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Performance of F_1 and F_2 Hybrids of Cotton (G*gossypium hirsutum* L.) for Yield and Yield Components

[1]M. Iqbal, K. Hayat, [1]R.T. Ahmad and [2]N.I. Khan
[1]Cotton Research Station, Multan, Pakistan
[2]Cotton Research Institute, Faisalabad, Pakistan

Abstract: The objective of this study was to evaluate the potential of F_2 hybrids by comparing them with parents, commercial varieties and $F_{1,s}$ for yield, yield components and fibre quality. The genetic design was half diallel, consisting of five parents and additional five direct crosses were attempted to study inbreeding depression (CIM-496, MNH-554, FH-901, FH-945, LRA-5166, 10 F_1 and 10 F_2). The difference among genotypes were determined. The highest yielding parent was CIM-496 with 3521 kg ha^{-1} followed by MNH-554 with 3268 kg ha^{-1}. While the variety FH-901 with 2391 kg ha^{-1} showed minimum yield among the parents. The cross combinations MNH-786 × VH-144, MNH-554 × LRA-5166 and CIM-499 × LRA-5166 showed minimum inbreeding depression i.e., -39.72, -27.85 and -22.72 for seed cotton yield, yield components and fibre traits than expected inbreeding depression i.e., 50.0%. General combining ability mean squares were significant for all traits and specific combing ability mean squares were also significant for all traits. The GCA effects were higher than SCA effects for all traits, which indicates that additive gene action is prevailing with dominant gene action for expression of these traits. The variety FH-901 was the best general combiner for the yield and yield components. It is concluded that F_2 can be used for availing the heterosis after evaluating the proper cross combinations, be reduced.

Key words: Heterosis, hybrid, yield component, self-pollination, Combining ability, specific combining ability, general combining ability

INTRODUCTION

Cotton is a nearly self pollinated crop (less than 1% cross pollination) in our environment due to indiscriminate use of insecticides. The improvement in its plant type can be brought through hybridization. It brings together certain superior genes from different promising cotton strains. Combining ability is a tool to predict combining potentials of different strains for various traits and to select the best from them. Using heterosis to increase yield of cotton has been objective of breeders, but no use in world except in countries where a vast labour force was available to make emasculation and crosses by hand, (Chaudhry, 1977b). In India at least 40% of cotton production is from intra-specific hybrid of *G. hirsutum* and 8% of its production is from *G. hirsutum* × *G. barbadense* hybrids (Chaudhry, 1977b). The yield increase of hybrid over the better parents or best commercial varieties due to sufficient magnitude of heterosis. Meredith (1998) using recent data showed heterosis of 21.4% for F_1 hybrid and 10.7% for F_2 but heterosis of fibre properties was small averaging from 0-2% and concluded that both F_1 and F_2 hybrids can produce significantly higher yields than the best yielding parents or the commercial cultivars. In Pakistan the hybrid of NIAB Karishma × CIM-435 was given to the growers for testing in the field which showed 10.5 increase in seed cotton yield over the best parent and best commercial variety as NAIB Karishma was the best variety during 1999-2000 (Anonymous, 2000). The magnitude of heterosis has been documented by Loden and Richmond (1951), Davis (1978), Meredith (1984), Baru (1995), Meyer (1975), Sheetz and Quisenberry (1986) and Iqbal *et al.* (2003). Breeding research needs to address all possibilities to increase yield, including the use of heterosis. The average cotton yield for Pakistan and world has showed no increase since 1992 (Chaudhry, 1977a). The major limiting factor to use 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) give encouragement to breeders that hybrids in cotton are obtainable. However the complexities of developing good combiner with dependable fertility restoration percent are major problems

Corresponding Author: M. Iqbal, Cotton Research Station, Multan, Pakistan

for hybrid production. To avoid inconsistency of results from male sterile and restorer factor and cost of producing F_1 seed, the commercial use of F_2 hybrids has been proposed by Olvery (1986) and Iqbal *et al*. (2003). One method circumventing this inconsistence is to use male gametocytes (Sheetz and Quisenberry, 1986). However, due to lack of dependable and economic method of controlling the insect pattern carrier, it still has not been practical to produce F_1 hybrids. The 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 environment and reported 11.8% higher yields than that of commercial verities. Weaver (1984) reported 13.2 and 7.1% heterosis over mid parents for F_1 and F_2, respectively. The advantage of use $F_{2,\ s}$ is that it might have a broad range of adaptation than commercial varieties due to genetic variations. Reid (1995) reported that F_2 superiority over their best parents was only detected under stress conditions. Baure and Gereen (1996) also reported $F_{2,\ s}$ greater superiority over their best parents was in lower yielding sites. Iqbal *et al.* (2003) revealed that F_2 generation can also be cultivated in field for use of heterotic vigor and cost of seed production can be decreased. The objective of this study was to compare the yield and fibre properties of F_1, F_2 and combining ability of the genotypes.

MATERIALS AND METHODS

A half diallel genetic design consisting of five parents, 10 F_1 and 10 F_2 hybrids grown in three replications at Cotton Research Station, Multan during 2003-2004. In addition to ten F_2 hybrids of diallel, five promising direct crosses were also included for testing inbreeding depression. The F_1 seeds were produced by hand crosses, F_2 seeds were produced by selfing the hybrids 2004-2005. The parents were CIM-496, MNH-554, LRA- 5166, FH-901 and FH-945. The experimental design was Randomized Complete Block Design with three replications. Standard cultural methods for Multan region were used. The parents and F_1 were grown in four rows plot of 30ft long, while each genotypes of F_2 was grown in ten rows plot of 30ft long. Ten single guarded plant samples were hand harvested from each replication of F_1 and parent, while 50 guarded plants were hand harvested from each replication of F_2. These samples were used to determine the boll weight, lint % and fibre quality traits. The seed cotton yield ha^{-1} was determined from the total plot weight while combining ability (both general combining ability and specific combining ability) analysis were made using the method given by Griffing (1956) (method-2, model-2).

RESULTS AND DISCUSSION

The objective of this study was to compare consistency of performance of F_1 and F_2 generations. Mean yield, yield components and fibre properties for five parents, are given in Table 1, which showed wide genetic differences for all characters under study among parents. The yield superiority of F_1 hybrid over F_2 and their parents is presented in (Table 2). Usually the heterosis denoted mid parent value H but the major interest in present study was the yield comparison of F_2 hybrid with F1 and established variety i.e., CIM-496, which covered about 40% area in Punjab (Anonymous, 2005, 2006). The highest yielding varieties CIM496 averaged 3521 kg ha^{-1}. The increase and decrease percentage in yield of F_2 hybrid over F_1 and standard varieties is given in Table 2, from which it is evident that several F_2 hybrids were superior in yield to well established variety CIM-496. The highest yielding F_2 hybrid MNH - 786×VH-144, CEDIX×CIM-499 and LRA-5166×CIM-499 yielded seed cotton 6013.6, 5864 and 5857.3 kg ha^{-1}, respectively. Assuming that dominant gene action causes the Heterosis, the F_2 yield is expected to loss 50% of the heterosis expressed by F_1. The maximum hybrid vigor loss for yield was observed -42.12% in cross MNH-554×LRA-5166 followed by CIM-499×LRA-5166 and CIDEX×CIM-446 showed -39.7 and -27.85% loss of heterosis for yield, respectively. While the minimum hybrid vigor loss for yield was recorded -3.04 and -5.54% for CIDEX×CIM-499 and MNH-554×FH-945, respectively. The highest yielding F_2 hybrids MNH-786×VH-144, CEDIX×CIM-499 and LRA-5166×CIM-499 loose -12.03, -42.12 and -39.72% hybrid vigor over F_1 but the yield was quite higher than the best commercial variety CIM-496. The increase in yield of these three F_2 hybrid was 34.41, 15.41 and 14.65% over CIM-496, respectively. The inbreeding depression of highest yielding F_1 hybrids was about what was expected on a 50% decrease in dominance from F_1 to F_2. Several crosses however shown little inbreeding depression in Table 2. Meyer (1975), Sheetz and Quinseberry (1986) and Iqbal *et al*. (2003), have reported high yielding F_2 hybrids that produced greater yield than expected on the basis of their F_1 and parental performance. This deviation of F_2 from expected could be due to non-additive gene

Table 1: Mean yield, yield components and fiber properties of five parents

Parents	NFB	Yield/Plant (kg)	No. of bolls	B.wt. Av.	GOT	SL (mm)
CIM-499	7.0	2788	37.0	3.1	37.0	28.0
LRA-5166	9.1	2529	21.0	4.0	41.5	28.5
FH-901	8.5	2391	23.0	2.3	33.3	30.0
MNH-554	6.5	3268	28.0	3.5	38.0	27.5
FH-945	8.1	2972	35.0	3.9	37.5	29.5
CIM-496	8.9	3521	32.5	3.1	40.4	28.1

Table 2: Mean yield, yield components and comparison of F_1, F_2 and STD

Cross	Generation	B.Wt	No. of bolls	Yield kg ha^{-1}	GOT	SL (mm)
CIDEX×CIM-499	F_1	3.2	42.5	5018.2	35.8	27.5
	F_2	3.1	38.9	4870.1	32.1	26.7
	Std.	3.1	32.5	3521	40.4	28.1
	Inc/dec. over F_1	-3.22	-9.25	-3.04	-11.52	-2.99
	Inc / dec. over F_2	0	16.45	27.70	-25.85	-5.24
CIDEX×CIM-446	F_1	3.1	40.2	5113	35.8	27.5
	F_2	3.1	36.9	3999	32.9	27.3
	Std.	3.1	32.5	3521	40.4	28.1
	Inc/dec. over F_1	0	-8.94	-27.85	-8.81	-0.73
	Inc/dec. over F_2	0	11.92	11.95	-22.8	-2.93
MNH-554×LRA-5166	F_1	3.8	34.5	5864	41.8	27.9
	F_2	3.5	33.9	4126	39.3	27.0
	Std.	3.1	32.5	3521	40.4	28.1
	Inc/dec. over F_1	-8.57	-1.77	42.12	-6.36	-3.33
	Inc/dec. over F_2	11.42	4.13	14.65	-2.79	-4.07
MNH-554×FH-901	F_1	3.4	31.4	4200	40.6	27.2
	F_2	2.7	30.8	3422	38.6	27.7
	Std.	3.1	32.5	3521	40.4	28.1
	Inc/dec. over F_1	-25.93	-1.95	-22.72	-5.18	1.81
	Inc/dec. over F_2	-14.81	-5.52	-2.88	-4.66	-1.44
LRA-5166×CIM-499	F_1	3.5	33.5	5857.3	41.3	28.7
	F_2	3.4	30.9	5186.9	38.1	28.3
	Std.	3.1	32.5	3521	40.4	28.1
	Inc/dec. over F_1	-2.94	-841	-12.92	-8.39	-1.41
	Inc/dec. over F_2	8.82	-5.17	32.11	-6.03	-0.70
CIM-499×LRA-5166	F_1	3.2	39.5	5861.2	38.1	28.3
	F_2	3.4	38.1	4162.7	37.5	27.9
	Std.	3.1	32.5	3521	40.4	28.1
	Inc/dec. over F_1	5.88	-3.67	-39.72	-1.6	-1.43
	Inc/dec. over F_2	8.82	14.69	15.41	-7.73	0.71
CIM-499×FH-901	F_1	3.2	-36.4	5339.1	39.6	27.6
	F_2	3.1	37.2	4923.6	39.0	27.4
	Std.	3.1	32.5	3521	40.4	28.1
	Inc/dec. over F_1	-3.22	2.15	-8.43	-1.53	-1.43
	Inc/dec. over F_2	0	12.63	28.48	-3.58	-0.71
CIM-499×MNH-554	F_2	3.1	32.5	3718	43.0	28.5
	F_2	2.9	31.5	4122	40.0	28.1
	Std.	3.1	32.5	3521	40.4	28.1
	Inc/dec. over F_1	-6.89	-3.17	9.78	-7.5	-1.42
	Inc/dec. over F_2	-6.89	-3.17	14.57	-1.0	0.0
CIM-499×FH-945	F_1	3.5	41.8	4463	44.0	27.3
	F_2	3.4	40.6	4817	41.0	27.2
	Std.	3.1	32.5	3521	41.1	28.1
	Inc/dec. over F_1	-2.94	-2.95	7.34	40.9	-0.36
	Inc/dec. over F_2	8.82	19.95	26.9	-7.05	-3.31
LRA-5166×FH-901	F_1	3.4	38.2	5137.51	1.70	27.9
	F_2	3.2	37.5	4771.43	40.6	28.0
	Std.	3.1	32.5	3521	40.6	28.1
	Inc/dec. over F_1	-6.25	-1.86	-7.67	39.8	0.35
	Inc/dec. over F_2	3.12	13.33	26.20	40.4	-0.35
FH-901×FH-945	F_1	3.5	40.8	5285.59	-2.01	28.2
	F_2	3.3	38.7	5544.73	-1.50	28.5
	Std.	3.1	32.5	3521	40.5	28.1
	Inc/dec. over F_1	-6.06	-5.42	4.67	38.9	1.05
	Inc/dec. over F_2	6.06	-16.02	36.49	40.4	1.40
LRA-5166×FH-945	F_1	3.5	45.6	5158.08	-4.11	27.8
	F_2	3.2	45.3	4742.63	-3.85	27.7
	Std.	3.1	32.5	3521	41.1	28.1
	Inc/dec. over F_1	-937	0.66	-8.75	37.9	-0.36
	Inc/dec. over F_2	3.1	28.25	25.75	40.4	-1.44
MNH-554×FH-945	F_1	3.4	36.1	5153.96	-8.49	27.4
	F_2	3.3	35.7	4376.55	42.6	27.8
	Std.	3.1	32.5	3521	41.4	28.1
	Inc/dec. over F_1	-3.02	-1.12	17.76	40.4	1.28
	Inc/dec. over F_2	6.06	8.96	19.54	2.89	-1.08

Table 2: Continued

Cross	Generation	B.wt	No. of bolls	Yield kg ha^{-1}	GOT	SL (mm)
FH-945×MNH-554	F_1	3.6	41.5	4697.39	02.41	27.6
	F_2	3.3	39.6	4450.59	40.6	27.6
	Std.	3.1	32.5	3521	40.4	28.1
	Inc/dec. over F_1	4.09	-4.79	-5.59	-01.5	00.0
	Inc/dec. over F_2	6.06	17.92	20.88	-01.0	-1.81
MNH-786×VH-144	F_1	3.4	47.2	6013.64	42.5	15.0
	F_2	3.2	45.8	5367.86	41.6	28.7
	Std.	3.1	32.5	3521	40.4	28.1
	Inc/dec. over F_1	-6.25	-3.05	-12.03	-02.16	-2.13
	Inc/dec. over F_2	3.12	29.03	34.40	02.88	0.0

Table 3: Mean square of various plant characters of cotton of 5×5 diallel

SOV	DF	Total No. of bolls	Seed cotton yield/plant	B. wt	GOT	SL (mm)	NFB
Genotype	14	1469.46**	6729.11**	10.126**	262.81*	24.68*	30.93**
Block	2	169.73	149.37	0.432	001.198	00.209	00.26
Error	28	185.60	617.95	0.5434	003.46	00.825	02.93

*Significant, **Highly significant

action other than dominance or plant competition with in the plant population. The results of present studies showed, for total yield and yield components of F_2 hybrids could be competitive with established commercial variety. The percent increase for yield components and fibre quality traits over best commercial variety of F_1 and F_2 population is presented in Table 2. These above mentioned crosses showed heterosis for almost all traits under consideration from commercial variety except for GOT (%) and staple length. Meredith (1984) summary of 18 states research experiment on heterosis in cotton reported on an average total yield heterosis of 18.5%. The hybrid vigor loss in F_2, for cross CEDIX × CIM-499 and MNH-554 × FH-945 was -3.04 and - 5.54 for seed cotton yield, respectively. The hybrid MNH786 × VH144 showed highest yield loosed hybrid vigor - 6.25, -3.05, -12.03, -2.16, -2.13 %, for boll weight, boll no, seed cotton yield, GOT and staple length, respectively (Table 2). The hybrid vigor loss for LRA-5166 × FH-901 was -2.94, -8.41, -12.92, -8.39 and -1.41 for boll weight, No. of boll, yield , G.O.T. and staple length respectively (Table 2). Similarly inbreeding depression for MNH-554 × LRA-5166 was - 8.17, -1.77, -42.12, -6.36 and -3.33% for boll weight., boll no, seed cotton yield, GOT and staple length, respectively (Table 2). These results indicated that inbreeding depression for these crosses is less than 50% for all traits under study. It is also concluded from these results that F_2 generation can also be cultivated in field for the use of heterotic vigor and cost of seed production can be decreased. The results are also in according to the previous findings of Meyer (1975), Sheetz and Quinseberry (1986) and Iqbal *et al*. (2003). The significant deviation of F_2 in hybrid vigor (Inbreeding depression) from expected 50% could be due to non additive gene action other than dominance. From these results it can also be concluded that $F_{2,s}$ can produce better combination of yield and fibre quality e.g., CIM-499 × LRA-5166, LRA-5166 × FH-901. On the basis of genetic variation within F_2, it might have broader range of adaptation than conventional varieties and F_1. So the question concerning the stability across environments of parents, F_1, F_2 remains open as it will require a greater range of climate, soils, pest management and environments to determine while F_2 hybrids are more adoptable than their parents in F_1 hybrids. In general the inter actions of yield components with environments were of lesser magnitude than for total yield. From Table 3 and 4 it is evident that GCA variances were significant for all the traits and SCA variances were also significant at p = 0.05%. The variety FH-945 is the best general combiner for No. of bolls per plant, boll weight, seed cotton yield, GOT and staple length and similarly FH-901 is good general combiner for earliness (NFB), but MNH-554 is also good combiner for GOT (Table 5). The cross combinations MNH- 554 × LRA- 5166, LRA-5166 × CIM-499, are valuable crosses for seed cotton yield and its components as these crosses had high SCA effect for seed cotton yield and its components (Table 6). These results suggested that at least one parent should be well adopted for developing hybrid having high yield. The crosses MNH-554 ×FH-901, CIM- 499 ×FH- 901 and LRA-5166 × FH- 901 showed low inbreeding depression had also low specific combining ability for all traits under study (Table 2 and 6). As SCA effect are due to dominant gene action, if dominant gene action will be present the expected inbreeding depression in F_2 will be 50%. As in these three crosses the value of SCA effect is low indicating that other than dominant gene action is prevailing due to the reason, inbreeding depression for these three crosses is less than 50%. As in these three

Table 4: Mean square of combining ability analysis in 5×5 diallel crosses of cotton

SOV	DF	Total No. of bolls	Seed cotton yield plant	B. wt	GOT	SL (mm)	NFB
GCA	4	38.65**	88.25**	0.678**	14.16*	1.29**	1.458**
SCA	10	33.55**	1890.05**	0.067**	3.11**	0.134**	0.447**
Error	28	02.20	07.356	0.006	0.041	0.009	0.034

*Significant, **Highly significant

Table 5: Estimation of general combining ability effects for yield, yield components and fibre tester in a set of 5×5 diallel crosses among five cotton varieties

SOV	Total No. of bolls	Seed cotton yield plant	B. wt	GOT	SL (mm)	NFB
P 1	2.48	-1.43	-0.28	-0.190	-0.08	-0.44
P 2	-2.85	-1.52	0.33	1.920	-0.18	0.46
P 3	-1.13	-3.57	-0.35	-2.060	0.49	0.02
P 4	0.89	5.71	0.05	0.143	-0.69	-0.48
P 5	2.39	0.81	0.26	0.190	0.47	0.44

Table 6: Estimation of special combining effects for yield, yield components and fiber tester in a set of 5×5 diallel crosses among five cotton varieties

SOV	Total No. of bolls	Seed cotton yield plant	B. Wt	GOT	SL (mm)	NFB
CIM-499 × MNH-554	-0.922	0.338	-0.144	1.826	0.0032	-0.0585
LRA-5166 × CIM-499	6.380	24.900	0.1376	1.016	0.2358	-0.0750
CIM-499 × FH-901	1.096	-5.756	-0.0742	0.315	0.4428	0.1503
CIM-499 × FH-945	0.972	-3.218	-0.473	1.1015	0.5932	0.7415
MNH-554 × LRA-5166	7.054	19.042	0.2128	-0.0423	-0.2074	-0.1697
MNH-554 × FH-901	5.770	4.386	0.0010	1.0567	0.0996	0.2557
MNH-554 × FH-945	0.646	5.924	0.1022	1.1431	0.1500	0.1469
LRA-5166 × FH-901	1.072	0.948	0.0826	1.1463	-0.5678	0.0391
LRA-5166 × FH-945	4.948	-3.514	0.3838	1.7327	0.2826	0.0303
FH-901 × FH-945	2.664	6.83	0.072	0.8317	-0.1104	1.2557

crosses FH- 901, which has the high GCA effect for seed cotton yield, NFB and boll weight. Table 5, indicating that FH-901 is a good general combiner for above mentioned traits. For hybrid vigor choosing of second parent is bit more difficult. No pattern of variety related for the selection for second parent was evident. An expectation exists when fibre quality is major breeding objective, then one must choose at least one parent that has above average fiber properties. The genetic differences among the potential parents required high heterosis, it is no assurance that diverse parents will produce high heterosis. It is not essential that diverse parents should have high hybrid vigour than commercial variety. Further research has to be conducted to identify the parents/hybrids that show high hybrid vigour in F_1 and maintained in F_2 with low inbreeding depression for commercial utilization of F_2 hybrids to overcome the CLCV and other field problems.

REFERENCES

Anonymous, 2002. Annual progress report of CCRI, Multan, 1990.

Anonymous, 2006. Crop Reporting Department, Report, 2005-2006.

Baru, A.K., 1995. Hybrid Cotton Results and Prospectus. In: Constable, G.A. and N.W. Foreter (Eds.), Challenging the Future. Proc. World Cotton Res. Conf. -1., Brisbane Australia. 14-17 Feb. 1994. CSIRO, Australia, pp: 335-341.

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

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

Chaudhry, M.R., 1977b. Commercial Cotton hybrid. The lint cotton Advisory Committee Recorder XY.

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.

Iqbal, M., M.Z. Iqbal, M.A. Chang and K. Hayat, 2003. Yield and Fibre Quality Potential For second Generation Cotton Hybrids. Pak. J. Bio., Sci., 6: 1883-1887.

Loden, H.D. and T.R. Richmond, 1951. Hybrid vigor in cotton. Cytogenesis aspect and practical application. Econ. Bot., 5: 387-408.

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

Meredith, W.R. Jr., 1998. Heterosis in Cotton. In: Heterosis in Crop. CIMMYT. Workshop ASA and CSSA Madison Wl., pp: 101-102.

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

Olvery, J.M., 1986. Performance and Potential of F_2 hybrids. In: Nelson, T.C. (Ed.) Beltwide cotton prod. Res. Conf. Las Vegas, N.V., 4-9 Jan 1986. Natl. Cotton Council of Am., Memhis, T.N., pp: 101-102.

Reid, P.F., 1995. Performance of F_1 anf F_2 hybrid between Australia and USA commercial cotton cultivars. In: Constable, G.A. and N.W. Forester (Eds.), 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. Nelson, T.C. (Ed.), Beltwide Cotton prod. Res. Conf. Las Vegas, 4-9 Jan. 1986. Natl. Cotton Council of Am. Memplins, TN., pp: 94-98.

Tang, B., J.N. Jenkis, T.C. Mecanty and C.E. Walson, 1993. F_2 hybrid of host plant germplasm and Cotton Cultivation. Heterosis and Combining ability for lint yield and yield Components. Crop Sci., 33: 700-705.

Weaver, B., 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. and Jr., 1984. Agronomic properties of F_1 hybrid and open pollinated $F_{2,s}$ among twelve cultivars of cotton Conf. Atlanta, GA., Jan. 1984. Nat. Cotton Council of Am. Memphis, TN., pp: 8-12.