Transgressive Segregation in Upland Cotton

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Abstract

The United States traditionally markets upland cotton, *Gossypium hirsutum*, with a High Volume Instrument (HVI) upper half mean length (UHML) of 1.06 in. although international trade requires a minimum of 1.09 in. Strains and cultivars have been developed that exhibit UHML of approximately 1.26 in. that may be referred to as long staple uplands (LSU). Further improvement in fiber length could provide the opportunity for the U.S. to produce a unique fiber type that could be instrumental in maintaining global competitiveness. Breeders often cross a parent exhibiting one extreme of a trait with a parent exhibiting the opposite extreme in order to evaluate the combining ability and heritability of the trait. However, should cotton breeders combine parents exhibiting the positive extreme of the trait in question and search for transgressive segregates that move the trait beyond both improved parents or simply look for transgressive segregates using only one parent exhibiting the extreme of the trait in question? TAM 94L-25 (Smith, 2003), a LSU, was crossed with three LSU and one short staple upland (SSU) phenotypes. Parents and their F_2 generations were grown in a randomized complete block design at College Station, TX in 2001 and 2002. Two extra long staple upland (ELSU) genotypes, TAM B182-39 (unreleased breeding line) and TAM C155-22 (PI 654366; Smith et al., 2009) were intercrossed and each crossed with Deltapine 491 (PVP 200100159, PI 618609), a LSU, and Deltapine 50 (PI 529566), a medium staple upland (MSU) cultivar. These parents and their F_2 populations were grown at Weslaco, Texas in 2008. Hand harvested seedcotton from individual plants of parents and F_2s were ginned on a laboratory gin, and HVI and Advanced Fiber Instrument System (AFIS) fiber properties determined. The objectives of this research were to determine [1] the parental and F_2 associated fiber length parameters among LSU / LSU, LSU / SSU, ELSU / LSU, ELSU / MSU, and ELSU / ELSU, and [2] transgressive segregation in each combination. Transgressive segregates were found in all F_2 populations.

Introduction

Upland cotton, *Gossypium hirsutum*, is grown in all southern states of the U.S. and in more than 70 countries worldwide. The fibers of upland cotton constitute about 95% of the farm gate value of the crop. Fiber quality parameters such as length, strength, micronaire (combination of fineness and maturity), and uniformity of length, in addition to color, trash content, and preparation, determine the value of raw cotton fibers. Traditionally, a majority of upland cotton produced in the U.S. was processed and consumed within the country. However, today the majority of the cotton produced in the U.S. is exported for spinning into yarn and subsequent weaving into textiles and thus U.S. producers must compete with producers in other countries for market share. Average length of fibers is one of the characteristics receiving renewed attention because of its impact on yarn quality, especially yarn produced with traditional ring spinning and with the newer vortex spinning technology, both drafting and twisting technologies. The U.S. traditionally marketed fibers with an upper half mean length (UHML), which is the average length of the longest 50% of the fibers in the sample, of 1.06 in. World markets set 1.09 in. as the base UHML and the International Cotton Advisory Committee suggest 1.13 in. as the base UHML (Hequet, 2006). Fiber length traditionally is referred to as staple or staple length.

Yarn quality parameters such as strength, elongation of yarn at break, hairiness, and yarn evenness are correlated strongly with average fiber length (Perkins, et al., 1984; El Mogahzy, 1999; El Mogahzy and Chewing, 2001). Fiber length is critical to manufacturing yarn of specific size on draft spinning systems (El Mogahzy and Chewing, 2001). Spinners require UHML information in order to set the drafting rollers at the proper distance (Perkins, et al., 1984; El Mogahzy and Chewing, 2001), which improves yarn evenness, and reduces floating fibers and fiber breakage. Longer fibers will improve the frictional resistance among fibers within the yarn and thus increase yarn strength (Balasubramanian, 1995). Holding other fiber properties constant, longer fibers require less twist to produce the desired yarn strength. Thus, improvements in fiber length parameters could be important for U.S. producers in maintaining or increasing world market share in upland cotton.

Two systems currently are used to measure fiber length, those being the HVI system that also is used by the U.S. Department of Agriculture-Agricultural Marketing Service to determine the quality of each bale of cotton sold in the U. S., and the Advanced Fiber Instrument System (AFIS). The HVI system measures UHML cotton on the basis of the classical Fibrograph method of Hertel (1940) in which the span length of a beard of cotton fibers is measured (El

Mogahzy and Chewning, 2001). The AFIS is a sophisticated and versatile instrument that determines fiber parameters by measuring individual fibers passing through a light sensor. The output of AFIS is average fiber length, number basis, (Ln) that is an unbiased measurement of fiber lengths in the sample. Average fiber length, weight basis, (Lw) is calculated from Ln and, according to Hequet (2006) incorrectly assumes that all fibers have the same linear density. The Upper Quartile Length (UQLw) (average length of the longest 25% of the fibers in the sample) is derived also from the AFIS length histogram based on fiber weight. UQLw is a much used value since it closely mimics the HVI UHML data used in the USDA classification.

Long staple upland (LSU) cotton for purposes of this presentation is defined as having UHML equal to or exceeding 1.26 in. Pima, *G. barbadense,* has traditionally been referred to as ELS cotton in the U.S. and the shortest category for UHML in the 2008 USDA pima loan chart was 1.37 in. Pima fibers are longer, finer, and stronger than upland fibers. Improved quality of upland fibers is a component of many breeding programs in the U.S. and this often involves hybridization of *G. hirsutum* and *G. barbadense*, although little, if any, success in recovering the fiber traits of pima in upland has been reported since the first efforts were reported in the 1860s (Smith, et al., 1999). The USDA National Plant Germplasm Collection (http://www.ars-grin.gov/) identifies several *G. hirsutum* accessions as having UHML ranging from 1.33 to 1.41 in. A primary deterrent in the development and acceptance of viable extra long staple upland (ELSU) cultivars appears to have been poor yield and poor lint percent. All of the USDA Collection ELSU accessions have percent lint of 28 to 29 % while current upland cultivars range as high as 42 % lint.

Three upland cotton cultivars that often exhibit the LSU UHML trait under optimum growth conditions are available in the U.S. today (‘Deltapine 491’ (PVP 200100159, PI 618609), ‘Fibermax 832’ (Constable, et al., 2001), and ‘Acala 1517-99’ (Cantrell, et al., 2000; PI 612326)). In addition to these, Smith (2003) developed and released TAM 94L-25 (PI 631440), and Auld et al. (2000) developed and released TTU 202 (PI 613162), which also exhibits this LSU UHML trait. Smith et al. (2009) developed and released eight germplasm lines (PI 654359 - 654366), that exhibit ELSU UHML under optimum growth conditions. Lint percent in these ELSU lines were slightly better than those reported in GRIN for ELSU accessions, ranging from 31 to 34 percent.

The objectives of this research were to determine [1] the parental and F_2 associated fiber length parameters among LSU / LSU, LSU / SSU, ELSU / LSU, ELSU / MSU, and ELSU / ELSU, and [2] transgressive segregation in each combination.

Long Staple Upland Combinations

Breeders often cross a parent exhibiting one extreme of a trait with a parent exhibiting the opposite extreme in order to evaluate the combining ability and heritability of the trait. However, should cotton breeders combine parents exhibiting the positive extreme of the trait in question and search for transgressive segregates that move the trait beyond both improved parents or simply look for transgressive segregates using only one parent exhibiting the extreme of the trait in question? Braden et al. (2009) and Smith et al. (2009a, 2009b) reported on the genetic analysis of Fibermax 832, Acala 1517-99, TTU 202, all LSU, and Tamcot CAMD-E, a SSU, when crossed with TAM 94L-25, a LSU. All of the LSU genotypes were from diverse backgrounds with Fibermax 832 a product of the Australian Commonwealth Scientific and Industrial Research Organization **(**CSIRO), Acala 1517-99 from the New Mexico Agricultural Experiment Station, TTU 202 from the mutation breeding program at Texas Tech University on the Southern Great Plains, and TAM 94L-25 from the Texas A&M AgriLife Research program at College Station, TX. Thus, while there are some common parentage, environmental selection pressure was applied to segregating populations in vastly different environments.

Transgressive segregates are defined in this presentation as individual plants in the F_2 population that exhibited fiber length greater than the average of the longer parent. In all LSU / LSU combinations, as well as the TAM 94L-25 / Tamcot CAMD-E combination, transgressive segregates were found for FLw, FLn, and UQLw (Table 1). The F_2 means were generally intermediate to the parents and the percent transgressive segregates ranged from a low of 9.5 % for TAM 94L-25 / Fibermax 832 FLw to a high of 38.5 % for UQLw in the same parentage.

These data **do not support** the premise that crossing elite lines for these fiber length parameters would be preferred to crossing lines where one was superior and one inferior since the LSU / SSU, i.e., TAM 94L-25 / Tamcot CAMD-E, produced several transgressive segregates with fiber length exceeding that of the longer parent as did the LSU / TAM 94L-25. Smith et al. (2009a) reported that the majority of the gene effects for TAM 94L-25 / Tamcot CAMD-E was additive while being much more complex in the LSU / TAM 94L-25 combinations.

Table 1. Parental and F_2 AFIS fiber length characteristics of LSU / LSU[1], and LSU / SSU and the percent of F2 exceeding the average length of the longer parent when plants were grown with irrigation at College Station, TX in 2001 and 2002.

Population[2]	FLw	FLn	UQLw
	(in)	(in)	(in)
TAM 94L-25	1.08	0.84	1.32
Fibermax 832	1.12	0.90	1.36
F2 population	1.10	0.87	1.35
% of F2 > mean of longest parent	9.5	20.0	38.5
TAM 94L-25	1.08	0.84	1.32
TTU 202	1.05	0.83	1.28
F2 population	1.09	0.86	1.33
% of F2 > mean of longer parent	23.5	19.3	26.0
TAM 94L-25	1.08	0.84	1.32
Acala 1517-99	1.06	0.86	1.26
F2 population	1.08	0.85	1.31
% of F2 > mean of longer parent	35.5	33.0	24.8
TAM 94L-25	1.08	0.84	1.32
Tamcot CAMD-E	0.94	0.76	1.12
F2 Population	1.04	0.83	1.27
% of F2 > mean of longer parent	28.5	31.0	14.5

1. LSU = long staple upland = Acala 1517-99, Deltapine 491, Fibermax 832, and TAM 94L-25; SSU = short staple upland = Tamcot CAMD-E.
2. n = 20 for each parent and 400 for F_2 population.

Extra Long Staple Upland Combinations

To further examine transgressive segregates for fiber length in upland cotton, two ELSU genotypes, TAM B182-39 (unreleased breeding line) and TAM C155-22 (PI 654366; Smith et al., 2009) were intercrossed and each crossed with Deltapine 491, a LSU current cultivar, and Deltapine 50 (PI 529566), a MSU obsolete cultivar. HVI and selected AFIS fiber properties of parents and their F_2 populations grown at Weslaco, Texas in 2008 are shown in Tables 2 and 3, respectively. These data verify that the two ELSU parents possess average fiber length equal to pima, i.e., HVI UHML of 1.37 in. or greater. Other fiber traits are not unlike Deltapine 491 or Deltapine 50, indicating normal upland fiber phenotypes but exhibiting good fiber bundle strength and finer fibers.

Table 2. HVI fiber characteristics[1] of two ELSU[2] lines, Deltapine 50, and Deltapine 491 and their F_2 populations grown at Weslaco, Texas during 2008.

Population		Mic	UHML	UI	Str	Elong
		(units)	(in)	(ratio)	(g/tex)	(%)
TAM B-182-39[3]	avg	3.8	1.41	85.8	35.4	7.6
TAM B-182-39	min	3.0	1.33	84.9	33.6	7.0
TAM B-182-39	max	4.8	1.46	86.9	38.3	8.2
TAM C-155-22	avg	3.9	1.37	84.9	35.1	7.1
TAM C-155-22	min	3.0	1.28	82.5	30.2	6.0
TAM C-155-22	max	4.6	1.46	87.2	38.2	8.1
Deltapine 491	avg	4.6	1.20	84.0	33.3	7.5
Deltapine 491	min	3.7	1.13	81.7	28.7	6.6
Deltapine 491	max	6.1	1.29	85.6	35.4	8.6
Deltapine 50	avg	4.8	1.13	84.2	30.0	9.1
Deltapine 50	min	3.8	1.03	82.8	26.7	8.3
Deltapine 50	max	5.3	1.21	85.8	32.5	10.4
TAM B-182-39 / TAM C-155-22	avg	4.0	1.35	84.6	34.2	7.5
TAM B-182-39 / TAM C-155-22	min	3.2	1.28	82.7	30.9	6.6
TAM B-182-39 / TAM C-155-22	max	4.5	1.40	86.1	36.4	8.4
Deltapine 491 / TAM B-182-39	avg	4.2	1.29	84.5	34.4	7.3
Deltapine 491 / TAM B-182-39	min	3.1	1.19	81.1	30.8	6.4
Deltapine 491 / TAM B-182-39	max	5.4	1.42	86.9	36.8	8.4
Deltapine 491 / TAM C-155-22	avg	4.0	1.30	84.0	34.3	7.1
Deltapine 491 / TAM C-155-22	min	3.1	1.20	82.5	29.3	6.0
Deltapine 491 / TAM C-155-22	max	4.9	1.46	86.3	36.8	8.3
Deltapine 50/TAM B-182-39	avg	4.3	1.27	84.7	33.5	7.9
Deltapine 50/TAM B-182-39	min	3.1	1.10	81.7	28.3	6.6
Deltapine 50/TAM B-182-39	max	5.3	1.39	85.9	38.9	10.3
Deltapine 50 / TAM C-155-22	avg	4.3	1.28	84.8	34.2	7.7
Deltapine 50 / TAM C-155-22	min	3.1	1.19	82.9	30.1	5.9
Deltapine 50 / TAM C-155-22	max	5.2	1.40	86.7	37.9	9.2

1. High volume instrument (HVI) fiber characteristics: Mic = micronaire, UHML = upper half mean length, UI = fiber length uniformity index, Str = fiber bundle strength, Elong = fiber elongation at break.
2. ELSU = extra long staple upland
3. n = 27

Table 3. AFIS fiber characteristics[1] of two ELSU[2] lines, Deltapine 50, and Deltapine 491 and their F_2 populations grown at Weslaco, Texas during 2008.

Population		Lw	Ln	UQLw	SFCw	SFCn	Fine	IFC	Mat Ratio
		(in)	(in)	(in)	(in)	(in)	(mTex)	(%)	(ratio)
TAM B-182-39[3]	avg	1.22	0.94	1.47	5.2	24.6	146	5.9	0.90
TAM B-182-39	min	1.15	0.86	1.39	3.3	16.8	127	4.2	0.85
TAM B-182-39	max	1.27	1.03	1.52	6.8	31.9	160	7.5	0.94
TAM C-155-22	avg	1.18	0.90	1.43	5.87	25.8	150	6.1	0.91
TAM C-155-22	min	1.07	0.70	1.35	2.9	15.3	135	3.7	0.78
TAM C-155-22	max	1.26	1.02	1.51	12.9	43.1	162	16.9	0.96
Deltapine 491	avg	1.06	0.85	1.25	5.7	22.7	161	5.8	0.91
Deltapine 491	min	0.99	0.70	1.20	4.1	17.4	137	3.7	0.84
Deltapine 491	max	1.11	0.91	1.32	10.4	36.8	187	9.0	0.98
Deltapine 50	avg	1.02	0.84	1.18	5.0	20.9	182	5.0	0.91
Deltapine 50	min	0.93	0.74	1.07	3.6	16.7	158	3.7	0.87
Deltapine 50	max	1.11	0.93	1.28	8.6	30.4	196	6.9	0.96
TAM B-182-39/TAM C-155-22	avg	1.17	0.89	1.41	6.1	26.3	152	6.0	0.91
TAM B-182-39/TAM C-155-22	min	1.06	0.67	1.31	3.3	17.0	135	4.6	0.83
TAM B-182-39/TAM C-155-22	max	1.25	1.03	1.49	12.8	45.1	169	8.6	0.95
Deltapine 491/TAM B-182-39	avg	1.12	0.86	1.35	6.2	25.7	155	6.2	0.91
Deltapine 491/TAM B-182-39	min	1.03	0.72	1.23	3.6	16.2	130	4.8	0.83
Deltapine 491/TAM B-182-39	max	1.18	0.98	1.46	9.7	40.4	171	9.6	0.97
Deltapine 491/TAM C-155-22	avg	1.13	0.87	1.37	6.3	26.0	149	6.4	0.90
Deltapine 491/TAM C-155-22	min	1.04	0.78	1.25	3.6	16.1	129	4.8	0.85
Deltapine 491/TAM C-155-22	max	1.22	0.98	1.50	8.8	33.0	163	8.4	0.93
Deltapine 50/TAM B-182-39	avg	1.11	0.87	1.33	5.9	24.5	164	5.8	0.91
Deltapine 50/TAM B-182-39	min	0.98	0.70	1.15	3.1	14.2	138	3.4	0.85
Deltapine 50/TAM B-182-39	max	1.25	1.03	1.48	11.2	39.8	186	9.1	0.97
Deltapine 50/TAM C-155-22	avg	1.12	0.87	1.34	6.2	25.7	161	5.9	0.91
Deltapine 50/TAM C-155-22	min	1.02	0.69	1.25	3.5	14.6	133	4.0	0.83
Deltapine 50/TAM C-155-22	max	1.24	0.99	1.47	12.0	41.2	180	9.6	0.96

1. Advance fiber instrument system (AFIS) characteristics: Lw = average fiber length - weight basis, UQLw = average fiber length of the longest 25% - weight basis, SFCw = percent of fibers less than 0.5 in. - weight basis, Ln = average fiber length - count basis, SFCn = percent of fibers less than 0.5 in. - count basis, Fine = standard fineness, IFC = immature fiber content, and Mat Ratio =maturity ratio.
2. ELSU = extra long staple upland
3. n = 27

The percent of F_2 plants exceeding the average of the longer parent for FLw, FLn, and UQLw was lower in 2008 when ELSU genotypes were intercrossed or crossed with Deltapine 491 or Deltapine 50 than that shown in Table 1 for LSU and SSU combinations with TAM 94L-25 (Table 4). Although the data for the ELSU crosses are dealing with fiber length at a significantly higher level, data in Table 4 are encouraging in that transgressive segregates exceeding the average length of the longer parent were found for FLn regardless of combination and for FLw and UQLw for all combinations except TAM B182-39 / Deltapine 491. Larger percentages of the F_2 populations exceeded the average of the longer parent for FLn than for either of the length by weight measurements in the ELSU F_2, which also is encouraging because there is not a weight bias in the FLn measurement. **Again, these data do not support** the suggestion that crossing elite lines for these length measurement would be preferred to crossing lines where one was superior and one inferior since the ELSU / MSU, i.e., TAM B182-30 or TAM C155-22 crossed with Deltapine 50, combinations produced as many or more F_2 transgressive segregates that exceeded the longer parent for the length parameter of interest as when crossing ELSU / LSU or ELSU / ELSU.

Table 4. Average AFIS[1] fiber length parameters of two ELSU[2] lines, Deltapine 50, and Deltapine 491, their F_2 populations, and the percent of their F_2 plants exceeding the average length of the longer parent. Weslaco, Texas, 2008.

Population	FLw	FLn	UQLw
	(in)	(in)	(in)
TAM B182-39[3]	1.22	0.94	1.47
Deltapine 491	1.06	0.85	1.25
F2 Population	1.12	0.86	1.35
% of F2 > mean of longer parent	0	11.1	0
TAM B182-39	1.22	0.94	1.47
Deltapine 50	1.02	0.84	1.18
F2 population	1.11	0.87	1.33
% of F2 > mean of longer parent	3.7	18.5	3.7
TAM C155-22	1.18	0.90	1.43
Deltapine 491	1.06	0.85	1.25
F2 population	1.13	0.87	1.37
% of F2 > mean of longer parent	3.7	29.8	3.7
TAM C155-22	1.18	0.90	1.43
Deltapine 50	1.02	0.87	1.18
F2 population	1.12	0.87	1.34
% of F2 > mean of longer parent	14.8	37.0	7.4
TAM B182-39	1.22	0.94	1.47
TAM C155-22	1.18	0.90	1.43
F2 population	1.17	0.89	1.41
% of F2 > mean of longer parent	3.8	23.1	7.7

1. Advance fiber instrument system (AFIS) characteristics: Lw = average fiber length - weight basis, Ln = average fiber length - count basis, and UQLw = average fiber length of the longest 25% - weight basis.
2. ELSU = extra long staple upland
3. n = 27

Conclusions

These data, using LSU or ELSU parents, do not support the premise that crossing genotypes having superior UHML, Ln, Lw, or UQLw would be preferred to crossing lines where one was superior and one inferior in a breeding program where the objective was to develop improved fiber length in upland cotton. Transgressive segregate data from 2001 and 2002 using LSU / SSU, i.e., TAM 94L-25 / Tamcot CAMD-E, produced several transgressive segregates with fiber length exceeding that of the longer parent as did the LSU / TAM 94L-25. The same results relative to transgressive segregates were observed in the ELSU /ELSU, ELSU / LSU, and ELSU / MSU in 2008.

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