Trends in Varietal Fiber Properties

O. Lloyd May

Research Geneticist

United States Department of Agriculture, Agricultural Research Service

2200 Pocket Road, Florence, SC 29506-9706

Proceedings of 12th Engineered Fiber Selection Conference, 17-19 May 1999, Greenville, SC. www.cottoninc.com/EFSConference/may99c.pdf

May, O. L. 1999. Trends in varietal fiber properties. In Proc. 12th Engineered Fiber Selection Conf., 17-19 May, Greenville, SC. 13 pp. <www.cottoninc.com/EFSConference/may99c.pdf>

Abstract

The U.S. cottonseed market is changing to reflect the dominance of transgenic genetically engineered cotton cultivars and the entrance of new companies into the market. Grower acceptance of transgenic cultivars has been widespread and thus, transgenic cultivars are rapidly replacing traditional cultivars. Yarn manufacturers are challenged with buying fiber produced by new cultivars that have supplanted old favorites. Fortunately, Official State Cultivar Trial data suggests that most of the new cultivars, including the transgenic cultivars that have been trialed, produce acceptable fiber properties. Cultivars that represent improvements in fiber length, fiber strength, and length uniformity include the AgrEvo Cotton Seed International cultivar FiberMax 832, and Agripro cultivar 6102. In the public sector, the Agricultural Research Service germplasm line PD 94042 was released in 1998 for its combination of high yield potential and desirable fiber properties, highlighted by enhanced fiber maturity that can promote even dye uptake in yarn. Priorities for fiber quality modification to promote open-end spinning performance include enhanced fiber strength, increasing fiber length uniformity/decreasing short fiber. These characteristics are heritable indicating that breeding can result in fiber properties desired for open-end spinning performance.

Introduction

The genetic enhancement of cotton fiber quality is an essential component of a long-term strategy to maintain the economic health of the U.S. cotton industry. Fiber quality that promotes yarn and textile performance contributes to domestic industries and helps maintain World market share for U.S. raw fiber. This paper will review trends in fiber quality among commercial cultivars and public germplasm with special emphasis on fiber properties that contribute to open-end spinning performance.

Trends in Fiber Quality Among Commercial Cultivars

The cultivar cottonseed market is currently being driven by the race to garner market share for genetically engineered (transgenic) cultivars that express insect or herbicide tolerance. In the span of three years, acreage planted to transgenic cultivars has increased from a minor portion of the upland cotton crop (USDA-AMS, 1995), to about 45% of the 1998 U.S. cotton acreage (USDA-AMS, 1998). Projections for 1999 are that transgenic acreage will increase further. Such a drastic change in cultivars in the U.S. cotton industry last occurred in the late 1800s when the boll weevil invaded and resulted in the wholesale replacement of long-fibered, but late maturing cultivars, with lesser fiber quality earlier-maturing types (May and Lege, 1999). This wholesale change in cultivars suggests that fiber properties of this new class of cultivars be scrutinized for acceptibility. In Tables 1-3 are 1998-crop year HVI fiber properties from Official State Cultivar Trials for some of the new transgenic and non-transgenic cotton cultivars. Among earlier maturing conventional cultivars, Agripro 6102, SureGrow 501, and Deltapine 5111 exhibit the best fiber strength in this trial (Table 1), with Agripro 6102 and Deltapine 5111 being new cultivars. Later maturing transgenic cultivars with excellent fiber strength include Deltapine NUCOTN 35B (A 'Deltapine 5690' derivative; B or BG=Bollgard® *Bacillus thuringiensis* insect resistance gene), Deltapine 90B (Bollgard® version of Deltapine 90), and conventional cultivar FiberMax 832. FiberMax 832 is a okra-leaf type cotton bred by CSIRO, Australia and marketed in the U.S. by AgrEvo Cotton Seed International. FiberMax 832 is a sister line to the popular Siokra V-15 cultivar grown extensively in Australia and around the world for its combination of excellent fiber length, strength, fineness, maturity, and less short fiber content compared with existing cultivars. Although not shown in this particular trial data in Table 2, FiberMax 832 typically has 3-4% less short fiber content than other cultivars in the same trial. AgrEvo Cotton Seed International intends to make fiber quality improvement a goal of their international cultivar development efforts. In Table 3 are fiber data for the newest experimental germplasm and a few transgenic cultivars with Roundup Ultra® (abbreviated RR in cultivar name) and Bollgard genes stacked together. The Deltapine BG/RR cultivars are anticipated to have major market share in 1999 and are derived from old favorite cultivars Deltapine 5415 (DP458BG/RR) and Deltapine 5690 (DP655BG/RR). Both 458BG/RR and 655BG/RR have good fiber strength (Table 3).

Table 1. High Volume Instrument Fiber Properties of Early Maturing Cotton Cultivars Including New Transgenic Cultivars.

CULTIVAR	UHM LENGTH ----IN----	LENGTH UNIFORMITY -----%---	FIBER STRENGTH ---G/TEX---	MICRONAIRE READING
PM1330 BG	1.14	83.8	27.6	3.2
AP6102	1.14	82.5	31.0	4.1
SG501	1.13	84.2	31.7	4.2
SG105	1.12	82.9	28.4	4.1
1220BG/RR	1.10	83.7	28.0	3.8
1220RR	1.09	83.8	29.1	4.1
ST474	1.09	81.5	28.3	3.9
DP5111	1.08	82.6	31.5	4.1
BXN 47	1.08	82.7	26.1	4.0
1244RR	1.06	83.6	28.4	3.7
LSD0.10	0.04	NS	2.1	0.4

Source: South Carolina Official Cultivar Trials - May et al. 1998.

Table 2. High Volume Instrument Fiber Properties of Later Maturing Cotton Cultivars Including New Transgenic Cultivars.

CULTIVAR	UHM LENGTH ----IN----	LENGTH UNIFORMITY ----%----	FIBER STRENGTH ---G/TEX---	MICRONAIRE READING
SG248	1.14	82.6	28.4	4.2
NUCOTN35B	1.11	81.9	30.9	3.5
DP 90BG	1.11	81.8	30.3	3.5
FMAX 832	1.11	82.2	29.5	4.4
PM 1560 BG	1.09	82.9	29.9	3.5
USDA 94042	1.09	82.0	27.6	4.4
FMAX 989	1.06	80.2	28.7	4.1
DP5690RR	1.05	80.9	28.6	4.2
DP5415RR	1.04	80.6	27.6	4.2
LSD0.10	NS	NS	2.5	0.4

Source: South Carolina Official Cultivar Trials - May et al. 1998.

Table 3. High Volume Instrument Fiber Properties of a Selection of Newest Germplasm Tested in 1998 South Carolina Preliminary Cultivar Trial.

CULTIVAR	UHM LENGTH ----IN----	LENGTH UNIFORMITY ----%----	FIBER STRENGTH -----G/TEX----	MICRONAIRE READING
APX 9263	1.16	83.9	32.5	4.7
ACSI 0222	1.12	82.5	34.6	4.3
DP655BG/RR	1.11	82.0	33.8	4.1
DPX 9775	1.11	82.4	34.9	4.5
DP458BG/RR	1.10	81.6	31.7	4.5
NUCOTN33B	1.08	81.2	31.6	4.3
DP 51	1.09	81.6	27.6	4.6
LSD0.10	0.04	1.5	2.6	NS

Source: South Carolina Official Cultivar Trials - May et al. 1998.

Collectively, data in Tables 1-3 suggest that fiber quality of transgenic cultivars is acceptible. The other good news is that companies such as Agripro Seeds and AgrEvo Cotton Seed International are emphasizing fiber quality improvement in their cultivar development programs. Clearly, however, transgenic cultivars will dominate the cottonseed market from 1998 forward. Thus, yarn manufacturers that have purchased fiber from specific cultivars in the past will need to keep abreast of cultivar name changes to know what they are buying.

Among the few remaining public-breeding efforts, the ARS cotton-breeding program at Florence, SC continues research towards the genetic modification of fiber properties to meet the needs of open-end yarn manufacture. On-going breeding projects include enhancing fiber strength, developing finer more mature fibers, and increasing fiber length uniformity/reducing short fiber content.

To enhance fiber strength, we need genetic sources of high fiber strength. Sea Island (*G. barbadense* L.) germplasm is one source of high levels of fiber strength not found in upland cotton. While introgression of fiber properties from *G. barbadense* into an upland *G. hirsutum* background is difficult (Stephens, 1949), documented successes in this endevour include the cultivar Sealand 542, developed by ARS, Florence SC in the 1950s (Culp and Harrell, 1980); and certain New Mexico Acala upland germplasms that are stably introgressed with *G. barbadense* genes (Cantrell, 1995). The introgressed New Mexico Acalas express possibly the highest fiber strength available in upland cotton. In 1994, we began an introgression program with Sea Island germplasm obtained from R. Percy, USDA-ARS, Pheonix, AZ and R. Cantrell, New Mexico State University. We created F1 populations between the Sea Island germplasm and several upland ARS germplasm lines. Since 1994, we have proceeded to create several backcross generations to the upland parent, while concurrently selecting smoothleaf upland type plants with high fiber strength and desirable fiber lengths and micronaire readings. In Table 4, is a brief synopsis of the introgression program from the 1998 field trials.

Table 4. Examples of Germplasm (BC2F2 plant selections) Developed Through Introgression – Fiber Properties Measured By Single-Instrument

GERMPLASM	2.5% LENGTH ----in----	UR --%--	T1 G/TEX	MIC
NMSI 1915-1/3*PD-3-14-1	1.15	0.48	25.4	3.10
NMSI 1915-1/3*PD-3-14-2	1.09	0.50	27.4	3.00
NMSI 1915-1/3*PD-3-14-3	1.07	0.49	24.9	3.80
NMSI 1915-1/3*PD-3-14-4	1.03	0.52	25.1	4.40
NMSI 1915-1/3*PD-3-14-5	1.25	0.48	24.5	4.00
NMSI 1915-1/3*PD-3-14-6	1.03	0.50	25.9	3.30
GIZA 45/3*PD5363-1	1.07	0.55	29.1	4.90
GIZA 45/3*PD5363-2	1.03	0.54	28.4	3.90
GIZA 45/3*PD5363-3	1.19	0.52	30.2	4.30
TEXAS M-1 CHECK	1.10	0.50	18.7	4.30
3-79 CHECK	1.34	0.48	29.8	3.88

2.5% length= 2.5% fiber span length measured with fibrograph; UR=fiber length uniformity ratio; T1=fiber strength by stelometer measurement; MIC=micronaire reading measured with fibronaire instrument.

Compared with the upland genetic standard (TM-1; Kohel et al., 1970) and the *G. barbadense* genetic standard (3-79), the plant selections exhibit enhanced fiber strength (T1), but maintain upland fiber lengths (2.5% span length) and micronaire readings. Apparently, recombination has successfully combined enhanced fiber strength with upland 2.5% fiber span lengths. The data in Table 4 summarizes only a fraction of the germplasm we are currently evaluating. Of course, the simultaneous improvement of yield and fiber quality is necessary to meet the needs of growers and yarn manufacturers. Thus, the future utility of this genetic material depends on identifying segregates with yield potential and enhanced fiber properties. Yield testing of the introgressed germplasm will begin in 2000.

Short fiber (fibers <12.7mm length) is a source of waste in yarn manufacture and it contributes to weaker yarns (Deussen, 1992). Reducing short fiber content has thus become an important goal of the cotton industry. With the advent of the Advanced Fiber Information System (AFIS; Bragg and Shofner, 1993), that provides direct measurement of short fiber (as opposed to indirect measures of short fiber such as length uniformity ratio from HVI instruments), a concerted research effort to reduce short fiber is now possible. Ameliorating short fiber content through breeding is however, difficult for several reasons. First, the growth environment highly influences the expression of short fibers (Bradow et al., 1999). Therefore, genetic variation for short fiber content can be confounded with environmental influences. Second, short fiber content varies by fruiting location on the plant (Lewis, 1998), and thus boll location where fiber samples are derived in breeding trials for genotypic comparisons can confound efforts to choose the germplasm with least short fiber. Another consideration in breeding for reduced short fiber content is that fiber derived from boll samples in breeding trials may not be representative of that delivered to the yarn mill. Cotton breeding typically begins with early generation advance of small seed quantities derived from hand picked boll samples ginned on small laboratory model gins that do not have lint cleaners. The above considerations led May and Jividen (1999) to speculate that short fiber in breeder fiber samples derives mostly from fibers that fail to lengthen past 12.7mm rather than those that break from spindle picker harvest and lint cleaning in the ginning process. The heritability (heritability takes value between 0 and 1 and is a statistic breeders employ to assess the degree to which traits will respond to selection) of short fiber from breeder fiber samples was found to be low (average=0. 7; May and Jividen, 1999). Consequently, breeding efforts to reduce the class of short fibers that fail to lengthen past 12.7mm will result in slow progress. A collateral approach to reduce short fiber might be to examine fiber properties such as enhanced single fiber strength to determine if this would result in less fiber breakage from mechanical handling. In summary, reduction in short fiber through breeding will have to address fibers that fail to lengthen past 12.7mm and those that break through mechanical handling.

Immature fiber contributes to dye variation in textiles and reflects incomplete secondary wall development (Bradow et al., 1996). Secondary wall development was shown by Kohel et al. (1974) to be genetically controlled. Because AFIS conveniently provides a measure of immature fiber content, this trait could become a breeding priority for public sector germplasm development. There would seem insufficient monetary return on such a breeding investment by the private sector to raise fiber maturity to the level of a selection criterion. May and Jividen (1999) provided the first heritability estimates (0.52-0.68) for immature fiber content as measured by AFIS. These reasonable heritability estimates suggest that breeding can reduce immature fiber content. A designed experiment to test this hypothesis is currently underway.

In summary, trends in cultivar fiber properties suggest that fiber strength is increasing, and in a few non-transgenic cultivars, short fiber content has been reduced. The impact of new non-transgenic cultivars on the overall supply of quality fiber available to mills remains unclear, due to rapid adoption of transgenic cultivars. Fiber quality data for transgenic cultivars from Official State Cultivar Trials suggests that the transgenic cultivars produce acceptable fiber properties.

References

Bradow, J.M., O. Hinojosa, L.H. Wartelle, and G. Davidonis. 1996. Applications of AFIS fineness and maturity module and x-ray fluorescence spectroscopy to fiber maturity evaluation. Textile Res. J. 66:545-554.

Bragg, C.K., and F.M. Shofner. 1993. A rapid, direct measurement of short fiber content. Textile Res. J. 63:171-176

Cantrell, R.G. 1995. New Mexico State University report to Regional Research Project S-258 (Evaluate Cotton Germplasm to Identify Useful Characters for Genetic Mapping).

Culp, T.W., and D.C. Harrell. 1980. Registration of extra-long staple cotton germplasm. Crop Sci. 20:291.

Deussen, H. 1992. Improved cotton fiber properties – the textile industry's key to success in global competition. p. 43-63. *In* C.R. Benedict and G.M. Jividen (ed.) Cotton Fiber Cellulose: Structure, Function, and Utilization Conference. 1992. Natl. Cotton Council, Memphis, TN.

Kohel, R.J., T.R. Richmond, and C.F. Lewis. 1970. Texas Marker 1: A description of a genetic standard for *Gossypium hirsutum* L. Crop Sci. 10:670-673.

Kohel, R.J., J.E. Quisenberry, and C.R. Benedict. 1974. Fiber elongation and dry weight changes in mutant lines of cotton. Crop Sci. 14:471-474.

Lewis, H.L. 1998. Genetic short fiber content of American upland cotton. *In* C.H. Chewning (ed.) Proceedings of the 11th Engineered Fiber Selection System Conference, June, 1998, Memphis, TN.

May, O.L., M.J. Sullivan, D.K. Barefield, Jr., D.M. Robinson, and G.M. Veazy. 1998. Performance of field crops in South Carolina – Cotton. South Carolina Agric. & Forestry Expt. Stn Circular 184.

May, O.L., and K.E. Lege. 1999. Development of the world cotton industry. *In* C.W. Smith and J.T. Cothren (ed.) Cotton. John Wiley & Sons, New York, NY (In press).

May, O.L., and G.M. Jividen. 1999. Genetic modification of cotton fiber properties with single- and high-volume instruments. Crop Sci. 39:328-333.

Stephens, S.G. 1949. The cytogenetics of speciation in Gossypium. I. Selective elimination of the donor parent genotype in interspecific backcrosses. Genetics 34:627-637.

USDA-AMS, 1995. Cotton varieties planted – 1995 crop. USDA-AMS, Memphis, TN.

USDA-AMS, 1998. Cotton varieties planted – 1998 crop. USDA-AMS, Memphis, TN.