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Yield and Fiber-Quality Potential for Second–Generation Cotton Hybrids

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Abstract: Exploiting heterosis is one method to increase cotton yield that has stagnated in recent years. One primarily to difficulty of producing F_1 seed, use of heterosis in cotton (*Gossypium hirsutum* L.) has been limited. The objective of this study was to evaluate the potential of using F_2 hybrids by comparing them with parents, commercial variety and F_1,S for yield, yield components and fiber quality. The second objective of this study was to determine if parental research organization of origin was related to mid parent and useful heterosis. The genetic design was a half diallel consisting of six parent (evolved by different research organization), 15 F_1,s and 15 F_2,s. The 36 genotypes were grown in 2002-2003. Yield, yield components fiber length, strength and micronaire reading were determined. The highest yielding parent was FH-901 (3517 kg ha^{-1}) with good yield components (recommended commercial variety for general cultivation), while the variety Reshmi had best quality traits among these parents. The cross combinations MNH439 X CIM-448, FH-901 X CIM-448 and NIAB-78 xX CIM-448 showed minimum inbreeding depression (-34.6, -20.0 and –21.8%, respectively) for seed cotton yield. These crosses also showed less inbreeding depression for yield components and fiber traits than expected inbreeding depression i.e 50.0%. General combining ability mean squares were significant for all traits and specific combining ability mean squares were also significant for all traits except boll weight and fiber strength. The GCA effects were higher than SCA effects for all traits, which indicated that additive gene action is prevailing with dominant for expression of these traits. The variety CIM448 was the best general combiner for the yield and yield components.

Key words: Fibre quality, cotton hybrids, mean yield, yield components

INTRODUCTION

Using heterosis to increase yield of cotton has been objective of breeders. Except in countries where a vast labour force was available to make emasculations and crosses by hand, no commercial use of heterosis currently exists in cotton (Chaudhry, 1997b). In India, at least 40% of cotton's production is derived from intraspecific hybrids of *G. hirsutum* and 8% of its production is from *G. hirsutum* X *G. barbadense* L hybrids (Chaudhery, 1997b). The yield increase of hybrids over the better parent or best commercial variety due to sufficient magnitude of heterosis has been documented by Loden and Richmond (1951), Davis (1978), Meredith (1984), Baru (1995), Meyer (1975), Sheetz and Quisenberry (1986). A review using more recent data (Meredith, 1998) showed an average useful heterosis of 21.4% for F_1 hybrids and 10.7% for F_2S, But heterosis for fiber properties was small averaging from 0 to 2.0% for most characteristics. These reviews conclusively showed that both F_1 and F_2 hybrids can produce significantly higher yields than the best yielding parents or the best yielding commercial cultivars. In Pakistan a hybrid of NIAB Krishma X CIM435 was given to growers for testing in the field which showed 10.5% increase in seed cotton yield over the best parent and best commercial variety, as NIAB Krishma was the best commercial variety during 1999-2000 by CCRI, Multan (Anonymous, 2000). Breeding research needs to address all possibilities to increase yield, including the use of heterosis. The average cotton yield for Pakistan and world has shown no increase since 1992 (Chaudhry, 1997a).

The major limiting factor for using heterosis in cotton is the lack of an efficient dependable crossing system. The discovery of male sterile cytoplasm (Olvery, 1986) and restorer factor (Weaver and Weaver, 1977) gave encouragement to breeders that hybrid cottons are obtainable. However, the complexities of developing good combiners with dependable fertility restoration present major problems for hybrid production. To avoid inconsistency of results from male sterile and restorer factors and cost of producing F_1 seeds, the commercial use of F_2 hybrids has been proposed (Olvery, 1986). One method of circumeting this inconsistency is to use male gametocides (Sheetz and Quisenberry, 1986); however, due to lack of a dependable and economic method of controlling the insect pollen carrier, it still has not been practical to produce F^1 hybrid.

However, several well designed studies showed the potential for using F_2 hybrids Tang *et al.* (1993), evaluated yield performance of 64 F_2'S from four environments and reported 11.8% higher yields than that of commercial varieties. Weaver (1984), reported 13.2 and 7.1% heterosis over mid parents for F_1 and F_2, respectively. The advantage of use of F_2'S is that it might have a broader range of adaptation that conventional varieties due to genetic variation. Reid (1995) reported that F_2 superiority over their best parents was only detected under stress conditions. Baure and Green (1996) also reported F_2'S greater superiority over their best parents was in lower yielding sites. The objective of this study was to compare the yield and fibre properties of F_1, F_2 and combining ability of the genotypes originated by different research organizations.

MATERIALS AND METHODS

A half diallel genetic design consisting of six varieties and 15 F_1 and F_2 hybrids were grown in three replications at Cotton Research Station, Multan during 2001-2002. The F_1 seeds were produced by hand crosses, F_2 seeds were produced by selfing the F_1 hybrids during 2002-2003.

The parents were Reshmi, MNH439, NIAB-78, CRIS-9, CIM446 and FH-901. The detail of research organizations which developed these varieties is given below:-

Varieties	Research orgnization
Reshmi	Cotton Research Station, Tandojam
MNH439	Cotton Research Station, Multan
NIAB-78	Nuclear Institute of Agri and Biology, Faisalabad
CRIS-9	Cotton Research Institute, Sakrand
CIM448	Central cotton Research Institute, Multan
FH-901	Cotton Research Institute, Faisalabad.

These six genotypes originated from six major cotton Research Organization in Pakistan. The experimental design was randomized complete block design with three replication. Standard cultural methods for Multan region were used. The parents and F_1 were grown in four rows plot of 30 ft long, while; each genotypes of F_2 was grown in ten rows plot of 30 ft long. Fifty bolls samples were hand harvested from each replication of all generations. These samples were used to determine the boll weight, lint percentage and fiber quality traits. The seed cotton yield per acre was determined from the total plot weight, combining ability analysis were made using the method given by Griffing, 1956 (Method-2 and model-2).

RESULTS AND DISCUSSION

The objective of this study was to compare consistency of performance of parents, F_1'S and F_2'S crosses. Mean yield, yield components and fibre properties for the six parents, are given in Table 1, significant differences were detected for all characters under study among parents. The yield superiority of F_1 hybrids over the F_2 and their parents is evident (Table 2). Usually the heterosis denote mid parent heterosis (Comparison of F_1 or F_2 Vs parent mean) but the major interest in the present study was the yield comparison of F_2 hybrids with established varieties, (Table 3). The highest yielding variety, FH-901 averaged 3517 kg ha^{-1}. Maximum heterosis was observed in NIAB-78 X CIM448 (% increase over best commercial variety is 36.8). It is evident from Table-2 that several F_2 hybrids were superior in yield to well established varieties (FH901 and CIM448). The highest yielding F_2 hybrids, MNH439 X CIM448, FH901 X CIM448 and NIAB-78 X CIM448, averaged 3546, 3739 and 3761 kg ha^{-1}respectively.

Table 1: Mean Yield, Yield Components and Fibre Properties of Four Parents

Parent	Yield Kg ha^{-1}	No. of bolls	Boll wt. (g)	GOT (%)	Staple length (mm)	Fineness	Strength (tppsi)
RESHMI	1592	12	3.43	35.9	33.1	3.91	95.5
MNH439	2283	27	3.64	48.9	25.4	4.20	94.5
FH901	3517	18	3.96	40.2	28.2	4.10	91.2
NIAB-78	2506	17	3.62	37.1	26.0	4.81	90.4
DPL-54	2064	22	4.46	35.3	26.54	5.12	92.5
CIM448	2454	25	3.86	37.6	28.20	4.51	90.6

Assuming that dominance gene action causes the heterosis, the F_2 yield was expected to loose 50% of the heterosis expected by F_1. However, for total yield, the F_2 produced significantly more than the expected. The maximum hybrid vigour loss for yield was observed –47.4% in cross Reshmi X CIM448, whereas minimum hybrid vigour loss for yield was recorded –1.9 and –1.6% for Reshmi X NIAB-78 and MNH439 X FH-901 respectively. The highest yielding F2 hybrids MNH439 X CIM448, FH-901 X CIM448 and NIAB-78 X CIM448 loosed –36.6, -20.0 and –12.8% hybrid vigour over F_1 but the yield was quite significantly higher than best commercial variety FH901. The inbreeding depression of highest yielding F_1 hybrids was about what was expected on a 50% decrease in dominance from the F_1 to F_2. Several crosses, however showed little inbreeding depression (Table 2). Other authors (Meyer, 1975; Sheetz and Quisenbery, 1986) have reported higher yielding F_2 hybrids that produced greater yields than expected on the basis of their F1 and parental performance. Significant deviation of the F_2 from expected could be done to non-additive gene action other than dominance, or plant competition within the F2 population. These results showed that for total yield and yield components, F_2 hybrids could be competitive with established commercial variety. The percent increase for yield component and fiber quality traits over best commercial variety of F_1 and

Table 2: Mean Yield, Yield Components and Fibre Properties Of, 15 F_1, 15 F_2 Population and Comprison of F_1 and F_2

Cross	Generation	YieldKg ha^{-1}	No. of bolls	Boll wt. (g)	GOT (%)	Staple length (mm)	Fineness	Strength (tppsi)
RESHMI x MNH439	F1	3361	25	3.71	43.2	32.5	4.2	95.1
	F2	2206	13	3.50	40.3	29.8	4.1	92.6
	± Inc/Dec.	-34.4	-48.0	-5.4	-6.7	-7.02	-2.3	-3.12
RESHMI x FH901	F1	3668	21	3.80	39.65	33.65	4.1	95.9
	F2	2917	19	3.70	37.1	30.4	4.0	92.57
	± Inc/Dec.	-20.47	-9.5	-2.6	-6.4	-9.6	-2.4	-3.5
RESHMI x NIAB-78	F1	2930	20	3.61	36.55	30.72	4.71	94.2
	F2	2873	20	3.40	36.0	29.6	4.2	90.7
	± Inc/Dec.	-1.9	0.0	-5.8	-1.5	-3.6	-10.6	-3.7
RESHMI x DPL-54	F1	4401	26.0	4.29	35.65	31.65	4.98	94.5
	F2	2519	14	4.0	34.5	29.2	4.21	92.5
	± Inc/Dec.	-42.8	-42.30	-6.8	-3.2	-7.7	-11.6	-2.1
RESHMI x CIM448	F1	5907	38	3.98	36.80	34.19	4.42	95.1
	F2	3105	19	3.80	35.4	32.8	4.2	92.9
	± Inc/Dec.	-47.4	-23.68	-4.5	-3.8	-4.1	-4.5	-2.84
MNH439 X FH901	F1	2936	21	4.0	45.75	28.13	4.15	95.9
	F2	2889	18	3.9	44.8	27.5	4.10	92.2
	± Inc/Dec.	-1.6	-14.28	-2.5	-2.1	-2.2	0.01	-3.85
MNH439 X NIAB-78	F1	2939	21	3.73	44.05	27.56	4.65	93.8
	F2	2717	20	3.7	43.8	27.1	4.3	29.1
	± Inc/Dec.	-7.5	-4.76	-0.8	-0.6	-1.8	-7.5	-1.8
MNH439 X DPL-54	F1	3063	18	4.31	42.90	26.52	4.92	94.2
	F2	2653	15	4.0	41.0	26.1	4.3	91.7
	± Inc/Dec.	-13.4	-16.6	-7.2	-4.4	-1.58	-12.2	-2.65
MNH439 X CIM448	F1	5422	34	4.07	44.10	28.37	4.41	94.0
	F2	3546	30	3.9	42.6	27.0	4.2	91.9
	± Inc/Dec.	-34.6	-11.7	-4.2	-3.4	-4.8	-4.4	-2.23
FH-901 X NIAB-78	F1	2188	19	3.75	39.05	27.57	4.75	95.1
	F2	2090	18	3.6	38.0	27.3	4.3	92.3
	± Inc/Dec.	-4.48	-5.2	-4.0	-2.7	-0.979	-9.5	-2.94
FH-901 X DPL-54	F1	3956	24	42.2	38.70	28.32	4.89	94.8
	F2	2653	17.21	4.0	38.8	26.8	4.4	93.5
	± Inc/Dec.	-32.9	-11.5	-5.2	-0.25	-5.36	-10.02	-1.37
FH-901 X CIM-448	F1	4676	29	4.09	39.30	27.27	4.43	94.5
	F2	3739	23	3.70	38.80	27.10	4.30	93.9
	± Inc/Dec.	-20.0	-20.7	-9.5	-1.3	-0.6	-2.9	-0.6
NIAB-78 X DPL-54	F1	3489	21	4.19	36.10	27.45	4.85	92.8
	F2	2738	16	3.80	36.0	25.8	4.8	92.5
	± Inc/Dec.	-21.5	-23.8	-9.3	-0.3	-6.0	-1.0	-0.3
NIAB-78 X CIM448	F1	4810	30	4.11	37.40	27.27	5.10	93.5
	F2	3761	24	3.60	36.9	27.0	4.5	92.5
	± Inc/Dec.	-21.8	-20	-12.4	-1.3	-0.3	-11.3	-1.1
DPL-54 X CIM448	F1	4565	39	4.32	38.50	28.44	4.95	93.2
F1	F2	2966	17	3.90	37.1	27.30	4.6	92.2
F2	± Inc/Dec.	-35.0	-56.4	-9.7	-3.6	-4.0	-7.1	-1.1

F_2 population is presented in Table 3. These crosses showed heterosis for almost for all traits under consideration except staple length and GOT. Meredith,s (1984) summery of 18 states research on heterosis in cotton reported on an average total yield heterosis of 18.5%. The hybrid vigor loss in F2 for cross MNH-439 x CIM-448 was –11.7, -4.2, -3.4, -4.8, -4.4 and -2.23 %for number of boll per plant, boll weight, GOT%, staple length, fineness and fiber strength respectively. The hybrid vigor loss in F2 for cross combination FH-901 x CIM-448over F_1 was –20.7, -9.5, -1.3, -0.6, -2.9 and –0.63% for number of bolls per plant, boll weight, GOT%, staple length, fineness and fiber strength, respectively (Table 2). Similarly inbreeding depression in F2 for cross NIAB-78 x CIM-448 was –20.0, -12.4, -1.3, -0.3, -11.3 and -1.1% for number of bolls per plant, boll weight, GOT%, staple length, fineness and fiber strength respectively (Table 4). These results indicated that inbreeding depression for these three crosses is less than 50.0% for all traits under study. It is also concluded from these results that F_2 generation can also be cultivated in field for use of hetrotic vigor and cost of seed production can be decreased. These results are also in according to the previous findings of Meyer (1975) and Sheetz and Quisenbery (1986). The significant deviation of F_2 in hybrid vigour (in breeding depression) from expected (50%) could be due to non-additive gene action other than dominance. From these results it can also be concluded that F_2S can produce better combinations of yield and fiber quality than their parents. On the basis of genetic variation within F_2, it might have a broader range of adaptation than conventional variety and F_1. So the question concerning the stability across environments of

Table 3: Comparison of Seed Cotton Yield of F_1 and F_2 with Best Parent (Fh-901)

Cross	Generation	Yield Kg ha^{-1}	B. Variety	% inc/dec
RESHMI x MNH439	F1	3361	3517	-4.435598521
	F2	2206	3517	-37.27608757
RESHMI x FH901	F1	3668	3517	4.293431902
	F2	2917	3517	-17.05999431
RESHMI x NIAB-78	F1	2930	3517	-16.6903611
	F2	2873	3517	-18.31106056
RESHMI x DPL-54	F1	4401	3517	25.13505829
	F2	2519	3517	-28.37645721
RESHMI x CIM448	F1	5907	3517	67.95564401
	F2	3105	3517	-11.71452943
MNH439 X FH901	F1	2936	3517	-16.51976116
	F2	2889	3517	-17.85612738
MNH439 X NIAB-78	F1	2939	3517	-16.43446119
	F2	2717	3517	-22.74665908
MNH439 X DPL-54	F1	3063	3517	-12.90872903
	F2	2653	3517	-24.56639181
MNH439 X CIM448	F1	5422	3517	54.16548194
	F2	3546	3517	0.824566392
FH-901 X NIAB-78	F1	2188	3517	-37.7878874
	F2	2090	3517	-40.54735314
FH-901 X DPL-54	F1	3956	3517	12.48222917
	F2	2653	3517	-24.56639181
FH-901 X CIM-448	F1	4676	3517	32.95422235
	F2	3739	3517	6.312197896
NIAB-78 X DPL-54	F1	3489	3517	-0.796133068
	F2	2738	3517	-22.14955928
NIAB-78 X CIM448	F1	4810	3517	36.76428775
	F2	3761	3517	6.937731021
DPL-54 X CIM448	F1	4565	3517	29.79811234
	F2	2966	3517	-15.66676144

parents, F_1 and F_2 remain open, as it will require a greater range of climates, soils, pests and management environments to determine whether F_2 hybrids are more adaptable than their parents in F_1 hybrids. In general the interactions of yield components with environments were of lesser magnitude this for total yield.

From Table 5, it is evident that general combining ability (GCA) variances were significant for all the traits and specific combining ability (SCA) variances were also significant at P=0.05 except for boll weight and fibre strength. The variety MNH448 is the best general combiner for number of bolls per plant, boll weight and seed cotton yield per plant. Reshmi is good general combiner for fiber quality traits (Table 6). The crosses combinations NIAB-78 X CIM448, FH901 X CIM448, Reshmi X CIM448 are valuable for seed cotton yield and its components as these crosses had high SCA effect for seed cotton yield and its components (Table 7).

These results suggest that at least one percent should be well adapted for developing hybrid having high yield. The three crosses MNH439 X CIM448, FH901 X CIM448 and NIAB-78 X CIM448, which showed low inbreeding depression had also low Specific Combining Ability effects for all traits under study. As SCA effects are due to dominant gene action, if dominant gene action will be present the expected inbreeding depression in F_2 will 50%. As in these three crosses the value of SCA effects is low indicating that other than dominance gene action is prevailing due to the reason, inbreeding depression for these three crosses is less than 50%. In these three crosses the common parent is CIM448, which has high GCA effect for seed cotton yield and its components (Table 5) indicating that CIM448 is good general combiner for yield and yield components. For hybrid vigour choosing of second parent is bit more difficult. No pattern of variety related to research organizations for the selection of second parent was evident. An expectation exist when fibre quality is a major breeding objective then, one must choose at last one parent that has above

Table 4: Mean squares for various plant characters of cotton in F_1 generation of 6 x 6 half diallel cross

Source of variation	D.F	Total No. of bolls per plant	Seed cotton yield per plant	Boll weight	G.O.T. (%)	Staple length	Fibre strength	Fibre fineness
Block	2	3.249	1.679	0.166	0.954	0.253	0.047	0.094*
Genotypes	20	155.024**	2138.08**	0.276**	25.08**	17.452**	4.934**	0.409**
Error	40	4.138	2.153	0.049	0.120	1.202	0.063	0.019

Table 5: Mean squares for combining ability analysis in 6x6 half diallel cross of cotton

Source of variation	D.F	Total No. of bolls per plant	Seed cotton yield per plant	Boll weight	G.O.T. (%)	Staple length	Fibre strength	Fibre fineness
G.C.A	5	264.450**	4876.550**	0.527**	61.750**	34.860**	8.398**	0.756**
S.C.A	15	27.780**	36.070**	0.026	6.190**	1.810**	0.615	0.017**
R.C.A	15	4.640**	1.350	0.013	0.520**	0.126	0.452	0.007
Error	40	1.380	0.720	0.016	0.040	0.400	0.021	0.006

*: $P \leq 0.05$; ** : $P \leq 0.01$, G.C.A = General combining ability affect, S.C.A = Specific combining ability affect, R.C.A = Reciprocal affect

Table 6: Estimates of general combing ability effects for yield, yield components and fiber traits in a set of half diallel cross among six cotton varieties

variation	Total No. of bolls per plant	Seed cotton yield per plant	Boll weight	G.O.T. (%)	Staple length	Fibre strength	Fibre fineness
Reshmi	-1.361	-7.709	-0.193	-1.652	3.349	0.795	-0.239
MNH-439	-0.861	-6.259	-0.135	4.721	-1.042	0.286	-0.176
FH-901	-3.028	-14.900	-0.042	1.011	-0.352	1.030	-0.214
N-78	-3.861	-15.922	-0.141	-1.540	-1.151	-1.063	0.223
DPL-54	-0.028	7.321	0.343	-1.901	-0.882	-0.697	0.362
CIM-448	9.138	37.469	0.165	-0.653	0.078	-0.355	0.044

Table 7: Estimates of specific combing ability effects for yield, yield components and fiber traits in a set of half diallel cross among six cotton varieties

Cross combinations	Total No. of bolls per plant	Seed cotton yield per plant	Boll weight	G.O.T. (%)	Staple length	Fibre strength	Fibre fineness
Reshmi xMNH439	2.167	2.719	-0.120	0.530	0.693	-0.182	-0.061
Reshmi x FH-901	0.361	1.424	0.061	0.682	0.612	-0.140	-0.065
Reshmi x N-78	0.195	2.729	-0.011	0.132	-0.574	0.243	-0.072
Reshmi xDPL54	2.361	12.422	0.192	-0.401	0.147	-0.172	-0.011
Reshmi x CIM-448	5.195	15.979	0.051	-0.511	1.716	0.433	-0.053
MNH439 x FH-901	-0.139	0.399	0.010	0.432	1.312	-0.031	-0.041
MNH439 x N78	-0.305	1.479	-0.051	-0.721	0.708	0.354	-0.082
MNH439xDPL54	-6.139	-18.981	0.151	-0.512	-0.601	0.383	0.070
MNH439xCIM-448	0.698	3.704	0.080	0.433	0.284	0.145	0.052
FH-901xN-78	0.861	6.669	-0.021	-0.022	0.032	1.211	-0.064
FH-901 xDPL54	2.028	9.644	-0.030	0.001	0.512	-0.252	0.041
FH-901 x CIM-448	-2.139	-4.371	0.011	-0.666	-0.665	-1.220	0.062
N-78 xDPL54	-0.139	0.219	0.032	-0.051	0.527	0.031	-0.071
N-78 x CIM-448	-0.305	-0.346	0.131	-0.025	-0.703	0.293	0.080
DPL54x CIM-448	4.861	17.689	-0.141	1.462	0.197	0.333	0.074

average fiber properties. The genetic differences among potential parents are required to detain high heterosis, it is no assurance that diverse parents will produce high heterosis.

The crosses Reshmi X CIM448 is valuable not only for seed cotton yield but also for fiber quality traits (having staple length 34.29 mm, fiber fineness 4.42 micronaire and fiber 95.1 tppsi of F_1 hybrid) to meet the international market requirement. The progenies of this cross should be used for three way cross or modified back cross method or reciprocal recurrent selection method to incorporate the yield components of CIM448 from the advance early progenies of cross Reshmi X CIM448 having desirable fiber quality traits.

REFERENCES

Anonymous, 2000. Annual progress report of CCRI Multan 1999.

Baru, A.K., 1995. Hybrids cotton results and prospectus. In G.A. constable and N.W. Foreter (Ed.) challenging the future. Proc. Word Cotton Res. Conf.–1., Brisbane Australia. 14-17 Feb. 1994. CSIRO, Australia, pp: 335-341.

Baure, P.J. and C.C. Gereen, 1996. Evaluation of F_2 genotypes of cotton for conservation tillage. Crop Sci., 36: 655-658.

Chaudhry, M.R., 1977b. Commercial cotton hybrids. The lint cotton advisory committee Recorder XY

Chaudhry, M.R., 1997a. Cotton yield stagnating. The lint cotton Advisory Committee Recorder XY., pp: 3-7.

Davis, D.D., 1978. Hybrids cotton: Specific problem and potential. Adv. Agron., 30: 129-157.

Griffing, B., 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Bot., Sci., 9: 463-493.

Loden, H.D. and T.R. Richmond, 1951. Hybrid vigour in cotton. Cytogenetics aspect and Practical application. Econ. Bot., 5: 387-408.

Meredith, W.R. Jr., 1984. Quantitative genetics. In R.J. Kohel and C.F. Lewis (Ed.) cotton. Agron 24. USA, CSSA, Madison, WI., pp: 131-150.

Meredith, W.R. Jr., 1998. Heterosis in cotton. *In* Heterosis in crops. CIMMYT workshop ASA and CSSA, Madison, WI., pp: 17-22.

Meyer, V.G., 1975. Male sterlity from Gossypium hurkenssi. J. Herred., 66: 23-27.

Olvery, J.M., 1986. Performance and potential of F_2 Hybrids. In T.C. Nelson (Ed.) Beltwide cotton prod. Res. Conf. Las Vegas, NV. 4-9 Jan. 1986. Natl. Cotton Council of Am., Memphis, TN, pp: 101-102.

Reid, P.F., 1995. Performance of F_1 and F_2 hybrids between Australian and USA commercial cotton cultivars. In G.A. Constable and N. W. Forester (Ed.) challenging the future. Proc. World Cotton Res. Conf-1. Brisbane, Australia, pp: 346-349.

Sheetz, R.H. and J.E. Quisenberry, 1986. Heterosis and combining ability effects on upland cotton hybrids. In T.C. Nelson (Ed.) Beltwide cotton prod. Res. Conf. Las Vegas, NV. 4-9 Jan. 1986. Natl. Cotton Council of Am., Memphis, TN, pp: 94-98.

Tang, B., J.N. Jenkins, T.C. McCarty and C.E. Walson, 1993. F_2 hybrids of host plant germplasm and cotton cultivation. Heterosis and combining ability for lint yield and yield components. Crop Sci., 33: 700-705.

Weaver, D.M. and J.B. Weaver, 1977. Inheritance of pollen fertility restoration in cytoplasmic male sterile upland cotton. Crop Sci., 17: 497-499.

Weaver, J.B., Jr., 1984. Agronomic properties of F_1 hybrids and open pollinated F_2s among twelve cultivars of cotton. In J.M. Brown (Ed.) Proc Beltwide cotton Conf. Atlanta, GA. Jan. 1984. Natl. Cotton Council of Am., Memphis, TN, pp: 8-12.