STRENGTH AND ELONGATION OF TEXAS COTTON VARIETIES: FIBER AND YARN RESULTS

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Abstract

The tensile properties of cotton fibers include both breaking strength and elongation-before-breaking. The lack of HVI calibration for elongation prevents its commercial use in the market; however, results from a single HVI machine may be utilized to evaluate the impacts of elongation on these tensile properties. Strength and elongation results for six major varieties at three locations on the Texas Plains in 2008 are presented and the impacts of elongation on yarn are emphasized. The transference of elongation from cotton fibers to ring-spun yarns is highly reliable and this property deserves a distinct consideration by plant breeders and textile manufacturers.

Introduction

Cotton varieties were grown and harvested from large-scale variety evaluations conducted in three locations across the Texas Plains. Six varieties were replicated in all three of the locations; these are used here to evaluate the behaviors of strength and elongation results on the fibers and the yarns made from them. The importance of elongation-before-breaking is well known in textile applications and is the basis for manufacture and use of diverse synthetic fibers. However, it is not much in the consciousness of people in the cotton industry. This is unfortunate, because the "work-to-break", which reflects the combined impacts of tensile (breaking) strength and the elongation-before-breaking, gives a superior indication of the ability of a yarn or fabric to survive the rigors of mechanical and other physical stresses.

A primary reason why fiber elongation is not emphasized by the cotton production sector is its omission from USDA classing data and from the government loan premiums-and-discounts schedule for cotton. This reality is dictated by the lack of calibration standards for cotton fiber elongation, which prevents the replication of elongation measurements at diverse locations using different high volume instruments (HVIs). However, using one HVI within the same laboratory, the relative values for elongation may be reliably used for analysis and evaluation. This is what was done at the Fiber and Biopolymer Research Institute, using a single Uster 1000 HVI.

Methods

The six cotton varieties are denoted by A, B, C, D, E, and F. The three locations are denoted by 1, 2 and 3. Locations 1 and 2 have abundant irrigation applied with low-elevation spray systems. Location 3 has limited irrigation applied with a low-energy, precision application system. The 2008 growing season was extraordinarily benevolent and record yields were obtained across much of the Texas Plains on both irrigated and dryland acres. While micronaire values were generally good, a long and warm fall season enabled the harvest of a large 'top crop', which probably resulted in a small portion (by weight) of the fibers having low micronaire values.

High volume instrument (HVI) fiber measurements were done on the Uster 1000, using a high-accuracy protocol consisting of 10 replicated measurements on length and strength, 4 on micronaire and 4 on color. Yarns were made on the Suessen Fiomax system using the conventional ring spinning setup. Results are reported for carded (i.e., not combed) cotton used to spin Ne 30 size yarns. Yarn strength and elongation results reported were obtained from the Uster Tensorapid. A total of 18 fiber and yarn results are included in this report, consisting of six varieties grown on three locations.

Results

Results of the fiber property measurements are summarized in Table 1. Results for each variety at each location are given, along with the average for each variety at each location. Inspection reveals significant variations among both varieties and locations. Micronaire values range from 3.66 to 4.33. Micronaire values at locations 1 and 2 are

generally close together, with values at location 3 generally being significantly higher. The upper half mean length values range from 1.10 to 1.20 inches, with varieties A and B being noticeably longer than the other four varieties. Length uniformity indexes ranges from 79.0% to 82.8%, with only variety A averaging below 81% and only variety C averaging above 82%. Fiber breaking strength ranges from 27.2 to 31.7 g/tex, while fiber elongation-before-breaking ranges from 7.7% to 10.5%. The evaluation of breaking strength and elongation will be the focus of the remainder of this report.

Table 1. High Volume Instrument Results on Six Varieties at Three Locations

Variety	Location	Micronaire	Length	Uniformity	Strength	Elongation	Rd	+b
A	1	3.69	1.15	79.0	27.7	7.7	81.3	8.9
	2	3.66	1.20	80.8	28.8	7.8	80.0	8.7
	3	4.07	1.19	81.7	28.4	7.7	81.8	8.4
	Average	3.81	1.18	80.5	28.3	7.7	81.0	8.7
B	1	3.88	1.18	80.9	31.7	8.0	82.8	8.70
	2	4.05	1.20	82.7	29.8	8.4	80.5	8.7
	3	4.16	1.16	82.1	29.2	8.3	79.2	9.3
	Average	4.03	1.18	81.9	30.2	8.2	80.8	8.9
C	1	3.97	1.15	82.8	29.7	10.2	78.8	10.0
	2	3.74	1.15	82.7	28.5	10.1	74.4	10.2
	3	4.33	1.10	82.1	27.2	10.1	77.3	9.9
	Average	4.01	1.13	82.5	28.5	10.1	76.8	10.0
D	1	3.69	1.13	81.5	31.2	9.4	80.1	9.9
	2	3.92	1.13	82.4	29.5	9.5	78.8	9.0
	3	3.80	1.11	81.7	28.2	10.0	82.4	8.5
	Average	3.80	1.12	81.9	29.6	9.6	80.4	9.1
E	1	3.73	1.12	80.5	29.5	10.5	81.1	10.3
	2	3.70	1.18	82.0	28.9	9.7	75.7	10.2
	3	4.22	1.10	81.0	27.5	10.5	81.8	8.8
	Average	3.88	1.13	81.2	28.6	10.2	79.5	9.8
F	1	3.68	1.12	81.7	30.6	9.3	79.2	10.2
	2	3.81	1.12	80.7	28.5	9.7	75.3	10.9
	3	4.05	1.11	81.6	27.7	9.7	78.9	9.1
	Average	3.85	1.12	81.3	28.9	9.6	77.8	10.1

Figure 1 shows the individual fiber breaking strength results for all varieties at all locations, along with the average strength results at each location. This method of presentation will be used in subsequent figures.

In Figure 1, the variety-location interaction effects were generally large and all varieties except one exhibited the same ranking (highest-to-lowest strength values) across locations. The exception was variety A. All other varieties produced the highest strength values at Location 1, but variety A exhibited the lowest of the three strength values at this location. The reason for this divergent interaction effect for variety A is not known.

The average values for each variety in Figure 1 reveal distinct genetic variations in fiber strengths. These range from a high of 30.2 grams per tex for variety B to a low of 28.3 grams per tex for variety A.

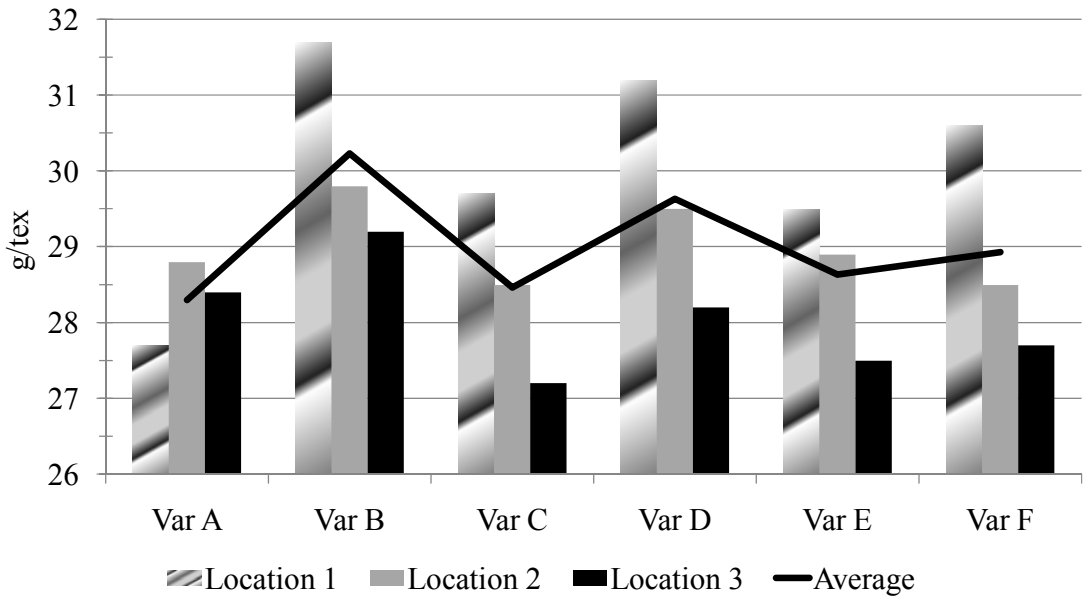

Figure 1. Fiber Strength Results

Figure 2 shows the comparable chart for fiber elongation-before-breaking. Comparing it with results in Figure 1, at least three observations are apparent:

1. The variety-location interaction effects are quite small compared with those for fiber strength; this suggests that the genetic expression of elongation is more independent of environmental conditions than it is for fiber strength.
2. The average varietal differences are large for elongation, ranging from 7.7% for variety A to 10.2% for variety E. This represents nearly a 33% increase between varieties A and E.
3. Rankings for elongation are different than for strength. The two best elongation values are for Varieties C and E, yet both of these had lower strength values.

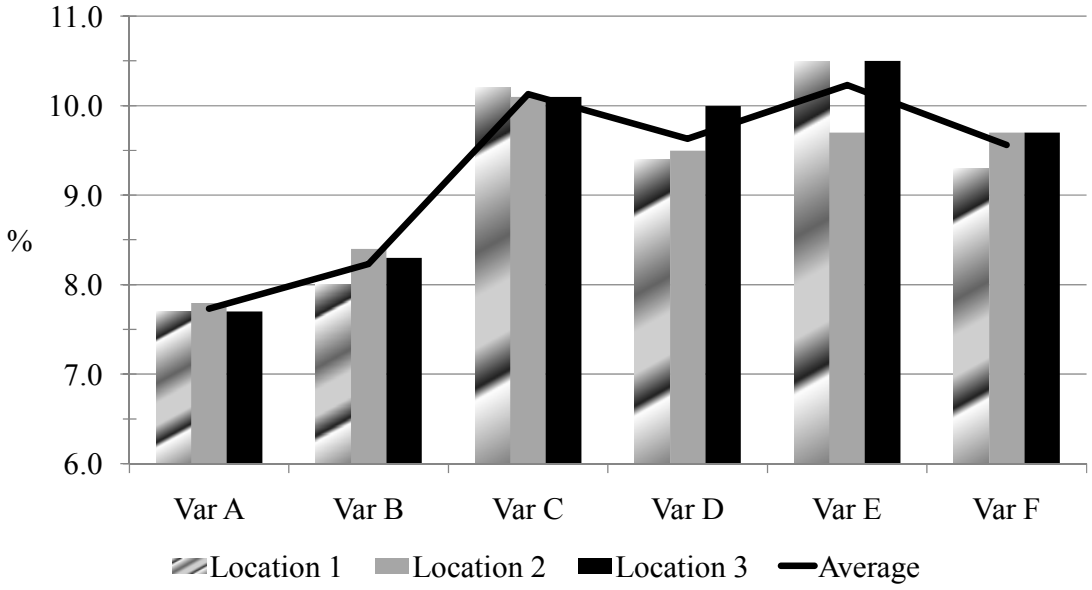

Figure 2. Fiber Elongation Results

Figures 3 and 4 show the results for yarn strength and yarn elongation, respectively. In order to better reveal the relationships between the fiber and yarn results, these are plotted together in Figures 5 through 8. Average variety results for fiber and yarn strength are plotted in Figures 5 and 6, while individual results for all 18 samples are plotted in Figures 7 and 8.

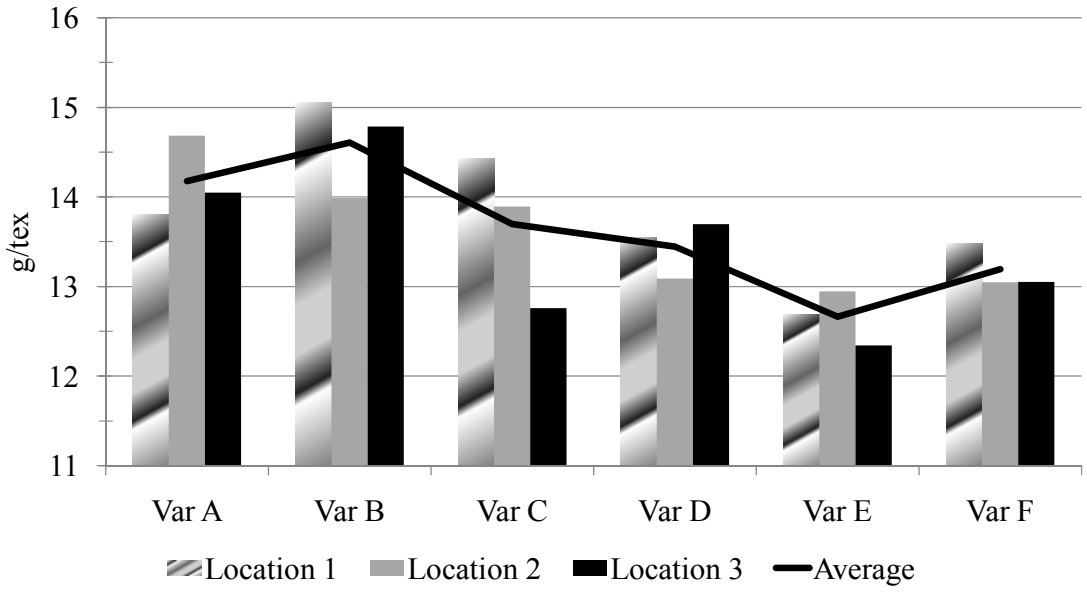

Figure 3. Results for Yarn Strength

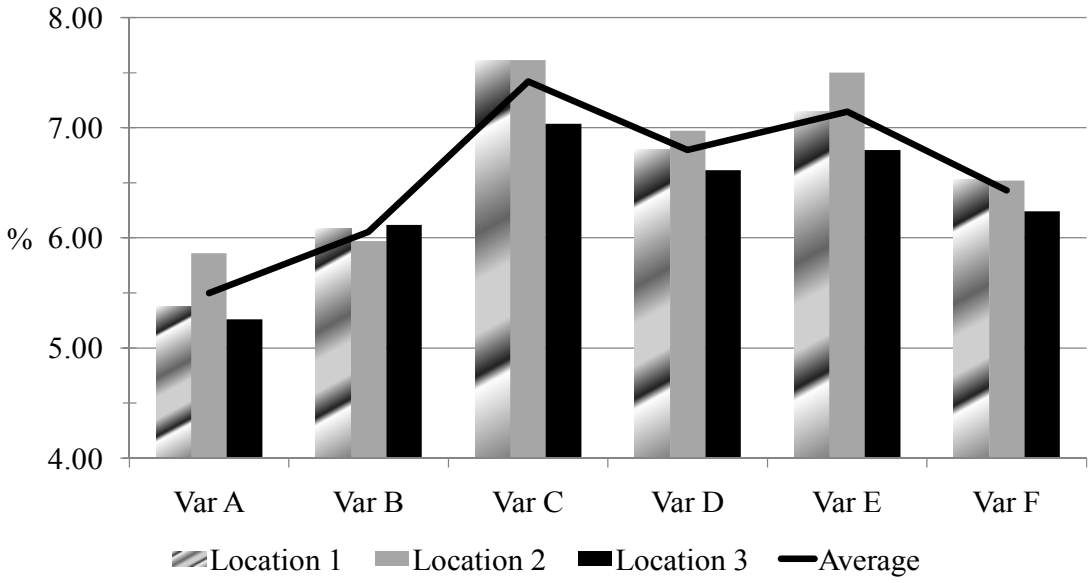

Figure 4. Results for Yarn Elongation

Obviously, the relationship between average fiber and yarn strength, although significant, is fairly weak (Figure 5). The correlation coefficient is 0.42. But for average fiber versus yarn elongation, the correlation coefficient is quite high at 0.95 (Figure 6). The weaker correlation coefficient for fiber versus yarn strength is not surprising, because it is well known that a variety of factors impact strength of ring-spun yarns (e.g., upper half mean length, short fiber

content, etc.). But the strong correlation coefficient for fiber versus yarn elongation is remarkable; it indicates that factors other than fiber elongation may not be important for adequate prediction of prediction of yarn elongation.

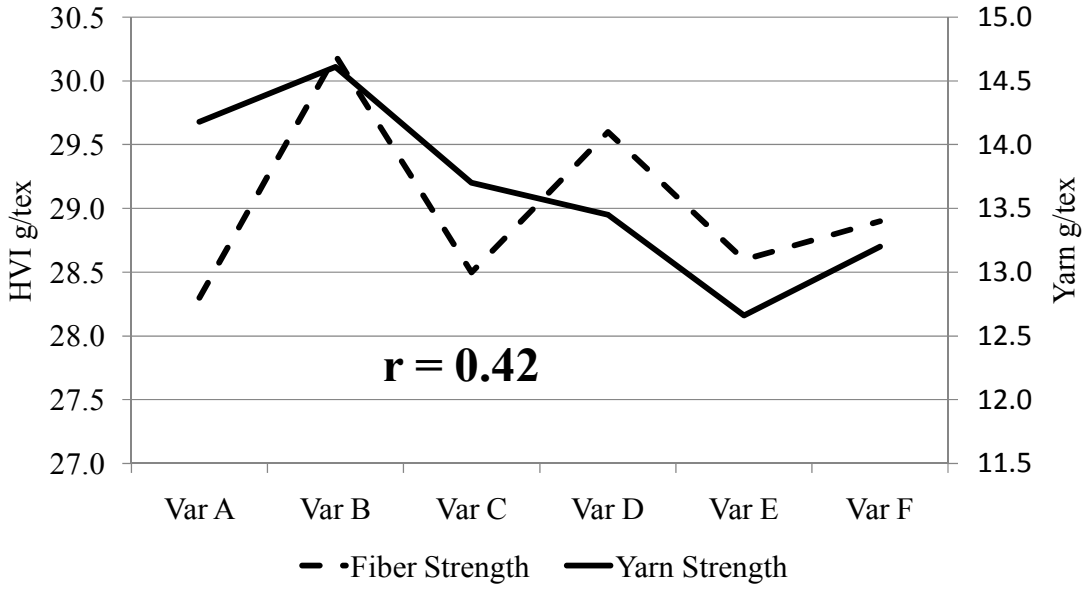

Figure 5. Average Fiber Strength Versus Average Yarn Strength

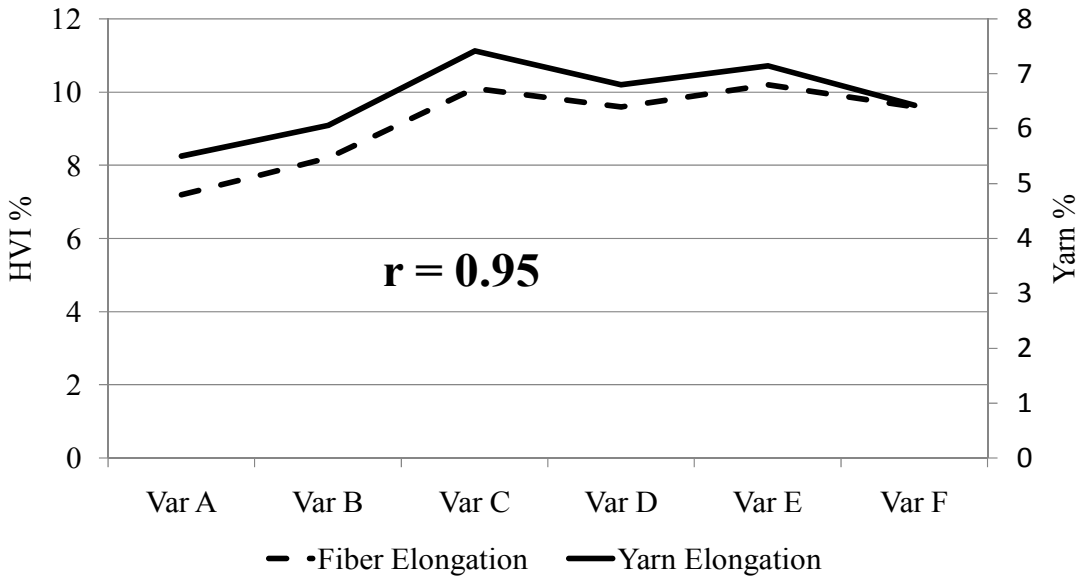

Figure 6. Average Fiber Elongation Versus Average Yarn Elongation

Using all eighteen observations from the study, a simple linear regression of yarn values on fiber values may be done. For yarn versus fiber strength, the resulting coefficient of determination is only 0.20, which means that variations in fiber strength are explaining only 20% of the total variation in yarn strength. But for yarn versus fiber elongation, about 73% of the total variation in yarn elongation is explained by variations in fiber elongation.

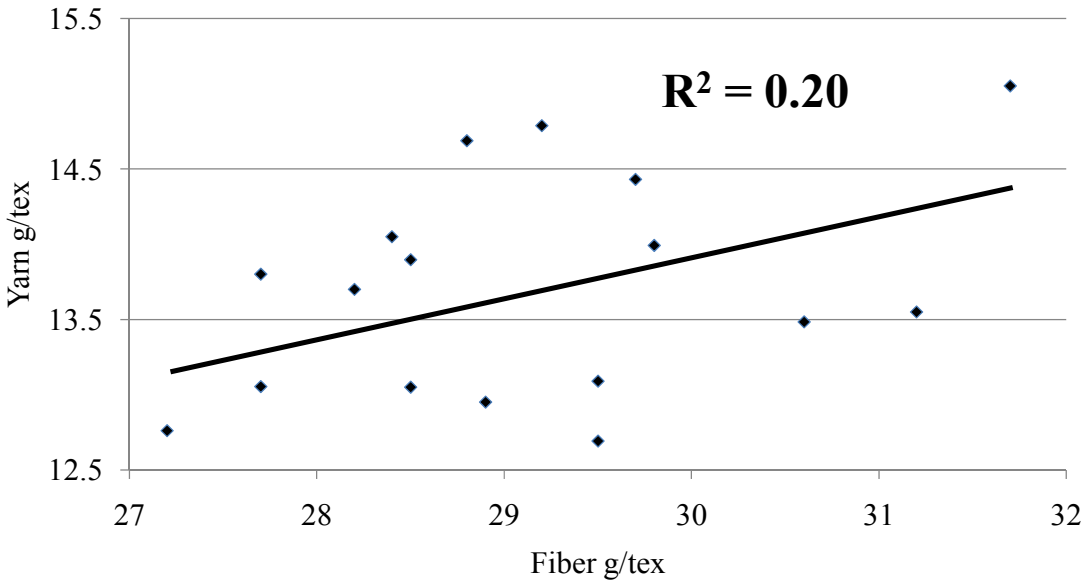

Figure 7. Regression of Yarn Strength on Fiber Strength

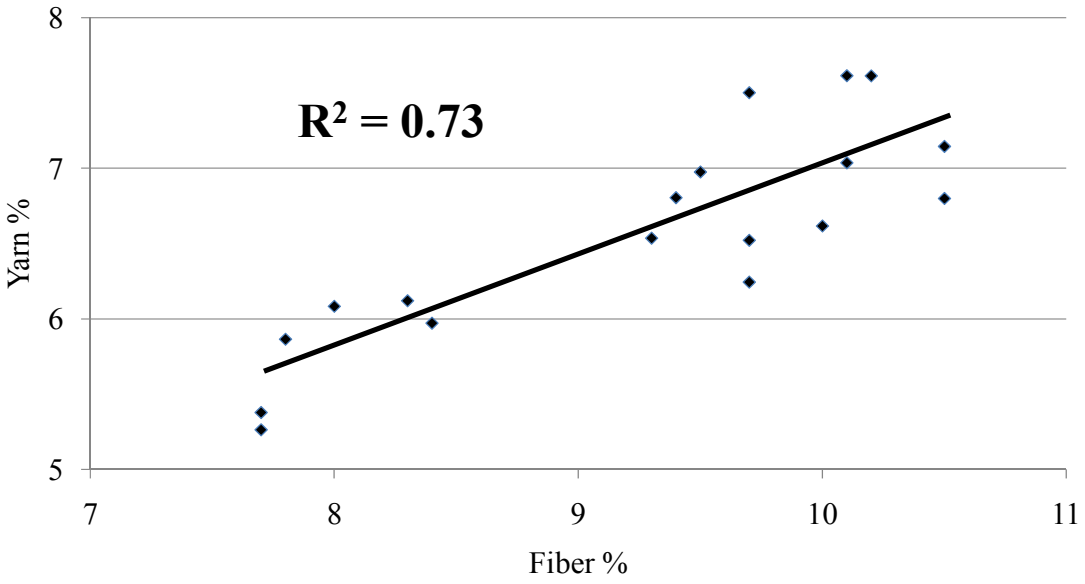

Figure 8. Regression of Yarn Elongation on Fiber Elongation

Yarn work-to-break is the integral of the area under the force curve provided by the Uster Tensorapid; therefore, it incorporates both the elongation and the breaking strength of yarns. A compatible indicator for fiber is provided by the product of HVI breaking strength and HVI elongation (g/tex · %). These results are given in Figure 9 for fiber and in Figure 10 for yarn. Comparing these results reveals that, except for a somewhat higher peak for variety C, the shapes are quite similar. Note that the rankings in Figure 10 are quite different from those for breaking strength. While varieties A and B exhibited the largest breaking strengths, these rank near the bottom for work-to-break. Variety C, which ranked near the bottom for breaking strength, now ranks at the top for work-to-break.

As before, the average fiber and yarn results are plotted together in Figure 11. The associated correlation coefficient is 0.84, which is intermediate between the correlation coefficients for strength and elongation separately. Results

from using all eighteen observations to regress yarn work-to-break on fiber strength · elongation, Figure 12 shows that the coefficient of determination is 0.55, which is also intermediate between the regression results for strength and elongation separately.

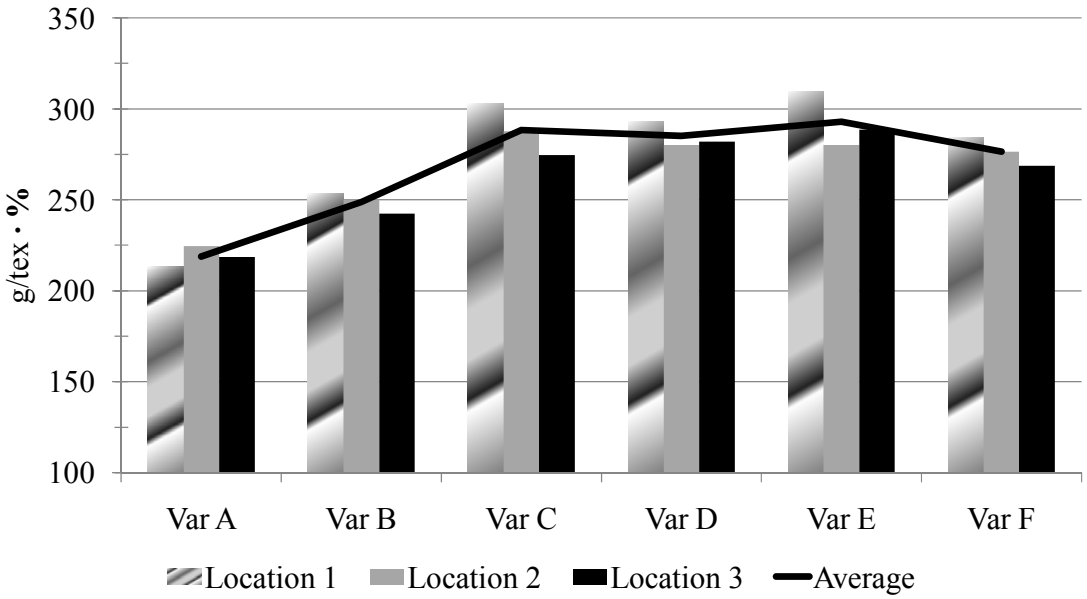

Figure 9. Fiber Strength · Elongation

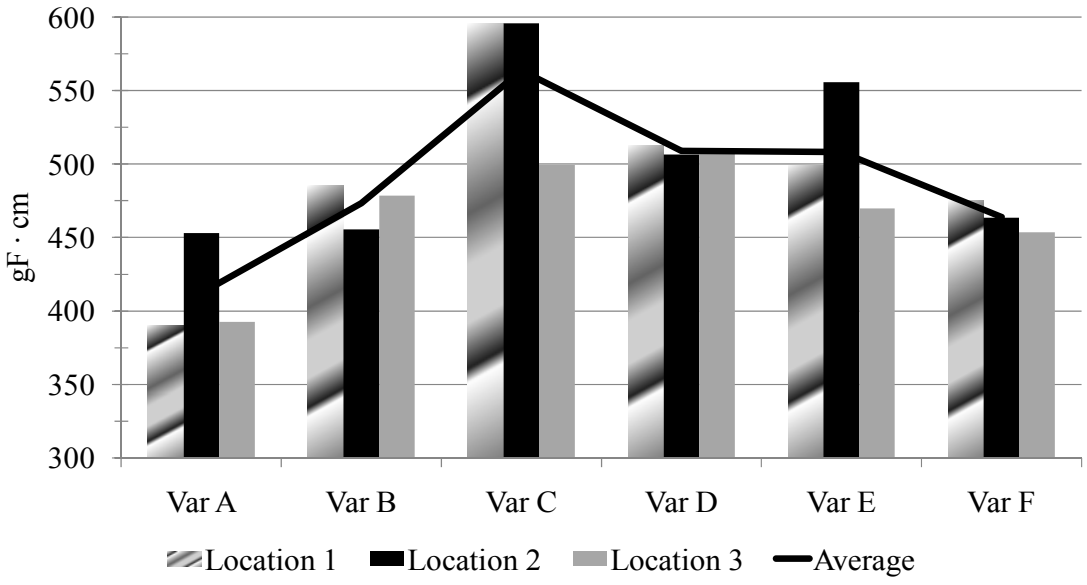

Figure 10. Yarn Work-to-Break

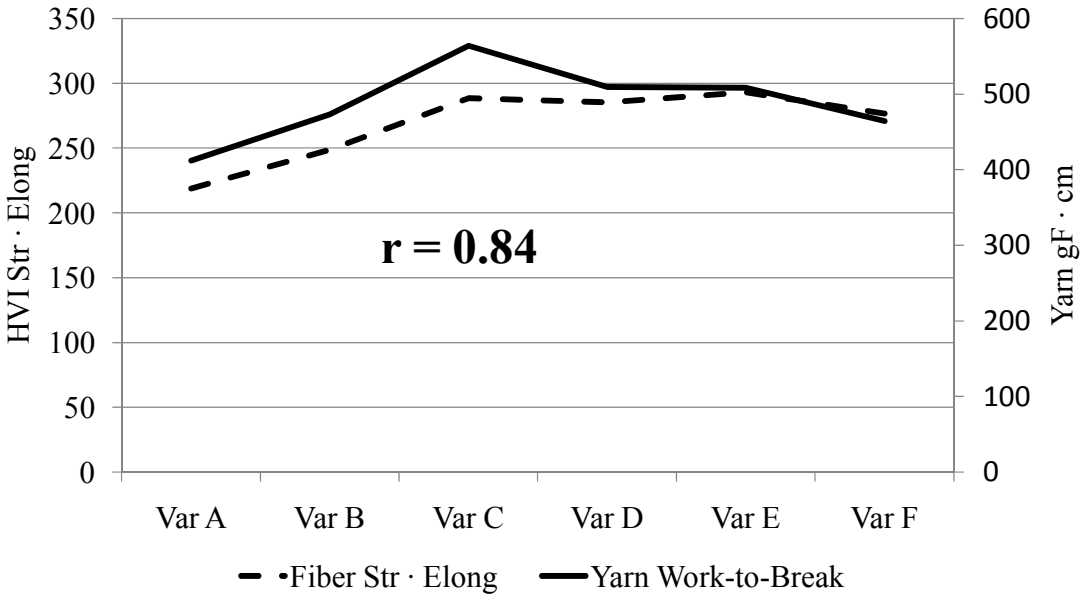

Figure 11. Average HVI Strength · Elongation Versus Average Yarn Work-to-Break

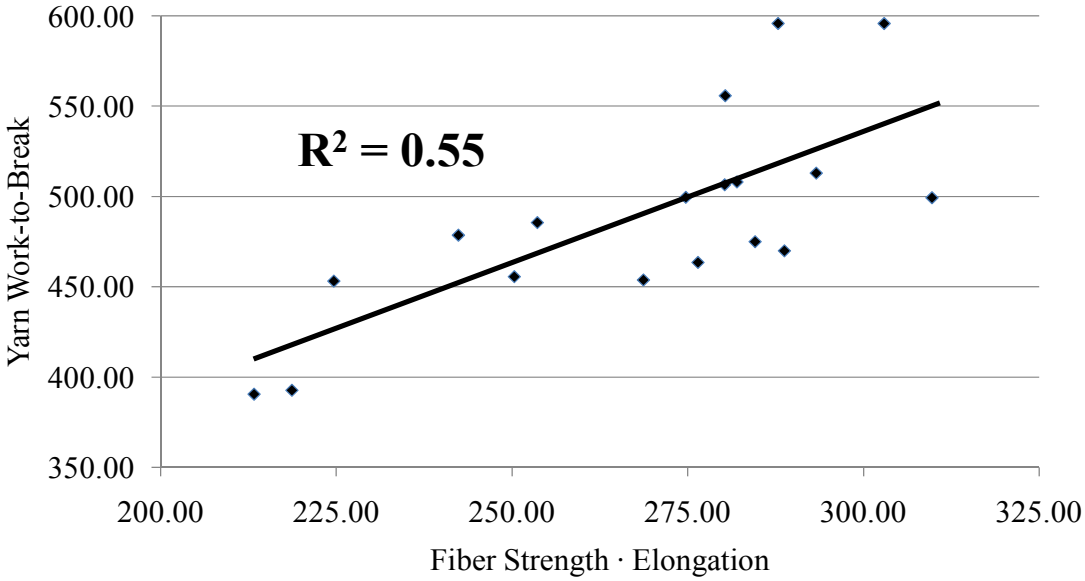

Figure 12. Regression of Yarn Work-to-Break on Fiber Strength · Elongation

Conclusion

The transference of fiber elongation to ring-spun yarn elongation is more straightforward than is the transference from fiber strength to yarn strength. Given that yarn work-to-break is the result of both elongation and breaking strength and is a superior indicator of mechanical stress resistance, elongation deserves to receive separate consideration in plant breeding and in fiber purchases by textile manufacturers. This may already be done in plant breeding by taking care to utilize the same HVI for comparing alternative samples of germplasm. In order for it to be done in commercial marketing channels, a reliable method of HVI calibration for elongation must be developed.

Reference

Boman, R. and M. Kelley. 2008. *Systems Agronomic and Economic Evaluation of Cotton Varieties in the Texas High Plains: 2007 Final Report*. Texas AgriLife Extension Service, Texas AgriLife Research and Extension Center, Lubbock, Texas.