Some Statistical Relationships Models to Predict Yarn Properties Using Fiber Properties for Two Categories of Egyptian cotton Varieties under Two Spinning Systems

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Abstract: The present investigations were carried out to determine prediction equation and the relative contribution of six fiber properties to estimate yarn strength, yarn neps and yarn evenness for two categories of cotton varieties (Extra long staple and long staple) under two spinning systems (ring and compact). The full model regression and stepwise multiple linear regression model were used to satisfy the target of work. The results of the supposed models of regression differed according to the category of the used cotton variety and also the applying spinning system. Generally, under ring spinning system, fiber strength and fineness were the most effective fiber properties to predict yarn properties for the category of extra long staple. While the fiber strength, fiber elongation and fineness were the most important fiber traits contributing to yarn properties using the category of long staple cotton variety. Under the compact ring spinning system, the upper half mean length, fiber strength and maturity had the greatest influence on the studied yarn properties for the category of extra long staple while both fiber elongation and fineness ranked the first fiber properties that used to predict the yarn properties for the category of long stable cotton variety. All the supposed models of regression were significant and reflected large part of the variation of studied yarn properties expressed as high values of R^2 and near values of the corresponding adjusted R^2 indicating the validity and goodness of fit for these models.

Keywords: yarn strength, yarn neps and yarn evenness, cotton.

INTRODUCTION

Fiber physical and yarn strength properties play an exceptionally important role as principle determinants of textile product quality. Yarn nep count and evenness are the most important features that influence the appearance of yarns and consequently the quality of the end product, especially in fine yarns which are needed in manufacturing fine and luxurious end products. Information concerning the relative contribution of fiber properties to yarn strength, yarn nep count, and evenness in different types of spinning system for various categories of cotton (extra long stable and long stable), is one of the important targets for each of cotton breeder to explore yarn quality of his large number of new selections also for the spinner in order to choose cottons that are best suited to the manufacture of specific end product.

Many authors used the full model regression as an important statistical procedure to estimate the relative contribution of the fiber properties, as independent variables, in the total variation of yarn properties as dependent variable. Also, the stepwise multiple linear regression was used to construct a regression equation that includes fiber properties accounting for the most variation of yarn properties.

Marth *et al.* (1952) reported that micronare value was an excellent index of the number of neps expected in card web. Fiori *et al.* (1954) concluded that fiber strength does not significantly affect the evenness of silver. Grosberg (1956) obtained a relationship between yarn unevenness coefficient of variation and the means of fiber length and diameter. Leitgeb and Wakeham (1956) pointed that neps increased with increasing fiber fineness. Phillip (1957) found that fiber fineness and maturity were related to neppiness. Balasubramanian and Lyengar (1961) reported that fiber length variation coefficient contributed more to yarn irregularity. Louis *et al.* (1961) concluded from their study on pima cottons that nep count is influenced by fiber elongation. Louis *et al.* (1968) stated that 50% span length was better than 2.5% span length to explain effect of fiber length on yarn strength. Rusca (1970) stated that neps rapidly decreased with increase in micronaire reading while yarn irregularity slightly decreased with either extra-long fine or extra-coarse micronaire reading. Amin (1971) found that fiber strength and elongation were more effective than micronaire value with regard to their contribution to yarn strength. Garawain (1971) showed that yarn added unevenness was not highly related to micronaire reading. Sallouma *et al.* (1973) and Aboul –Fadl (1976) found a strong association between micronaire value and the number of neps in yarn.

El-Ghawas *et al.* (1978) found that, within a variety, micronaire value and 50% Span length were negatively correlated with yarn evenness. The net effect of 50% Span length on yarn evenness was more pronounced than that of micronaire value. They also added that, on the basis of the relative net effect on pertinent fiber properties on yarn neppiness, micrónaire value ranked first, followed by fiber length. Ahmed *et al.* (1984) stated that micronaire value exerted the greatest influence, wethear directly of indirectly, upon yarn neppiness, followed by fiber length which appeared a moderate effect. Monsour (1984) found that the three fiber properties (2.5% span length, fiber strength and micronaire value)were the most influential on evenness in spite of their rank which differed from one variety to another and within the some variety from count to count. Working on the Egyptian Extra-long staple variety Giza 45, Seif (1984) found that fiber strength and micronaire values their interaction arose as the prominent factors contributing to yarn strength different counts and twist. Hegab *et al.* (1985) found that fiber strength, fiber length their interaction were the contributors to yarn strength in variety of Giza 70. Abdel-Fattah (1988) found that 2.5% span length was the most contributer to yarn strength. Fares *et al.* (2010) indicated that fiber strength and short fiber content were the most important contributing cotton fiber properties in carded ring skein strength under four counts of spinning.

The present investigation was carried out to determine the relative importance of fiber properties to explain the variation of yarn strength, yarn nep count and evenness in two spinning systems (ring and compact) using two categories of cotton varieties (extra long staple and long staple).

MATERIALS AND METHODS

The present study was carried out on two categories of Egyptian cotton varieties, that are, extra long staple (Giza 70, Giza 88 and Giza 92) and long staple (Giza 86, Giza 89, Giza 85, Giza 80 and Giza 90) during 2009 season at laboratories of Cotton Technology Division of the Cotton Research Institute. Cotton samples were obtained from the commercial cotton samples of 2008 crop that belong to Cotton Maintaince Research Section. Cotton samples were spun into two spinning systems (Ring and Compact) at one count (50s) with 3.6 twist factor.

Lab labour

Three yarn quality properties were used as dependent variables in the current study that are, yarn skein strength (y_1), nep count (y_2) and yarn evenness (y_3). Yarn skein strength was measured on the Good Brand Lea Tester to determine the lea strength in pounds (A.S.T.M. 1967, D1578). Nep count and yarn evenness (c.v. %) were measured by Uster tester 3 according to the standard methods testing of textile material (A.S.T.M. 1986, D- 1425- 60 T).

Data were recorded for six fiber properties as independent variables viz. upper half mean length (UHML) (x_1), uniformity index (UI) (x_2), fiber strength (FS) (x_3), fiber elongation (FE) (x_4), maturity (M) (x_5) and fineness (F) (x_6).

Fiber properties were tested according to the following methods:

H.V.I Instrument System was used according to A.S.T.M (D-4603-86-1776-98) to determine Upper Half Mean Length (UHML) by mm., Uniformity Index (UI %), fiber Strength (cn/ tex) and fiber elongation (FE%) was used according to the A.S.T.M.(D-1440-65).

Statistical analysis

The full model regression and stepwise multiple linear regression were used to evaluate the relative contribution of the aforementioned fiber properties (x_1, x_2,...,x_6) as explanatory variables on each of three quality yarn characters (yarn skein strength (y_1), nep count (y_2) and yarn evenness (y_3) as dependent variables.

1-Full model regression was applied as outlined by Draper and Smith (1981) to predict the quality yarn properties using fiber properties and also to estimate the relative importance of the fiber properties expressed as coefficient of determination (R^2 value) in the total variation of yarn characters.

2- Stepwise multiple linear regression analysis was used to determine what of the fiber properties that accounted for the majority of the total variation of yarn quality properties as described by Draper and Smith (1981).

RESULTS AND DISCUSSION

The results of multiple linear regression analysis between each one of three yarn properties (yarn strength, neps and evenness) as dependent variable and six fiber properties as explanatory variables under Ring spinning system for two categories of cotton varieties are presented in Table (1). The results revealed that the supposed multiple regression models were significantly explained the most variability of the three yarn properties over the two types of cotton variety.

Table (1): Full model regression analysis to predict three yarn properties using six fiber properties for two categories of cotton varieties under ring spinning system.

	Yarn properties	Regression coefficients							Goodness of fit	
		Constant	X_1	X_2	X_3	X_4	X_5	X_6	R^2 %	Adj. R^2
Extra Long Stable	Yarn strength (Y_1)	2900	-7.2	5.4	27.3	24.8	-495	-4.57	89.8	84.3
	Neps (Y_2)	155.3	0.56	0.38	-0.62	14.1	-264	0.065	91.6	87
	Evenness (c.v%) (Y_3)	13.97	0.302	-0.22	0.316	-0.66	-1.1	-0.002	93.4	89.7
Long Stable	Yarn strength (Y_1)	-265	95.9	35.3	6.34	-453	-151	-1.53	95.5	92.2
	Neps (Y_2)	147.4	-3	1.76	0.286	-11.8	33.7	-0.496	78.3	61.9
	Evenness (c.v%) (Y_3)	24.07	0.218	-0.061	-0.003	0.013	0.87	-0.07	81.6	67.9

X_1 Upper Half Mean Length (UHML) (mm), X_2 Uniformity Index (UI %), X_3 Fiber Strength (cn/ tex), X_4 Fiber Elongation (FE%), X_5 Maturity (%) and X_6 Fineness(mtex).

Statistically, goodness of fit was satisfied for the six supposed models where the coefficients of determination (R^2 %) ranged from 78.3 to 95.5 indicating that the most yarn properties variation was attributed to the tested fiber properties. The residuals content (1- R^2 %) may be returned to some errors during measuring the fiber and yarn properties, some fiber properties were not into account under the current investigation and/or unknown variation (random error).

On the other hand, the values of adjusted R^2 were very close to their corresponding R^2 values giving evidence on the goodness of fit for the supposed models. Similar trend of results was obtained by Fares *et al.* (2010).

The stepwise multiple linear regression was usually used to determine the more effective fiber properties that explained the most variation of yarn properties. The accepted fiber properties and their regression parameters according to stepwise multiple linear regression under the ring spinning system are shown in Table (2).

Concerning the category of extra long staple cotton variety, the stepwise multiple linear regression indicated that the accepted limiting properties of cotton fiber that were significantly accounted for the most variation of yarn strength (y_1) were fiber strength (x_3), maturity (x_5) and fineness (x_6) while upper half mean length (x_1), fiber strength (x_3), fiber elongation (x_4) and maturity (x_5) were most important properties using the neps (y_2) as a dependent variable. For evenness, only the two fiber properties of fiber strength (x_3) and fineness (x_6) were accepted using the stepwise model. The three proposed models were responsible for 89.6, 91.5 and 90.4 of the total variation (expressed as R^2 %) of yarn strength (y_1), neps (y_2) and evenness (y_3) respectively. According to the previous results, it could be concluded that fiber strength (x_3), fineness (x_6) and maturity (x_5) were the most effective fiber properties overall the three yarn properties (y_1, y_2 and y_3) for the category of extra long staple cotton variety.

Considering the category of long staple cotton variety, the stepwise regression approach accepted upper half mean length (x_1), uniformity index (x_2), fiber strength (x_3) and fiber elongation (x_4) as the most effective fiber properties in yarn strength (y_1). For neps (y_2), the stepwise model selected fiber strength (x_3), fiber elongation (x_4) and fineness (x_6) while only two fiber characters (upper half mean length (x_1) and fineness (x_6)) were accepted taking the evenness (y_3) as a dependent variable. The three models accounted for 95.5, 75 and 79 % expressed as R^2 of the total variation of yarn strength (y_1), neps (y_2) and evenness (y_3), respectively.

The above results indicated that fiber strength (x_1), fiber elongation (x_4) and fineness (x_6) were the most important fiber traits contributing to yarn properties under the category of long staple variety. The current results are portly in accordance with those reported by Amin (1971) and Sawires *et al.* (1990). Remarkable results were obtained from the previous result, it is that, the fiber properties which significantly contributing to yarn properties differed according to the category of the used cotton variety (Sawires *et al.*, 1990).

When the yarn properties (yarn strength (y_1), neps (y_2) and evenness (y_3) individually regressed on the tested fiber properties under compact ring spinning system for the two studied categories of cotton variety, the results were as in Table (3).

All postulated regression models were significant and reflected the most variation of the three yarn properties expressed as high values of the R^2 ranged from 81 to 94.7% the previous results proved the validity of the supposed models of regression, in addition, the clear closeness between R^2 values and their crossponding adjusted R^2 values gave another evidence. Accordingly, the present regression equations would be accurately applied to predict the three yarn properties using fiber traits. The current results are in harmony with El-Hariry *et al.* (1990), Sawires *et al.* (1990) and Fares *et al.* (2010).

Table (4) showed the prediction equation of the accepted fiber properties and their parameters (R^2, adjusted R^2 and model significance) according to stepwise regression procedure under the compact ring spinning system.

Table (2): Stepwise multiple linear regression to predict three yarn properties using six fiber properties for two categories of cotton varieties under ring spinning system.

	Yarn properties	Regression Equation	R^2 %	Adj. R^2 %
Extra Long Stable	Yarn strength (Y_1)	$3260 + 27.2\ X_3 - 338\ X_5 - 5.48\ X_6$	89.6	87.4
	Neps (Y_2)	$189.5 + 0.91\ X_1 - 0.50 X_3 + 13.4\ X_4 - 269\ X_5$	91.5	88.9
	Evenness (c.v%) (Y_3)	$-5.3 + 0.295\ X_3 + 0.042\ X_6$	90.4	89.2
Long Stable	Yarn strength (Y_1)	$-619.2 + 82\ X_1 + 41\ X_2 + 6.1\ X_3 - 459\ X_4$	95.5	93.7
	Neps (Y_2)	$276.4 + 0.34\ X_3 - 11.5 X_4 - 0.77\ X_6$	75	68.2
	Evenness (c.v%) (Y_3)	$20.69 - 0.155\ X_1 - 0.061\ X_6$	79	75.6

X_1 Upper Half Mean Length (UHML) (mm), X_2 Uniformity Index (UI %), X_3 Fiber Strength (cn/ tex), X_4 Fiber Elongation (FE%), X_5 Maturity (%) and X_6 Fineness(mtex)

It is worthwhile to note the different results obtained from the two categories of cotton variety; therefore, the discussion was done for the two categories separately.

Regarding the category of Extra long staple cotton variety, the stepwise regression approach revealed that the traits of upper half mean length (x_1) maturity (x_5) and fineness (x_6) were the accepted characters that effectively reflected the most variation of yarn strength (y_1). For neps (y_2) the upper half mean length (x_1), uniformity index (x_2) and fiber strength (x_3) were the fiber properties that had pronounced effect on neps while the two traits of upper half mean length (x_1) and maturity (x_5) represented the important components to estimate the evenness (y_3). Statistically, the previous models succeeded to be accounted for the most variation of yarn strength (y_1), neps (y_2) and evenness (y_3) expressed as (R^2 %) recording 86.5, 83.1 and 93.1 for the three yarn properties, respectively. According to the aforementioned results, it could be said that upper half mean length (x_1) fiber strength (x_3) and maturity (x_5) ranked the first fiber properties that used to predict the studied yarn properties (y_1, y_2 and y_3) for the category of extra long staple cotton variety.

Different results were obtained when taken the category of long staple cotton variety into account. In the current case, the technique of stepwise regression accepted upper half mean length (x_1), fiber elongation (x_4) and fineness (x_6) as the fiber properties that they had greatest influence on yarn strength (y_1). The traits of fiber elongation (x_4), maturity (x_5) and fineness (x_6) had a clear effect on the neps (y2). Only, two fiber properties being uniformity index (x_2) and fiber elongation (x_4) were the most important traits contributing to the evenness (y_3) variation. The values of 93.8, 91 and 75.2 (expressed as R^2 %) were the ability of the three proposed models to predict the variation of the three tested yarn properties (y_1, y_2 and y_3), respectively. It may be reported that, both fiber elongation (x_4) and fineness (x_6) were the important fiber properties to predict yarn properties using the category of long staple cotton variety. Similar trend of results were obtained by Seif (1984), Hegab *et al.* (1985), El – Hariry *et al.* (1990), Sawires *et al.* (1990) and Fares *et al.* (2010).

Table (3): Full model regression analysis to predict three yarn properties using six fiber properties for two categories of cotton varieties under compact ring spinning system.

	Yarn properties	Regression coefficients							Goodness of fit	
		Constant	X_1	X_2	X_3	X_4	X_5	X_6	R^2 %	Adj. R^2
Extra Long Stable	Yarn strength (Y_1)	-338	-17.5	21.9	23.5	-31.7	2276	-2.12	87.8	81.1
	Neps (Y_2)	1.1	0.72	0.68	-1.66	6.27	-56.6	0.183	84.6	76.1
	Evenness (c.v%) (Y_3)	-67.31	-0.16	0.30	-0.16	-0.43	61.4	0.09	94.1	90.9
Long Stable	Yarn strength (Y_1)	4704	206	-20.6	-0.15	-533	-1159	-11.9	94.7	90.7
	Neps (Y_2)	6.2	-0.81	0.43	0.054	17.4	-49.5	-0.146	91.9	84.9
	Evenness (c.v%) (Y_3)	20.6	0.001	-0.140	-0.011	0.816	2.18	-0.004	81	66.8

X_1 Upper Half Mean Length (UHML) (mm), X_2 Uniformity Index (UI %), X_3 Fiber Strength (cn/ tex), X_4 Fiber Elongation (FE%), X_5 Maturity (%) and X_6 Fineness(mtex)

Table (4): Stepwise multiple linear regression to predict three yarn properties using six fiber properties for two categories of cotton varieties under compact ring spinning system.

	Yarn properties	Regression Equation	R^2 %	Adj. R^2 %
Extra Long Stable	Yarn strength (Y_1)	$2379 + 37.1X_1 + 530\ X_5 - 6.6\ X_6$	86.5	83.6
	Neps (Y_2)	$95.83 + 0.238X_1 - 0.94X_2 - 1.37\ X_3$	83.1	79.5
	Evenness (c.v%) (Y_3)	$-23.98 + 0.238\ X_1 + 31.2\ X_5$	93.1	92.1
Long Stable	Yarn strength (Y_1)	$2899 + 149\ X_1 - 514\ X_4 - 8.2\ X_6$	93.8	92.1
	Neps (Y_2)	$40.86 + 17.3\ X_4 - 61\ X_5 - 0.238\ X_6$	91.0	88.0
	Evenness (c.v%) (Y_3)	$23.94 - 0.151\ X_2 + 0.62\ X_4$	75.2	71.0

X_1 Upper Half Mean Length (UHML) (mm), X_2 Uniformity Index (UI %), X_3 Fiber Strength (cn/ tex), X_4 Fiber Elongation (FE%), X_5 Maturity (%) and X_6 Fineness(mtex)

Finally, the current investigation stated the following conclusions or remarks:-

1-The results of the supposed regression models differed according to the category of the used cotton variety and also the kind of the applying spinning system.
2-The current results helps the spinner to predict the spinning performance using the available fiber properties as well as choosing cotton that are best suited to the manufacture of the end products.
3-Statistically, goodness of fit was satisfied for all regression models under the present investigation.
4-The residuals content ($1-R^2$) may be attributed to three reasons being the committed errors during measuring fiber and yarn properties, some considerable fiber properties were not into account and/ or unknown variation (random error).
5-The stepwise regression procedure determined the minimum number of fiber characters that are accounted for the most variation of various yarn properties which save the time and effort.

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استخدام بعض نماذج العلاقات الاحصائية لتوقع صفات الخيط باستخدام صفات التيلة لفئتين من أصناف القطن المصري تحت نظامين من الغزل.

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*** المعمل المركزي لبحوث التصميم والتحليل الإحصائي - مركز البحوث الزراعية – الجيزة – مصر.

يهدف هذا البحث لدراسة مدى مساهمة صفات التيلة في صفات الخيط الناتجة (متانة الشلة، العقد، انتظامية الخيط) وذلك لفئتين من أصناف القطن المصري (فائق الطول، طويل) تحت نظامين من الغزل (حلقي، مدمج). وقد اشتملت الأصناف فائقة الطول علي صنف جيزة ٧٠، جيزة ٨٨ و جيزة ٩٢ بينما كانت الأصناف الطويلة هي جيزة ٨٦، جيزة ٨٩، جيزة ٨٥، جيزة ٨٠ و جيزة ٩٠ – حيث تم استخدام عينات من المحصول التجاري لعام ٢٠٠٨.

وقد تم استخدام كل من تحليل الانحدار المتعدد، تحليل الانحدار المتعدد المرحلي لتحقيق هذا الهدف.

وقد أوضحت النتائج أن صفات التيلة الأكثر إسهاماً في صفات الخيط تختلف من صنف لآخر ومن فئة إلي أخري كما تتوقف أيضا على نظام الغزل المتبع.

- وبوجه عام أشارت النتائج أنه تحت نظام الغزل الحلقي كانت صفتي متانة التيلة والنعومة هي الأكثر تأثيراً في صفات الخيط وذلك لأصناف القطن فائق الطول بينما كانت صفات متانة التيلة، الاستطالة والنعومة هي الأهم في توقع صفات الخيط لأصناف القطن طويلة التيلة.
- بالنسبة لنظام الغزل المدمج كانت صفات طول التيلة عند ٢,٥ % ، متانة التيلة و النضج هي أكثر صفات التيلة إسهاماً في صفات الخيط لأصناف القطن فائقة الطول في حين أن صفتي استطالة التيلة والنعومة هما أهم مكونات التيلة تأثيراً في صفات الخيط.
- من ناحية أخرى فإن جميع نماذج الانحدار المقترحة كانت معنوية وأعطت قيم مرتفعة من معامل التحديد (R^2) كما كانت قيم التحديد المعدل ($Adj.R^2$) قريبة من قيم معامل التحديد مما يشير إلى جودة التوفيق لهذه النماذج.