ANALYSIS OF RESULTS FROM THE NATIONAL COTTON VARIETY TESTING PROGRAM

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Abstract

The National Cotton Variety Testing Program reports data from annual, experimental cotton trials grown across the US Cotton Belt. The trials, in existence since 1960, are conducted at approximately twenty locations throughout six regions around the country. Data were obtained from conventional High-Volume Instrument (HVI) measurements along with the breaking strength of yarns spun from the test cottons. The fiber and yard property data for the National Standards from 2014 to 2016 were analyzed by analysis of variance and correlational analysis by year, growth region, and variety. Special consideration was given to HVI measures of elongation (ELO) and spinning consistency index. As a whole, the standard cottons did not exhibit significant differences in micronaire, length, length uniformity or strength within the three years of study. Within the same variety and location, annual changes in ELO were apparent. Yarn tenacity follows the trend of elongation.

Introduction

The National Cotton Variety Testing Program (NCVT) is a uniform system of reporting data from cotton-yield trials across the US Cotton Belt. It has been in existence since 1960 (Suszkiw, 2012). The trials are conducted annually at selected locations involved in the variety-testing programs of the cooperating State Agricultural Experiment Stations and the Agricultural Research Service. The NCVT committee is responsible for coordinating program plans from year to year. There are eight separate regional trials conducted at nineteen (as of 2016) locations. These include six regional variety tests, a so-called Regional High Quality trial, and a Pima trial. Typically, at least 10 or 12 individual varieties are tested at any given location. There are some differences among the varieties planted at each location. However, in each year four National Standard varieties are planted at each of the locations. The same National Standards are used for three consecutive years. Data is obtained on yield, seed quality, raw fiber physical properties, and miniature yarn spinning. Fiber physical properties are obtained using both the High-Volume Instrument (HVI) and the Advanced Fiber Information System (AFIS). In 2013, responsibility for the testing was transferred from Star Lab Inc., Knoxville, TN to the ARS, Southern Regional Research Center (SRRC), Cotton Structure and Quality Unit in New Orleans. The purpose of the present study was to examine the consistency and quality of the NCVT data generated by the ARS with special emphasis on the effectiveness of the miniature-spinning component.

One recent application of the NCVT involved Meredith et al. (2012) using the 2001 through 2007 Regional High-Quality tests to study the total variation of 26 fiber traits as related to yield, seed and fiber quality. These included environment, genotype, and genotype X environment variance components. The results of this study suggested that during the last fifty years (since the inception of the NCVT) little has changed in these variance components. In the present study, we will be using data from the six Regional Variety Trials looking at the same four national standard varieties grown in all six regions for three consecutive years (2014-2016). This study should give the opportunity to observe the impact of genetics and environment on fiber quality. Emphasis will also be on fiber elongation to break (ELO) and the spinning consistency index (SCI) neither of which are included in standard HVI data output and are not part of conventional bale classing. When considering elongation, it is especially important to note that the product of ELO and force to break (STR) represents work or energy to break sometimes referred to as the "toughness" or "work of rupture" (Benzina, et al., 2007). We introduce here the toughness index (TI) defined by

$$TI = [.01*3.175* ELO] * STR$$

The factor [.01*3.175*ELO] is the distance traveled at break by the HVI breaker jaws having a gap of 3.175 mm.

Likewise, this represents the first opportunity to check on the new testing program carried out by SRRC, especially their newly renovated miniature spinning system protocol.

Materials and Methods

The present study involved the four national standard cotton varieties grown at all the locations during years 2014, 2015, and 2016. The four National Standards Cottons that were used included: Phytogen 499WRF* (PHY 499), Delta Pine 0912B2RF* (DP 0912), Phytogen 725RF* (PHY 725), and Fiber Max 2484B2F* (FM 2484). The results discussed in this paper are based upon these cottons having been grown across the cotton belt as part of the NCVT Regional Variety Trials. As shown in Table 1, these included the six customary NCVT regions listed alphabetically: Blacklands, Central, Delta, East, Plains, and West. The locations that comprised each of the regions in 2015 are included in Table 1. It should be noted that there was no data reported for Blacklands in 2016. The decision was made that for the purpose of the analyses used in this paper, results would be based upon the different regions using averages of fiber properties over the locations in each region.

Table 1. List of the six Regions and twenty-one locations where the four National Standard cottons were grown by the NCVT in 2015.

Blacklands	**Central**	**Delta**
Commerce, TX	Beeville, TX	Jackson, TN
Thrall, TX	College Station, TX	Keiser, AR
	Weslaco, TX	Portageville, MO
		St. Joseph, LA
		Stoneville, MS
East	**Plains**	**West**
Florence, SC	Chillicothe, TX	Five Points, CA
Griffin, GA	Fort Cobb, TX	Las Cruces, NM
Rocky Mount, NC	Lamesa, TX	
Starkville, MS	Lubbock, TX	
Suffolk, VA		

For each of the varieties tested at each of the locations, two field replicates are planted. Approximately fifty bolls are picked from each of the replicates and are ginned at each location. The ginned lint from each variety is sent from each location to the SRRC. At that point 10 grams of lint from each of the reps are run on the HVI-1000 following standard procedures (ASTM D 5867, 2012). In addition, 60 grams lint from each rep are run through a standard small-scale spinning protocol (Manandhar and Delhom, 2018). This yields 2 bobbins each of yarn containing at least 120 yards of 22's count yarn with a twist multiplier of 4.1. A single skein is wound from each bobbin of yarn and tested (ASTM D 1578, 2015) and then averaged to give a final tensile strength value or yarn tenacity (YT) for the replicate. A list of the relevant fiber and yarn properties along with any specific units of measure and the symbolic abbreviations are given in Table 2. It should be noted that the HVI parameter Rd (brightness) was not included here as we found that Rd was strongly dependent on trash content which was inconsistent for the various locations as each location was responsible for picking and ginning.

Table 2. Relevant fiber and properties and their respective symbols reported in this study.

Property	**Symbol**	**Property**	**Symbol**
Micronaire	MIC	Reflectance	Rd
Upper Half Mean Length (in)	UHML	Yellowness	+b
Uniformity Index (%)	UI	Spinning Consistency Index	SCI
Strength (gf/tex)	STR	Yarn Tenacity (mN/tex)	YT
Elongation (%)	ELO		

Results and Discussion

Variance Analysis

The results of ANOVA analysis of the NCVT data for the four National Standards are shown in Tables 3, 4, and 5. Changes in average values of the relevant parameters (Table 2) (lumped together for the four standard cottons grown over all six regions) for the years in question (2014-2016) are given in Table 3. Micronaire (MIC) and length (UHML) did not change significantly while the uniformity (UI) for 2016 was higher. STR was highest for 2015, while ELO was highest in 2014 and significantly different for all three years. Yellowness (+b) was lower in 2014 than for the other two years. It is interesting to note that, for 2014, STR is lowest and ELO is highest resulting in the fact that the TI for 2014 is the highest; and, although STR was greatest in 2015, ELO is lowest causing TI for 2015 to be the smallest. Results for the YT are consistent with the SCI relative to the three years.

Table 3. Results of ANOVA analysis of the NCVT data for the four National Standards as a function of year. *

YEAR	MIC	UHML	UI	STR	ELO	+b	TI	YT	SCI
2014	4.51 a	1.16 a	83.68 b	31.78 b	8.51 a	6.95 b	8.59 a	75.84 b	140.54 b
2015	4.57 a	1.16 a	83.95 b	32.53 a	7.56 c	8.16 a	7.83 c	76.79 b	143.52 ab
2016	4.61 a	1.17 a	84.45 a	32.05 ab	7.95 b	8.23 a	8.09 b	80.95 a	144.17 a

*Means followed by the same letter in each column are not different based on Tukey's studentized range test ($p \leq .05$).

Differences in average values of the relevant parameters for each of the standard varieties (lumped together for the three years and overall six regions) are given in Table 4. MIC is highest for DP 0912 and lowest for PHY 725. The highest values for UHML are associated with PHY 725 and FM 2484, and the shortest cotton is DP 0912 that, logically, is also the coarsest of the four. The UI for PHY 725 (84.28) is a good bit larger than the lowest (74.39) associated with DP 0912. Consistent with the finest and longest values, PHY 725 is the strongest of the four and DP 0912, the coarsest and shortest, is the weakest. The ELO was significantly the highest for PHY 499 and lowest for FM 2484. b+ was highest for PHY 725 and significantly the lowest for FM 2484. The two Phytogen varieties (PHY 725 and PHY 499) had the highest TI (8.98), and because of its much lower elongation FM 2484 exhibited the lowest toughness. Consistent with the findings for years (Table 3), results for the YT are consistent with the HVI SCI relative to the three years.

Table 4. Results of ANOVA analysis of the NCVT data for the four National Standards as a function of variety. *

VARIETY	MIC	UHML	UI	STR	ELO	+b	TI	YT	SCI
PHY 725	4.41 c	1.200 a	84.28 a	34.55 a	8.18 b	8.29 a	8.98 a	81.23 a	153.81 a
FM 2484	4.22 d	1.195 a	83.86 b	32.21 b	6.93 c	7.14 c	7.09 c	79.38 ab	148.34 b
PHY 499	4.69 b	1.138 b	76.43 bc	32.04 b	8.83 a	7.96 b	8.98 a	76.43 bc	141.78 c
DP 0912	4.91 a	1.109 c	74.39 c	29.68 c	8.09 b	7.73 b	7.62 b	74.39 c	127.04 d

*Means followed by the same letter in each column are not different based on Tukey's studentized range test ($p \leq .05$).

Average values for the relevant parameters for each of the standard cottons (lumped together for the varieties and years) overall six regions are given in Table 5. Micronaire was highest in the Plains and lowest in Blacklands. The highest values for UHML occurred in the Delta and were lowest in Blacklands. The UI index was significantly higher in the Delta and East regions and significantly lower in the Plains and Blacklands. STR values are fairly close over five of the regions, but the Delta region is significantly higher. There is quite a larger variation in the elongation over the regions, varying from a high of 8.63% in Plains to 7.35% in the Blacklands. The spread in TI is consistent from 8.76 (Plains) and 7.35 (Blacklands). Unlike what was found in Tables 3 and 4, results for the YT and SCI are not consistent where the Plains and Central regions show the highest and lowest YT, whereas the Delta and Central regions show the highest and lowest SCI.

Table 5. Results of ANOVA analysis of the NCVT data for the four National Standards as a function of region. *

REGION	MIC	UHML	UI	STR	ELO	+b	TI	YT	SCI
Delta	4.61 ab	1.205 a	84.88 a	33.18 a	7.81 c	7.38 b	8.23 b	79.59 ab	152.97 a
East	4.55 bc	1.174 b	84.56 a	32.28 ab	8.23 b	7.50 b	8.42 ab	76.68 bc	144.98 b
West	4.66 ab	1.172 b	83.86 bc	32.22 ab	8.29 ab	7.88 a	8.47 ab	77.43 abc	143.04 bc
Central	4.48 bc	1.163 b	84.37 ab	31.99 b	7.73 cd	8.14 a	7.76 c	74.38 c	144.23 b
Plains	4.73 a	1.140 c	83.41 c	31.58 b	8.63 a	7.87 a	8.76 a	82.48 a	137.92 cd
Blacklands	4.34 c	1.110 d	83.08 c	31.46 b	7.35 d	7.91 a	7.37 c	76.57 bc	133.32 d

*Means followed by the same letter in each column are not different based on Tukey's studentized range test ($p \leq .05$).

Correlation Analysis

Relationships between the various test parameters for the year 2014 are given in the correlation matrix shown in Table 6. Here, values shown in bold represent Pearson correlation coefficients that are highly significant ($p \leq .0001$). MIC correlates inversely with UHML and SCI and directly with ELO. UHML correlates with UI, STR, and SCI. The UI correlates with STR and SCI. STR correlates with UHML, UI, TI, YT, and SCI. ELO correlates with MIC, +b, and TI. +b correlates with ELO and TI. Conversely, TI correlates with STR, ELO, and +b. YT correlates with STR while the SCI correlates inversely with MIC and directly with UHML, UI, and STR.

Table 6. Correlation matrix indicating the relationships between the various test parameters for the year 2014. *

Variables	MIC	UHML	UI	STR	ELO	+b	TI	YT	SCI
MIC	**1**								
UHML	**-0.388**	**1**							
UI	0.090	**0.642**	**1**						
STR	-0.231	**0.625**	**0.497**	**1**					
ELO	**0.466**	-0.289	0.032	-0.011	**1**				
+b	0.208	-0.168	-0.088	0.213	**0.390**	**1**			
TI	0.273	0.074	0.282	**0.518**	**0.848**	**0.447**	**1**		
YT	-0.024	0.057	0.051	**0.318**	0.135	0.136	0.292	**1**	
SCI	**-0.368**	**0.872**	**0.754**	**0.840**	-0.167	-0.046	0.297	0.266	**1**

* Values shown in bold are highly significant ($p \leq .0001$).

Relationships between the various test parameters for the year 2015 are given in the correlation matrix shown in Table 7. MIC correlates inversely with UHML, STR, and SCI and directly with ELO. UHML correlates with UI, STR, and SCI. UI correlates with STR, TI, and SCI. STR correlates inversely with MIC and directly with UHML, UI, TI, YT, and SCI. ELO correlates with MIC and TI. +b shows no significant correlations with any of the other parameters. TI correlates with UI, STR, ELO, and SCI. YT correlates with STR and SCI while the SCI correlates inversely with MIC and directly with UHML, UI, STR, TI, and YT.

Table 7. Correlation matrix indicating the relationships between the various test parameters for the year 2015. *

Variables	MIC	UHML	UI	STR	ELO	+b	TI	YT	SCI
MIC	**1**								
UHML	**-0.454**	**1**							
UI	-0.031	**0.671**	**1**						
STR	**-0.320**	**0.636**	**0.485**	**1**					
ELO	**0.358**	-0.164	0.254	0.159	**1**				
+b	-0.059	-0.267	-0.174	-0.002	0.233	**1**			
TI	0.094	0.215	**0.447**	**0.669**	**0.838**	0.182	**1**		
YT	-0.198	0.275	0.164	**0.552**	-0.097	0.010	0.235	**1**	
SCI	**-0.522**	**0.825**	**0.721**	**0.840**	0.054	-0.067	**0.497**	**0.464**	**1**

* Values shown in bold are highly significant ($p \leq .0001$).

Relationships between the various test parameters for the year 2016 are given in the correlation matrix shown in Table 8. MIC correlates inversely with UHML and SCI and directly with ELO. UHML correlates directly with UI, STR, and SCI and inversely with ELO. UI correlates with STR and SCI. STR correlates with UHML, UI, TI, and

SCI. ELO correlates directly with MIC, UHML, and TI. Again, +b shows no significant correlations with any of the other parameters. TI correlates with STR and ELO. YT shows no significant correlations with any of the other parameters. SCI correlates inversely with MIC and directly with UHML, UI, and STR.

Table 8. Correlation matrix indicating the relationships between the various test parameters for the year 2016.

Variables	MIC	UHML	UI	STR	ELO	+b	TI	YT	SCI
MIC	**1**								
UHML	**-0.514**	**1**							
UI	-0.031	**0.547**	**1**						
STR	-0.272	**0.683**	**0.439**	**1**					
ELO	**0.531**	**-0.452**	-0.039	-0.086	**1**				
+b	-0.027	-0.242	-0.161	-0.064	0.252	**1**			
TI	**0.301**	-0.006	0.215	**0.491**	**0.823**	0.194	**1**		
YT	0.138	0.086	0.191	0.268	0.072	0.003	0.210	**1**	
SCI	**-0.367**	**0.731**	**0.629**	**0.687**	**-0.301**	-0.190	0.134	0.130	**1**

* Values shown in bold are highly significant ($p \leq .0001$).

The relationships among the various NCVT fiber parameters as given above in Tables 6, 7, and 8 are not totally consistent. We have summarized in Table 9 the instances of significant ($p < .0001$) correlations using a singular digit notation for the year (i.e., 4 = 2014, etc.). In these cases, we will consider only those instances where there was significance for all three years (i.e., 456). Thus, MCI correlates directly with ELO and inversely with UHML and SCI. UHML directly correlates with UI, STR, SCI, and, of course, inversely with MIC. UI correlates with UHML, STR, and SCI. STR correlates with UHML, UI, TI, and SCI. ELO correlates with MIC and TI. Naturally, the TI will be correlated with STR and ELO. Finally, the SCI correlates directly with UHML, UI, and STR and inversely with MIC.

Table 9. Compilation of the results from the correlation matrices from 2014 (4), 2015 (5), and 2016 (6).

Parameters	MIC	UHML	UI	STR	ELO	+b	TI	YT	SCI
MIC		(-)456		5	456			5	(-)456
UHML	(-)456		456	456	6			5	456
UI		456		456			5	5	456
STR	5	456	456				456	45	456
ELO	456	6				4	456		6
+b					4		4		
TI	6		5	456	456	4			5
YT				45					
SCI	(-)456	456	456	456	6		5	5	

Summary and Conclusions

Considered as a whole, the standard cottons exhibited little or no change with respect to micronaire, length, length uniformity or strength over the three years. Conversely, the elongation changed significantly over the same period with the highest in 2014 and the lowest in 2015. +b was significantly lower in 2014. It is reasonable that IT should follow the exact same trend as the elongation, especially since there was little difference exhibited by fiber strength. YT was highest in 2014 and lowest in 2015, and the SCI followed suit with essentially the same yearly trend.

The best performing standard cotton was PHY 725 having the lowest MIC and the highest UHML, UI, STR, YT, and SCI. The consistently poorest performer was DP 0912 where it exhibited the highest MIC and ranked lowest with regard to all of the above-mentioned parameters. PHY 499 had the highest elongation and FM 2484 the lowest.

With regards to the regions, the performance of the standards was relatively consistent. MIC was highest in the Plains and lowest in the Blacklands where environment plays a significant role.

The fact that SCI tracks quite faithfully all the basic fiber quality factors (UHML, STR, UI, and MIC) is not surprising since it is based on an algorithm in the HVI software. The fact that the YT does not appear to be nearly as sensitive to fiber properties is probably reflective of the fact that the NCVT spinning protocol uses relatively coarse

22’s yarn with a fairly tight twist (4.1 TM). A finer count and lower twist would allow the yarn to show more sensitivity to fiber properties.

Finally, as we begin to study the factors influencing fiber ELO, the results obtained here that ELO correlates with MIC exclusive of the other fiber physical properties. The next logical step in this study will be to investigate results from AFIS analysis of the same cottons.

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