COMBINING ABILITY FOR YIELD AND EARLINESS OF PIMA X EGYPTIAN COTTON CULTIVARS CROSSES

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Abstract

The current study was initiated to widen the genetic base of Egyptian cotton and to develop a practical foundation for breeding high lint- yielding and early mature cottons (*Gossypium barbadense*). For this purpose a factorial mating design II was used to study genodiversity among and between three populations viz. parents, F1's, and F2's. Five accessions of American Pima cottons (males) tested as a source of genes for improving earliness and productivity of adapted Egyptian cottons. They were mated with twelve lines of Egyptian cottons. The large number of Egyptian parents is justified because the behavior of these adapted Egyptian cultivars has not been previously studied when mated to Pima cottons in such a breeding program. The resultant sixty families (each consisting of an F1, a derived F2, and the original parents) were planted in a randomized Complete Block Design using a split plot arrangement of treatments with families as main plots and generations as split plots. Data showed that the additive gene action was greater than dominance gene action for yield and earliness characters studied. Over all bases, the cultivars G89, G85, G83, and Dandera among female parents were found to be good combiners. Among male parents P7 and P6 are the best combiners. The implications of the results in cotton breeding are discussed.

Introduction

One of the most important objectives of cotton breeding in Egypt is to improve, simultaneously, lint yield and earliness. Knowledge of the underlying gene action within the breeding population and better understanding of combining ability of the potential parents (that is their capacity to produce improved descendants) to be used in hybridization programs are keys for the right choice of parents and selecting procedures that will emphasize the achievement of characters studied. Marani (1963 and 1967) and Singh et al. (1971) suggested that the selection of parents for cotton breeding should be based on parental performance per se and general combining ability (GCA) effects. They added also the selection based on parental performance can be used to improve the general combining ability of the lines.

On the other hand, mating designs are rules for arranging controlled crossing. These rules were initially derived to allow the estimation of genetic parameters and create the next generation (Cockerham, 1954 and 1963; Kempthorne, 1957 and 1996; Griffing, 1956; Gallis, 1990). The factorial mating design is an analogue of the North Carolina Design II of Comstock and Robinson 1948 and is also acclaimed as the line X tester design (Murty et al., 1967; Arunachalam, 1976). Design II provides information about GCA of parents and SCA of there derived crosses. At the same time, it has advantages for estimating various types of gene action. Virk et al. (1985) concluded that mating design II provides almost the same genetic information as the Diallel analysis. Chahal et al. (1978) reported that the use of North Carolina approach with a wide genetic base tester seems to be more suitable in screening a large number of lines which may further evaluated by using the analysis of the diallel. The main feature of this design is to cross m females by n males; thus mn full sib and half sib-families are produced. These descendants, along with or without their parents, are tested in replicated trials using appropriate design.

The objective of our study is to utilize the accurate choice of parents and crosses to develop a genetic base for future breeding programs and provide a better insight into the genetic control of the traits considered.

Material and Methods

I. Experimental Materials

Five American Pima lines (PS3, PS4, PS5, PS6 and PS7) used as male parents were crossed with 12 Egyptian females parents (Dandera, G45, G70, G75, G76, G77, G80, G83, G85, G86, G88, and G89). These Egyptian and Pima cultivars are selected because they possess varying levels of lint yield and yield components and earliness as well as date of release type of release, origination program, and their fiber qualities, however, all of them are long and Extra-long staple varieties. The 12 female parents were considered as a representative and sufficient sample of Egyptian, long and extra-long, cotton germplasm. The large number of Egyptian parents is justified because the behavior of these adapted Egyptian cultivars has not previously studied when mated to Pima cottons in such a breeding program.

The experiments were conducted at Cairo University Agriculture Experiment Station during 1995-1997 growing seasons. In the summer of 1995, set of twelve Egyptian parents used as female parents, were crossed with five Pima pollen parents in a Factorial Mating Design II using hand emasculation and pollination techniques. In 1996 season, parents were re-crossed to obtain more hybrid seeds and artificial selfing for F1 hybrid plants made to obtain F2 selfed seed. On March 29, 1997 selfed seed of parents and their filial generations were planted in a replicated trial with three replications using Split-Plot Design with families as main plot and generations as sub plots. Plants of each parents and F1's were grown in single row while F2's in two rows. The rows were 5m long and 0.60m apart. Sowing was done by hand in hill spaced 0.25m apart. Soon

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after complete emergence, seedlings were thinned to two plants per hill. Standard practices were followed through the growing season as usual done with ordinary cotton culture.

Beginning on September 15, 1997 five guarded plants from each parent and F1 rows and ten plants of each F2 rows were hand harvested at frequent intervals until all bolls had been harvested, almost three times, and their mean values were used for statistical analysis. Samples containing 50 bolls hand harvest at random from sampled plants of each plot during harvest time to determine boll weight values and lint percentage, 50-boll sample weight was added to its related harvest time.

Characters Studied

a) Yield characters:

1. Seed Cotton Yield gms **-** total weight of sampled plants over the three harvests.
2. Boll Weight gms **-** the average weight in grams of fifty sound, open, random, bolls.
3. Lint Percentage **-** the amount of lint in seed cotton sample, expressed as percentage.

b) Earliness characters:

1. Earliness Index **-** ratio of weight of seed cotton harvested at the first picking to total weight of seed cotton harvested, expressed as percentage.
2. Production Rate Index **-** the total seed cotton plot weight divided by the MMD, (Bilbro and Quisenberry, 1973); where MMD=((W1H1) + (W2H2) +...+ (WnHn))/ W1 + W2 +...+ Wn; where, W=weight of seed cotton; H=number of days from planting to harvest; and 1,2, ..., n=cosecutive periodic harvest number. Chirstidis and Harrison (1955).

II. Statistical Analysis

Analysis of variance was performed based on plot means of the data. First, data were subjected to a Split-Plot Design in factorial arrangement of treatment with three replications. The whole plots were the families and the split-plots were the genotypes (Parents, F1, F2) within each family. Second, factorial mating Design II Scheme is employed for studying genetic variation in a sixty **-** family population for each of F1 and F2. The variation among generation is further divided into genetic variation components attributable to general (GCA) and specific combining ability (SCA) following the method suggested by Singh and Chaudhary (1979). Estimation of combining ability and type of gene actions were as follows:

gca = $(1/r(2mf\text{-}m\text{-}f)((((m\text{-}1)Mm+(f\text{-}1)Mf)/(m+f\text{-}2))\text{-}(Mmf)))$

sca = $(Mmf\text{-}Me)/r$

gca = $((1+F)/4)$ Additive

sca = $((1+F)/2)^2$ Dominance

Where m= male, f= female and F=1.

Results and Discussion

Analysis of Variance

The analysis of variance revealed that families and generations are highly significant for all characters except for seed index (Table 1). This indicates those parental genotypes as well as the crosses possess a reasonable degree of variability for yield and earliness characters. Further analysis of variance for individual generation showed significant difference for all characters except seed index. The contribution of male X female in no case was significant this may ascertain the assumption for the modification of genetic background for *barbadense* parents involved in crosses of this study. Male X female interaction also was insignificant over generations for all traits and this may reflect the stability of hybrids for these traits. Hayman (1958) reported that the F2 population resulting from a cross of the two inbred lines that differ by any number of unlinked loci is expected to lose 50% of the F1 dominance effects, whereas the additive effects should be constant from one generation to the next. Given that in mind and some other assumptions discussed with details by Tang et. al 1993 we are discussing the results of F2 data only. Let us first take a short glance on the mean performance of parents for each character.

Mean Performance of Parents

Cultivar means are presented in Table 2. Duncan's multiple range test was used to measure the significance among the mean performance of the parents. The cultivars that yielded the highest seed cotton yield were G83, PS7, G89, and PS6, and no significant difference in yield between these varieties. The lowest seed cotton yield was in cultivars PS3, G70, and G45.

The lint percentage in cultivar G80 was the highest while the lowest was in cultivar PS5. PS5 was the highest boll weight cultivar and PS7 was the lowest. Seed index was the lowest in cultivar G76 while it was the highest in cultivar PS5. The cultivar PS6 possessed the largest value for earliness index while the cultivar G45 was the lowest earliness index. G83, G89, PS6, and PS7 were found to be the highest cultivar for production rate index and they did not differ significantly between themselves.

These results indicate that first there are significant differences among all parents for yield and earliness characters studied. This may be helpful for using them in a crossing program aimed at cotton improvement. Second the cultivars that were found to be the highest yield might be due to their higher mean performance in the present yield components i.e., boll weight and seed index. Third, cultivar PS5 could be excluded of this clarification by reason of showing the highest boll weigh and the highest seed index and the lowest seed cotton yield, this was due to the less of retention of this cultivar. Fifth, some kind of association was clear between the traits seed cotton yield and production rate index since the highest varieties were the same for both characters.

Combining Ability Analysis

Table 3 showed the analysis of variance for the data of F2. Mean squares due to males and females were significant for all characters except for seed index. Male X female interaction was not significant for all characters. This may indicate that the additive type of gene action controls these characters. Because of the significance of both males and females mean squares we may conclude that most of variability expressed in crosses for every trait was due to the effect of both males and females parent. Table 4 showed that the covariance of half sibs was significant for all traits with the exception of seed index. GCA variances were significant for seed cotton yield and boll weight. Negative SCA variances were set to equal zero. These result more or less similar to the earlier reports by several workers (Baker et al., 1975; Chahal and Singh, 1978; Khan et al., 1991). Unlike these findings, higher SCA than GCA variances showing predominance of non additive part of gene action have been reported by many workers especially for boll weight and seed cotton yield. These differences may be attributed to differences in experimental materials, the accuracy of handling the entries and data, and environmental conditions where these experiments were conducted. Because the additive gene action was predominant in this study use of simple breeding procedures involving selection in early generations based on progeny performance may be recommended for improving characters studied.

Table 4 revealed that the relative contribution of females in the total genetic variance was almost twice that of male contribution except for earliness index. This may reveal the superiority of Pima germplasm regarding this character only. Generally, the per cent contribution of general combining ability (males and females) and specific combining ability (males X females) components to sum of squares of the crosses revealed the predominance of parental components in all characters.

General Effects

Table 5 shows general combining ability effects of the characters studied. Dandera, G83, G89 among females and PS6, PS7 among males showed significant desirable general combing ability effects for seed cotton yield. Genotypes G80, G89, PS7 showed positive general combining ability effects for lint percentage. Genotypes G75, G85 and PS5 exhibited significant desirable general combining ability effects for boll weight. Regarding earliness index genotypes, G83, G85, G87, PS6 and PS7 appeared to be good combiners with significant positive general combining ability effects. For production rate index, Dandera, G83, G85, G89, PS7 showed positive general combining ability effects.

Generally, G83, G89, and Dandera among females and PS6 among males were best combiners since they showed significant desirable combining ability for the majority of the characters studied. As a result, these genotypes could be involved in further crossing programs to improve cotton yield and earliness. The other genotypes, which indicated desirable significant general effects for one or two traits, will also be useful in integral breeding program aimed at genetic enhancement of individual component characters in cotton breeding program. On comparison of *per se* performance of the genotypes with their general combining ability effects, no abundantly clear association was evident. This may reflect the magnitude of the information on combining ability in selecting the parents for hybridization program.

Specific Effects

The number of crosses showing a positive specific combining ability were large and varied from character to character (20 for seed cotton yield, 23 for lint percent, 31 for boll weight, 30 for seed index, 34 for earliness index and 26 for production rate index). However, the number of crosses, which expressed significant positive specific combining ability, was very small. This was expected because the male X female interaction was insignificant Halluer and Miranda (1988). The specific combining ability represents the non fixable part of variation i.e., dominance and epistatic components that we may like to eliminate, however, if the cross showing high specific combining ability involves both the parents which are also good general combiners it could be adopted in cotton breeding program. The highest ten-percent of specific combining ability regarding each character is shown in Table 6. Based upon the previous discussion, we recommend the crosses Dandera X PS5, G85 X PS7, G89 X PS3, G83 X PS7 and G86 X PS3 for cotton genetic enhancement program. In some cases like crosses G89 X PS3 and G86 X PS3 since we have one parent good combiners (G89, G86) and the other poor combiner (PS3) we may expect to get a desirable transgressive segregation if the additive genetic system present in the good combiner. Generally, we noticed that the majority of the cross combinations showing positive specific combining ability effects for seed cotton yield showed positive specific combining ability effects for production rate index, this may support the suggestion that a close association exists between these two characters.

Potential of Breeding Materials

The results from this study suggests that there is no clear potential for use Pima cotton germplasm in the improvement of their Egyptian ancestors. However, the potential for cultivars PS7 and PS6 for GCA with earliness characters suggests that there is a need for further studies with these genotypes in the narrow scale of hybridization with the Egyptian germplasm. Simple breeding procedures could exploit the additive type of gene action for yield and earliness. Intercrossing of high general combiners resulting from this study may be prove well to fulfill their potentials and to combine desirable characters and consequently accumulate additive genetic variability.

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References

Arunachalam V. 1976. The utility of covariance of combining ability in plant breeding. Theor. Appl. Genet. 47:303-306.

Bilbro, J. D. and J. E. Quisenberry. 1973. A yield-related measure of earliness for cotton *G. hirsutum* L. Crop Sci. 13:392-393.

Comstock, R. E. and H. F. Robinson. 1948. The components of genetic variance in populations of biparental progenies and their use in estimating the average degree of dominance. Biometrics 4:254-266.

El-Adl, A. M. and P. A. Miller. 1971. Transgressive segregation and nature of gene action for lint yield in an intervarietal cross of upland cotton. Crop Sci. 11:381-384.

Falconer, D. S. 1981. Introduction to quantitative genetics. 2nd edition. Longman Press, London.

Griffig, B. 1956. The concept of general combining ability in relation to diallel crossing system. Aust. J. Biol. Sci. 9:463-494.

Gwen, G. C. and C. W. Smith. 1997. Combining ability for within-boll yield components in cotton, *G. hirsutum* L. Crop Sci. 37:1118-1122.

Hallaur, R. and J. B. Miranda. 1988. Quantitative genetics in maize breeding. Second Edition. Iowa State University Press/Ames.

Hyman, B. I. 1954. The theory and analysis of diallel crosses. Genetics 39:789-809.

Kempthorne O. 1957. An introduction to genetic statistics. Wiley and Sons, London.

Marini, A. 1967. Heterosis and combining ability in intraspecific and interspecific crosses of cotton. Crop Sci. 7:552-555.

Murray, J. C. and L. M. Verhalen. 1969. Genetic studies of earliness, yield, and fiber properties in cotton *Gossypium hirsutum* L. Crop Sci. 9:751-755.

Simods, N. W. 1979. Principles of crop improvement. Longman Group Ltd, London.

Sharma, D. R. 1979. Heterosis and combining ability in cotton. Mysore J. Agric. Sci. 13:4-9.

Singh, R. K. and B. D. Chaudhary. 1979. Biometrical methods in quantitative genetic analysis. Kalyani press, New Delhi, India.

Virk, D. S and A. S. Khehra. 1985. Comparative genetic analysis of metric trials using diallel and factorial mating design in bread wheat. Thero. Appl. Gen. 69:325-328.

Table 1. Analysis of variance table

Source	Df	Seed Cotton Yield	Lint Percent	Boll Weight	Seed Index	Earliness Index	PRI
Reps	2	**	**				**
Family	59	**	**	**		**	**
Error (a)	118						
Generation	2	**	*	**		**	**
Family x Generation	118			**		**	*
Error(b)	236						
Reps	2	**	*				*
Parents	16	**	**	**	*	**	**
F1	59	**	*	*		**	**
Male	4	**	**	*	*	**	**
Female	11	**	**	**	*	**	**
Male x Female	44						
Error	118						
Reps	2	*		*			**
F2	59	**	*	*		**	**
Male	4	**	**	*	*	**	**
Female	11	**	**	**	*	**	**
Male x Female	44						
Error	118						

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.
PRI - Production Rate Index

Table 2. Mean performance of 17 parents

Parent	Seed Cotton Yield	Lint Percent	Boll Weight	Seed Index	Earliness Index	PRI
Dandera	325.84c	35.70d	2.71d	10.64abcdef	17.20d	1.81b
Giza 45	186.66e	34.85def	2.26e	10.19edf	12.05e	1.01d
Giza 70	182.08e	34.34ef	2.25e	9.90f	12.37e	.98d
Giza 75	272.00d	37.81abc	3.13ab	11.05abcd	18.48bcd	1.50c
Giza 76	206.16e	35.36de	2.74d	9.55f	16.03d	1.12d
Giza 77	187.12e	37.03c	2.83dc	9.98ef	13.31e	1.02d
Giza 80	273d	38.82a	2.84dc	11.11abcde	18.67bcd	1.51c
Giza 83	374.07a	37.17bc	3.12ab	11.53abc	20.83b	2.07a
Giza 85	305.60c	37.17bc	3.15ab	11.70ab	20.40cb	1.71b
Giza 86	271.65d	35.40de	2.45e	10.56bcdef	16.10d	1.48c
Giza 88	317.07c	38.11abc	3.15abc	9.96ef	17.42d	1.75b
Giza 89	350.91ab	38.39ab	2.96bcd	11.10abcde	21.4b	1.96a
Pima S-3	205.08e	35.08def	2.92bcd	11.16abcd	16.23d	1.12d
Pima S-4	264.64d	35.72d	2.77d	10.40cdef	18.58bcd	1.47c
Pima S-5	278.68d	33.92f	3.22a	11.93a	17.60cd	1.54c
Pima S-6	349.87ab	35.40de	2.22e	11.36abc	44.95a	2.02a
Pima S-7	362.83a	37.94abc	2.33e	11.59ab	46.03a	2.10a
Mean	281.83	36.37	2.7	10.95	22.91	1.57
C.V. %	14.28	4.53	12.36	13.74	17.5	14.1

Means within a column followed by the same letter are not significantly different (*P*=0.05)

Table 3. Combining ability analysis

Source	df	Ms					
		Seed Cotton Yield	Lint Percent	Boll Weight	Seed Index	Earliness Index	PRI
Reps	2	19206.7	15.961	0.288	0.167	19.98	0.53
Hybrids	59	10290.9**	4.33*	0.10*	1.271	105.04*	035*
Male	4	24463.7**	18.33**	0.18*	2.77*	966.83**	0.93**
Female	11	36579.7**	9.16*	0.26**	2.35*	144.56**	1.238**
Male x Female	44	2430.3	1.85	0.054	0.86	16.82	0.075
Error	118	2253.8	2.87	0.056	0.92	21.11	0.068

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

Table 4. Estimation of variance components for F2

Source	Seed Cotton Yield	Lint Percent	Boll Weight	Seed Index	Earliness Index	PRI
Cov HSm	612.04	0.4577	0.035	0.053	26.389	0.024
Cov HSf	2276.63	0.4876	0.0138	0.099	8.5162	0.078
GCA	100.06	0.315	0.006	0.005	1.123	0.034
SCA	58.83	-0.3395	-0.006	-0.02	-1.4299	0.023
Additive	200.12	0.06316	0.012	0.01	2.246	0.069
Dominance	-58.83	-0.3395	-0.006	-0.02	-1.4299	0.023
G/S	1.70	*	*	*	*	1.478
Error	11.61	0.16	0.003	0.05	1.0825	0.061

Table 5. Contribution of females and males and their interactions to the total genetic variance.

Source	Seed Cotton Yield	Lint Percent	Boll Weight	Seed Index	Earliness Index	PRI
Male	0.1611	0.2868	0.12	0.148	0.624	0.179
Female	0.6627	0.3944	0.48	0.345	0.25	0.66
Male x Female	0.1761	0.3187	0.39	0.506	0.119	0.16

Table 6. General combining ability effects for each male and female inbred used from F2

Parent	Seed Cotton Yield	Lint Percent	Boll Weight	Seed Index	Earliness Index	Production Rate Index
Females						
Dandera	37.88	-1.05	-0.01	-0.19	2.33	0.23
Giza 45	-57.58	-1.24	-0.24	-0.18	-4.54	-0.34
Giza 70	-52.39	-1.04	-0.07	0.06	-4.48	-0.31
Giza 75	10.43	0.29	0.21	0.69	1.34	0.06
Giza 76	-48.24	-0.08	-0.14	-0.5	-1.73	-0.28
Giza 77	-71.68	0.33	-0.1	-0.5	-3.68	-0.41
Giza 80	0.79	0.94	-0.09	-0.11	-0.61	0.01
Giza 83	82.89	0.31	0.06	0.55	3.48	0.47
Giza 85	55.17	0.86	0.18	0.37	3.64	0.32
Giza 86	-9.47	-0.43	0.04	0.04	-1.05	-0.06
Giza 88	12.14	0.16	0.05	-0.4	2.06	0.07
Giza 89	40.05	0.95	0.1	0.17	3.23	0.24
S.E.(gi)	12.257	0.437	0.0613	0.247	1.1862	0.067
Males						
Pima S1	-21.63	-0.11	-0.05	-0.26	-4.09	-0.13
Pima S2	-19.24	-0.03	0.02	-0.06	-3.94	-0.12
Pima S3	-16.07	-1.09	0.11	0.48	-3.19	-0.1
Pima S4	-27.86	0.81	-0.07	-0.07	4.58	0.17
Pima S5	29.08	0.42	-0.01	-0.08	6.63	0.18
S.E.(gi)	7.9122	0.2823	0.0396	0.16	0.7657	0.044

Table 7. Specific combining ability effects of the highest ten percent crosses

Cross	Seed Cotton Yield	Cross	Lint Percent	Cross	Boll Weight
Dan.X PS5	62.99	Dan.XPS5	1.46	G76XPS3	0.27
G85X PS7	53.52	G8 3XPS3	1.24	G80XPS4	0.24
G89XPS3	52.53	G45XPS4	1.18	G85XPS5	0.22
G86XPS3	51.49	G45XPS7	1.13	G83XPS4	0.17
G85XPS6	41.29	G87XPS3	1.11	Dan.XPS3	0.15
G75XPS6	38.07	G80XPS4	0.91	G77XPS7	0.15
Error	27.40	Error	0.98	Error	0.13
Cross	Seed Index	Cross	Earliness Index	Cross	PRI
Dan.XPS7	1.12	Dan.XPS6	4.00	Dan.XPS5	0.35
G45XPS6	1.01	G45XPS7	3.69	G85XPS7	0.30
G87XPS3	0.85	G85XPS4	3.69	G89XPS3	0.30
G87XPS5	0.83	G83XPS7	3.40	G86XPS3	0.29
G85XPS7	0.75	G76XPS4	3.14	G83XPS6	0.21
G87XPS4	0.45	G87XPS6	2.63	G85XPS6	0.21
Error	0.55	Error	2.65	Error	1.20