Kasetsart J. (Nat. Sci.) 38 : 11 - 20 (2004)

Heterosis and Combining Ability for Yield and Yield Components of Cotton (*Gossypium hirsutum* L.)

Zerihun Desalegn[1], Ngamchuen Ratanadilok[2], Rungsarid Kaveeta[2], Pradit Pongtongkam[3] and Ananchai Kuantham[4]

ABSTRACT

Heterosis and combining ability for yield and yield components were determined in a population derived from half diallel crossing of six cotton genotypes. Heterosis and heterobeltiosis occurred in varying degrees. The highest heterosis for lint yield was 66.4 % and for seedcotton yield was 46.3 %. Five of fifteen crosses showed significant heterobeltiosis for seedcotton yield. Significant heterobeltiosis was predicted for crosses of GL-7 X Cucurova1518 and Del Cerro X Cucurova1518 for seedcotton yield, which resulted in 19.5 and 19.0 %, respectively. The analysis of variance to compare between parents and F_1 crosses showed that the mean squares of genotypes and general combining ability (GCA) were significant (P<0.01) for all traits studied. However, the mean square of specific combining ability (SCA) was significant only for lint percentage and seed index. The magnitude of GCA was higher than SCA in all cases, indicating that additive gene action was more important than non-additive in the inheritance of the traits. In this study, Cucurova 1518 and GL-7 were good combiners for yield and yield components. The two best crosses for seedcotton yield were GL-7 X Cucurova1518 and Del Cerro X Cucurova1518. Best parents and best crosses could be used to develop high yield breeding materials.

Key words: cotton, heterosis, heterobeltiosis, diallel cross

INTRODUCTION

Cotton is one of the most important industrial crops in Ethiopia. Recent local and foreign trade situations are such that it is necessary to accelerate the breeding work and produce better cotton and cotton products. The progress in the textile factory, a pressure from synthetic fibers and blended fibers, has promoted cotton textile manufacturers in advance of better and more efficient ways to manufacture products containing cotton fiber. Improved ginning technology, high speed spinning technology, new and creative ways of blending and finishing fiber, have all put increase demand on cotton lint (Herbert, 1986; Benedict *et al*., 1999).

Among the various technological options available for the improvement of cotton productivity, heterosis breeding is a possibility since it has been successfully used in many crops in different parts of the world. Further progress in improvement of lint yield may be achieved by knowledge of combining ability of potential parents and with better understanding of the relationship

[1] Ethiopian Agricultural Research Organization (EARO) Werer, Addis Ababa 2003, Ethiopia.
[2] Department of Agronomy, Faculty of Agriculture, Kasetsart University, Nakhon Pathom 73140, Thailand.
[3] Department of Genetics, Faculty of Science, Kasetsart University, Bangkok 10900, Thailand.
[4] Department of Statistics, Faculty of Science, Kasetsart University, Bangkok 10900, Thailand.

Received date : 08/01/04 Accepted date : 30/03/04

of yield and yield components. Combining ability give general direction as to which crosses are likely to be superior in producing desirable segregates and the possibility of using heterosis.

This information is really needed because the breeding methods employed for maximum genetic improvement of quantitative traits was dependent upon the types and relative magnitude of genetic variability for those traits in the population of interest. The diallel cross technique was utilized herein since it allowed the breeder to detect the kinds and to estimate the relative magnitudes of each possible sources of variability among a given set of parents. In addition, the diallel is a systematic method for identifying those parents and hybrids that have superior combinations of the characters of interest.

Although the commercial significance of hybrid cotton has presently been limited to only few countries, there are reports showing the existence of significant heterosis to produce hybrid cotton (Meredith and Bridge, 1972; Davis, 1978; Basu, 1995). Studies of Meredith (1999) indicated that F_2 hybrids from upland X upland strains had good potential in producing higher yield than the conventional cultivars.

The primary exception was India, where more than 40 % of their cotton was produced from F_1 intra-specific hybrids and 8% from inter-specific hybrids. China grows about 330, 000 hectare of F_1 and F_2 hybrids (Meredith, 1999). In Uzbekistan the average yield and income from hybrid were almost 50% more than the standard check variety (Rakhimzamov and Ibrahimov, 1990).

Numerous investigators have studied gene actions in cotton, but their results vary from experiment to experiment. In general, highly variable results for heterosis have been reported for many traits. Heterosis seems to be of primary importance in yield and in certain components of yield. However, there have been several studies, which show the existence of significant heterobeltiosis or superior hybrid performance above the best available check cultivars. Breeding efforts need to address all possibilities, including the use of heterosis to increase lint yield and existing relationship between heterosis and combining ability at different environmental conditions.

The purpose of the present research was to estimate the level of heterosis, general and specific combining ability effects for yield and yield components among six different cotton genotypes and to determine appropriate parents and crosses for the investigated traits.

MATERIALS AND METHODS

The six parents representing well-adopted, genetically diverse and best germplasm of *G. hirsutum* available to Ethiopian breeders for the characters of commercial importance, originally from U.S.A., Turkey, Pakistan and Ethiopia were Del Cerro, Arba, GL-7, Cucurova 1518, Niab-78 and Acala SJ2. Cucurova 1518 and Acala SJ2 were released for irrigated and Arba for rainfed areas of Ethiopia. These varieties have been multiplied yearly by National Cotton Research Program of Werer Agricultural Research Center (WARC). They were assumed to be homozygous for their characteristics as evidenced by their status of developments, which were hybridized as half diallels. All parents had *G. hirsutum* background (Table 1).

Crosses and all subsequent evaluations were conducted at Werer Agricultural Research Center in Ethiopia. Diallel crosses among the parents, ignoring reciprocals, were made during the main cropping season (mid April-mid September) of 2002. Two rows of ten-meter long for male lines were arranged between four lines of ten-meter long for female lines, with a spacing of 0.3 m between plant and 0.9 m between rows. Crosses were made by hand emasculation and pollination. Six parents and 15 F_1 hybrids obtained from half diallel crosses were planted during 2002

Table 1 Description of six parents used to form the diallel progenies.

Parents	Varietal description
Del Cerro	Developed in U.S.A, with a very complex parentage involving *G. turburi* Tod., G.*arboreum* L., *G. barbadense*, and *G. hirsutum* var. punctarium. (medium to long fiber length).
Arba	Developed in West Africa and selected at WARC in Ethiopia, with medium fiber length and strength and known for its high gin turn out (40).
GL- 7	Glandless cultivar developed in U.S.A. and known for high fiber strength, but susceptible to insect and rodent pests.
Cucurova 1518	Developed in Turkey, with high yielding and medium fiber length and strength.
Niab-78	Developed in Pakistan, with medium performance (average yield and lint quality).
Acala SJ2	Developed in U.S.A, with average lint quality and big boll size.

second cropping season in a randomized complete block design and replicated three times. Selfing of F_1 to produce F_2 generation was done simultaneously. Parents, F_1 and F_2 generations making a total of 36 entries, from previous harvesting, were planted using a randomized complete block design during the main cropping season of 2003. The planting was made on four rows of 8.0 meter long with a spacing of 0.2 m between plants and 0.9 m between rows. The plots were hoed, weeded, irrigated and sprayed against insect pests according to the cultural practices recommended for the area. Data collected include seedcotton yield (SCY) = plot yield / plot area (later converted to kg / ha), boll weight (BW) = weight of bolls / number of bolls (sample), boll number per plant (B/P) = (SCY/BW)/ number of plants per plot, lint percentage (LP) = lint weight / total weight of seedcotton (sample), lint yield (LY) = (SCY) X (LP), seed index (SI) = seed weight / seed (100 seeds per sample), lint index (LI) = lint weight / seed (100 seeds per sample) (Worley *et al*., 1976).

Analysis of variance and diallel analysis was applied using computer software suitable for Griffing method IV model I, which involved only one set of crosses (Griffing, 1956). Analysis of variance in conjunction with Duncan multiple range test (Duncan, 1955) was used to determine mean differences of the heterosis and heterobeltiosis. The mathematical model for the combining ability analysis was:

$$Y_{ij} = \mu + g_i + g_j + s_{ij} + e_{ijk}$$

Where Y_{ij} was the mean phenotypic value, μ was the general mean, g_i (g_j) was the general combining ability (GCA) effect, s_{ij} was the specific combining ability (SCA) effect and e_{ijk} was the error term.

RESULTS

Parents: Performances of parents are given in Table 2. The six parental cultivars used in this study represent a considerable range of expression (significant at $P < 0.01$) for all characters investigated. The inbred parental lines ranged in seedcotton yield from 2057 to 3170 kg / ha. The highest performing variety was Cucurova 1518 followed by Del Cerro and Arba, at 3170, 2791 and 2621 kg / ha, respectively. The highest lint yield was obtained from Cucurova 1518, and Arba at 1251, 1043 kg / ha, respectively. The highest boll number per plant was from Arba, Cucurova 1518, and Niab-78 followed by Del Cerro with the number of 24.6, 23.9, 23.7, and 19.9, respectively. Four of the six parents showed the same significant levels for boll weight. The highest lint percentage (41.9) was obtained from GL-7 (Table 2).

F_1 crosses*:* The mean performance of F_1 crosses is presented in Table 2. Highly significant difference between F_1 crosses was observed for all parameters presented. Seedcotton yield ranged from 2846 to 3789 kg / ha. The best performing crosses for seedcotton yield were GL-7 X Cucurova 1518, followed by Del Cerro X Cucurova 1518 and GL-7 X Niab-78 which resulted in 3789, 3772 and 3588 kg / ha, respectively. Best crosses for boll weight were obtained from crosses of Cucurova 1518 X Acala SJ2 and Del Cerro X Cucurova 1518 at 6.0 and 5.7 gram, respectively. For lint yield the best results were obtained from crosses of GL-7 X Cucurova 1518 followed by GL-7 X Niab-78 at 1627 and 1498 kg / ha, respectively. The best lint percentage values of 42.9, 41.8, 41.5 and 41.1 were from crosses of GL-7 X Cucurova 1518, GL-7 X Niab-78, Arba X GL-7 and Arba X Cucurova 1518, respectively (Table 2).

Table 2 Average performances of parents and 15 F_1 crosses for yield and its components.

Parents	SCY $x10^2$kg /ha	B/P	BW g	LY $x10^2$kg / ha	LP	LI	SI
Del Cerro	27.9 ab	19.9 ab	5.0 a	9.65 b	34.6 d	6.3 ab	11.9 ab
Arba	26.2 ac	24.6 a	3.7 b	10.43 ab	39.8 b	5.7 bc	8.6 d
Gl-7	23.9 bc	17.8 bc	4.9 a	9.99 b	41.9 a	7.3 a	10.1 cd
Cucurova 1518	31.7 a	23.9 a	4.8 a	12.51 a	39.4 b	6.8 ab	10.5 bc
Niab-78	25.1 bc	23.7 a	3.8 b	9.21 b	36.7 c	5.1 c	8.9 d
Acala SJ2	20.6 c	14.9 c	5.0 a	6.88 c	33.4 d	6.4 ab	12.8 a
Crosses							
Del Cerro X Arba	30.7 bd	21.4 cd	5.2 bd	11.5 de	37.6 e	7.2 ac	12.0 ab
Del Cerro X GL-7	33.8 ad	21.3 cd	5.7 ab	12.8 cd	37.9 de	7.9 ab	13.0 a
Del Cerro X Cucurova 1518	37.7 a	23.7 ac	5.7 ab	13.7 bc	36.4 fg	6.9 cd	12.2 ab
Del Cerro X Niab-78	29.8 bd	21.9 bd	4.9 ce	10.5 e	35.3 hi	5.9 e	10.9 cd
Del Cerro X Acala SJ2	30.3 bd	19.9 d	5.5 ac	10.5 e	34.5 I	6.8 cd	13.0 a
Arba X GL-7	31.9 ad	23.5 ac	4.9 ce	13.3 bd	41.5 b	7.1 bc	10.1 de
Arba X Cucurova 1518	32.1 ad	25.0 ab	4.6 de	13.2 bd	41.1 b	6.8 cd	9.9 de
Arba X Niab-78	29.7 cd	24.5 ac	4.4 e	11.7 ce	39.5 c	6.3 de	9.6 e
Arba X Acala SJ2	31.4 bd	21.7 cd	5.2 bd	11.8 ce	37.6 e	7.0 cd	11.6 bc
GL-7 X Cucurova 1518	37.9 a	24.4 ac	5.6 ac	16.3 a	42.9 a	7.8 ab	10.4 de
GL-7 X Niab-78	35.9 ab	26.0 a	5.0 be	15.0 ab	41.8 b	7.0 cd	9.9 de
GL-7 X Acala SJ2	31.1 bd	19.6 d	5.7 ab	12.2 ce	39.0 c	7.9 a	12.5 ab
Cucurova1518 X Niab-78	32.8 ad	26.3 a	4.5 de	12.7 cd	38.7 cd	6.0 e	9.6 e
Cucurova1518 X Acala SJ2	35.5 ac	21.4 cd	6.0 a	13.2 bd	37.2 ef	7.6 ac	12.8 a
Niab-78 X Acala SJ2	28.5 d	21.9 bd	4.7 de	10.2 e	35.8 gh	5.7 e	10.2 de

Values in each column, followed by the same letters are not significantly different from one another, at P £ 0.05 by DMRT for parents and crosses, separately.

Note: SCY = seedcotton yield ($x10^2$ kg / ha), B/P = boll number per plant, BW = boll weight, LY = lint yield ($x10^2$ kg / ha), LP = lint percentage, LI = lint index, SI = seed index, and g = gram

Heterosis: Heterosis with highly significant difference ($P \leq 0.01$) was predicted for all traits (Table 3). Crosses of GL-7 X Cucurova 1518 and Del Cerro X Cucurova 1518 followed by GL-7 X Niab-78 showed 46.3, 45.6 and 38.5 % heterosis for seedcotton yield and 66.4, 40.4 and 53.1 % for lint yield, respectively. For boll number per plant, crosses of Cucurova 1518 X Niab-78 and GL-7 X Cucurova 1518 followed by Arba X Cucurova 1518 showed 26.5, 25.0 and 20.2 %, respectively. For boll weight crosses of Cucurova 1518 X Acala SJ2 followed by Del Cerro X Cucurova 1518, GL-7 X Acala SJ2 and Del Cerro X GL-7 showed 31.0, 25.6, 25.6 and 25.5 %, respectively. Crosses of GL-7 X Cucurova 1518 followed by GL-7 X Niab-78, Arba X GL-7 and Arba X Cucurova 1518 for lint percentage, crosses of GL-7 X Acala SJ2 followed by Del Cerro X GL-7, GL-7 X Cucurova 1518 and Cucurova 1518 X Acala SJ2 for lint index, crosses of Del Cerro X Acala SJ2, Del Cerro X GL-7, Cucurova 1518 X Acala SJ2 and GL-7 X Acala SJ2 for seed index showed the highest and significant heterosis over mid parent values (Table 3). For seedcotton yield, heterosis with the lowest value was predicted for cross of Niab-78 X Acala SJ2 at 9.9 %. For boll number per plant, crosses of GL-7 X Acala SJ2 and Del Cero X Acala SJ2 showed –5.6 and –4.3 % heterosis, respectively. For boll weight, crosses of Arba X Niab-78 and Cucurova 1518 X Niab-78 showed –4.2 and –1.3 % heterosis, respectively. For lint yield cross of Niab-78 X Acala SJ2 showed 4.1 %. For lint percent crosses of Del Cero X Acala SJ2 showed –8.3 %. For lint index, Niab-78 X Acala SJ2 showed –9.0 % (Table 3).

Heterosis over the best check parent or heterobeltiosis is more important than heterosis. Meredith and Bridge (1972) suggested a term “useful heterosis” for comparing the yield of hybrids with the highest yielding, adapted commercial check variety. In this study Cucurova 1518 was used as commercial check variety. Heterobeltiosis with highly significant differences was predicted in all traits (Table 3). Five of the fifteen crosses showed significant heterobeltiosis for seedcotton yield. For seedcotton yield, crosses of GL-7 X Cucurova 1518 and Del Cerro X Cucurova 1518 showed 19.5 and 19.0 %, respectively. For lint yield crosses of GL-7 X Cucurova 1518 followed by GL-7 X Niab-78 showed 30.1 and 19.7 %, respectively. Crosses of Cucurova 1518 X Niab-78 and GL-7 X Niab-78 for boll number per plant, crosses of Cucurova 1518 X Acala SJ2 followed by GL-7 X Acala SJ2, Del Cerro X Cucurova 1518 and Del Cerro X GL-7 for boll weight, and crosses of GL-7 X Acala SJ2 followed by Del Cerro X GL-7 and GL-7 X Cucurova 1518 for lint index, showed the highest and significant heterobeltiosis. For seed index crosses of Del Cerro X Acala SJ2 and Del Cerro X GL-7 showed 1.0 and 0.8 %, respectively. Very small but positive heterobeltiosis for lint percentage was observed in GL-7 X Cucurova 1518 at 2.4 % (Table 3).

Since the primary interest in cotton was centered on lint yield, a more detailed graphic representation of heterosis and inbreeding depression was shown in Figure 1 and 2. The generation mean of F_2 was higher than their respective parents for lint yield, except in Cucurova 1518 (Figure 1). The highest performing parents contributed more towards the highest performing crosses except GL-7 (Figure 1 and 2). The performance of GL-7 for lint yield was in the third place, but mean performances of F_1’s was on the second place (Figure 1).

Combining ability: Mean squares of general combining ability (GCA) were highly significant in all traits measured, whereas the mean squares of specific combining ability (SCA) were significant in lint percentage and seed index (Tables 4 and 5).

Varieties Cucurova 1518 and GL-7 for seedcotton yield, Acala SJ2, Del Cerro, GL-7 and Cucurova 1518 for boll weight, Cucurova 1518 and Niab-78 for boll number per plant, GL-7 and Cucurova 1518 for lint yield, and GL-7 for lint

Table 3 Heterosis and heterobeltiosis for yield and its components.

Crosses	SCY		B/P		BW		LY		LP		LI		SI	
	Ht[1/]	Htbt	Ht	Htbt	Ht	Htbt	Ht	Htbt	Ht	Htbt	Ht	Htbt	Ht	Htbt
Del Cerro X Arba	18.4^{bc}	-3.3^{bc}	2.7^{cd}	-13.2^{cd}	14.0^{ae}	3.4^{ae}	17.9^{ce}	-7.8^{ce}	-0.1^{eg}	-10.2^{eg}	15.2^{ac}	-1.3^{ac}	14.5^{ab}	-6.6^{ab}
Del Cerro X GL-7	30.4^{ac}	6.5^{ac}	2.4^{cd}	-13.5^{cd}	25.5^{ab}	13.8^{ab}	30.9^{be}	2.3^{be}	0.7^{df}	-9.5^{df}	25.6^{ab}	7.6^{ab}	23.7^{a}	0.8^{a}
Del Cerro X Cucurova 1518	45.6^{a}	19.0^{a}	13.9^{ad}	-3.8^{ad}	25.6^{ab}	13.9^{ab}	40.4^{ac}	9.7^{ac}	-3.2^{gh}	-13.1^{gh}	11.3^{ad}	-4.7^{ad}	16.8^{ab}	-4.8^{ab}
Del Cerro X Niab-78	15.2^{bc}	-5.9^{bc}	5.3^{bd}	-11.0^{bd}	7.4^{be}	-2.6^{be}	7.8^{de}	-15.7^{de}	-6.2^{hi}	-15.7^{hi}	-5.6^{ef}	-19.1^{ef}	3.9^{bd}	-15.3^{bd}
Del Cerro X Acala SJ2	17.2^{bc}	-4.3^{bc}	-4.3^{d}	-19.1^{d}	20.3^{ad}	9.1^{ad}	7.1^{de}	-16.3^{de}	-8.3^{i}	-17.7^{i}	9.0^{be}	-6.6^{be}	24.0^{a}	1.0^{a}
Arba X GL-7	23.4^{ac}	0.9^{ac}	12.8^{ad}	-4.7^{ad}	7.6^{be}	-2.4^{be}	35.9^{bd}	6.2^{bd}	10.3^{b}	-0.9^{b}	14.3^{ac}	-2.1^{ac}	-3.5^{d}	-21.3^{d}
Arba X Cucurova 1518	24.0^{ac}	1.3^{ac}	20.2^{ac}	1.5^{ac}	1.1^{ce}	-8.3^{de}	34.9^{bd}	5.5^{bd}	9.3^{b}	-1.9^{b}	8.9^{be}	-6.7^{be}	-5.8^{d}	-23.2^{d}
Arba X Niab-78	14.6^{bc}	-6.3^{bc}	17.6^{ac}	-0.6^{ac}	-4.2^{e}	-13.2^{e}	20.0^{ce}	-6.2^{ce}	5.0^{c}	-5.7^{c}	0.3^{cf}	-14.0^{cf}	-8.1^{d}	-25.1^{d}
Arba X Acala SJ2	21.2^{ac}	-1.0^{ac}	4.5^{cd}	-11.7^{cd}	14.3^{ae}	3.7^{ae}	20.6^{ce}	-5.7^{ce}	-0.2^{eg}	-10.3^{eg}	12.0^{ad}	-4.0^{ad}	10.9^{ac}	-9.6^{ac}
GL-7 X Cucurova 1518	46.3^{a}	19.5^{a}	17.1^{ac}	-1.0^{ac}	22.9^{ac}	11.4^{ac}	66.4^{a}	30.1^{a}	14.0^{a}	2.4^{a}	25.4^{ab}	7.4^{ab}	-0.5^{cd}	-18.9^{cd}
GL-7 X Niab-78	38.5^{ab}	13.2^{ab}	25.0^{ab}	5.6^{ab}	9.0^{be}	-1.2^{be}	53.1^{ab}	19.7^{ab}	10.9^{b}	-0.4^{b}	12.2^{ad}	-3.9^{ad}	-5.3^{d}	-22.8^{d}
GL-7 X Acala SJ2	20.2^{ac}	-1.8^{ac}	-5.6^{d}	-20.3^{d}	25.6^{ab}	13.9^{ab}	24.3^{ce}	-2.9^{ce}	3.6^{cd}	-6.9^{cd}	27.5^{a}	9.3^{a}	18.9^{a}	-3.1^{a}
Cucurova1518 X Niab-78	26.7ac	3.5^{ac}	26.5^{a}	6.9^{a}	-1.3^{de}	-10.5^{de}	29.7^{be}	1.4^{be}	2.7^{ce}	-7.7^{ce}	-3.6^{df}	-17.4^{df}	-8.7^{d}	-25.6^{d}
Cucurova 1518XAcalaSJ2	37.1^{ac}	12.0^{ab}	2.8^{cd}	-13.1^{cd}	31.0^{a}	18.8^{a}	35.2^{bd}	5.7^{bd}	-1.1^{fg}	-11.2^{fg}	20.7^{ab}	3.5^{ab}	22.0^{a}	-0.6^{a}
Niab-78 X Acala SJ2	9.9^{c}	-10.2^{c}	5.5^{bd}	-10.8^{bd}	2.6^{ce}	-7.0^{ce}	4.1^{e}	-18.6^{e}	-4.8^{h}	-14.5^{h}	-9.0^{f}	-22.1^{f}	-2.2^{cd}	-20.3^{cd}

Values in each column, followed by the same letters are not significantly different from one another, at P£0.05 by DMRT.

[1/] Ht = heterosis and Htbt = heterobeltiosis

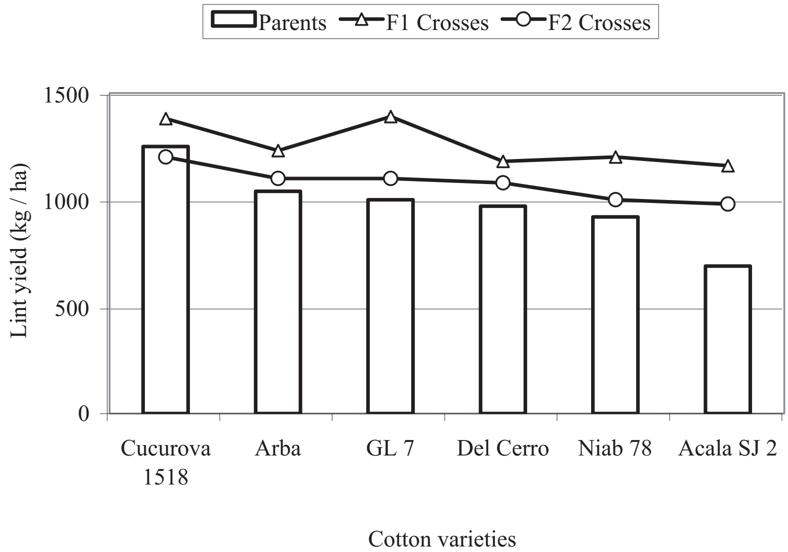

Figure 1 Average lint yields of parents, F_1 and F_2 generations. Mean values of parents were arranged in descending order and their respective F_1 and F_2 crosses according to their parents.

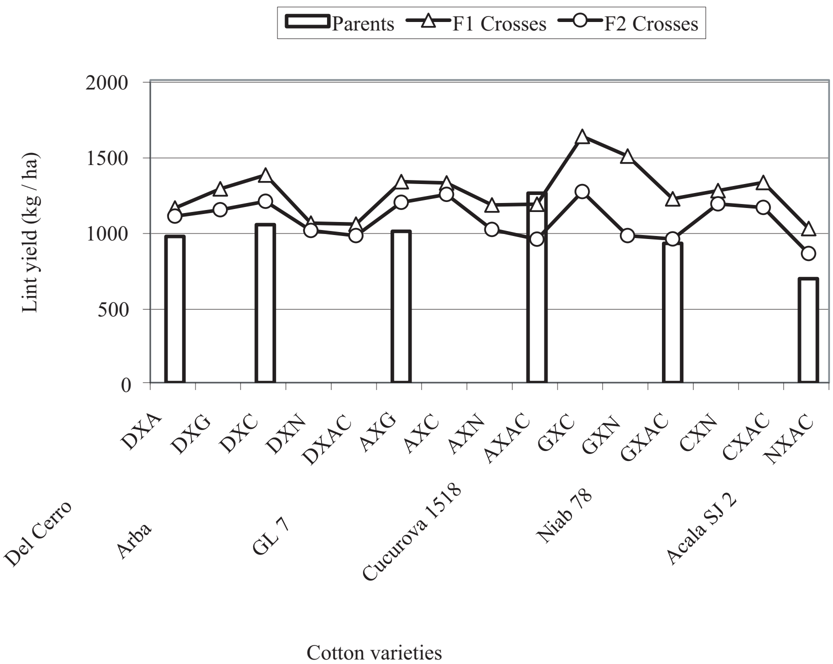

Figure 2 Lint yields of parents, F_1 and F_2 crosses. Abbreviation used in the graph (D X A) was the first group of letters of the parent's (variety) name as the code and "x" designates crosses.

Table 4 General combining ability (GCA) and specific combining ability (SCA) mean squares of yields and their components.

Source	df	SCY	B/P	BW	LY	LP	LI	SI
Rep	2	19.46	7.52	0.34	5.87*	0.52	0.22	0.42
Cross	14	32.34**	13.08**	0.78**	8.36**	18.96**	1.53**	5.06**
Error	28	9.31	2.67	0.15	1.16	0.26	0.17	0.35
GCA	5	23.20**	10.74**	0.63**	6.57**	16.87**	1.29**	4.23**
SCA	9	3.88	0.84	0.05	0.68	0.46**	0.11	0.27*
Error	28	3.10	0.89	0.05	0.39	0.09	0.06	0.12

*, ** = Significant at 0.05 and 0.01 level of probability, respectively.

Table 5 General combining ability effects (GCA) on yield and yield components.

Parents	SCY	B/P	BW	LY	LP	LI	SI
Del Cerro	0.10 [ac]	-1.49 [bc]	0.29 [a]	-0.95 [b]	-2.63 [d]	-0.01 [b]	1.29 [a]
Arba	-2.37 [c]	0.48 [ab]	-0.37 [b]	-0.32 [b]	1.26 [b]	-0.06 [b]	-0.66 [b]
GL-7	2.16 [ab]	0.16 [ab]	0.26 [a]	1.66 [a]	2.69 [a]	0.77 [a]	-0.01 [b]
Cucurova 1518	3.53 [a]	1.63 [a]	0.13 [a]	1.55 [a]	1.02 [b]	0.14 [b]	-0.26 [b]
Niab-78	-2.14 [c]	1.61 [a]	-0.61 [b]	-0.69 [b]	-0.30 [c]	-0.95 [c]	-1.41 [c]
Acala SJ2	-1.28 [bc]	-2.39 [c]	0.31 [a]	-1.26 [b]	-2.05 [d]	-0.10 [d]	1.06 [a]

Values in each column, followed by the same letters are not significantly different from one another, at P£0.05 by DMRT.

percent and lint index, Del Cerro and Acala SJ2, for seed index showed significant and positive GCA. Crosses Cucurova 1518 X Acala SJ2 and Del Cerro X GL-7 showed significant SCA in lint percentage (Table 6).

DISSCUSIONS

Parents and F_1 crosses showed significant differences in all parameters. All crosses also showed significant heterosis and heterobeltiosis. The highest performing parents gave the highest performing crosses. The best yield was recorded with the presence of varieties Cucurova 1518 and GL-7. Cross of GL-7 X Cucurova 1518 showed high heterotic results for seedcotton yield, lint yield, boll number per plant, boll weight and lint index, while the second best cross Del Cerro X Cucurova 1518 was for seed cotton yield, boll number per plant and boll weight. Crosse of GL 7 X Niab –78 showed high heterotic results for seedcotton yield, lint yield and lint percentage. Boll number per plant and boll weight contributed differently for yield improvement in crosses. Combination of higher lint index and lower seed index contributed highly for the improvement of lint percentage and lint yield. The highest performing parents showed the highest GCA with the exception of lint yield in which Arba showed good performance with negative GCA. Significant GCA and SCA for lint percentage and seed index showed that these traits are governed by additive

Table 6 Specific combining ability (SCA) of 15 F_1 crosses on yield and its components.

Crosses	SCY	B/P	BW	LY	LP	LI	SI
Del Cerro X Arba	0.6	0.2	-0.4	0.5	0.3	0.2	0.1
Del Cerro X GL-7	3.7	1.5	-0.5	0.8	0.9*	1.1	0.7*
Del Cerro X Cucurova 1518	7.6	2.4	1.9	-0.7	0.1	0.4	0.6*
Del Cerro X Niab-78	-0.3	-0.8	0.1	-1.8	-1.0	-0.9	-0.2
Del Cerro X Acala SJ2	0.2	-0.8	-1.9	-2.6	-0.1	1.2	0.4
Arba X GL-7	-0.2	-0.6	0.0	-0.9	-0.5	-0.4	-0.2
Arba X Cucurova 1518	-0.1	-0.7	1.5	-1.3	-0.8	-0.6	-0.4
Arba X Niab-78	-5.8	-2.2	1.0	-2.9	-1.4	-0.9	0.7*
Arba X Acala SJ2	-0.8	-2.1	-1.7	-4.9	0.7	1.1	0.2
GL-7 X Cucurova 1518	-0.2	0.5	-0.3	0.8	0.0	-0.5	0.0
GL-7 X Niab-78	-2.2	-0.8	1.4	-0.4	-0.9	-1.0	-0.6
GL-7 X Acala SJ2	-7.0	-3.6	-5.0	-3.2	0.1	1.6	0.2
Cucurova1518 X Niab-78	-0.9	-0.8	0.2	-0.5	-0.1	0.1	-0.2
Cucurova 1518XAcalaSJ2	1.8	-0.2	-4.7	-2.0	1.5*	3.3	1.3*
Niab-78 X Acala SJ2	-0.5	-0.5	0.1	-0.3	-0.4	-0.6	-0.2

* = Significant at 0.05 probability level

and non-additive gene action. The results were in accordance with the previous works of Miller and Mariani (1963). They have found significant heterosis ranging 11-57 % and large GCA effects. Meredith (1990) also examined the level of heterosis in modern American cultivars and found F_1 superiority to be 15%. The results of this study revealed the predominance of additive gene action. Similar findings were recorded in works of Meredith and Bridge (1972). They concluded that most of the superior hybrids combinations involved at least one parent had good GCA. In works of Wells and Meredith (1988) was recorded that the magnitude of GCA was higher than SCA in all cases, which indicated the importance of additive gene action. The estimates of sizeable amounts of additive genetic variances has breeding implication and certainly suggest that significant advances can be made through the use of selection procedures which increase the frequency of favorable genes showing primarily additive effects (Davis, 1978). An average performance of F_2 generation was better than their respective parents for lint yield. This is in agreement with earlier findings of Baker and Verhalen (1975), Meredith (1990) and Tang *et al*. (1993). They were able to obtain 14.0 to16.0, 7.4 to 17.9 and 4.7 to 18.0 % F_2 heterosis over the parents, respectively. And thus the F_2 seed may be used as planting materials if necessary, in order to safe the cost of seed. The performance of parents could be used to predict the performance of crosses. Thus parents with best general combining ability (GCA) and per se performance can be used to develop high yielding breeding materials.

CONCLUSION

The obtained results have demonstrated the importance of diallel analysis in detecting heterosis and identifying parents with general and specific combining ability that help to choose appropriate breeding procedure. Additive gene action predominated in all characters of the study. Cucurova 1518 and GL-7 were found to be good combiners for yield and yield components. It was also demonstrated that certain hybrids were clearly superior in yield to best commercial variety. Crosses of GL-7 X Cucurova1518 and Del Cero X Cucurova1518 were the best performing crosses for yield and yield components. Estimates of the magnitude of the superiority might be in the order of 20 %. Best parents and crosses could be used to develop high yield breeding materials. Such information is valuable to evaluate the economic feasibility of various methods of hybrid seed production. To meet the future challenge for increasing fiber production, high priority should be given to heterosis breeding.

ACKNOWLEDGEMENTS

We would like to thank Agricultural Research Training Project (ARTP) Ethiopia for supporting this research financially, Werer Agricultural Research Center (WARC) for multidirectional assistance during the field and laboratory research work and Dr. Bedada Girma, Kulumsa Agricultural Research Center (KARC) for his assistance in conducting the research in Ethiopia.

LITERATURE CITED

Baker, J.L. and M.Verhalen.1975. Heterosis and combining ability for several agronomic fiber properties among selected lines of upland cotton. **Cotton Grow. Rev**. 52: 209-223.

Basu, A.K. 1995. Hybrid cotton results and prospects, pp. 335-341. *In* G.A. Constable and N.W. Forester (eds.). Challenging the future. **Proc. World Cotton Res. Conf. Brisbane**.

Benedict, C.K., R.J. Kohel and C.F. Lewis. 1999. Cotton Fiber Quality, pp 324-363. *In* C.W Smith and J.T. Cothren (eds.). **Cotton: Origin, History, Technology and Production**. Wiley and Sons. New York.

Davis, D.D. 1978. Hybrid cotton: specific problems and potentials. **Adv. Agron**. 30: 129-157.

Duncan, D. B. 1955. Multiple range and multiple F tests. **Biometrics**. 11: 1-42.

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

Herbert, T. 1986. Cotton fiber requirement towards the year 2000, pp3-6. *In* **Cotton Production and Fiber Quality Needs Towards 2000**. ICAC 45th Plenary meeting. Buenos Aires. Argentina.

Meredith, W.R. 1990. Yield and fiber quality potential for second-generation cotton hybrids. **Crop Sci**. 30: 1045-1048.

Meredith, W.R. 1999. Heterosis in cotton, pp 451-462. *In* J.G. Coors and S. Pandey (eds.). **The Genetics and Exploitation of Heterosis in Crops**. Madison, Wisconsin.

Meredith, W.R, Jr. and R.R. Bridge. 1972. Heterosis and gene action in cotton, *Gossypium hirsutum*. **Crop Sci.** 12: 304-310.

Miller, P.A and A. Mariani. 1963. Heterosis and combining ability in diallel crosses of upland cotton, *Gossypium hirsutum* L. **Crop Sci**. 3: 441-444.

Rakhimzanov, A. and P. Ibrahimov. 1990. Hybrid cotton in Uzbekistan, pp.123. *In* **Proc. FAO-ICAR Reg. Exp. Consultation on hybrid cotton**. CICR, Nagapur.

Tang, B., J.N. Jenkins and Jc Jr. McCarty 1993. F2 hybrid of host plant germplasm and cotton cultivars. Heterosis and combining ability for lint yield and lint components. **Crop Sci**. 33: 700-705.

Wells, R. and W.R. Meredith Jr. 1988. Heterosis in upland cotton. II relationship of leaf area to plant photosynthesis. **Crop Sci**. 28: 522-525.