaco location was Hidalgo sandy clay loam while the College Station plantings were on a Westwood silt loam. Planting dates corresponded as close as possible to those used by farmers in the area. Harvests at Weslaco were made on several dates. Data for each measurement were subjected to an analysis of variance. Weslaco fiber samples were analyzed by the International Textile Research Center, Texas Tech University, Lubbock, TX. College Station samples were analyzed by Cotton Fiber Lab, Louisiana State University, Baton Rouge, LA.

Results and Discussion

Yield trial results for 1997 and 1998 at College Station and for 1996, 1997 and 1998 in Weslaco are summarized in Tables 1, 2, 3, 4 and 5. Only hybrids that produced more lint than the mean of the check varieties are shown. Trial results for 1993 and 1994 at Weslaco have been previously reported (3,4).

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:450-453 (1999)
National Cotton Council, Memphis TN

In 1997, four hybrids exceeded lint per acre yields of the mean of two check varieties (Table 1). No significant difference was found in lint per acre yields so these yields were not used in summary tables. Fiber and boll data from the trial are used in summaries since these measurements are derived from a single bulk sample from each entry. Yield data at College Station in 1998 showed that five hybrids in this group of twelve hybrid entries exceeded the check mean by seven percent (Table 2). The top yielding hybrid gave an eighteen percent increase in yield over the check variety mean. All yields in 1998 were truncated by extreme heat leading to a harvest approximately one month ahead of normal harvest dates. Fiber measurements for micronaire, length, and strength are included in these tables. All hybrid entries produced acceptable fiber properties but there is considerable variation. These variations are considered normal for this type of germplasm since broad based populations are normally used in development of parental lines.

Yield trials grown at Weslaco in 1996 are summarized in Table 3. The top yielding hybrid produced thirty eight percent more yield than the mean of the two check varieties. Five hybrid entries exceeded the mean of the check varieties by fourteen percent. In 1997, nine hybrids exceeded the mean of three check varieties by fourteen percent (Table 4). The best yielding hybrid exceeded the check variety mean by forty percent. This same hybrid was also the top yielder in 1998, as shown in Table 5 with a sixteen percent increase over the check variety. All seven hybrids exceeded the check variety in 1998 showing a mean yield increase of nine percent and the top hybrid increase of sixteen percent.

Performance of the four top yielding hybrids are summarized in Table 6 for 1997 and 1998. Lint yield per acre advantage for the two top hybrids grown in 1998 at Weslaco and College Station were sixteen and eight percent. The two hybrids giving the best yield in 1997 Weslaco plus both Weslaco and College Station locations in 1998 gave a lint yield increase of eighteen and eleven percent. These two hybrids were developed at Weslaco and would be considered too early for the typical maturity of varieties grown at College Station. When only the data from Weslaco is summarized, these two hybrids gave an advantage in yield of thirty and seventeen percent. One of these hybrids, R418 x B429/A32, is a three-way hybrid. Three-way hybrids are of interest because increased seed yields have been reported through use of single cross females. This three-way hybrid is very uniform in height and maturity.

Lint percent, boll weight and earliness are considered significant yield components and are probably strong contributors to the heterotic response in cotton. Table 7 compares these three items over a period of years and locations from data collected in 1996 Weslaco as well as 1997 and 1998 Weslaco and College Station trials. Comparisons were made for the means of five top yielding hybrids in each test with the mean of the check varieties. Lint percents were very close over years. Boll weights in 1997 and 1998 show larger bolls for hybrids. The hybrids are earlier in the 1996 Weslaco trial but later in 1997. Weslaco yield trials reported in 1993 and 1994 were of similar origin and all ten hybrids listed each year were significantly earlier to maturity than DPL 50 (3,4). These trends for hybrids to produce larger bolls and earlier maturity are significant factors in maximizing heterotic response in this group of hybrids.

Production of F_1 hybrid cotton seed for commercial use by farmers has not been successfully accomplished in the United States. Successful seed production for hybrid cotton is routine in India and China (2). India reported 9,583,600 acres (3,880,000 ha) or forty five percent of their acreage in F_1 or F_2 hybrids in 1995. China is reported to have grown 815,000 (330,000 ha.) of F_1 and F_2 in 1996. Pakistan, Israel, and Pakistan have evaluated hybrids but do not grow significant hybrid acreages at the present time. India and China depend almost exclusively on hand pollination techniques for seed production of hybrids.

Progress in reducing cost of hybrid cotton seed has been reported from Texas (7). Critical aspects of lowering cost include site selection, genotype selection and production technique. Hybrid cotton seed production has also been studied on an experimental basis in North Carolina (1). In pollination studies, indigenous bumblebees were perhaps the most effective pollinators of cotton and they were present at the two locations in both years of the study. Seed cotton yields on the female rows were equal to that of the male rows at two environments, two thirds as productive at one environment, and half as productive at the fourth environment. The author concluded that given adequate synchronization of male and female blooming plus late season insect control, these locations could efficiently produce hybrid cotton seed. A ratio to two male rows alternated with four female rows was considered optimum for seed yield.

Proposals for modified hybrid cotton seed production plans have been evaluated. One plan involves physical mixing of various combinations of male and female seed then planting the blend in a single row. Pollination is generally much improved with this approach but the male seed harvested in the blended seed could tend to depress overall hybrid performance. Another technique would involve naked-seed restorer lines grown in a blend of male and female seed. Light acid-delinting of the seed would allow removal of the naked seed on a screen cleaner. Use of herbicide resistant lines as parents of hybrids might be feasible but the necessity of leaving the pollinator line in the field until completion of blooming presents logistic challenges if blend production methods are used. Gametocides that are suitable for creating male sterility in cotton have been developed and used on a wide scale by Chembred, Inc. (2) This company reached a decision to produce F_1 seed with the use of the

gametocides and subsequent increase of the F_1 to allow farmers to grow F_2 seed in their field. Ten or more hybrids were distributed to various regions of the cotton belt and these F_2 hybrids occupied a significant acreage. This F_2 program was terminated in 1995.

Heterotic responses for yield in cotton hybrids are shown in these trials at a level comparable to previous reports. The data for lint yield per acre advantage for the top hybrid compared to the mean of the check varieties in 1996, 1997 and 1998 at Weslaco show 38%, 40% and 16% increase. Similar data from the 1998 College Station location show an 18% advantage. Fiber properties and lint percentages were comparable for the hybrids and the check varieties. Earliness percent and boll size consistently favor the hybrids.

Hybridization of cotton could offer some distinct advantages in the development of new or different fiber properties in response to market demand or unique fiber hybrids for specialized markets. Creation of new or different combinations of fiber traits could be possible in a hybridization program in one-third to one-half the time needed for development of standard varieties. These same features of hybrids could also be used in accelerating the addition of disease and insect resistance traits to hybrids.

Restorer lines used in the hybrids for this study appear to be little affected by environmental factors for the locations of Weslaco and College Station. All restorer breeding lines have an exotic component but selection and out-crossing have resulted in more stable, better adapted restorer lines.

Results of this study indicate the availability of a useful amount of heterosis in certain cotton hybrids. More environmentally stable and better adapted parent lines are also available. The parents of the best yielding hybrids in these tests would be competitive in most trials with currently available varieties. If production costs can be minimized, hybrid cottons should be useful for increasing yields and improving fiber quality.

References

1. Bowman, Daryl. 1992. Hybrid Seed Production in North Carolina. Proceedings Beltwide Cotton Conferences. p. 581.
2. Chaudhry, M. Rafiq. Commercial Cotton Hybrids. 1997. The International Cotton Advisory Committee Recorder. p. 3-14.
3. Cook, C. G. and L. N. Namken. 1993. Yield and fiber quality of F1 hybrids. Proceedings Beltwide Cotton Conferences. p. 1539-1540.
4. Cook, C. G. and L. N. Namken. 1994. Performance of F1 hybrids in the lower Rio Grande Valley. Proceedings Beltwide Cotton Conferences. p. 674-675.
5. Davis, D. D. 1978. Hybrid Cotton: Specific problems and potentials. Advances in Agron. 30:129-157.
6. Jones, J. E. and H. D. Loden. 1951. Heterosis and combining ability in upland cotton. Agron. J. 43:514-516.
7. Keim, Don L. and Richard F. Holland. 1991. Hybrid Cotton: Progress in commercial development. Proceedings Beltwide Cotton Conferences. p. 571.
8. Lee, J. A., P. A. Miller, and J. O. Rawlins. 1967. Interaction of combining ability effects with environments in diallel crosses of upland cotton (*Gossypium hirsutium* L.). Crop Sci. 7:477-481.
9. Meredith, W. R. and R. R. Bridge. 1972. Heterosis and gene action in cotton, *Gossypium hirsutium* L. Crop Sci. 12:304-310.
10. Percy, Richard G. and E. L. Turcotte. 1990. Effect of *Gossypium barbadense* parental selection upon F_1 interspecific hybrid plant height, earliness, and yield. Proceedings Beltwide Cotton Conferences. p. 62.
11. Sheetz, R. H. and J. B. Weaver, Jr. 1980. Inheritance of a fertility enhancer factor from pima cotton when transferred into upland cotton with *Gossypium harknessii* Brandegee cytoplasm. Crop Sci. 20:272-275.

Table 1. 1997 Yield Trial, College Station, TX

Entry	Lint	Fiber Properties		
	per acre (lbs)	mic	UHM	stren (g/tex)
C2067AxC2235 R	1478	3.8	1.09	27
R418xA429/A32	1054	4.0	1.13	27
C2006AxC2135R	1008	5.0	1.11	27
DPL5409-check variety	960	4.6	1.17	28
C2067AxC2234R	954	4.1	1.13	30
PBR941 -check variety	899	4.4	1.21	29

LSD(P=0.05) ns
Total entries in trial - 25
Check mean of two check varieties - 929 lbs/acre

Table 2. 1998 Yield Trial, College Station, TX

Entry	Lint	Fiber Properties		
	per acre (lbs)	mic	UHM	stren (g/tex)
C2214AxC2235R	993	4.0	1.10	30
C2067AxC2233R	920	4.2	1.10	28
DPL5409-check variety	915	4.8	1.13	31
C2214AxC2233R	870	4.3	1.10	27
C2067AxC2238R	871	3.8	1.12	27
R418xB429/A32	847	4.0	1.13	31
PBR941 -check variety	774	51	1.16	34

LSD(P=0.05) 188
Total entries in trial – 15
Mean yield of two check varieties-845 lbs/acre
Top hybrid yield compared to check mean 18% increase
Mean yield of five hybrids compared to check mean 7% increase

Table 3. 1996 Yield Trial, Weslaco, TX

Entry	Lint	Fiber Properties		
	per acre (lbs)	mic	UHM	stren (g/tex)
R418xA9	1423	3.9	1.03	28
R418xDPL20	1301	4.2	1.13	28
DPL50-check variety	1170	4.8	1.13	29
R10715xDPL20	1089	4.3	1.10	28
R418xA39	1047	4.5	1.14	28
C2026AxC2233R	1039	3.9	1.07	29
Stv.132 -check variety	889	3.4	1.10	30
LSD(P=0.05)	239	0.5	0.05	1.6

Total entries in trial - 22Mean lint per acre yield of two checks varieties-1030lbs.Top hybrid yield compared to check mean 38% increase
Mean yield of five hybrids compared to check mean 14 % increase

Table 4. 1997 Yield Trial, Weslaco, TX

Entry	Lint	Fiber Properties		
	per acre (lbs)	mic	UHM	stren (g/tex)
A418xA32	1370	3.5	1.07	26
Stv.132-check variety	1188	4.7	1.15	29
R418//B429/A39	1149	4.0	1.15	30
R418xA39	1135	4.3	1.16	28
C2214xC2238R	1134	4.2	1.12	30
C2067AxC2234R	1075	4.1	1.18	30
R418//B429/A32	1067	3.7	1.14	29
R418xA21s	1056	3.8	1.17	27
R418xA13	1037	4.0	1.16	29
C2015AxC2213R	991	3.4	1.17	32
SG125-check variety	934	4.8	1.15	28
DPL50 -check variety	812	4.0	1.18	30
LSD(P=0.05)	210	0.6	0.05	2.1

Total entries in trial - 38Check mean of 3 check varieties - 978
Top hybrid yield compared to check mean 40% increase
Mean yield of nine hybrids compared to check mean 14% increase

Table 5. 1998 Yield Trial, Weslaco, TX

Entry	Lint	Fiber Properties		
	per acre (lbs)	mic	UHM	stren (g/tex)
R418xA32	923	3.8	1.09	28
R411//B429/A32	913	4.2	1.10	29
C2214AxC2235R	910	4.4	1.11	26
C2067AxC2233R	848	42	1.07	27
C2214AC2157R	841	3.8	1.14	30
C2214AxC2213	810	4.2	1.14	30
C2067AxC2238R	805	4.8	1.08	27
DPL5409 -check variety	793	4.2	1.06	28
LSD (P=0.05)	108	0.2	0.03	1.2

Total entries in trial - 8
Top hybrid yield compared to check mean 16% increase
Mean yield of seven hybrids compared to check mean 9% increase

Table 6. Top Preforming Hybrids - 1997, 1998

Entry Tested	Loc.	lint yld cks per acre (lbs)	lint yld hyb per acre (lbs)	yield advan %
C2214AxC2235R	98 Wes., C.S.	819	952	16
C2067AxC223R	98 Wes., C.S.	819	884	8
R418xA32	97,98 Wes.; 98 C.S.	872	1030	18
R418xB429/A32	97,98 Wes.; 98 C.S.	872	969	11
R418xA32	97, 98 Wes.	885	1147	30
R418xB429/A32	97, 98 Wes.	885	1031	17

Table 7. Comparison of means of hybrids and check varieties for lint percent, boll weight and percent earliness

	Weslaco			College Station	
	lint %	boll wt (g)	early %	lint %	boll wt (g)
1996 Hybrids[1]	36	.	67.6	.	.
Check Var.[2]	35	.	74.0	.	.
1997 Hybrids	39.0	.	89.5	37	5.8
Check var.	39.1	.	79.9	36	5.0
1998 Hybrids	37.2	5.5	.	32	4.9
Check Var.	37.7	4.5	.	34	4.4

[1] Mean of five best yielding lint per acre hybrids
[2] Mean of check varieties
[3] Percent of total harvest obtained on first pick