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BREEDING AND GENETICS

Development of Sea Island/Upland (SIUP) Germplasm with Unique Fiber Properties

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ABSTRACT

Improvement of fiber properties is necessary for Upland cotton, *Gossypium hirsutum* L., to remain competitive in today's global market. The objective of this study was to develop Sea Island/ Upland (SIUP) biotypes with improved fiber length and strength. 'NMSI 1331' a Sea Island (*G. barbadense* L.) breeding line was crossed with Upland germplasm to develop SIUP biotypes. Individual plants were selected from the F_3 generation grown in a spaced nursery. Plants were selected based on apparent yield and fiber quality potential. Eight $F_{3:4}$ progeny rows were selected in 2003 and evaluated in performance trials at College Station, TX during 2004, 2006, and 2007. These interspecific, introgressed lines ranged in lint production from 618 kg/ha^{-1} to 979 kg/ha^{-1} and exhibited fiber properties equal to or exceeding those of 'Fiber Max 832' (PI 603955) and 'Deltapine 491' (PI 618609). Introgression of interspecific alleles is thought to have manifested unique fiber qualities with acceptable agronomic performance in this group of SIUP breeding lines.

Longer and stronger fibers sell for premium prices in current markets (National Cotton Council, 2011). Broadening the genetic base of Upland cotton is needed to help with genetic improvement programs. Introgression of alleles from Sea Island genotypes into Upland genotypes has long been pursued by breeders as a method to improve fiber properties of Upland genotypes while maintaining desirable agronomic traits (Smith et al., 1999). Numerous studies have investigated the use of interspecific hybrids for producing F_1 cotton hybrids with the high quality fiber properties of *Gossypium barbadense* L. and the desirable agronomic traits of *G. hirsutum* L. (Marani, 1968; Percy and Turcotte, 1991, 1992). Evidence of successful introgression of *G. barbadense* introgression was reported by Culp (1979) and Culp and Harrell (1977) who noted that selections from 'Sealand 542' (PI 528730) and 'Earlistaple 7,' were grown commercially on a small scale; however, they were more valuable for their potential as breeding tools. Both of these cultivars exhibit High Volume Instrument (HVI) upper half mean (UHM) fiber length equal to *G. barbadense* in otherwise *G. hirsutum* phenotypes.

Beasley and Brown (1942) reported that plants in an F_2 population derived from a *G. hirsutum* /*G. barbadense* cross were sterile. Kearney (1923) reported similar scenarios with segregating F_2 and F_3 populations. Genetic breakdown has been reported to be prevalent in later generations of interspecific hybrids (Percival et al., 1999; Stephens, 1949). Culp and Harrell (1974) stated that there is a strong inverse relationship between lint yield and fiber length, and possibly an even stronger inverse relationship between lint yield and fiber strength present in interspecific, introgressed lines (SIUP) genotypes. For example, Earlistaple 7 and Sealand 542 exhibited significantly lower yields than 'Coker 100 A,' while exhibiting significantly greater fiber length, strength, and micronaire measurements (Culp and Harrell, 1974).

Although there have been difficulties introgressing desirable alleles from *G. barbadense* into *G. hirsutum*, numerous studies cited successful introgression of traits from *G. barbadense* into *G. hirsutum* (Culp, 1979; Culp and Harrell, 1974; Jenkins et al., 1946). The objective of this study was to develop SIUP biotypes with improved fiber length and strength.

MATERIALS AND METHODS

Two single-cross hybrids were created in 1999 at College Station, TX. 'Tamcot 94 L-25' (Smith, 2003) was crossed with 'NMSI 1331' (Roberts et al., 1997). NMSI 1331 was crossed with 97 M-16 (unreleased breeding line). The resulting progeny were increased during the winter of 1999 at the Cotton Winter Nursery

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in Colima, Mexico and the resulting F_2 was grown at College Station, TX in 2001. The F_2 populations were bulk harvested in the fall of 2001. Lint yield and High Volume Instrumentation (HVI) fiber quality (Upper half mean length (UHM), strength, Uniformity Index (UI), and fiber elongation (Elong.)) performances of the Upland parental lines are compared in a truncated format from earlier trials at College Station and Corpus Christi, TX (Table 1). Because 97 M-16 was discarded at an early generation from the program, a sister-line, 97 M-17, was used for comparison purposes. Comparison between NMSI 1331 and Upland germplasm is not valid because NMSI 1331 is so far from its region of adaptability when grown in College Station, TX, that genotypic values cannot be estimated from field trials.

The SIUP F_3 generation was grown in a nursery in College Station, TX, in 2002, with individual plants spaced approximately 1 m x 30 cm. The soil type at College Station is a Westwood silt loam, a fine-silty, mixed thermic Fluventic Ustochrept, intergraded with Ships clay, a very fine, mixed, thermic Udic Chromustert. Individual plants were selected on the basis of apparent yield and reselected based on HVI-measured fiber quality. Selected plants were grown in a progeny row nursery in 2003 with rows exhibiting uniform appearance bulked for performance testing. Eight SIUP strains were performance tested during 2004, 2005, and 2007 at the AgriLife Research Farm near College Station, TX. All performance trials were planted in a randomized complete block design, with plots consisting of two rows, 1 m x 12 m, and replicated four times. Lint percent and fiber properties were determined from grab samples taken from two replications. Plots were harvested with a one-row mechanical picker modified for plot harvest. Seedcotton grab samples were ginned on a laboratory saw gin, and fiber measured with HVI at the Fiber and Biopolymer Research Institute in Lubbock, TX. Data was analyzed using a mixed ANOVA using SAS 9.1, with means separated using the Waller-Duncan LSD (SAS, 1993).

RESULTS AND DISCUSSION

Year, genotype, and year x genotype sources of variation were significant for lint yield and percent lint (Table 2). Variation attributed to genotype was ninefold the amount attributed to genotype by environmental interactions. All SIUP lines exhibited similar yield, (p = 0.05), with the exception of F-98, when means were averaged across years (Table 3). Genotypes were averaged over years because the introgression of UHM length and fiber bundle strength into Upland phenotypes was the primary purpose of this research and not the development of yield-competitive phenotypes. SIUP lines averaged 56 to 89% of FiberMax 832, the lowest yielding check cultivar. E-63 exhibited the highest lint yield among the SIUP at 979 kg ha^{-1}, whereas F-98 exhibited the lowest lint yield at 618 kg ha^{-1}. All SIUP lines averaged lower lint percent than Deltapine 491, but SIUP E-61 and E-162 were not significantly different than FiberMax 832 in terms of lint percent. Historically, extremely low lint percent, below 30%, has been reported when *G. barbadense* was used as a donor species for the improvement of fiber properties in Upland types (Culp, 1979; Culp and Harrell, 1974).

Table 1. Truncated comparison of parents (97 M-16 and 94L-25) versus Deltapine 491 and FiberMax 832 at Corpus Christi, TX, in 2002 and at College Station, TX, in 2007[z].

Corpus Christi, TX							
Genotype	**Lint Yield**	**Lint Percent**	**Micronaire units**	**UHM mm**	**Strength kN m kg^{-1}**	**UI ratio**	**Elong. %**
FiberMax 832	**913a**	**36.7a**	**4.5a**	**30.0a**	**339a**	**86a**	**3.8a**
97 M-17	**878a**	**37.7a**	**4.5a**	**29.5a**	**319b**	**85a**	**4.1a**
TAM 94L-25	**650b**	**37.7a**	**4.5a**	**30.5a**	**346a**	**85a**	**2.9b**
College Station, TX							
Genotype	**Lint Yield**	**Lint Percent**	**Micronaire units**	**UHM mm**	**Strength kN m kg^{-1}**	**UI ratio**	**Elong. %**
Deltapine 491	**1366a**	**40.9a**	**4.2a**	**29.5a**	**302a**	**81a**	**4.0a**
FiberMax 832	**967b**	**39.1a**	**4.1a**	**29.7a**	**310a**	**83a**	**3.8a**
TAM 94L-25	**858b**	**33.7b**	**3.6b**	**29.5a**	**316a**	**82a**	**4.0a**

[z] Means with the same letter are not significantly different at the 0.05 probability level as calculated by the Waller-Duncan *K*-ratio *t*-test within the respective trial.

Table 2. Mean squares from ANOVA for eight SIUP lines and check cultivars across 3 yr at College Station, TX in 2004, 2005, and 2007.

Effect	df	Lint Yield	Lint Percent
Year	2	2163119.68[z]	8.92[y]
Error A	9	88924.02	1.71
Genotype	9	392610.01[y]	41.39[y]
Genotype x Year	17	43703.78[y]	4.23
Error B	77	24685.70	2.23

[z] Significant at (p = 0.01)

[y] Significant at (p = 0.05)

Table 3. Lint yield and lint percent for eight SIUP lines and check cultivars at College Station, TX in 2004, 2005, and 2007[z].

Genotype	Lint Yield -kg/ha-	Lint Percent -%-
Deltapine 491	1335 a	41.8 a
Fiber Max 832	1106 b	37.2 b
E-63	979 c	32.7 e
E-106	978 c	34.4 cde
E-162	955 c	36.0 bc
E-67	931 c	34.0 de
E-148	908 c	34.1 de
E-177	860 c	35.2 cd
E-61	833 c	35.5 bc
F-98	618 d	32.8 e
LSD (k=100)	119.91	1.69
CV	16.34	4.22

[z] Means with the same letter are not significantly different at the 0.05 probability level as calculated by the Waller-Duncan *K*-ratio *t*-test within the respective trial.

Years had a significant impact on genotypes for all fiber properties except fiber bundle strength, whereas genotypes differed (p = 0.05 or less) for micronaire, UHM fiber length, fiber bundle strength, fiber length uniformity, and elongation (Table 4). A significant genotype x year interaction was observed for micronaire, which is a measurement of fiber weight per unit length. Repeatability of micronaire across years might have been confounded by crop maturity interactions. Some of the SIUP lines were too late maturing for the length of the growing season at College Station, TX.

All genotypes in this study averaged within the non-discount range of 3.5 to 4.9 for Upland types (National Cotton Council, 2007), therefore the significant interaction with years was ignored and averaged values reported in Table 4. SIUP lines of E-63, E-67, E-106, E-148, E-162, and F-98 averaged lower (p = 0.05) micronaire than either of the control cultivars. Two SIUP lines, E-61 and E-177, had micronaire not significantly different (p = 0.05) than FiberMax 832.

Table 4. Mean squares from ANOVA for eight SIUP lines and two commercial check cultivars across 3 yr at College Station, TX in 2004, 2005, and 2007.

Effect	df	Micronaire units	UHM mm	Strength kN m kg^{-1}	UI ratio	Elong. %
Year	2	2.16[z]	4.60[z]	2650.63	36.86[z]	16.38[z]
Error A	3	0.01	0.47	568.64	0.35	0.20
Genotype	9	0.20[y]	4.73[z]	1857.29[z]	4.47[z]	1.58[z]
Genotype x Year	17	0.13[z]	0.55[y]	233.90[y]	1.33	0.11
Error B	25	0.79	0.28	104.93	0.78	0.07

[z] Significant at (p = 0.01)

[y] Significant at (p = 0.05)

All genotypes had fiber length UI above the premium level of more than 79.5 as defined by the National Cotton Council (2007) (Table 5). Deltapine 491 had the lowest fiber length UI of 81.7, whereas F-98 averaged 84.6, significantly higher than both cultivars and four of the SIUP lines. F-98 also had the best fiber elongation at break of 5.0%, which exceeded both controls and other SIUP lines.

The primary selection criteria during the development of these SIUP lines were fiber length and bundle strength. Fiber length is a primary determinate of yarn quality when a drafting system of spinning is employed, such as ring spinning, whereas fiber bundle strength is a major consideration in open-end, or rotor spinning. A significant genotype x year interaction was observed for fiber length and strength (Table 4). For fiber length, this interaction was attributed to a change in ranking within SIUP lines across years. For example, E-177 was in the longest significance group in 2004, but ranked in the lowest group in 2007 (Table 6). Regardless of the interaction, E-148 exhibited a fiber length greater (p = 0.05) than both commercial cultivars during all years, whereas E-61, E-63, E-67, E-162, and F-98 had longer fiber than either cultivar in two of the three years. These data suggest possible introgression of alleles for fiber length from *G. barbadense* into an Upland phenotype or beneficial epistasis. F-98 had the highest (p = 0.05) fiber bundle strength in all years tested (Table 6). This again suggests possible introgression of alleles from NMSI 1331 into this specific SIUP line.

Table 5. Fiber properties for eight SIUP lines and check cultivars at College Station, TX in 2004, 2005, and 2007[z]

Genotype	Micronaire units	UI ratio	Elong. %
Deltapine 491	4.8 a	81.7 e	4.3 b
Fiber Max 832	4.4 ab	82.9 cd	4.3 b
E-61	4.4 ab	83.1 cd	3.6 c
E-177	4.2 bc	84.0 abc	3.5 c
E-148	4.1 cd	84.2 ab	3.6 c
E-162	4.0 cd	83.3 bcd	3.6 c
E-63	4.0 cd	83.8 abc	4.3 b
F-98	4.0 d	84.6 a	5.0 a
E-106	3.9 d	83.4 bcd	3.4 c
E-67	3.9 d	82.4 de	4.4 b
LSD (k=100)	0.2	1.09	0.30
CV	4.27	1.06	6.77

[z] Means with the same letter are not significantly different at the 0.05 probability level as calculated by the Waller-Duncan *K*-ratio *t*-test within the respective trial.

Table 6. Mean UHM and strength for eight SIUP lines and commercial cultivars across 3 yr at College Station, TX in 2004, 2005, and 2007[z].

Genotype	UHM, mm			Strength, kN m kg^{-1}		
	2004	2005	2007	2004	2005	2007
E-148	32.50 a	31.20 ab	31.50 bc	339.3 b	317.3 abc	325.6 b
E-162	32.20 a	30.15 c	30.61 cd	342.8 b	307.0 bcd	320.6 bc
F-98	31.70 ab	30.90 abc	31.24 bc	379.6 a	333.0 a	349.3 a
E-63	31.55 ab	31.20 ab	32.51 a	318.3 bcd	273.6 f	295.9 e
E-67	31.30 abc	31.30 a	31.62 ab	305.0 d	289.3 ef	300.3 de
E-177	31.05 abc	30.30 bc	30.10 de	336.4 bc	332.5 a	327.2 b
E-106	31.05 abc	30.45 abc	30.73 bcd	331.0 bc	321.2 ab	321.9 b
E-61	30.80 abc	30.90 abc	32.77 a	300.6 d	297.2 de	298.9 de
Fiber Max 832	30.30 bc	28.40 d	30.23 de	313.3 cd	301.1 cde	310.1 cd
Deltapine 491	29.55 c	27.80 d	29.47 e	303.1 d	278.0 f	291.8 e
LSD (k=100)	1.86	0.90	0.90	25.58	16.54	11.76
CV	2.28	1.37	1.16	1.37	2.48	3.25

[z] Means with the same letter are not significantly different at the 0.05 probability level as calculated by the Waller-Duncan *K*-ratio *t*-test within the respective trial.

CONCLUSIONS

Introgression of desirable alleles from *G. barbadense* into Upland phenotypes has long been sought and sometime achieved to varying degrees as an effective method of introducing genetic variation desirable to breeders. Germplasm derived using this method has the potential to provide breeders with new allelic combinations useful for fiber improvement. E-148 and F-98 exhibited lower yield potential and lint percent than the commercial cultivars, yet possessed fiber length and bundle strength greater than Deltapine 491 or FiberMax 832. These data suggest improvement in length and fiber bundle strength were possibly the result of introgression from *G. barbadense* into *G. hirsutum* or from epistatic interactions created by the introgression because all other fiber traits were within the ranges of those found in Upland parents involved in this study.

Although these lines yielded less lint than commercial cultivars, their improved fiber quality makes them suitable candidates for use as parental lines. E-148 and F-98 should provide cotton breeders with excellent parental material to improve fiber length and bundle strength.

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