1614 Evidence on the possibility to develop cotton source germplasm based on the F_1 cultivar cross and F_2 and BC_1 generation performance data

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ABSTRACT

The current cotton (*G. hirsutum)* cultivars are of high yielding potential and early maturity combined with good fiber quality traits. Breeders face the challenge to improve yielding potential, both as lint and fiber quality taking into account the great difficulties in improving fiber traits while maintaining yield and fiber quality. The possibility to develop genetic variability from six crosses using as parents adapted and introduced cotton commercial cultivars to be utilized in applied variety development program was the aim of this study. The six generations (P_1, P_2, F_1, F_2, BCP_1, and BCP_2) from each F_1 cross were field evaluated in 2005. A randomized complete block design (RCB) arrangement with three replications was used. The analysis of variance for seed cotton yield produced significant generation effects in four out of the six crosses evaluated. Data provided evidence on effective differentiation among some of the generations evaluated, such as the BCP_1 in cross GR1 x GR3 and BCP_1, BCP_2 in cross GR1 x GR5, whereas significant mid-parent F_1 and F_2 heterosis effects were observed. Regarding earliness significant generation effects in five out of the six crosses evaluated were observed. On the contrary non-significant F_1 and F_2 mid-parent heterosis were observed. Regarding the fiber quality traits, significant generation effects associated with F_1 mid-parent heterosis were observed in four out the six crosses for fiber length. The same response was observed for the traits: micronaire, strength and uniformity in three, two and one cross respectively. The data provided preliminary evidence on the value of the particular segregating populations studied to be useful germplasm sources in applied variety development programs.

Keywords: *backcrosses - cotton (G. hirsutum) -* F_1 *-* F_2 *- heterosis.*

Introduction

Cotton, grown primarily for its lint, is a major world crop grown in more than 60 countries, and is mainly planted, about 96%, to Upland *G. hirsutum* (Meredith**,** 1999). Current cotton cultivars have high yielding potential and early maturity combined with good fiber quality traits. In spite of this, cotton yields worldwide ending the 20th century seem to be on a plateau in all cotton producing countries except for India and Turkey (Chaudhry, 1997a). Thus, breeders face the challenge to improve yielding potential, both as lint and fiber quality, taking into account the great difficulties in improving fiber traits while maintaining yield and fiber quality (Worley et al. 1976**;** Calhoun and Bowman**,** 1999). The majority of cotton breeders in developing varieties have used conventional pedigree selection or some variation of this method, like modified pedigree or modified bulk pedigree, as summarized by Calhoun and Bowman (1999**).** The main difference among selection methods is the managing of the segregating population and especially the effectiveness of the early generation evaluation. Thus, selection among rather than within early generation populations seems to be more effective**.** Furthermore, pedigree selection has been effective in improving quality traits such as micronaire and fiber length, lint percent, seedcotton yield, lint yield and earliness in appropriate populations in spite of the fact that these traits express low heritability (Calhoun and Bowman, 1999). The multi-adversity resistance (MAR) breeding approach aiming to improve host plant resistance to diseases and other stresses while maintaining or increasing yield is worth mentioning (Calhoun and Bowman, 1999**,** and references herein).

Cotton cultivars are developed by pedigree selection methodology but rarely if ever are developed as pure lines as in small grains or soybean (Pelhman and Sleper, 1995). This indicates that both heterogeneity and heterozygosity are present in cultivars and was capitalized in developing derived varieties through selection within existing cultivars (Calhoun and Bowman, 1999).

Backcross breeding has been also used to transfer morphological traits into various genetic backgrounds for genetic studies and breeding lines development and to transfer major genes for fiber strength (Meredith, 1993). This, of course, does not rule out use of backcross for transferring quantitative traits, as well.

Cotton hybrid variety breeding has been employed since both F_1 and F_2 useful heterosis has been reported as summarized by Meredith(1999). In India F_1 hybrids are widely grown **(**Chaudhry 1997b). No hybrid cotton cultivars were commercialized in USA by the end of the 20^{th} century although the advent of commercialized transgenic traits may make hybrid cotton cultivars more attractive (Calhoun and Bowman, 1999).

No matter the type of varieties, lines or hybrids, to be developed, the choice of germplasm sources (parental material) to form the genetic variability necessary for selection to be practiced is crucial. Obsolete cultivars, introduced germplasm or lines from other species and race stocks, developed by germplasm enhancement programs are potential sources, but the first choice is existing cultivars. Such commercial cultivars have an accepted agronomic performance and usually some or few less desirable traits that must be eliminated or improved. Such traits that are of prime commercial breeder’s concern are yield, fiber quality and appropriate maturity (Calhoun and Bowman, 1999)**.** The same holds true even for hybrid variety development since the highest-yielding hybrids generally are derived by crossing the highest-yielding parents (Davis, 1978).

High seedcotton yielding ability, early maturing and good fiber quality traits are needed for cultivars to become commercially successful under Greek cropping conditions. A wide range of proprietary line cultivars, including early to late maturing cultivars, having variable high seedcotton yielding ability and fiber quality traits are currently used by farmers. Therefore research to investigate the possibility to develop new germplasm using successful cultivars as promising source material in applied breeding programs was initiated.

To develop genetic variability from six crosses using as parents adapted and introduced cotton commercial cultivars to be utilized in applied variety development program was the objective of this study.

Materials and Methods

Seven proprietary commercial line cotton cultivars were evaluated; five cultivars are currently grown in Greece whereas the other two grown in India. Cultivars will be referenced to herein as GR-1, GR-2, GR-3, GR-4, GR-5, IND-1 and IND-2. The cultivars have early to medium maturity, and high seedcotton yielding potential combined with good fiber quality traits. Their performance according to each variety's label is summarized in Table 1**.**

In 2003, cultivar GR-1, which is one of the most popular cultivars among Greek farmers, was crossed as common parent to each of the other six cultivars resulting in the following F_1 combinations: GR-1 x GR-2, GR-1 x GR-3, GR-1 x GR-4, GR-1 x GR-5, GR-1 x IND-1 and GR-1 x IND-2. During 2004 growing season, each of the six F_1 was advanced to the corresponding F_2 and crossed on to its respective parents to produce the appropriate backcross (BC_1). Thus from each initial F_1 cross, seed for six generations, namely P_1, P_2, F_1, F_2, BC_1P_1 and BC_1P_2 were available. The six generations for each initial F_1 cross were field evaluated during 2005 growing season in Almyros, located in Thessaly which is the main cotton producing area in Greece. A randomized complete block design (RCB) field arrangement with three replications for each of the six crosses was employed. Three row plots were used. Rows were 0.95 m spaced apart 5.0 m long. Planting density was 15 plants m^{-2}. Standard cultivar practices applied to official variety evaluation trials were followed throughout the growing season. Number of days to first open boll in 50% of the plants in each plot (DBO) was recorded as an estimate of earliness. Individual plants were hand harvested and the sum of their seedcotton yield was recorded on a per plot basis as an estimate of each generation's yielding potential. Furthermore from each plot, a 50 boll sample was taken to determine fiber length, strength, uniformity and micronaire using High Volume Instrument (HVI). Conventional RCB analysis of variance was conducted separately for each trait and for each cross. Means were separated using Fisher's protected LSD and/or selected one degree of freedom comparisons (Steel and Torrie, 1980)**.** Heterosis estimates for seedcotton yield and for fiber quality traits were obtained as follow: Heterosis (Het F_1 and Het F_2) = F_1 – Mid-parent and F_2 – Mid-parent, respectively. Useful heterosis (Uhet F_1 and Uhet F_2) was defined as superiority of F1 or F2 over the highest performing parent (Meredith, 1999).

Results and discussion

The analysis of variance for seedcotton yield produced significant generation effects in four out of the six crosses evaluated (Table 2). Data provided evidence of effective differentiation among some of the generations evaluated whereas significant mid-parent F_1 and F_2 heterosis effects were observed. This evidence was further confirmed from the detailed seedcotton yield generation performance data (Table 3). The common parent cultivar GR-1 was equivalent to GR-2, GR-4, GR-5 and IN-1 and significantly inferior than GR-3 and IN-2 by 21.0% and 18.1% respectively. The significant F_1 and F_2 mid-parent heterosis observed in the four varietal crosses ranged from 10.0% to 24.3% and from 8.6% to 26.7% for F_1 and F_2 respectively. This performance was not necessarily associated with significant difference in the yielding ability between each cross' parents. The heterosis estimates observed were within the range of the respective estimates summarized by Meredith (1999). On the contrary significant useful heterosis was observed only in two crosses. Estimates were 17.4% and 24.2% for F_1 useful heterosis in GR-1 x IN-1 and GR-1 x GR-5 crosses respectively, whereas the corresponding F_2 useful heterosis was 23.8% and 23.2% (Table 3). Observed values were higher than those reported (Meredith, 1999). F_1 and F_2 useful heterosis are in agreement with the concept that high-yielding hybrids are usually derived from crossing high-yielding parent (Davis, 1978)**.** In spite of this, no useful heterosis was observed in the crosses between GR-1 and its respective two superior parents. These findings, pertinent to the specific set of crosses, provide preliminary evidence on the value of the specific cultivars to be useful germplasm sources in applied line and/or variety development programs. Furthermore the BC_1P_1 from GR-1 x GR-3 and GR-1 x GR-5 crosses out yielding significantly the recurrent parent GR-1 by 30.0% and 25.0% respectively whereas the BC_1P_2 from the GR-1 x GR-5 cross out yielded significantly the recurrent parent GR-5 by 37.2%. This performance, although unexpected, provides preliminary evidence on the possibility the yielding ability of the recurrent parent to be substantially upgraded. Such data need further testing to be confirmed before any conclusions could be reached on their implications in applied breeding programs. Summarizing the data previously discussed the cultivar GR-1 has good GCA and could be a valuable germplasm source to be utilized in breeding program.

Earliness is an interesting trait, especially when it does not sacrifice yield. Under our conditions DBO seems to be a reliable earliness criterion. Analysis of variance produced significant generation effects in five out of the six crosses evaluated (Table 4). The F_1 and F_2 mid-parent heterosis effect were essentially non significant. Useful heterosis estimates for earliness, meaning earlier F_1 or F_2 than the common parent GR-1, were not observed. Detailed DBO performance data (Table 5) showed that five of the cultivars were significantly later than the common parent. The F_2, BCP_1 and BCP_2 performance indicated that in using this material as segregating populations, genotypes that are slightly later than the early common parents and earlier than the late parents could be expected.

Analysis of variance data for length, strength, micronaire and uniformity are presented in Table 6. Significant generation effects associated with F1 mid-parent heterosis were observed in four out the six crosses for fiber length; for three, two and one cross for micronaire, strength and uniformity, respectively. Fiber data (Table 7) indicated that for the common parent cultivar GR-1, fiber length was higher than GR-2, GR-3, GR-4, GR-5, and IND-1 and micronaire was higher than GR-4 and IND-2 but lower than GR-3. On the contrary, no differentiation was observed for fiber strength and uniformity with the exception of GR-1 which was higher than GR-3. Significant mid-parent F_1 heterosis was observed in four, two, and one out of the six crosses for fiber length, both strength and micronaire, and uniformity, respectively. The estimates obtained were minimal and in agreement with reported data (Meredith, 1998). The mean performance of the F_2 and BC generations were not particularly encouraging in selecting genotypes with better quality for fiber traits than parental cultivars although selection within some of the segregating populations, which is in progress, does not rule out identification of desirable genotypes.

Developing cotton varieties which will maintain the high yielding ability and having the appropriate time of maturity combined with good fiber quality traits is a breeding objective under our cotton farming conditions. Data indicated that cultivar GR-1, used as a common parent in this study, although seemed to be satisfactorily meeting this requirement, could be improved in both seedcotton yield and micronaire by using parent cultivar GR-3.

Summarizing the data discussed, preliminary evidence indicate that some of the segregating populations derived from the particular crosses evaluated such as the BCP_1 in cross GR1 x GR3 and BCP_1, BCP_2 in cross GR1 x GR5 could be useful as germplasm sources in applied variety development programs. Our research in progress, including detailed generation means analysis and selection within the segregations populations, might provide useful information on genetic estimates (variance, heritability, etc) and the possibilities to effective selection for each of the individual trait studied and / or combinations of yielding ability with fiber quality traits and earliness.

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Table 1. Cultivar expected agronomic performance.

	Varieties						
Traits	**GR1**	**GR2**	**GR3**	**GR4**	**GR5**	**In1**	**In2**
Yielding Potential	**H**	**H**	**H**	**H**	**H**	**H**	**H**
Earliness^z	**VE**	**ME**	**ME**	**E**	**ME**	**E**	**E**
Ginning %	**37**	**38**	**38**	**36**	**38**	**35**	**37**
Span Length (2.5%)	**30.0**	**28.9**	**28.5**	**28.5**	**29.9**	**28.5**	**29.0**
Strength (gr/tex)^y	**29**	**30**	**27**	**30**	**30**	**31**	**29**
Micronaire	**4.1**	**4.1**	**4.2**	**4.0**	**4.0**	**4.1**	**3.9**

^{z} **VE= Very Early, ME= Medium Early, E= Early, H= High.**

^{y} **Metric mN/tex = g/tex X 9.81**

Table 2. Seedcotton yield variance effects of four generations derived from six cotton cultivar crosses.							
	Seedcotton (Mgha-1)						
			Crosess				
Effects	df	GR1 x GR2	GR1 x GR3	GR1 x GR4	GR1 x IN1	GR1 x GR5	GR1 x IND2
Generations[z]	5	ns	*	ns	+	**	**
MP vs F1	1	-	+	-	*	**	*
MP vs F2	1	-	*	-	*	**	+
CV(%)		11.4	6.2	6.1	11.0	4.8	5.6

[z] MP = Midparent

[y] '+, *, ** effect significant at p=0.10, 0.05 and 0.01respectively.

Table 3. Seedcotton yield performance (Mg/ha) for each of four generations derived from six cotton variety along with heterosis estimates.

	Crosses					
Generations[z]	GR1 xGR2	GR1 x GR3	GR1 x GR4	GR1 x IN1	GR1x GR5	GR1xIND2
P1	4.8 a	4.3 c	5.2 a	4.0 bc	4.9 c	4.7 c
P2	5.1 a	5.3 ab	5.0 a	3.8 c	4.9 c	5.5 ab
F1	4.9 a	5.3 ab	5.2 a	4.7 ab	6.1 b	5.6 a
F2	5.8 a	5.8 a	5.3 a	4.9 a	6.1 b	5.5 ab
BCP1	5.1 a	5,7 a	5.0 a	4.0 bc	6.2 b	4.9 c
BCP2	5.6 a	5.5 a	5.7 a	4.4 c	6.6 a	5.8 a
HETEROSIS(%)						
F1 vs MP	-1.8 ns	10.1 +	2.8 ns	20.8 *	24.8 **	10.6 *
F2 vs MP	16.4 ns	20.0 **	3.8 ns	26.8 *	23.6 **	8.6 +
F1 vs BP	-4.4 ns	0.3 ns	1.6 ns	17.4 +	25.9 *	2.3 ns
F2 vs BP	13.4 ns	9.4 ns	2.6 ns	23.1 *	24.8 *	0.6 ns

z MP = Mid parent, BP = Best parent.

y Means within a column followed by the same letter are not significantly according to the Fisher's Protected LSD test.

x '+, *, ** effect significant at p=0.10, 0.05 and 0.01respectively, one degree of freedom comparisons.

Table 4. Earliness variance effects of four generations derived from six cotton cultivar crosses.

	Days to boll opening from planting (DBO)						
		Crosses					
Effects	df	GR1 x GR2	GR1 x GR3	GR1 x GR4	GR1 x IN1	GR1 x GR5	GR1 x IND2
Generations[z]	5	**	**	ns	*	**	**
MP vs F1	1	+	ns	ns	ns	ns	ns
MP vs F2	1	ns	ns	ns	ns	*	ns
CV(%)		2.2	2.1	2.7	3.8	1.6	2.8

z MP = Midparent

y '+, *, ** effect significant at p=0.10, 0.05 and 0.01respectively.

Table 5. Earliness performance (DBO) for each of four generations derived from six cotton variety along with heterosis estimates.

	Crosses					
Generations[z]	GR1 x GR2	GR1 x GR3	GR1 x GR4	GR1 x IN1	GR1 x GR5	GR1 x IND2
P1	105 e	111 d	107 a	106 c	104 d	103 c
P2	123 a	122 a	109 a	120 a	118 a	115 a
F1	111 cd	115 bc	107 a	116 ab	112 bc	109 b
F2	116 b	115 b	110 a	115 ab	114 b	111 ab
BCP1	108 de	111 cd	104 a	113 ab	112 bc	112 ab
BCP2	118 b	117 b	107 a	117 ab	114 b	112 ab
HETEROSIS(%)						
F1 vs MP	3.2 +	1.1 ns	1,2 ns	-2.5 ns	-1.2 ns	-0.6 ns

F2 vs MP	-1.7 ns	0.9 ns	-1.8 ns	-1.6 ns	-3.0 *	-2.1 ns

[z] MP = Mid parent, BP = Best parent.

[y] Means within a column followed by the same letter are not significantly according to the Fisher's Protected LSD test.

[x] '+, *, ** effect significant at p=0.10, 0.05 and 0.01respectively, one degree of freedom comparisons.

Table 6. Fiber quality traits variance effects of four generations derived from six cotton cultivar crosses.

		Crosses					
Effects	df	GR1 x GR2	GR1 x GR3	GR1 x GR4	GR1 x IN1	GR1 x GR5	GR1 x IND2
a. Length							
Generations[z]	5	**	**	+	**	+	ns
MP vs F1	1	**	*	ns	*	*	ns
MP vs F2	1	**	ns	ns	ns	ns	ns
CV(%)		1.0	1.5	1.2	0.8	1.6	2.4
b. Strength							
Generations	5	*	+	ns	ns	ns	ns
MP vs F1	1	**	*	ns	ns	ns	ns
MP vs F2	1	ns	ns	ns	ns	ns	ns
CV(%)		2.0	3.4	2.0	3.6	2.8	2.9
c. Micronaire							
Generations	5	ns	**	**	ns	ns	*

	MP vs F1	1	ns	*	*	ns	ns	ns
	MP vs F2	1	ns	ns	ns	ns	ns	ns
	CV(%)		4.3	3.2	2.8	4.3	6.6	7,8
	d. Uniformity							
Generations		5	ns	*	ns	ns	ns	ns
	MP vs F1	1	ns	*	ns	ns	ns	ns
	MP vs F2	1	ns	ns	ns	ns	ns	ns
	CV(%)		0.7	0.5	0.5	0.9	0.5	1.1

[z] MP = Midparent

[y] '+, *, ** effect significant at p=0.10, 0.05 and 0.01respectively.

Table 7. Quality performance for each of four generations derived from six cotton variety along with heterosis estimates.

	Crosses					
Generations[z]	GR1 x GR2	GR1 x GR3	GR1 x GR4	GR1 x IN1	GR1xGR5	GR1xIND2
	a. Length					
P1	31.1 bc	31.7 ab	31.6 a	32.0 ab	31.6 ab	31.6 a
P2	30.3 d	29.4 d	30.7 a	31.5 c	30.6 c	30.7 a
F1	31.8 a	31.4 ab	30.1 a	32.3 a	32.0 a	31.9 a
F2	31.5 ab	31.1bc	31.1 a	31.8 bc	31.8 ab	31.8 a
BCP1	31.5 ab	32.1 a	31.2 a	31.5 c	31.5 abc	30.6 a
BCP2	31.2 bc	30.4 c	30.6 a	32.5 a	31.5 abc	31.3 a
HETEROSIS (%)						
F1 vs MP	3.5 **	2.6 *	-0.5 ns	1.6 *	2.8 *	2.5 ns
F2 vs MP	2.7 **	1.7 ns	- ns	0.2 ns	2.3 ns	2.0 ns
F1 vs BP	2.2	-1.1	-2.1 ns	0.7	1.3	1.0 ns
F2 vs BP	1.4	-2.0	-1.5 ns	-0.7	0.7	0.6 ns

	b. Uniformity					
P1	85.0 a	86.1 ab	85.7 a	86.1 a	86.1 a	86.2 a
P2	84.5 a	85.0 c	85.0 a	84.4 a	86.1 a	84.6 a
F1	85.4 a	86.5 a	85.3 a	85.5 a	86.6 a	86.4 a
F2	85.0 a	85.5 bc	85.3 a	85.7 a	85.9 a	84.6 a
BCP1	85.7 a	85.8 abc	86.2 a	85.7 a	86.8 a	85.8 a
BCP2	84.7 a	86.1 ab	85.4 a	85.0 a	86.1 a	85.2 a
HETEROSIS (%)						
F1 vs MP	0.8 ns	1.1 *	-0.1 ns	0.3 ns	0.5 ns	1.1 ns
F2 vs MP	0.3 ns	-0.1 ns	- ns	0.5 ns	-0.2 ns	-1.0 ns
F1 vs BP	0.5 ns	0.5	-0.5 ns	-0.7 ns	0.5 ns	0.2 ns
F2 vs BP	1.1 ns	-0.7	-0.4 ns	-0.5 ns	-0.2 ns	-1.9 ns
	c. Strength					
P1	32.9 cd	33.3 bc	33.3 a	33.8 a	35.8 a	34.8 a
P2	32.6 d	32.4 c	34.2 a	32.7 a	36.2 a	33.9 a
F1	34.7 a	35.4 a	34.1 a	33.6 a	37.9 a	36.0 a
F2	33.5 bcd	33.4 bc	34.8 a	34.5 a	37.0 a	34.9 a
BCP1	34.5 ab	34.8 ab	35.0 a	34.6 a	37.1 a	33.9 a
BCP2	33.9 abc	34.1 abc	33.9 a	35.0 a	36.7 a	34.6 a
HETEROSIS (%)						
F1 vs MP	6.2 **	7.7 *	1.0 ns	1.2 ns	5.2 ns	4.9 ns
F2 vs MP	2.5 ns	1.8 ns	3.0 ns	3.8 ns	2.7 ns	1.7 ns
F1 vs BP	5.7	6.2	-0.3 ns	-0.5 ns	4.7 ns	3.6 ns
F2 vs BP	2.0	0.4	1.7 ns	2.1 ns	2.2 ns	0.4 ns
	d. Micronaire					
P1	4.3 a	4.2 c	4.3 a	4.2 a	4.3 a	4.4 a
P2	4.4 a	4.6 ab	3.8 c	4.2 a	4.6 a	3.8 b
F1	4.7 a	4.6 ab	4.3 a	4.1 a	4.8 a	4.3 ab
F2	4.3 a	4.6 ab	3.9 bc	4.2 a	4.5 a	3.8 b

BCP1	4.5 a	4.3 c	4.3 a	4.4 a	4.5 a	4.4 a
BCP2	4.3 a	4.8 a	3.9 bc	4.0 a	4.5 a	3.7 b
HETEROSIS (%)						
F1 vs MP	7.0 ns	5.3 *	5.3 *	-1.6 ns	8.1 ns	3.0 ns
F2 vs MP	-2.5 ns	3.7 ns	-3.4 ns	0.9 ns	2.0 ns	-7.0 ns
F1 vs BP	5.6 ns	0.1	-0.7	-1.8 ns	4.5 ns	-4.2
F2 vs BP	-3.9 ns	-1.4	-8.9	0.7 ns	-1.5 ns	-13.5

[z] MP = Mid parent, BP = Best parent.

[y] Means within a column followed by the same letter are not significantly according to the Fisher's Protected LSD test.

[x] '+, *, ** effect significant at p=0.10, 0.05 and 0.01respectively, one degree of freedom comparisons.