Published November, 1978

Effect of Durable-Press Resin Treatment on Tenacity and Elongation of Fiber from Upland Cotton Strains[1]

Reba Lawson, H. H. Ramey, Jr., and W. R. Meredith, Jr.[2]

ABSTRACT

Untreated and mercerized fiber samples from 14 cultivars and breeding strains of Upland cotton (*Gossypium hirsutum* L.) were evaluated for changes in tenacity when given durable-press (DP) treatment. The average loss of tenacity after DP treatment of untreated cotton was about 59%, with little variation among cultivars and strains. Mercerization increased fiber tenacity by 50%. The tenacities of premercerized-resinated samples were 25% lower than mercerized but 12% higher than that of untreated fibers. Strength uniformity, the ratio of the tenacity at 3.2-mm gauge length (T_1) to the tenacity at 0-gauge (T_0), was negatively correlated with the ratio of T_1 for premercerized DP-treated samples to T_1 for untreated samples.

Results of the study support the use of T_1 as a breeding criterion of high fiber quality. Strength uniformity may also be valuable for the selection of breeding strains because it is a measure of the stress points along the length of the cotton fiber.

Additional index words: **Strength uniformity, *Gossypium hirsutum*, Permapress resin treatment, Mercerization, Cotton breeding.**

FABRICS treated with resins to give durable-press finish (DP) have become increasingly popular. Those fibers that can be DP treated without serious loss of strength are in demand for use in fabrics. Such treatment of cotton (*Gossypium* spp.) fibers, yarns, or fabrics usually reduced their strength by 40 to 60% and reduced their resistance to abrasion. However, mercerization prior to DP treatment can result in retention of fiber strength or in some cases, an improvement in strength (5).

Samples of six Upland cultivars with a wide range in tenacity and maturity were found to differ in strength loss from formaldehyde crosslinking, a form of DP treatment (8). Lawson et al. (3) showed a negative relationship between the ratio of tenacities at 3.2-mm and 0-gauge lengths (strength uniformity) and the retention of fiber strength after mercerization-resination. Their report was based upon six samples of cotton, five from Upland (*G. hirsutum* L.) and one American Pima (*G. barbadense* L.).

Most of the reports on retention of fiber strength after DP treatment dealt either with fibers treated individually or with fibers removed from treated yarn or fabrics. In treating single fibers, there is a tendency to select the longer, stronger ones of a sample and therefore bias the results. The determination of strength loss of fibers removed from treated yarns also has a bias. From 10 to 40% of the fibers in a yarn swollen in NaOH do not exhibit properties consistent with mercerization (1). Fibers removed from yarns treated while under tension behaved as if no

[1] Contribution from Cotton Quality Laboratories, SEA, USDA, and Inst. of Agriculture, Univ. of Tennessee and the Cotton Physiology and Genetics Laboratory, SEA, USDA, and Delta Branch of the Mississippi Agric. and For. Exp. Stn., Stoneville, Miss. Published as Mississippi Agric. and For. Exp. Stn. Journal Paper No. 3919. Received 17 May 1978.

[2] Research physicist and research geneticist, USDA, SEA, Cotton Quality Laboratories, Inst. of Agriculture, Univ. of Tennessee, Knoxville, TN 37916 and research geneticist, USDA, SEA, Delta Branch of the Mississippi Agric. and For. Exp. Stn., Stoneville, MS 38776, respectively.

Table 1. Tenacity at 3.2-mm gauge of untreated and treated cotton samples, the ratio of mercerized-resinated to untreated tenacities (T_1MR/T_1U) and strength uniformity of untreated samples.

Sample ID	Cultivar	Tenacity U†	R	M	MR	T_1MR/T_1U	Strength uniformity
		mN/tex					
1	CP 828	209 A*	88 A	306 AB	233 AB	1.115 BC	0.524 DEFG
2	Acala SJ-1	209 A	90 A	299 B	229 BC	1.096 BCD	0.548 BC
3	PD 8619	206 A	86 A	294 B	212 CDE	1.029 D	0.568 A
4	CP 820-589	204 A	85 AB	310 A	246 A	1.206 A	0.516 FGHI
5	Coker 8103	193 B	80 BC	295 B	221 BCD	1.145 AB	0.525 DEFG
6	Coker 423	192 BC	75 C	299 B	233 AB	1.214 A	0.520 EFGH
7	DPL 607	190 BC	76 C	279 C	203 E	1.068 CD	0.528 DEFG
8	Stv. 804	192 BC	80 BC	301 AB	223 BCD	1.161 AB	0.503 HI
9	Coker 8215	190 BC	80 BC	297 B	212 CDE	1.116 BC	0.544 BCD
10	PD 4381-567	190 BC	78 C	281 C	208 DE	1.095 BCD	0.536 BCDE
11	PD 4381-54	188 BC	78 C	278 C	214 CDE	1.138 ABC	0.498 I
12	MO 63-07913	185 BC	76 C	280 C	198 E	1.070 CD	0.556 AB
13	Coker 310	184 C	74 C	282 C	207 DE	1.125 BC	0.532 CDEF
14	Coker 201	173 D	73 C	265 D	198 E	1.145 AB	0.509 GHI

* Averages within a column with no letter in common differ significantly at the 5% protection level based on Duncan's new multiple range test.
† U untreated, R resinated, M mercerized, MR mercerized-resinated.

Table 2. Elongation of untreated and treated cotton samples and ratio of mercerized-resinated to untreated elongations (E_1MR/E_1U).

Sample ID	Elongation U†	R	M	MR	E_1MR/E_1U
	%				
1	5.9 F*	3.0 F	9.2 DE	4.8 CDE	0.81 A
2	7.0 D	3.4 CDE	10.0 BCDE	5.2 ABC	0.74 BCD
3	7.6 B	3.4 CDE	11.1 AB	5.0 ABCD	0.66 EF
4	5.9 F	3.1 EF	9.1 E	4.7 DE	0.80 AB
5	6.4 E	3.4 CDE	9.7 CDE	5.1 ABCD	0.80 AB
6	6.5 E	3.2 DEF	9.4 DE	4.7 DE	0.72 CDE
7	7.2 CD	3.6 BC	10.7 ABC	5.1 ABCD	0.71 CDE
8	6.4 E	3.3 CDEF	9.2 DE	5.0 ABCD	0.78 ABC
9	7.4 BC	3.9 AB	10.8 ABC	5.3 AB	0.72 CDE
10	7.0 D	3.5 CD	9.7 CDE	4.9 BCD	0.70 CDE
11	6.2 EF	3.2 DEF	8.9 E	4.4 E	0.71 CDE
12	8.7 A	4.2 A	11.2 A	5.4 A	0.62 F
13	7.7 B	4.1 A	10.3 ABCD	5.2 ABC	0.68 DEF
14	7.1 CD	3.6 BC	10.3 ABCD	5.1 ABCD	0.72 CDE

* Averages within a column with no letter in common differ significantly at the 5% protection level based on Duncan's new multiple range test.
† U untreated, R resinated, M mercerized, MR mercerized-resinated.

tension had been applied to them (7). Raes and Verschraege (6) developed a procedure to maintain tension on bundles of fibers during NaOH and DP treatment and thereby minimize the bias. Differences in the reaction to the treatments were found among a group of commercial cotton samples.

We undertook to assess the strength loss due to DP treatment of some newly developed Upland cotton strains and to determine whether the relationship of strength uniformity and strength retention holds in the samples from these strains. If cottons with low strength uniformity can be greatly improved by mercerization, their value can be improved.

MATERIALS AND METHODS

The fiber samples used were remnants from a study of the effect of sampling procedures on yield components and fiber properties (4). The samples were from two replications of yield trials of 11 strains and three cultivars of Upland cotton grown at Scott and Stoneville, Miss., in 1971. These cottons represent a broad genetic base but differ only moderately in fiber properties.

The original fibers and three treatments were investigated: untreated control (U), durable-press treated (R), mercerized at 95% of original length (M), and mercerized at 95% of original length then resin treated (MR). For mercerization, a ribbon of fibers was clamped and held at 95% of the original length (3). The clamped fibers were soaked for 10 min in 0.4% Triton X-100[3], immersed for 10 min in 18% NaOH (by weight) at room temperature, rinsed in tap water, neutralized for 5 min in 1% acetic acid, rinsed in tap water, and dried for 20 min at 80C. The durable-press resin used was Permafresh LF-2[3], a dimethyloldihydroxyethyleneurea (DMDHEU) cross-linking reagent formulated by Sun Chemical Corportion. A ribbon of parallel fibers was held within a fold of filter paper for treating. The R specimens ranged between 0.2 and 0.3 g, and the MR specimens between 0.1 and 0.2 g. Specimens with no pretreatment (R) were soaked for 10 min in a solution of 20% Permafresh LF-2 that contained 3% $MgCl_2 \cdot 6H_2O$, as catalyst, and 0.4% Triton X-100, as wetting agent. Premercerized (MR) specimens were treated in a 15% solution of resin so that the unmercerized and premercerized specimens would receive about the same fixation. The specimens were padded to an average wet pickup of 37% for unmercerized and 44% for premercerized, or fixations of 3.2 and 2.9%, respectively. The percent fixation was calculated as the product of percent resin in the treatment solution, percent solids and percent wet pickup. The specimens were dried for 10 min at 80C and cured for 3 min at 170C.

The effects of the treatments were assessed from changes in the 3.2-mm gauge tenacity (T_1) and elongation (E_1), as measured on the Stelometer at 21C and 65% relative humidity (ASTM Method D-1445). The increase in tenacity with mercerization-resination was compared with strength uniformity (Tenacity at 3.2-mm gauge/tenacity at 0-gauge, T_1/T_0).

All the fiber samples could not be handled in a single continuous laboratory run. The fibers from each sampling procedure at each location were processed in different laboratory runs. This experimental design confounded differences in sampling procedures at locations with differences that could have occurred in laboratory runs. Nevertheless, our main interest was comparisons among strains and cultivars, and the blocking procedures used were appropriate for this purpose.

RESULTS AND DISCUSSION

Differences among the 14 genotypes in T_1 before U, and after R, M, and MR treatments, T_1MR/T_1U, and strength uniformity are shown in Table 1. The range in strength uniformity of untreated samples was moderate. The anticipated large drop in T_1 of resinated

[3] Mention of a trade name or firm is for information only and does not imply its endorsement by the USDA over similar products or firms not mentioned.

Table 3. Simple correlations among treatment: tenacity above diagonal and elongation below diagonal.*

		U†	R	M	MR	
	U		0.94	0.81	0.72	
	R	0.90		0.72	0.63	T_1‡
E_1‡	M	0.90	0.77		0.88	
	MR	0.76	0.79	0.79		

* Correlation coefficients of 0.532 and 0.661 are significant at the 5 and 1% levels, respectively. † U untreated, R resinated, M mercerized, and MR mercerized-resinated. ‡ T_1 tenacity at 3.2 mm gauge length, E_1 elongation.

samples averaged 59%. All strains exhibited an increase in T_1 from U to M, and the increase averaged 50%. MR samples had T_1 values larger than those for U samples by an average of 12% but they showed an average decrease of 25% from mercerized samples. Elongation of the four treatments and E_1MR/E_1U are given in Table 2. The average changes in E_1 due to the three treatments R, M and MR were —50, 44, and —28% respectively. The MR treatment increased T_1 but decreased E_1.

The difference between locations is not shown because the experimental design confounded treatment and testing variations with those due to locations of growth.

Correlations among the responses to treatments are shown in Table 3. All of the correlations were significant at the 1% probability level. The T_1 of untreated samples will not adequately predict the response of a fiber to mercerization-resin treatment where only 50 to 60% of the variation is explained by variation in the untreated parameter.

We calculated the correlations of strength uniformity with T_1M/T_1U ($r = -0.43$), with T_1MR/T_1U ($r = -0.73$), and with T_1MR/T_1M ($r = -0.58$). An analysis of variance of strength uniformity gave F values for genotypes and for genotypes $\times$ locations of 11.6 and 2.4, respectively. These values suggest that breeders could use strength uniformity as a selection tool. However, because its relationship to T_1MR/T_1U is not sufficiently strong, strength uniformity probably should not be used to predict response to treatments.

This is illustrated in Fig. 1. Two strains, 4 and 6, deviated positively and two strains, 7 and 11, negatively from the regression. We do not know what special fiber properties contributed to these responses. The deviations do suggest other areas for research. Also T_1MR/T_1U could not be accurately estimated from strength uniformity data.

An earlier study (3) with *G. hirsutum* and *G. barbadense* fibers showed a negative association between strength uniformity and T_1MR/T_1U. Our data indicate a similar but weaker relationship for *G. hirsutum* fibers only. The relationship between strength uniformity and T_1M/T_1U reported here ($r = -0.43$) is similar to that found earlier for Upland cotton (2). Our data, as well as earlier data cited (3), indicate that samples of low strength uniformity are improved more by MR than those of higher strength uniformity (Fig.1). As compared to the latter fibers, those with low strength uniformity are considered to be more disordered and to have more stress points, and hence, more weak places along the length. Mercerization, by

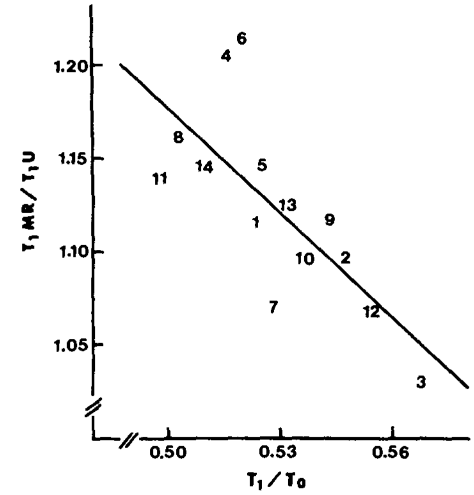

Fig. 1. The relationship between strength uniformity (T_1/T_0) and retention of fiber strength in mercerized-resinated (T_1MR/T_1U). The regression line $T_1MR/T_1U = -1.855 (T_1/T_0) + 2.105$ is shown. $S_{yx} = 0.0367$.

swelling the fiber, permits fibrils to reorient, and the reorientation reduces disorder and stress. Tension mercerization increases fibrillar orientation and decreases X-ray angle; hence it increases tensile strength (8). Thus, when mercerized, fibers with low strength uniformity should show greater increases in strength, T_1M/T_1U, and T_1MR/T_1U. Also, samples with low strength uniformity could be expected to be low in T_1, because of the disorder and stress points. Sample 4, however, behaved anomalously. It had a high T_1; yet it was greatly improved by mercerization. Further investigation is needed to determine the properties that allow fibers like sample 4 to be improved by mercerization.

Genetic selection for higher strength uniformity would reduce the disorder and stress points of fibers. This procedure would not increase MR/U, but should increase the T_1 of MR. The latter effect is desirable.

Our research indicates that cotton breeders should continue their use of T_1 as a selection criterion for increased fiber quality. In addition, strength uniformity may be a valuable selection criterion.

ACKNOWLEDGMENTS

We thank the following people for reviewing the manuscript and giving helpful suggestions for its improvement: T. W. Culp, J. A. Lee, M. L. Nelson, V. H. Reich, S. P. Rowland, C. W. Smith, E. L. Turcotte, and T. L. Vigo.

REFERENCES

1. de Boer, J. J., and H. Borsten. 1962. An empirical relation for the degree of penetration of a mercerizing solution into a cotton yarn. J. Tex. Inst. 53, T 497- T 510.
2. Lawson, R., and H. H. Ramey, Jr. 1977. Dependence of changes in tenacity with mercerization on strength uniformity and maturity of cotton samples. Tex. Res. J. 47:249-255.
3. ———, ———, and P. W. Elliott. 1975. Stress-strain properties of mercerized, stretched and durable-press treated cotton fibers. Text. Res. J. 45:510-514.
4. Meredith, W. R., H. H. Ramey, Jr., and R. R. Bridge. 1975. Determination of yield, yield components, and fiber properties as influenced by selective and nonselective samplings. Crop Sci. 15:432-435.

5. Murphy, A. L., M. F. Margavio, and C. M. Welch. 1974. Orientation-disorientation effects in tensioned, mercerized cotton. The pretreatment of yarns for wash-wear fabrics of high strength and durability. Text. Res. J. 44:904-914.
6. Raes, G. R., and L. Verschraege. 1976. Prediction of the response of various cottons to modern finishing processes. Melliand Textilber. (English Edition). p. 771-773.
7. Rebenfeld, L. 1962. Response of cottons to chemical treatments. Part V: Effects of tension during single-fiber resin finishing. Text. Res. J. 32, 202-211.
8. Venkatesh, G. M., and N. E. Dweltz. 1975. Behavior of untreated and crosslinked cotton fibers. I. Contribution of mautrity. J. Appl. Polymer Sci. 19:2067-2078.