Relationship between the Cotton Fiber Mechanical Properties and Length Distributions

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ABSTRACT

This investigation was conducted to investigate the relationship between different fiber properties measured by Shirley Comb Sorter, Stelometer, HVI and AFIS. Eleven Egyptian cotton genotypes; five extra long staple commercial verities and six new hybrids were cultivated in two locations.

There were highly significant correlation coefficients between mean lengths of the longer and mean length fibers measured by (Shirley, HVI and AFIS).

Highly significant correlation coefficients between the results of Stelometer and HVI fiber bundle tenacity and stiffness were found.

Regarding, the standard value of Shirley maximum length (Max.L.), effective length (E.L.), length uniformity percentage (L.U. %), mean length (Le) and short fiber percentage (SF %) could be predicted using the suggested equations and data attained from the HVI. There were highly significant correlations between estimated and predicted values of maximum, effective lengths and length uniformity percentage. Insignificant correlation between the estimated and predicted values of the mean length and short fiber percentage were found.

Similar equations were extracted to predict the same Shirley length parameters utilizing data attained from AFIS. There were highly significant correlations between estimated and predicted values of the maximum, effective and mean lengths. Insignificant correlation between the estimated and predicted values of the length uniformity percentage was found.

The standard value of stelometer fiber mechanical properties tenacity, work of rupture and stiffness could be predicted using the suggested equations and data attained from the HVI. Highly significant correlation among the values of predicted and estimated tenacity and stiffness were found.

Key words: ***Fiber length distribution; HVI; AFIS; Mechanical properties.***

INTRODUCTION

The cotton fiber intrinsic color, length and length distribution besides the bundle strength are the most important contributors to the fiber quality or technological value which greatly considered by both cotton spinners and breeders.

Fiber length is highly related to the other cotton fiber characteristics. Longer fibers are generally finer and stronger than shorter ones.

A strong and positive relationship between lint grade and color reflectance (Rd %) was confirmed by Abdel-Mohsen (1980), Kamal *et al.* (1987) and Abd El-Gelil (2001). In addition, Beheary (2005) stated highly significant differences between the two studied determining (HVI and conventional) methods in all studied traits, except 2.5% span length and elongation percentage. Bragg *et al.* (1998) showed that the length distribution is highly correlated with strength of individual fibers. Backe (1992) demonstrated a correlation ($r2$ = 0.90) between AFIS short fiber content measurements and the Sutter-Webb standard. Also, Riley (1997) stated that the comparisons of short fiber values from the HVI with AFIS and Sutter-Webb give correlations of 0.93 and 0.94. Hequet *et al.* (1998) found a strong correlation (R^2 = 0.93) between the old AFIS (length and diameter module) fiber length by weight (FLW) and HVI mean length. The AFIS FLW was slightly higher than those obtained with the HVI. The interrelationships between Sutter-Webb, AFIS and HVI yielded correlation coefficients between 0.6 and 0.7. Cui *et al.* (2003) and John *et al.* (2003) showed significant differences and high variations in short fiber contents measured by these different methods i.e., Sutter-Webb Array (SW), Advanced Fiber Information System (AFIS), and High Volume Instrument (HVI). Also, Cui *et al.* (2008) reported that, the Sutter-Webb array (SW) produced a wider distribution of short fiber measurement than either HVI or AFIS. The distributions of mean fiber lengths are similar for the three measurement methods, with Sutter-Webb differentiating somewhat more than HVI and AFIS among the lots. Likewise, the distributions of UQL and UHM are similar, again with Sutter-Webb producing (narrowly) the widest distribution of values. The linear associations among HVI (UHM), AFIS (UQL), and SW (UQL) are even stronger ($r \sim 0.98$). In cases where only the four basic HVI properties are known, an estimate of the HVI (SFI) could be obtained by regression using HVI (U.I.) and HVI (UHM) as predictors with $R2$ =0.96.

MATERIALS AND METHODS

This study was carried out at Plant Production Department, Faculty of Agriculture (Saba Basha), Alexandria University, Egypt, during 2009/2010 season to investigate relationship between the cotton fiber mechanical properties and fiber length distributions.

Eleven Egyptian cotton genotypes; five extra long staple commercial verities namely; i.e., Giza 45, Giza 70, Giza 87, Giza 88 and

Giza92 and six new hybrids i.e., H1 (Giza 77 × Pima S6), H2 (Giza 92 × Giza 70), H3 (Giza 76 × Giza 45), H4 (Giza 87 × Giza 70), H5 (Giza 87 × Giza 45) and H6 (Giza 45 × Giza 70) were cultivated in the two locations at Dakhlia and kfr El-Dwar by the cotton breeding Department, at Sakha Research Station, Cotton Research Institute, Agriculture Research Center, Giza, Egypt.

Cotton fiber samples were drawn in three replicates from each cotton strain for testing. Samples were opened and left for 24 hours at least under the standard condition of 65 ± 2 % relative humidity and 20 ± 1 C° temperature before being tested.

The fiber properties were tested according to the standard methods using the following four apparatus:

1. **Shirley Comb Sorter** at Faculty of Agriculture (Saba Basha), Alexandria.

2. **Stelometer** at the Laboratories of Cotton Arbitration for Testing General Organization (C.A.T.G.O), Alexandria.

3. **The High Volume Instrument (H.V.I.) Spectrum II System** was used to determine the fiber properties in (C.A.T.G.O).

4. **The Advanced Fiber Information System (AFIS)** at laboratories of Borg El-Arab for Textile and Fine Spinning (Eshra Tex), Borg El-Arab, Alexandria.

The present investigation was carried out in a completely randomized design with three replications. Data attained were statistically analyzed as a factorial experiment and least significant difference (L.S.D) between means as well as the multiple regressions was computed according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

The obtained results would be arranged in main and sub main titles as follows:

1. Relationship between studied characters measured by the four instruments (Shirley Comb Sorter, Stelometer, HVI and AFIS):

1.1. Relationship between mean lengths of fiber length parameters measured by the three instruments:

Descriptive statistics i.e. mean, median, maximum, minimum values, standard deviation and (C.V. %) for the fiber length parameters of the 66 tested samples measured by the three instruments, are shown in Table (1, 3 and 5).

The data presented in Table 2 revealed that there were highly significant correlation coefficients between the parameters of the longer fibers measured by the three instruments.

The highest Pearson's correlation (r = 0.76) was found between (Shirley **E.L** and AFIS **U.Q.L**), while the lowest one (r = 0.6) was noticed between (HVI **U.H.M** and AFIS **U.Q.L.**).

Similarity with those results were also obtained by Cui *et al.* (2008) who found that the linear associations among HVI (UHM), AFIS (UQL), and SW (UQL) were even stronger (*r* ~ 0.98).

As for the mean length, highly significant correlation between (Shirley **Le** and AFIS $L_{(w)}$) and (HVI **ML** and AFIS $L_{(w)}$), and insignificant association between (Shirley **Le** and HVI **ML**) were recorded, (Table 4).

These results were in the line with those obtained by Hequet ***et al.*** (1998), who found a strong correlation between the AFIS fiber length by weight (FL_W) and HVI mean length.

The highest Pearson's correlation (r = 0.512) was noticed between (HVI **ML** and AFIS $L_{(w)}$), meanwhile the lowest one (r = 0.21) was attained between (Shirley **Le** and HVI **ML**).

Worthy to mention that the correlation between the short fiber parameters measured by the three instruments were insignificant, (Table 6). Despite the correlation between Shirley (**SF%** and AFIS **SFC** $_{(w)}$) was negative.

1.2. Relationship between fiber mechanical properties measured by the two instruments (Stelometr and HVI):

The descriptive statistics for the bundle mechanical properties of the 66 tested samples measured by the two instruments are shown in Tables (7, 9, 11 and 13).

It could be noticed that there was highly significant association between Stelometer and HVI **bundle strength,** Table (8).

Data shown in Table (10) indicated that there was insignificant correlation between Stelometer and HVI **elongation%.**

The association between the **work of rupture** calculated from Stelometer and HVI data was insignificant, Table 12.

It could be noticed that there was highly significant correlation between HVI and Stelometer **stiffness**, Table 14.

2. Predicting the standard fiber characters using HVI and AFIS data:

2.1. Length parameters:

2.1.1. Predicting standard length parameters from (HVI) data:

The predicting equations for the standard fiber length parameters from HVI Data are presented in Table (15) indicate that the standard value of the Shirley maximum length (**Max.L.**) could be predicted by using the upper half mean length (U.H.M), short fiber index (SFI) and fiber bundle stiffness (Stiff) attained from the HVI.

The standard value of the Shirley effective length (**E.L.**) and length uniformity percentage (**L.U. %**) could be predicted utilizing the upper half mean length (U.H.M).

Equations presented in Table (15) showed that the standard values of the Shirley mean length (**Le**) and short fiber percent (**SF %**) could be expected by using the uniformity index (U.I.) attained from HVI.

Data presented in Table (16) showed that there were highly significant associations between estimated and predicted values of the maximum length (Max.L.), effective length (E.L.) and length uniformity percentage (L.U. %), while no significant correlation for the mean length (Le) and short fiber percentage (SF%) were found .

The highest correlation coefficients were attained between predicted and estimated values of the maximum length, and the lowest one was recorded by the length uniformity percentage.

2.1.2. Predicting standard length parameters from (AFIS) data:

The predicting equations for length parameters from AFIS data were shown in Table (17) indicated that the standard value of the Shirley maximum length (**Max.L.**) could be predicted using the mean length by weight ($L_{(w)}$), short fiber content by weight ($SFC_{(w)}$), upper quartile length (U.Q.L), fineness (Fine) and maturity ratio (M.R.) attained from AFIS.

The mean length by weight ($L_{(w)}$), short fiber content by weight ($SFC_{(w)}$), upper quartile length (U.Q.L) and fineness (Fine) attained from AFIS data could be used as predictors for the Shirley effective length (**E.L.**).

Whereas, the standard value of the Shirley mean length (**Le**) and Shirley length uniformity percentage (**L.U. %**) could be predicted using the mean length by weight ($L_{(w)}$).While the standard Shirley short fiber percent (**SF%**) could not be predicted using AFIS data.

Data presented in Table (18) showed highly significant associations between the estimated and predicted maximum length, effective length and mean length, meanwhile insignificant correlation between estimated and predicted length uniformity percentage was recorded.

The predicted and estimated values of the maximum length and effective length showed the highest correlation, while the values of mean length had the lowest one (Table 18).

2.2. Predicting mechanical properties:

2.2.1. Predicting standard mechanical properties from HVI data:

The prediction equations for the standard mechanical properties from HVI data are presented in Table (19) indicated that the standard value of **tenacity** could be predicted using the upper half mean length (U.H.M) and fiber bundle strength (St) attained from the HVI.

Suggested equations revealed that the standard value of the **work of rupture** could be predicted using the upper half mean length (U.H.M). Meanwhile the standard value of the fiber **stiffness** could be predicted using the fiber bundle strength (St) only attained from the same instrument.

Data shown in Table (20) indicated highly significant associations between the predicted and estimated values of fiber bundle **tenacity** and **stiffness.** While the association between the estimated and predicted value of the **work of rupture** was insignificant.

The highest correlation coefficient was recorded between the predicted and estimated values of **tenacity**, while the lowest one was found between those of stiffness.

Table (1): Descriptive statistics for the mean length of longer fibers parameters

	SHIRLEY E.L. (mm)	HVI U.H.M (mm)	AFIS U.Q.L (mm)
No.	66	66	66
MEAN	37.66	35.88	37.8
MED	37.91	36.04	37.85
MAX	41	37.69	41
MIN	33.17	32.77	33.9
S.D.	1.51	1.23	1.431
C.V.%	4.01	3.44	3.79

No.: number of samples. **MED: median value.**
S.D.: Standard deviation. **C.V. %: coefficient of variance.**

Table (2): Pearson's correlations (r ~ values) among the three measures of mean length of longer fibers.

	Shirley E.L	HVI U.H.M	AFIS U.Q.L
Shirley E.L	1		
HVI U.H.M	0.662**	1	
AFIS U.Q.L	0.756**	0.6**	1

Table (3): Descriptive statistics for the three measures of the fiber mean length.

	SHIRLEY Le (mm)	HVI ML (mm)	AFIS $L_{(w)}$ (mm)
No.	66	66	66
MEAN	29.84	31.94	31.85
MED	29.83	32.17	31.85
MAX	34.67	34.12	34.2
MIN	26.5	28.51	28.7
S.D.	1.319	1.3	1.21
C.V.%	4.42	4.06	3.8

Table (4): Pearson's correlations (r ~ values) among the three measures of the fiber means length.

	Shirley Le	HVI ML	AFIS $L_{(w)}$
Shirley Le	1		
HVI ML	0.21 n.s.	1	
AFIS $L_{(w)}$	0.389**	0.512**	1

Table (5): Descriptive statistics for the three measures of short fiber .

	SHIRELY SF (%)	HVI SFI (%)	AFIS SFC (w) (%)
No.	66	66	66
MEAN	4.89	6.02	2.63
MED	4.78	6	2.6
MAX	8.87	6.8	4.3
MIN	2.26	5.4	1.5
S.D.	1.39	0.31	0.6
C.V.%	28.48	5.07	22.75

No.: number of samples. MED: median value.
S.D.: Standard deviation. C.V. %: coefficient of variance.

Table (6): Pearson's correlations (r~ values) among the three short fiber percentage measured by (Shirley SF (%), HVI SFI (%) and AFIS SFC $_{(w)}$ (%)

	Shirley SF (%)	HVI SFI (%)	AFIS SFC (%)
Shirley SF (%)	1		
HVI SFI (%)	0.093 $^{n.s.}$	1	
AFIS SFC (%)	-0.123 $^{n.s.}$	0.232 $^{n.s.}$	1

Table (7): Descriptive statistics for the two measures of the fiber bundle strength.

	HVI Strength (g./tex)	Stelometer Tenacity (g./tex)
No.	66	66
MEAN	51.09	38.57
MED	51.2	38.15
MAX	57.1	42.7
MIN	45.8	35.6
S.D.	2.11	1.85
C.V.%	4.14	4.79

Table (8): Pearson's correlations (r ~ values) among the two measures of strength.

	HVI Strength	Stelometer Tenacity
HVI Strength	1	
Stelometer Tenacity	0.5 **	1

Table (9): Descriptive statistics for the two measures of the elongation (%).

	HVI Elongation (%)	Stelometer Elongation (%)
No.	66	66
MEAN	6.51	6.2
MED	6.5	6.2
MAX	7.3	7.5
MIN	5.6	5.1
S.D.	0.41	0.46
C.V.%	6.37	7.4

No.: number of samples. MED: median value.
S.D.: Standard deviation. C.V. %: coefficient of variance.

Table (10): Pearson's correlations (r ~ values) among the measures of elongation (%).

	HVI Elongation%	Stelometer Elongation%
HVI Elongation%	1	
Stelometer Elongation%	0.05 n.s.	1

Table (11): Descriptive statistics for the two measures of the work of rupture.

	HVI Work of Rupture	*Stelometer Work of Rupture*
No.	*66*	*66*
MEAN	*1.66*	*1.2*
MED	*1.64*	*1.19*
MAX	*1.92*	*1.40*
MIN	*1.39*	*0.94*
S.D.	*0.13*	*0.10*
C.V.%	*7.76*	*8.45*

Table (12): Pearson's correlations (r ~ values) among the two measures of work of rupture.

	HVI Work of Rupture	Stelometer Work of Rupture
HVI Work of Rupture	1	
Stelometer Work of Rupture	0.023 n.s.	1

Table (13): Descriptive statistics for the two measures of the stiffness.

	HVI Stiffness	Stelometer Stiffness
No.	66	66
MEAN	787.71	625.38
MED	779.99	624.43
MAX	1001.75	742.11
MIN	673.53	474.67
S.D.	60	53.81
C.V.%	7.62	8.60

Table (14): Pearson's correlations (r ~ values) among the two measures of stiffness.

	HVI Stiffness	Stelometer Stiffness
HVI Stiffness	1	
Stelometer Stiffness	0.356**	1

Table (15): The predicting equations for Shirley length parameters from HVI data:

Shirley Comb Sorter properties	Regression equations	R^2
Maximum length (Max.L.)	=11.053 + 0.93 U.H.M - 0.64 SFI – 0.000938 Stiff	0.52
Effective length (E.L.)	= 8.6 + 0.81 U.H.M	0.44
Mean Length (Le)	= 11.72 + 0.204 U.I.	0.024
Length Uniformity Percentage (L.U. %)	=120.252 – 1.14 U.H.M	0.19
Short Fiber Percentage (SF %)	= -16.15 + 0.24 U.I.	0.03

U.H.M = Upper half mean length. SFI= Short fiber index.
U.I. = Uniformity index Stiff = Stiffness.

Table (16): The correlation coefficient (r ~ values) between predicted and estimated values of the standard fiber length parameters predicted from HVI data.

Estimated	Predicted Max.L.	E.L.	Le	L.U. %	SF %
Max.L.	0.72**				
E.L.		0.66**			
Le			0.16 n.s.		
L.U. %				0.44**	
SF%					0.17 n.s.

Max.L. = Maximum length. E.L=Effective length. ML=Mean length. L.U. % = length Uniformity percentage. SF% = Short fiber percentage.

Table (17): The predicting equations for Shirley length parameters using AFIS data:

Shirley Comb Sorter properties	Regression equations	R^2
Maximum Length (Max.L.)	$= 35.411 - 1.08\ L_{(w)} - 0.649\ SFC_{(w)} + 1.585$ U.Q.L+ 0.097 Fine – 36.152 M.R.	0.6
Effective Length (E.L.)	$= 4.052 - 0.507\ L_{(w)} + 0.238\ SFC_{(w)} + 1.21$ U.Q.L + 0.024 Fine	0.61
Mean Length (Le)	$= 16.334 + 0.424\ L_{(w)}$	0.151
Length Uniformity Percentage (L.U. %)	$=99.973 - 0.647\ L_{(w)}$	0.06

$L_{(w)}$ = Mean length by weight (mm). $SFC_{(w)}$ = Short fiber content by weight (%).
U.Q.L = Upper quartile length (mm). Fine = fineness (millitex).
M.R. = Maturity ratio.

Table (18): The correlation coefficient (r ~ values) between predicted and estimated values of the Shirley fiber length parameters predicted from AFIS data.

Estimated	Predicted Max.L	E.L	Le	L.U. %
Max.L	0.78**			
E.L.		0.78**		
Le			0.39 **	
L.U. %				0.24 n.s.

Max.L = Maximum length. E.L = Effective length.
Le = Mean length. L.U. % = Length Uniformity percentage.

Table(19):The predicting equations for the Stelometer mechanical properties by using HVI data:

Stelometer mechanical properties	Regression equations	R^2
Tenacity	= 0.393 + 0.435 U.H.M + 0.442 St	0.34
Work of rupture	= 0.142 + 0.029 U.H.M	0.13
Stiffness	= 64.343 + 10.98 St	0.19

U.H.M = Upper half mean length. St = Fiber bundle strength.

Table (20): The correlation coefficient (r ~ values) between predicted and estimated values of the Stelometer mechanical properties predicted from HVI data.

	Predicted		
Estimated	Tenacity	Work of Rupture	Stiffness
Tenacity	0.58^{**}		
Work of Rupture		$0.12^{n.s.}$	
Stiffness			0.43^{**}

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الملخص العربى

العلاقة بين الصفات الميكانيكية و مؤشرات الطول لألياف القطن

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أجريت هذه الدراسة لدراسة العلاقة بين صفات الألياف المختلفة المقدرة بواسطة اجهزة إختبارات الألياف المختلفة التالية: (مجزئ شيرلى و الإستيلوميتر و الـــ HVI و الـــ AFIS).

استخدم فى هذه الدراسة ١١ تركيب وراثى من الأقطان المصرية تنتمى جميعها لمجموعة الأقطان فائقة الطول : خمسة أصناف تجارية و ستة من الهجن الجديدة. تم زراعة هذه التراكيب الوراثية فى منطقتين (الدقهلية وكفر الدوار) .

و يمكن تلخيص النتائج المتحصل عليها فيما يلى:

- معاملات التلازم بين متوسط طول الشعيرات الطويلة والشعيرات المتوسطة الطول كانت عالية المعنوية بين الثلاثة أجهزة .
- يوجد تلازم عالى المعنوية بين متانة الخصلة ومعامل الصلابة الأولى المقدرين بأجهزة الإستيلوميتر والـــ HVI.
- القيمة القياسية لأقصى طول والطول الفعال و نسبة إنتظام الشعيرات والطول المتوسط و نسبة الشعيرات القصيرة من مجزئ شيرلى يمكن التنبؤ بها باستخدام الصفات الناتجة من جهاز الـــ

HVI . وكان هناك تلازم عالى المعنوية بين القيم المقدرة و المتنبأ بها لصفات أقصى طول و الطول الفعال و نسبة إنتظام الشعيرات بينما وجد تلازم غير معنوى بين القيم المقدرة و المتنبأ بها لصفات الطول المتوسط و نسبة الشعيرات القصيرة.

- يمكن استخدام معادلات مماثلة للتنبؤ بالقيمة القياسية لأقصى طول والطول الفعال و نسبة إنتظام الشعيرات والطول المتوسط من مجزئ شيرلى باستخدام البيانات جهاز الـــ AFIS . وقد وجد تلازم عالى المعنوية بين القيم المقدرة و المتنبأ بها لصفات أقصى طول و الطول الفعال و الطول المتوسط بينما وجد تلازم غير معنوى بين القيم المقدرة و المتنبأ بها لصفة نسبة إنتظام الشعيرات.

- صفات المتانة النوعية القياسية و الشغل اللازم للقطع و معامل الصلابة الأولى المقدرة بجهاز الإستيلوميتر يمكن التنبؤ بها بإستخدام صفات متوسط طول النصف العلوى للشعيرات و متانة الخصلة الناتجين من جهاز الـــ HVI.