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Genetic Studies in Upland Cotton (*Gossypium hirsutum* L.) II. General and Specific Combining Ability

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ABSTRACT

The present experiment was carried out to assess the general combining ability (GCA) and specific combining ability (SCA) of six important commercial cultivars of *Gossypium hirsutum* L. of Venezuela, viz., 'Deltapine 16', 'Tamcot-SP-21', 'Cabuyare', 'Stoneville', 'Ospino' and 'Acala 90-1' and their 15 F_1 hybrids, respectively. The data were analyzed using Griffing's Model I Method II. Significant differences were found for all traits evaluated, except for seeds per boll and bolls per plant. Combining ability analysis of variance revealed significant differences for GCA and SCA effects among the parents and hybrids for almost all traits except for seed cotton yield ha^{-1} and fiber % for GCA and boll set, seed yield, and fiber % for SCA. The results suggested the presence of additive and non-additive gene action for almost all of the traits. The ratio GCA/SCA ranged from 0.59 for fiber fineness to 5.14 for plant height. Cultivars with the best (desired) GCA effects were *cv.* Cabuyare for blooming initiation, seed yield, and fiber fineness; Stoneville for plant height, stem diameter, number of fruit branches, number of set flowers, and boll weight; Tamcot-SP-21 for boll set and fiber fineness; Deltapine 16 for plant height, 100-seed weight and fiber length; Ospino for fiber strength. Also, the results revealed that Stoneville was the best general combiner for most of the traits. Finally, the correlations among GCA effects of the parents showed negative and significant associations of boll set with plant height and positive and significant associations of fruit branches with plant height, boll weight, and number of set flowers; of set flowers with plant height and boll weight; and of plant height with stem diameter.

Keywords: Cotton, Fiber quality, General and specific combining ability, *Gossypium hirsutum*, Yield components.

INTRODUCTION

Cotton is one of the major crops in the agriculture of Venezuela and one of the commodities more exploited in the rainy season, providing occupation to the rural population during almost half of the year. In addition, the fiber and the seed are important raw materials in the manufacturing of clothes and oils, respectively, as well as of other industrial products (León *et al*., 1980). During 2006 and 2007, cotton production was 15,073 and 17,982 tons, respectively, cultivated over 15,388 and 14,491 ha, with the corresponding seed cotton yields of 980 and 1,241 kg ha^{-1} (Fedeagro, 2011). In the same years, the global volumes of cotton production were 70,905,974 and 72,991,442 tons, respectively, cultivated over 34,705,765 and 33,635,326 ha, with seed cotton yields of 2,043 and 2,170 kg ha^{-1}, respectively (FAOSTAT, 2011).

The primordial purpose of the Griffing's methodology is the estimate of the combining ability related with the basic population in reference. The general combining ability is the average behavior of a line or variety in the hybrid combination: each line or variety is crossed with the rest of the lines or varieties in the group and the average behavior of the resultant F_1

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individuals is considered as the base to determine the general combining ability of that particular line or variety. But, the specific combining ability is used to designate those cases in which certain combinations behave relatively better or worse that the average behavior of the involved lines or varieties and constitute a deviation of the general combining ability of the two lines or varieties involved in the cross. The concepts of general and specific combining abilities have been broadly used in breeding of crop plants in connection with the use of heterosis and heterobeltiosis for the development of commercial hybrids.

The concept of combining ability plays a significant role in crop improvement since it helps the breeder to determine the nature and magnitude of gene action involved in the inheritance traits. Combining ability is useful in selection of desirable parents for exploitation of hybrids and transgressive expressions and also to assess the ability of parents to generate potential hybrids with a reasonable level of stability (Ashokkumar and Ravikesavan, 2008). Identification of potential parents in cotton on the basis of progeny performance requires a large number of crosses, which is very laborious. Diallel analysis is a mating design whereby the selected parents are crossed in a certain order to predict the combining ability of the parents and elucidate the nature of gene action involved in the inheritance of the traits. The phenomenon of heterosis of F_1 hybrids can also reflect SCA and GCA of parental lines. The combining ability works as the basic tool for improved production of crops in the form of F_1 hybrids. Heterotic studies can also provide the basis for exploitation of valuable hybrid combinations and their commercial utilization in future breeding programs. The combining ability and heterosis work as the principal methods for screening of germplasm and determination of the ability of the genotypes to be included or not in a breeding program on the basis of their GCA, SCA, reciprocal, and heterotic effects. Therefore, both methods are very contributive in choosing potential parents with desired genetic variance, vigor, and, in some cases, through maternal effects (Khan *et al.,* 2009).

The problems of low productivity of cotton are largely owed to the genetics of the crop. This has been studied by different researchers (Garg and Kalsy, 1988; Hapase *et al.,* 1987; Gupta and Singh, 1987) by comparing the yields and other agronomic aspects of parents and their offspring. Some researchers (Singh *et al.,* 1988; Mehla *et al.,* 1987; Gupta and Singh, 1986; Jagtap and Kolhe, 1987; Abro *et al*., 2009; Karademir *et al*., 2009; Singh *et al*., 2010) carried out trials to evaluate the general and specific combining ability of several cotton cultivars used in each trial and found good combiners with excellent materials for the genetic improvement in cotton.

Combining ability analysis provides an ample opportunity to cotton breeders to understand the basis on which certain parental lines could be exploited in the breeding program (Rauf *et al.,* 2005). The improvement of a new variety with high yield and fiber quality parameters is the unique target of all cotton breeders. The first step in a successful breeding program is to select appropriate parents. Diallel analysis provides a systematic approach for the detection of appropriate parents and crosses superior in terms of the investigated traits (Basal and Turgut, 2003).

Studies confirm the value of these asseverations. Soomro *et al.* (1995) performed a combining ability analysis for yield and yield components in line×tester involving 5 lines and 3 testers and found that variances due to GCA and SCA were highly significant for boll number and seed cotton yield per plant, suggesting the importance of additive and non-additive type of gene action for these traits. Keerio *et al.,* (1995) found that variance due to GCA and SCA were significant for all the characters except ginning percentage, the additive gene action was more important than non-additive and highly significant GCA effects were found in lines S-12 for all traits and CRIS-7-A for seed weight, lint weight and seed cotton yield. Recently, Khan *et al.* (2002) conducted a diallel cross experiment involving Stoneville-213, HG-6-1-N, Fregobract-83 and AG-hirsutum-87 cultivars of upland cotton to ascertain the type of gene action for different quantitative traits. Results demonstrated that ginning outturn and seed index were controlled by over dominant type of gene action, whereas seed cotton yield plant^{-1} was governed by partial dominance type of gene action. Rauf *et al.* (2005) found that the estimates of variance components for GCA, SCA and reciprocal effects showed that variance due to

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SCA was greater in magnitude and more important for seed cotton yield, number of bolls per plant, sympodial and monopodial branches and plant height; while variance due to reciprocal effects was higher in magnitude for ginning outturn and staple length, and additive gene action predominated in boll weight and fiber strength as a result of higher magnitude of GCA.

The objective of the present experiment was to determine the general and specific combining ability of six commercial upland cotton cultivars and their 15 hybrid combinations, respectively (excluding reciprocals) and to select those cultivars and F_1 hybrids that were good combiners for seed cotton yield ha^{-1} and fiber quality.

MATERIAL AND METHODS

The experiment was carried out in Jusepín Town, Monagas State, Venezuela. The six commercial cultivars of upland cotton used were L_1= Deltapine-16; L_2= Tamcot-SP-21; L_3= Cabuyare; L_4= Stoneville; L_5= Ospino and L_6= Acala-90-1. The experiment consisted of two phases:

Phase I

The first phase was denominated phase of crosses, from August to November (post rainy season). It was carried out in the Estación Experimental de Sabana (Experimental Station of Savanna) of the Universidad de Oriente, Venezuela, located in the Table of Piedemonte of the plateau of the Oriental Plains, in a savanna soil previously cultivated. Soil preparation consisted of three passes of harrow and lime application of 1,000 kg ha^{-1} 30 days before sowing. The cottons plants were fertilized at the rate of 600 kg ha^{-1} of a 15-15-15 fertilizer formulation applied in deep bands. Urea was applied in superficial bands 30 days after sowing, at a dose of 200 kg ha^{-1}. Two hills of plants were sown for each one of the cultivars used. The distance between plants was 0.20 m and between hills was 1 m. The hills, with a length of 35 m, were divided in 6 segments of 5 m each, separated from each other by 1 m. One of the segments was allocated for the self-fertilization and intra-cultivar crosses and the five remaining hills were used to carry out the crosses with the other cultivars to obtain the hybrid seeds for the second phase by means of diallel crosses excluding reciprocals.

The crosses began 36 days after sowing and one day before the flowers were expected to open. Following the methodology described by Poehlman (1981), in the first place, the corolla of the female parent flower was cut with small scissors, then, the anthers were eliminated (emasculation) and the stigma was protected using a soda straw to avoid the possibility of cross pollination. In the following morning, the pollination was carried out, collecting the male parent's pollen in a small piece of closed straw in one of its ends. This straw piece, partially full of pollen, was placed on the exposed stigma after removing the protector of the emasculated flower. To assure the pollination, the flower bracts were lifted up around the straw piece and were held together with a fine wire so that they stayed in place. Finally, the cross was marked with a color tape in order to facilitate its identification. Approximately 40 crosses were carried out for each segment with nearly 75% success, in agreement with that reported by Poehlman (1981).

For these crosses, care was taken to select flowers located in the middle third of the plant to assure a bigger germination percentage and vigor (Arturi 1984). The mature bolls from the crosses and from the self fertilization were collected in two harvests, 119 and 135 days after sowing.

Phase II

The second phase was evaluation that was carried out in the Estación Hortícola de Producción Vegetal (Horticultural Station of Crop Production of the Universidad de Oriente), from May to August (rainy season). Among the cultural practices carried out in this phase were: the soil preparation consisting of two passes of plow, three passes of harrow, and lime

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application at the rate of 1,000 kg ha^{-1}, 30 days before sowing. The last pass of harrow was made one day before sowing, jointly with a pass to make the furrows. Three hills of the six commercial cultivars of cotton and their 15 hybrid combinations were sown (excluding reciprocals) at a distance of 0.20 m between plants and 0.80 m between hills for an equivalent final population of 62500 plants ha^{-1}. Supplementary irrigation was applied to meet the water requirements of the crop due to the absence of rain during the crop development. The cotton plants were fertilized at the rate of 600 kg ha^{-1} of a 15-15-15 fertilizer formulation, placed in deep bands. Urea was applied in superficial bands 30 days after sowing at a rate of 200 kg ha^{-1}. Weeds were controlled chemically by using 4 liters ha^{-1} Round-up at pre-sowing. Also, 2 liters ha^{-1} H1-2000 was applied 20 days after sowing. Two manual weedings were carried out, 35 and 82 days after sowing.

The evaluated traits were: blooming initiation (days), plant height (cm), stem diameter (cm), height of first fruit branch (cm), fruit branches, boll set (%),set flowers, 100-seed weight (g), boll weight (g), seeds boll^{-1}, bolls plant^{-1}, fiber content (%), lint yield (kg ha^{-1}), seed yield (kg ha^{-1}), seed cotton yield (kg ha^{-1}) and the fiber quality traits: length (inches), uniformity (%), strength (103 lb inches^{-2}), and fineness (micronaire).

The experimental design used was randomized complete blocks with three replications and 21 treatments (6 cultivars and its 15 hybrids). Each treatment consisted of three hills of plants, the outer two hills were considered as borders and the central hill was used for the evaluation of the different parameters. The obtained data were analyzed by means of the conventional analysis of variance and analysis of variance for combining ability were calculated using Model I (the fixed effect model) and Method II (parents and one set of crosses) of Griffing (1956).

RESULTS AND DISCUSSION

The coefficient of variation and mean squares of genotypes of different agronomic characters evaluated for six commercial cultivars and their 15 hybrids are presented in Table 1. Conventional analysis of variance showed significant differences among all the characters, except the height of first fruit branch, number of seeds boll^{-1}, number of bolls plant^{-1}, lint yield and fiber

Table 1. Coefficients of variation and genotypes mean squares of the investigated characters of 6 commercial cultivars and their 15 hybrids of upland cotton (*Gossypium hirsutum* L.).

Character	Coefficient of variation (%)	Mean squares of genotypes	
Blooming initiation (days)	8.88	67.50	*
Plant height (cm)	14.72	990.85	*
Stem diameter (cm)	10.60	0.110	*
Height of first fruit branch (cm)	8.34	7.85	ns
Number of fruit branches plant^{-1}	17.00	34.94	*
Boll set (%)	16.03	63.05	*
Number of set flowers	22.61	220.50	*
100-Seed weight (cm)	6.62	1.39	*
Boll weight (g)	13.24	2.48	*
Number of seeds boll^{-1}	9.71	12.60	ns
Number of bolls plant^{-1}	29.66	21.88	ns
Lint yield (kg ha^{-1})	32.95	46382.83	ns
Seed yield (kg ha^{-1})	27.41	130461.23	*
Seed cotton yield (kg ha^{-1})	28.63	319182.00	*
Fiber content (%)	8.91	17.25	*
Fiber length (Inches)	3.10	0.003	*
Fiber uniformity (%)	5.36	5.52	ns
Fiber strength (10^3 lb inches^{-2})	3.95	24.62	*
Fiber fineness (Micronaire)	2.38	0.12	*

* Significant (P≤ 0.10), ns: Not Significant (P> 0.10).

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uniformity. Similar results were reported by Naveed *et al.* (2004) who found significant differences for plant height, seed cotton yield, boll weight and lint percentage and also for the number of bolls plant^{-1}. Lint yield, bolls plant^{-1}, seed cotton yield and seed yield had similar and high coefficients of variability while fiber traits had very low ones. These results were in agreement with Ali *et al.* (1998), who indicated that all the characters showed low coefficients of variability except yield of seed cotton and number of bolls per plant in a 4×4 complete diallel.

Table 2 shows the GCA effects of several characters evaluated for the six commercial cultivars of cotton. The analysis of variance for combining ability revealed significant differences for the GCA and SCA effects among parents for almost all of the evaluated traits, except for seed cotton yield ha^{-1} and fiber content for GCA effects and for boll set, seed yield ha^{-1} and fiber content for SCA effects. Similarly, Karademir and Gençer (2010) reported that mean squares of GCA were significant for ginning percentage, fiber length, fiber fineness and fiber elongation, revealing the important role of additive gene effects, but not for seed cotton yield, fiber strength and fiber uniformity. SCA was found to be significant for seed cotton yield, fiber length, fiber fineness, fiber strength, fiber elongation and fiber uniformity, revealing that non-additive gene effects, as dominant or epistatic, were important.

Parental cultivars and F_1 hybrids did not have significant differences for the yield components *viz.*: number of bolls plant^{-1} and number of seeds boll^{-1}, indicating that improvement of these characters and/or seed cotton yield ha^{-1} via indirect selection of these two traits could not be very effective since, in the population studied, the genetic variance for these traits was relatively very low. Fiber content (ginning outturn) had the same situation, although it presented significant differences for the 21 studied genotypes i.e. it did not show significant differences for the GCA and SCA effects among the parents and hybrids, respectively. Therefore, the influence of additive and non-additive gene action was not detected in the expression of fiber content, therefore, genetic improvement of this character could be very difficult.

The ratio GCA/SCA was 1.36; 1.27; 1.47; 1.07; 1.18; 0.80; 1.58 and 0.59 for blooming initiation, 100-seed weight, seed yield ha^{-1}, seed cotton yield, fiber content, fiber length, fiber strength, and fiber fineness, respectively. These results indicated that additive and non-additive gene actions had a very similar influence in the expression of these characters (Table 2). However, the ratio GCA/SCA was 5.14; 2.37; 2.34; 3.06; 2.13 and 1.91 for plant height, stem diameter, number of fruit branches, boll set, number of set flowers and boll weight, respectively, suggesting that additive gene action was the most important factor in the expression of these characters (Table 2). A generally higher magnitude of variance due to GCA effects compared to SCA effects indicates the importance of additive type of gene action involved in the manifestation of characters under study. Similarly, Karademir and Gençer (2010) reported that GCA effects were higher than SCA effects for the ginning percentage, fiber length, fiber fineness and fiber elongation. They also found that mean squares of the SCA were highly significant for seed cotton yield, fiber strength and fiber uniformity. The contrasting study of Ashokkumar (2010) indicated that GCA variances were lower than SCA variances for all the characters studied (seed yield, plant traits, fiber quality), as indicated by their lower ratios indicating predominance of non-additive gene action (dominant or epistasis). The difference in the finding might have resulted due to different breeding material tested under each particular environmental condition.

Cultivars with the best (desired) GCA effects were: 'Cabuyare' for blooming initiation, seed yield and fiber fineness; 'Stoneville' for plant height, stem diameter, number of fruit branches, and number of set

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Table 2. Effects of general combining ability of the investigated characters of 6 commercial cultivars of upland cotton (*Gossypium hirsutum* L.).

Cultivars	Blooming initiation (days)	Plant height (cm)	Stem diameter (cm)	Number of fruit branches	Boll set (%)	Number of set flowers	100-Seed weight (g)	Boll weight (g)	Seed yield (kg ha^{-1})	Seed cotton yield (kg ha^{-1})	Fiber content (%)	Fiber length (inches)	Fiber strength (1000 lb inch^{-2})	Fiber fineness (mic.)
Deltapine 16	0.640 *	5.535 *	0.0525 *	1.328 *	-1.952 *	2.142 ns	0.503 *	0.286 ns	-35.752 ns	ns	ns	0.011 *	-0.125 ns	0.0029 ns
Tamcot-SP-21	-0.944 *	-17.789 *	-0.1380 *	-2.094 *	3.625 *	-4.302 *	-0.031 ns	-0.512 *	-9.640 ns	ns	ns	0.003 ns	0.415 ns	-0.0933 *
Cabuyare	-2.359 *	4.853 *	0.0600 *	0.508 ns	1.472 ns	1.914 ns	-0.120 ns	-0.049 ns	117.420 *	ns	ns	0.006 ns	-0.500 ns	-0.0383 *
Stoneville	2.306 *	11.836 *	0.1138 *	2.043 *	-2.687 *	4.898 *	-0.069 ns	0.415 *	80.111 ns	ns	ns	-0.017 *	-2.000 *	0.0192 ns
Ospino	1.805	-2.821 ns	-0.0275 ns	-0.453 ns	-0.469 ns	0.380 ns	-0.119 ns	0.330 ns	-55.369 ns	ns	ns	-0.005ns	1.418 *	0.0692 *
Acala 90-1	-1.447 *	-1.614 ns	-0.0850 *	-1.323	0.011	-5.032 *	-0.269 *	-0.469 *	-96.499 *	ns	ns	0.002 ns	0.790	0.0404 *
GCA variance	28.052 *	834.053 *	0.064 *	20.272 *	42.483 *	121.944 *	0.552 *	1.354 *	54374.5 *	111688.6 ns	6.488 ns	0.0008 *	11.314 *	0.027 *
SCA variance	20.639 *	162.362 *	0.027 *	8.723 *	13.879 ns	57.358 *	0.436 *	0.709 *	36960.4ns	104642.8 *	5.502 ns	0.0010 *	7.175 *	0.046 *
GCA[a]/SCA[b]	1.36	5.14	2.37	2.34	3.06	2.13	1.27	1.91	1.47	1.07	1.18	0.80	1.58	0.59

[*] Significant ($P \leq 0.10$), ns: Not Significant ($P > 0.10$).
[a] General combining ability, [b] Specific combining ability.

flowers and boll weight; 'Tamcot-SP-21' for boll set and fiber fineness; 'Deltapine 16' for plant height, 100-seed weight and fiber length; 'Ospino' for fiber strength (Table 2). According to Simmond (1979), the GCA effect is considered as the intrinsic genetic value of the parent for a trait which is due to additive gene effect and it is fixable. The cultivars with the worst (undesired) GCA effects were: 'Stoneville' for blooming initiation, boll set, fiber length and fiber strength; 'Tamcot-SP-21' for plant height, stem diameter, number of fruit branches and boll weight; 'Acala 90-1' for number of set flowers, 100-seed weight, boll weight and seed yield and 'Ospino' for fiber fineness. These results suggested that none of the evaluated cultivars were good general combiners for all the traits studied, so that, for the improvement of a trait through any variety, the undesired GCA effects of this variety should be considered. Gutiérrez *et al.* (1998) found that cultivar 'Cabuyare' presented significantly positive GCA effects for seed cotton yield. Azhar and Naeem (2008) suggested that parents having good GCA for a particular character are expected to yield good hybrids and this suggestion appeared to be true in the present studies.

The ratio GCA/SCA was 1.07 for seed cotton yield ha^{-1} and there were not significant differences for the GCA effects among the parents, but there were significant differences for the SCA effects among the hybrids, indicating that non-additive action was the most predominant for this character. This indicates that over dominance effects are very important and heterosis and heterobeltiosis could be used to boost seed cotton yield ha^{-1}. In the analysis of the SCA effects among the F_1 hybrids obtained in this experiment (Table 3), significant positive effects were found for SCA among the hybrids 'Deltapine 16'×'Tamcot-SP-21' and 'Cabuyare'×'Stoneville'. These hybrids could be utilized as commercial cotton hybrids when production of hybrid seed would be easy and economical by virtue of the high yields that these two hybrids had, especially, 'Cabuyare'×'Stoneville' that had

Table 3. Effects of specific combining ability of seed cotton yield and some fiber properties of 15 hybrids of Upland cotton (*Gossypium hirsutum* L.).

Hybrids	Seed cotton yield (kg ha^{-1})	Fiber length (inch)	Fiber strength (1000 lb inch^{-2})	Fiber fineness (Mic)
Deltapine 16×Tamcot SP 21	388.24 *	-0.018 ns	-2.103 ns	0.358 *
Deltapine 16×Cabuyare	86.08 ns	-0..030 *	2.482 ns	-0.670 ns
Deltapine 16×Stoneville	358.65 ns	0.023 ns	-0.348 ns	0.046 ns
Deltapine 16×Ospino	-135.66 ns	0.051 *	-1.436 ns	0.126 *
Deltapine 16×Acala 90-1	-53.16 ns	0.004 ns	-0.808 ns	-0.246 *
Tamcot SP 21×Cabuyare	71.47 ns	-0.023 ns	-3.058 *	-0.041 ns
Tamcot SP 21×Stoneville	-85.17 ns	0.020 ns	-0.228 ns	-0.258 *
Tamcot SP 21×Ospino	121.32 ns	0.019 ns	3.024 *	0.052 ns
Tamcot SP 21×Acala 90-1	-439.55 *	0.001 ns	1.652 ns	0.121 *
Cabuyare×Stoneville	579.02 *	0.048 *	-1.643 ns	-0.113 *
Cabuyare×Ospino	-46.40 ns	-0.024 *	-1.391 ns	0.237 *
Cabuyare×Acala 90-1	106.03 ns	-0.001 ns	-4.103 *	-0.104 *
Stoneville×Ospino	85.12 ns	-0.031 *	-3.231 *	0.179 *
Stoneville×Acala 90-1	-335.85 ns	-0.059 *	-1.603 ns	-0.232 *
Ospino×Acala 90-1	-152.94 ns	-0.010 ns	-0.351 ns	0.088 ns

* Significant (P≤ 0.10), ns: Not significant (P> 0.10).

heterosis of 65.38; 58.52 and 45.55% over midparent, better parent, and best parent values, respectively (data not shown). On the contrary, hybrid ‘Tamcot-SP-21’×‘Stoneville’ showed negative SCA effects for this character. However, there were positive and negative SCA effects for fiber properties viz., fiber length, strength, and fineness.

The performance of a single cross progeny could be adequately predicted on the basis of GCA if the SCA mean squares are not significant (Griffing 1956) and the best performing progeny may be produced by crossing the two parents having the highest GCA. In the present investigation, the cultivars ‘Cabuyare’ and ‘Stoneville’ had the biggest GCA effects for seed yield ha^{-1} and its combination had the biggest F_1 performance as indicated for the biggest heterosis of 65.58; 59.02 and 56.72% over midparent, better parent, and best parent values, respectively (data not shown). Accordingly, this hybrid is regarded as a useful breeding material.

The correlations among GCA effects of the parents (Table 4) showed negative and statistically significant associations of boll set with plant height and positive and statistically significant associations of fruit branches with the number of set flowers, boll weight, and plant height and of set flowers with boll weight and plant height, and of plant height with stem diameter. GCA effects of seed yield did not have statistically significant association with the GCA effects of the rest of traits. Selection for a positive plant height significantly decreased the boll set and enhanced fruit branches, number of set flowers, and stem diameter suggesting that taller plants had more branches and produced more flowers, which, in turn, became more bolls that were not retained at harvest, decreasing boll set (productivity). Therefore, selection for better combining parents for taller plants will be an advantage over smaller ones to select for better combining ability for fruit branches, number of set flowers and stem diameter. On the other hand, selection for better combining parents for a bigger number of fruit branches will be an advantage over one with fewer fruit branches to select for better combining ability for boll weight and the number of set flowers.

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Table 4. Analysis of simple linear correlation coefficients between effects of general combining ability of the investigated characters of 6 commercial cultivars of upland cotton (*Gossypium hirsutum* L.).

Character	Blooming initiation (Days)	Stem diameter (cm)	Plant height (cm)	100-Seed weight (g)	Boll weight (g)	Number of set flowers	Number of fruit branches	Boll set (%)	Fiber length (Inches)	Fiber fineness (Mic.)	Fiber strength (1000 lb inch^{-2})
Seed yield	-0.086	0.070	0.429	-0.043	0.290	0.651	0.535	0.018	-0.244	-0.412	-0.762
Fiber strength	-0.223	-0.184	-0.658	-0.163	-0.391	-0.700	-0.750	0.418	0.424	0.207	
Fiber fineness	0.533	0.779	0.490	-0.147	0.520	0.221	0.291	-0.721	-0.391		
Fiber length	-0.671	-0.171	-0.315	0.450	-0.428	-0.391	-0.312	0.418			
Boll set	-0.704	-0.775	-0.838 *	-0.335	-0.793	-0.675	-0.807				
Fruit branches	0.502	0.659	0.924 *	0.444	0.842 *	0.948 *					
Set flowers	0.552	0.552	0.816 *	0.374	0.901 *						
Boll Weight	0.782	0.618	0.723	0.407							
100-Seed weight	0.259	0.031	0.198								
Plant height	0.350	0.861 *									
Stem diameter	0.252										

* Significant ($P \leq 0.05$), Correlation values without * mean not significant ($P > 0.05$).

In a line×tester analysis involving 11 lines and 3 testers, Mehla *et al.* (1987) found that SCA effects were predominant for seed cotton yield and 100-seed weight, while GCA effects were important for fiber content. Jagtap and Kolhe (1987) made a combining ability analysis and observed that both additive and non-additive gene action were significant for bolls plant^{-1}, boll weight, seed cotton yield and fiber %, but additive gene action was the more important. El-Zahab (1983) in a diallel cross of 10 cultivars found that additive effects were predominant for boll weight. El-Gohary *et al.* (1981) carried out a diallel cross, without reciprocals, involving six cotton varieties and found that GCA was significant for yield, bolls plant^{-1}, boll weight and fiber % and SCA was significant for bolls plant^{-1}, boll weight and seeds boll^{-1}. However, additive genetic variance was predominant for all the traits except seed boll^{-1}. Khajjidoni *et al.* (1984) crossed two *G. arboreum* lines with 10 testers of *G. herbaceum* in a line x tester analysis and found that GCA variances were higher than SCA variances for bolls plant^{-1}, boll weight and seeds boll^{-1}, indicating the importance of additive gene effects. However, SCA were higher than GCA variances for seed cotton yield and 100-seed weight only. Singh *et al.* (1987) evaluated a set of 45 crosses from 10 diverse parents of *G. hirsutum* for combining ability and found that non-additive genetic effects were the more important for fiber strength and fineness, whereas additive genetic effects were so for fiber length and no parent was a good general combiner for all traits. Rauf *et al.* (2005) found the estimates of variance component for GCA, SCA and reciprocal effects and showed that variance due to SCA was greater in magnitude and more important for seed cotton yield, bolls per plant, sympodial and monopodial branches and plant height. Additive gene action predominated in boll weight and fiber strength as a result of higher magnitude of GCA variance in these characters.

Considering the results of the aforementioned researchers, it can be stated that some of them are in agreement with the present findings, but some are contrary. This suggests that the results obtained in a particular trial depend on many factors such as the cultivars and/or species used in the study, as well as the location where the experiment was carried out. Thus, the conclusions drawn from the present experiment may only be applied to the conditions and cultivars similar to those used in the study.

CONCLUSIONS

Blooming initiation, 100-seed weight, seed yield ha^{-1}, seed cotton yield, fiber content, fiber strength and fiber fineness were dominated by both additive and non-additive gene actions, while plant height, stem diameter, number of fruit branches, boll set, number of set flowers and boll weight were dominated mostly by the additive gene action alone. Cultivars with the best GCA effects were: 'Cabuyare' for blooming initiation, seed yield and fiber fineness; 'Stoneville' for plant height, stem diameter, number of fruit branches, number of set flowers and boll weight; 'Tamcot-SP-21' for boll set and fiber fineness; 'Deltapine 16' for plant height, 100-seed weight and fiber length; 'Ospino' for fiber strength. Cultivars with the undesired GCA effects were: 'Stoneville' for blooming initiation, boll set, fiber length and fiber strength; 'Tamcot-SP-21' for plant height, stem diameter, number of fruit branches and boll weight; 'Acala 90-1' for number of set flowers, 100-seed weight, boll weight and seed yield and 'Ospino' for fiber fineness. The hybrids 'Deltapine 16'×'Tamcot-SP-21' and 'Cabuyare'×'Stoneville' showed significant positive effects for SCA.

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مطالعات ژنتیکی پنبه (*Gossypium hirsutum* L.)مناطق مرتفع. بخش۲: توانایی ترکیب عمومی و ویژه

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چکیده

هدف از مطالعه حاضر ارزیابی توانایی ترکیب عمومی(GCA) و ترکیب ویژه (SCA)شش رقم تجارتی مهم پنبه ونزوئلا به نام های 'Deltapine 16', 'Tamcot-SP-21', 'Cabuyare', 'Stoneville', 'Ospino' 'Acala 90-1' و ۱۵ هیبرید آنها بود. داده های به دست آمده با استفاده از مدل I روشII گریفینگ تجزیه تحلیل شد. در مورد همه صفات ارزیابی شده تفاوت های معنی داری به دست آمد به جز در مورد تعداد بذر در غوزه و تعداد غوزه در هرگیاه. تجزیه واریانس توانایی ترکیب، در مورد اثر GCA و SCA در میان والدین و هیبرید ها برای تقریبا همه صفات تفاوتهای معنی داری نشان داد به جز عملکر دانه پنبه(در موردGCA) و در صد فیبریا تار(در مورد SCA). این نتایج به حضور افزایشی و غیر افزایشی عمل ژن برای همه صفات اشاره داشت. نسبت GCA/SCA از ۰.۵۹ در مورد نرمی تار (فیبر) تا ۵.۱۴ در مورد بلندی گیاه تغییر میکرد. رقمهای دارایGCA مطلوب شامل Cabuyare(برای آغاز گلدهی، عملکرد دانه، و نرمی تار)، Stoneville (در مورد بلندی گیاه، قطر ساقه، تعداد شاخه های گل، تعداد گل، وزن غوزه) و Tamcot-SP-21 (در مورد غوزه بارور و نرمی تار) وDeltapine 16 (در مورد بلندی گیاه، وزن ۱۰۰ دانه ، و طول تار) بودند.همچنین، نتایج نشان داد کهStoneville از نظر ترکیب عمومی در بیشتر صفات ، بهترین بود. بالاخره اینکه همبستگی بین اثرات GCA والدین رابطه ای معنی دار و منفی بین غوزه بندی وبلندی گیاه بود. از طرف دیگر، همراهی معنی دار و مثبتی بین شاخه های غوزه دار با بلندی گیاه و وزن غوزه و تعداد گل بارور، و نیز بین گل بارور و بلندی گیاه و وزن غوزه، و بین قطر ساقه با بلندی گیاه وجود داشت.

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