Combining Ability for Fiber Properties in Influential Upland Cotton Varieties

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ABSTRACT

A great number of germplasm lines have been used as parents in cotton improvement. Those contributing a larger proportion of genes to modern cotton cultivars than other germplasm are called influential lines. Based on the pedigree analysis of 260 cotton cultivars released in the United States between 1970-1990, the most influential cotton varieties from 16 cotton breeding programs were identified. The objective of this study was to investigate the general and specific combining ability (GCA and SCA, respectively) for fiber properties among the most influential lines from 10 Upland cotton breeding programs. A half diallel crossing scheme with the parents and 45 F_1's was grown in replicated trials at two locations in 1997. Fiber properties measured by HVI included micronaire, strength, length, uniformity and elongation. The significance of GCA and SCA effects detected and how they can be used to develop varieties with improved fiber characteristics is discussed.

Introduction

As in many crops, there has been considerable interest as of late with regards to the narrowness of the genetic base in cotton (Bowman *et al.*, 1996). Calculating coefficient of parentage from pedigree data, May *et al.* (1995) found evidence that a significant amount of variability still existed among the 126 Upland cotton varieties released between 1980 and 1990 in the United States. Similar results were also found when all 260 Upland cotton varieties released in the United States between 1970 and 1990 were analysed (Bowman *et al.*, 1996). Nevertheless, recent trends in cotton variety development have favoured the crossing of closely related material or reselections among already released varieties.

It follows that many breeding programs favour the use of germplasm developed within their own program in generating new recombinations from which to extract varieties or germplasm lines. Bowman *et al.* (1996) recognised 16 major cotton breeding programs in existence between 1970 and 1990 based upon the number of cultivars released by a program and the number of times cultivars released by a program appeared in the pedigrees of the 260 cultivars released during this time frame. From each of these programs the most influential line was also identified. The objective of this study was to investigate the combining ability of a selected subset of these influential lines for fiber quality traits.

Material and Methods

Ten influential Upland cotton varieties/germplasm from 10 different breeding programs were evaluated. These were McNair 235 from McNair/Northrup King, Coker 100W from Coker Pedigreed Seed Co., Paymaster 54 from Paymaster/Cargill Seeds, Stoneville 2 from Stoneville Pedigreed Seed Co., Lankart 57 from Lankart Seed Farms, PD 2165 from USDA-ARS & South Carolina Agricultural Experiment Station (AES), Deltapine 15 from Delta and Pine Land Co., CA 614 from Texas AES-Lubbock, DES 56 from Mississippi State University Delta Experiment Station, and Delcott 277 from University of Missouri AES (Bowman *et al.*, 1996). The 10 Upland cotton varieties were crossed during the Summer of 1996 in Baton Rouge, Louisiana in all possible combinations excluding reciprocals (half-diallel) following Griffing's Method 2 (Griffing, 1956). The 45 different F_1 populations plus the 10 parents were planted on 16 May 1997 in two Louisiana Agricultural Experiment Station locations: Northeast Research Station, St. Joseph, LA and Macon Ridge Research Station, Winnsboro, LA. Trial design was a randomised complete block with three replications. Rows were 6m long and 1m apart. Plants were spaced 10-15cm apart within a row. Plots were maintained as per Louisiana Co-operative Extension Service recommendations.

At maturity, 50 open bolls were hand harvested from each plot. Seedcotton was ginned on a 10-saw laboratory gin and fiber samples were analysed by High Volume Instrumentation (HVI) at the Louisiana State University Cotton Fiber Lab. HVI parameters measured were micronaire, length (UHM), T_1 strength (g/tex), Uniformity Index (UI), and elongation. An analysis of variance (ANOVA) was conducted for parental data and differences were tested for significance using LSD. An SAS (SAS. 1989) program (Zhang and Kang, 1997) based on Griffing's (1956) method 2, model 1 was used for across location analysis of variance and for estimating GCA and SCA effects.

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Results and Discussion

Analysis of variance indicated that highly significant differences existed among the ten influential lines for all five HVI fiber properties (Table 1). There were also highly significant or significant differences between environments for all fiber properties except elongation. The lack of any significant environment by variety interactions, however, suggests that rank differences were not present and that for fiber properties, variety response to the environments was a reflection of the difference between the two environments. This also implies that selection for improved HVI fiber characteristics can safely be made in one environment and progress will transpose to other locations.

Mean fiber properties for the ten influential lines, averaged across locations, are presented in Table 2. DES 56 had the highest micronaire at 5.16 while Lankart 57 had the lowest at 4.52. The line PD 2165, which is a product of the USDA cotton breeding program in South Carolina which has a historical focus on developing germplasm with superior fiber characteristics, had the greatest upper-half mean length of 1.17. Interestingly Stoneville 2, the oldest line evaluated based upon release date, also had one of the longest fibers with UHM = 1.14. The shortest influential line was CA 614 with a UHM of 1.06. All ten influential lines had an average to high uniformity index ranging from a low of 82.5 for CA 614 to a high of 85.2 for PD 2165. PD 2165 had the strongest T_1 fiber strength with a mean of 28.9 g/tex. Both Lankart 57 and Deltapine 15 had the weakest fiber with a T_1 fiber strength of 24.1. Fiber elongation values amongst the ten influential lines were all average to high, ranging from 5.9 to 7.3, with Delcott 277 having the highest measured elongation.

A combined analysis of variance of HVI fiber properties was done to determine the amount of variability among ten influential lines and their F_1's. Highly significant differences amongst the lines and their F_1's were found for all traits except uniformity index (data not shown). Environments were highly significant or nearly so for length uniformity and upper-half mean length, respectively. Differences between environments for both T_1 fiber strength and elongation were significant at P=0.07. No significant differences between environments for the ten lines and their F_1's was detected for micronaire.

GCA effects were highly significant for micronaire, upper-half mean length, T_1 fiber strength and elongation (Table 3). This suggests that additive gene action is important for these traits in the influential lines studied. GCA x environment interactions were not significant for T_1 fiber strength or elongation which mirrors the lack of any significant environment by between the lines and between these lines and their F_1's were identified for all measured fiber properties. This contrasts with the results of Green and Culp(1990) who found differences for upper-half mean length genotype action for these traits from the other analyses of variance. For micronaire and upper-half mean length, GCA by environment interactions were significant and they were highly significant for uniformity index. SCA effects were significant only for upper-half mean length. Both micronaire and upper-half mean length had significant SCA by environment interactions. The SCA by environment interaction for uniformity index was not significant but just barely so. SCA by environment interactions were not significant for T_1 fiber strength or elongation, which is consistent with the lack of any environmental interactions for these traits in other ANOVA's reported in this study.

Estimates of GCA effects for each of the ten influential lines used in this study are presented in Table 4 and while GCA effects were not significant for uniformity index as a whole, several were significantly different from zero and are so indicated. Delcott 277 had the most negative GCA effect for micronaire (-0.174) whereas DES 15 and McNair 235 had the highest positive GCA effect estimates. PD 2165 had the most positive effect of the lines investigated for increasing fiber upper-half mean length as well as for uniformity index and T_1 fiber strength. As was the case with upper-half mean length, Deltapine 15 and McNair 235 grouped together with respect to their combining ability for T_1 fiber strength, both leading to decreases in measured g/tex in crosses in which they were involved. Delcott 277 had the most positive GCA effect estimate for elongation followed by Lankart 57. Only two of the ten lines involved had significant negative GCA effects for elongation, PD 2165 and CA 614. Looking at GCA effect estimates for measured fiber properties collectively, several lines, notably McNair 235, Deltapine 15, CA 614 and Paymaster 54 would not contribute positively to a breeding program seeking to develop cotton varieties with improved fiber traits. Delcott 277 is the only line that has combines significant effect estimates in the desired directions. Using it as a parent in a cross would lead to its contributing a desirable decrease in micronaire and desirable increases in fiber length, strength and elongation. PD 2165, a line developed to incorporate superior fiber properties, could make highly significant contributions to decreasing micronaire, increasing length and uniformity, and especially to increasing fiber strength.

Conclusions

Previous work on the combining ability for cotton fiber traits allows for a comparison to be made between these results and those of others. Given the diversity of the ten lines used in this study as parents, it is not surprising that significant differences

only, using HVI but found differences using laboratory instrumentation. Also, while they found no significant GCA for HVI fiber measurements in this study GCA effects were significant for all fiber properties except

uniformity index. Percy and Turcotte (1988) also found significant GCA mean squares for two diallel sets involving Pima germplasm. This study corroborates the findings of both Green and Culp (1990) and Percy and Turcotte (1988) with regards to the relative magnitude of GCA versus SCA effects. In all three studies GCA effects were more important than SCA effects suggesting that additive gene action is more important than dominant gene action or epistatic interactions. Baker and Verhalen (1973) drew similar conclusions concerning the importance of additive gene action with regards to fiber traits. Progress in developing cultivars with improved fiber characteristics should therefore be possible using simple mass selection. Results from this study suggest that the most rapid progress in doing so would be in populations in which Delcott 277 or PD 2165 (or cultivars with a high coefficient of parentage) were used as one of the parents.

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Table 1. Mean squares from analysis of variance for fiber properties of ten influential cotton lines at Winnsboro and St. Joseph, LA in 1997.

Source	df	MIC[1]	UHM	UI	T[1]	El
Environment (E)	1	0.43353*	0.03927**	13.269*	13.331*	0.69100
E(Replications)	4	0.03286	0.00181	1.448	1.243	0.15862
Lines (L)	9	0.33832**	0.00623**	3.226**	15.754**	1.22288**
E * L	9	0.02266	0.00107	1.793	2.708	0.36841
Error	35	0.02627	0.00070	1.023	2.290	0.22263

[1] MIC = micronaire; UHM = upper-half mean length; UI = uniformity index; T[1] = HVI fiber strength; El = elongation

*, ** Significant at P=0.05 and P=0.01, respectively

Table 2. Mean fiber properties of ten influential cotton lines at Winnsboro and St. Joseph, LA in 1997.

Parent	MIC[1]	UHM	UI	T[1]	El
CA614	4.77 cd[2]	1.06 e	82.5 c	26.0 bcde	5.9 d
Coker 100W	4.54 e	1.12 bc	83.6 bc	26.5 bcd	6.2 cd
Delcott 277	4.59 de	1.14 b	84.5 ab	27.1 abc	7.3 a
Deltapine 15	4.98 ab	1.09 de	83.4 bc	24.1 e	6.6 bc
DES 56	5.16 a	1.13 bc	84.1 ab	27.8 ab	6.4 bcd
Lankart 57	4.52 e	1.12 bcd	83.9 ab	24.1 e	6.9 ab
McNair 235	5.11 ab	1.10 cd	84.4 ab	25.7 cde	6.0 cd
Paymaster 54	4.91 bc	1.10 cd	83.9 ab	24.7 de	6.4 bcd
PD2165	4.69 de	1.17 a	85.2 a	28.9 a	5.9 d
Stoneville 2	4.56 de	1.14 ab	84.1 ab	27.7 ab	6.1 cd
LSD	0.19	0.03	1.2	1.8	0.6

[1] MIC = micronaire; UHM = upper-half mean length; UI = uniformity index; T[1] = HVI fiber strength; El = elongation

[2] Means within column followed by the same letter are not significantly different (P=0.05) by DNMRT

Table 3. Mean squares from analysis of variance for general (GCA) and specific (SCA) combining ability for fiber properties among 10 influential cotton lines at Winnsboro and St. Joseph, LA in 1997.

Fiber trait	Source	df	Mean Square	F	P
Micronaire	GCA	9	1.35598	22.04	0.0001
	SCA	45	0.06858	1.43	0.1175
	GCA*E	9	0.06152	2.10	0.0305
	SCA*E	45	0.04799	1.64	0.0109
	Error	216	0.02926		
UHM	GCA	9	15.78189	15.70	0.0002
	SCA	45	1.35485	1.82	0.0232
	GCA*E	9	1.00541	2.13	0.0280
	SCA*E	45	0.74248	1.58	0.0178
	Error	216	0.47139		
Uniformity Index	GCA	9	6.06928	1.47	0.2877
	SCA	45	1.18850	0.80	0.7747
	GCA*E	9	4.12942	3.65	0.0003
	SCA*E	45	1.49048	1.32	0.1012
	Error	216	1.13093		
T_1 fiber strength	GCA	9	46.09212	25.16	0.0001
	SCA	45	2.56223	1.50	0.0906
	GCA*E	9	1.83232	1.05	0.4020
	SCA*E	45	1.71384	0.98	0.5120
	Error	216	1.74641		
Elongation	GCA	9	4.30493	23.49	0.0001
	SCA	45	0.29404	1.44	0.1107
	GCA*E	9	0.18330	1.15	0.3271
	SCA*E	45	0.20359	1.28	0.1266
	Error	216	0.15903		

Table 4. Estimates of GCA effects for fiber properties among ten influential cotton lines at Winnsboro and St. Joseph, LA in 1997.

Parent	Micronaire		UHM		UI		T_1		Elongation	
McNair 235	0.201	**	-0.604	**	0.094		-0.859	**	-0.076	
Coker 100W	-0.061	**	0.052		-0.067		0.056		-0.059	
Paymaster 54	0.048	*	-0.272	**	-0.338	**	-0.700	**	0.043	
Stoneville 2	-0.117	**	-0.004		-0.034		0.309	*	-0.061	
Lankart 57	-0.145	**	0.465	**	0.323	**	-0.441	**	0.329	**
PD 2165	-0.079	**	0.684	**	0.415	**	1.714	**	-0.404	**
Deltapine 15	0.100	**	-0.396	**	-0.354	**	-0.905	**	0.007	
CA 614	0.023		-0.646	**	-0.399	**	-0.014		-0.257	**
DES 15	0.203	**	0.282	**	0.134		0.167		0.049	
Delcott 277	-0.174	**	0.440	**	0.225		0.674	**	0.428	**

*, ** Significant at P=0.05 and P=0.01, respectively