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Impact of Egyptian and CIS Long Staple Cotton Varieties on Yarn Tensile Properties at Ring and Compact Spinning Systems

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Abstract. Compact spinning system has proved itself better as compared to ring spinning system in improving the strength related properties of the yarn at low twist and high spindle speeds. The present study was undertaken to optimize the application of best combination of twist multiplier and spindle speed of ring and compact spinning system to Egyptian and CIS cotton varieties. Cotton varieties, twist multiplier and spinning system were found to be highly significant while spindle speed and all the interactions remained non-significant related to the tensile properties (yarn lea strength, single yarn strength, RKM and elongation) of the cotton varieties.

Keywords: cotton varieties, yarn properties, spinning systems

Introduction

On the basis of the physicochemical characteristics, the Egyptian cotton has an edge over other cotton varieties. Suitable length and strength of the fibre makes it possible to produce a yarn of good strength and ultimately fabrics of stronger and better resistance to stress. The ability to absorb liquids gives fabrics made of Egyptian cotton, deeper, brighter and more resistant colours and good dye ability (Egyptian Cotton, 2007). On the other hand, CIS cotton is grown in the States of Central Asian Republics of Armenia, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Tajikistan, Turkmenistan, Ukraine and Uzbekistan and is of medium staple American upland type.

Along with the cotton variety, the spinning system and different mechanical variables like twist multiplier and spindle speed also play major role in the yarn and fabric quality. No doubt, automation and synchronization of all operational elements on the ring spinning frame brought about a significant increase in production of better yarn quality, and greater flexibility and profitability of the yarn spinning on the ring spinning frame (Trajkovic, 2008). But the ring spinned yarn is not perfect. Therefore, new spinning systems like compact spinning technology have been gaining much more interest since their first commercial introduction.

Compact spinning is a modified ring spinning process which has special advantages and can be used in both short and long-staple yarn spinning areas. In compact yarn, fibres are uniformly oriented and made into the yarn right after the end of the drafting arrangement. Spinning triangle has a decisive/ adverse effect on yarn surface i.e., hairiness, yarn strength, yarn elasticity (work capacity), running performance, end-breakage and fly liberation. Peripheral fibres are not quite often integrated in the yarn structure. Therefore, better tenacity, elongation and hairiness properties can be ensured by reducing/eliminating the spinning triangle. Better tenacity of compact spun yarn, due to elimination of spinning triangle, provides opportunities to work with lower twist coefficients, resulting in an increase in production rate and also better handling properties of the end-product (Celik and Kadoglu, 2004).

This paper evaluates the performance of different physico-chemical properties of Egyptian and CIS cotton varieties on the tensile properties of the yarn at various settings of twist multiplier and spindle speeds for ring and compact spinning systems to optimize the tensile properties of yarn.

Materials and Methods

The research work was initiated at the Department of Fibre Technology and Institute of Animal Nutrition and Feed Technology, University of Agriculture, Faisalabad, while the processing of the samples was conducted at Nishat Textile Mills Ltd., Sheikhupura Road, Faisalabad, Pakistan.

Samples of cotton varieties of Egyptian and CIS were evaluated in this research study with physical characteristics: span length 35 and 33 mm, uniformity index 88 and 86%, fineness 4.30 and 4.20 microgram per inch, strength 40 and 36 g/tex and elongation 5.50 and 5.90%. Samples were processed in the blow room, carding, drawing and roving section at standard machinery setting and processing variables. The roving of 0.94 hank was processed at Zinsser compact spinning system and Toyota-RX240 Ring spinning

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system. CV percentage, 3.79 and 2.02%, was observed in case of roving and drawing, respectively. The following variables were selected for this research work, in order to spin the 80^{-s} yarn count:

Variables for research study

Cotton variety (C)		Twist multiplier	Spindle speed	Spinning system
Egyptian cotton	CIS cotton	T.M. (T)	(S)	(M)
C_1=Giza 70	C_4=Elisa	T_1=3.6	S_1=20000	M_1=Ring
C_2=Giza 86	C_5=Sultop	T_2=3.7	S_2=21000	M_2=Compact
C_3=Giza 88	C_6=Surex	T_3=3.8	S_3=22000	-

Yarn lea strength. Lea strength of yarn was determined in pounds according to the ASTM standards (ASTM, 2008a; 2008b). A pendulum type lea strength-testing machine was used to test the strength of yarn. This machine gives direct readings for lea strength.

Tensile properties of yarn. Tensile properties i.e., single yarn strength, elongation and rupture per kilometer were observed with Uster Tensojet which works on the principle of constant rate of extension (CRE). The principle describes the fact that the moving clamps are displaced at constant velocity as a result of which the specimen caught in between the stationary and moving clamps is extended at a constant rate. The breaking tenacity was measured from the maximum force which was applied anywhere between the beginning of the test and the final rupture of the specimen. The breaking elongation of yarn was measured from the clamp displacement at the point of peak force. The procedure has been described in the ASTM Standard (ASTM, 1997).The breaking length of yarn (KM) can also be derived from the following formula:

$$\text{RKM} = \text{single yarn strength (g)} \times \text{yarn count} \times 0.001693$$

Statistical analyses. Completely randomized design was applied in the analysis of variance of data for testing differences among various quality characteristics (Faqir, 2004). Duncan's multiple range test was also applied for individual comparison of means among various quality characters. The data were subjected to statistical manipulation on computer by employing M-Stat microcomputer program (Freed, 1992).

Results and Discussion

Yarn lea strength. The statistical analysis of variance and comparison of individual means for yarn lea strength are given in Table 1 and 1(a), respectively. The results indicate that the effect of cotton varieties (C), twist multiplier (T) and spinning system (M) is highly significant while spindle speed and all the interactions are non-significant.

Individual comparison of mean values given in Table 1(a) for yarn lea strength of Egyptian cotton varieties Giza-70, Giza-86 and Giza-88 and CIS cotton varieties Elisa, Sultop and Surex showed significant differences, with respect to each other. The stronger yarn was obtained by Egyptian cotton varieties Giza-88, Giza-86 and Giza-70 as 48.307, 48.216 and 48.078 pounds, respectively, followed by CIS cotton varieties Sultop, Elisa and Surex as 34.774, 34.503 and 34.347 pounds, respectively. These results show that fibre properties such as length, uniformity of length, micronaire, fibre strength and elongation along with spinning conditions contribute to yarn strength. Also the yarn tensile response is based on fibre parameters such as fibre strength, length, maturity and fineness (Amjad, 1999; Frydrych, 1992; Sheikh, 1991).

Comparison of individual means of yarn lea strength due to twist multiplier (T) is represented in Table 1(a). The highest value of yarn lea strength, 42.345 pounds, was recorded for T_3 (3.8) followed by 41.353 and 40.415 pounds for T_2 (3.7) and T_1 (3.6), respectively. The results show significant differences among one another. It indicates that as the twist multiplier increases, the value of lea strength also increases; with increase in twist factor, the yarn lea strength also increases but after a certain optimum level further increase in twist will cause the fibre rupture and strength of yarn suddenly decreases (Mahmood *et al*., 2004).

Comparison of individual means of the yarn lea strength due to spindle speed (S) is represented in Table 1(a); the highest value of yarn lea strength, 41.456 pounds, was recorded for S_3 (22000 rpm) followed by 41.384 and 41.272 pounds for S_2 (21000 rpm) and S_1 (20000 rpm), respectively. The results have non-significant differences with respect to each other.

Individual comparison of mean values given in Table 1(a) about yarn lea strength for spinning systems M_1 and M_2 shows significant difference with respect to one other. The stronger yarn is obtained at compact ring spinning machine (M_2) as 44.145 pounds followed by conventional machine (M_1) as 38.597 pounds. The results indicate that compact yarn has higher yarn lea strength value than the ring yarn as minimization or even elimination of the spinning triangle enables almost all fibres to be incorporated into the yarn structure with maximum possible length and pre-tension of the fibres, irrespective of their position in the spinning triangle. Uniform pre-tension of the majority of fibres enables their more synchronic breakage, which contributes higher yarn strength and better utilization of fibre tenacity from 65% up to even 80% (Nikolic *et al*., 2003).

Table 1. Analysis of variance for yarn lea strength

Source of variance	Degree of freedom	Sum of squares	Mean square	F. value	Prob.
M	1	4154.453	4154.453	4518.9071	0.0000*
C	5	25198.202	5039.640	5481.7481	0.0000*
MXC	5	9.593	1.919	2.0869	0.0660 NS
T	2	335.119	167.559	182.2586	0.0000*
MXT	2	0.241	0.121	0.1312	-
CXT	10	0.570	0.057	0.0620	-
MXCXT	10	0.437	0.044	0.0475	-
S	2	3.116	1.558	1.6947	0.1849 NS
MXS	2	0.026	0.013	0.0141	-
CXS	10	0.491	0.049	0.0534	-
MXCXS	10	0.445	0.044	0.0484	-
TXS	4	0.181	0.045	0.0492	-
MXTXS	4	0.336	0.084	0.0914	-
CXTXS	20	1.242	0.062	0.0675	-
MXCXTXS	20	0.828	0.041	0.0450	-
Error	432	397.159	0.919	-	-
Total	539	30102.438	-	-	-

CV = 2.32%; NS = non-significant; * = highly significant; (Ref: Freed, 1992).

Table 1(a). Comparison of individual mean values for yarn lea strength

Cotton variety (C)		Twist multiplier	Spindle speed	Spinning system
Egyptian cotton	CIS cotton	(T)	(S)	(M)
C_1=8.078[a]	C_4=34.503[bc]	T_1=40.415[c]	S_1=41.272	M_1=38.597[b]
C_2=8.216[a]	C_5=34.774[b]	T_2=41.353[b]	S_2=41.384	M_2=44.145[a]
C_3=8.307[a]	C_6=4.347[c]	T_3=42.345[a]	S_3=41.456	-

Mean values having different letters differ significantly at 5% level of significance.

Single yarn strength. The statistical analysis of variance and comparison of individual means for single yarn strength are given in Table 2 and 2(a), respectively. The results indicate that the effect of cotton varieties (C), twist multiplier (T) and spinning system (M) were highly significant while spindle speed (S) and all the interactions were non significant.

Individual comparison of mean values given in Table 2(a) regarding single yarn strength for Egyptian cotton varieties Giza-70, Giza-86 and Giza-88 and CIS cotton varieties Elisa, Sultop and Surex showed significant difference with respect to each other. The stronger yarn was obtained by Egyptian cotton Giza-88, Giza-86 and Giza-70 as 182.602, 182.257 and 181.734 g, respectively, followed by CIS cotton varieties Sultop, Elisa and Surex as 131.444, 130.422 and 129.831 g, respectively. From the results, it is clear that the strength of a spun yarn is recognized as one of the most important quality parameters of yarn. Predicting the strength of spun yarn is very important from technological point of view (Ghosh *et al*., 2004).

Individual comparison of means for single yarn strength due to different machines M_1 and M_2, presented in Table 2(a), showed that both the machines differed from one another significantly. The best value was obtained with machine (M_2) as 166.866 g followed by conventional machine (M_1) as 145.897 g.

Table 2. Analysis of variance for single yarn strength

Source of variance	Degree of freedom	Sum of squares	Mean square	F. value	Prob.
M	1	59360.618	59360.618	4397.2363	0.0000*
C	5	360042.477	72008.495	5334.1488	0.0000*
MXC	5	137.057	27.411	2.0305	0.0733 NS
T	2	4788.344	2394.172	177.3522	0.0000*
MXT	2	3.446	1.723	0.1276	-
CXT	10	3.446	0.814	0.0603	-
MXCXT	10	8.140	0.624	0.0462	-
S	2	6.240	22.259	1.6488	0.1935 NS
MXS	2	44.517	0.185	0.0137	-
CXS	10	0.370	0.702	0.0520	-
MXCXS	10	7.016	0.635	0.0471	-
TXS	4	6.353	0.647	0.0479	-
MXTXS	4	2.587	1.201	0.0889	-
CXTXS	20	4.803	0.887	0.0657	-
MXCXTXS	20	17.744	0.592	0.0438	-
Error	432	11.835	13.500	-	-
Total	539	5831.796	-	-	-

CV = 2.35%; NS = non significant; * = highly significant; (Ref: Freed, 1992).

Table 2(a). Comparison of individual treatment means for single yarn strength

Cotton variety (C)		Twist (T)	Spindle multiplier	Spinning system
Egyptian cotton	CIS cotton		(S)	(M)
C_1=181.734[a]	C_4=130.422[bc]	T_1=152.770[c]	S_1=156.008	M_1=145.897[b]
C_2=182.257[a]	C_5=131.444[b]	T_2=156.313[b]	S_2=156.433	M_2=166.866[a]
C_3=182.602[a]	C_6=129.831[c]	T_3=160.063[a]	S_3=156.705	-

Mean values having different letters differ significantly at 5% level of significance.

In a previous study, breaking strength of compact yarn spun on Suessen ring spinning machine was also found higher than conventional ring spun yarn (Nikolic *et al*., 2003).

Moreover, improvements in yarn strength appeared to be greater for medium staple cottons than for the long staple lengths (Krifa *et al*., 2002). These results made it clear that the fibres that were inadequate for use in conventional ring spinning might be spun satisfactorily on the compact system.

Comparison of individual means for single yarn strength due to twist multiplier shows that all these values are significant. The best value was that of T_3 as 160.063 g followed by T_2 and T_1 as 156.313 and 152.770 g, respectively. The results show that when twist multiplier increases, single end strength also increases, because twist in the yarn has a two-fold effect; firstly the twist increases cohesion between the fibres by increasing the lateral pressure in the yarn, thus giving enough strength to the yarn. Secondly, twist increases the helical angle of fibres and allowing maximum fibre strength to the yarn. Due to the above effects, as the twist increases, the yarn strength increases up to a certain level, beyond which the increase in twist actually decreases the strength of staple yarn (Palaniswamy and Mohamed, 2005).

Comparison of individual means concerning single yarn tstrength due to spindle speed (S) is represented in Table 2(a). The highest value of single yarn strength 156.705 g was recorded for S_3 (22000 rpm) followed by 156.433 g and 156.008 g for S_2 (21000 rpm) and S_1 (20000 rpm), respectively. The results have non-significant differences with respect to each other.

Breaking length (RKM). Statistical analysis of variance and comparison of individual means for breaking length (RKM) are given in Table 3 and 3(a), respectively. The results indicate that the effect of cotton varieties (C), twist multiplier (T) and spinning system (M) were highly significant while spindle speed (S) and all the interactions were non significant.

Individual comparison of mean values given in Table 3(a) regarding RKM values of Egyptian cotton varieties Giza-70, Giza-86 and Giza-88 and CIS cotton varieties Elisa, Sultop and Surex showed significant differences with respect to each other. The stronger yarn was obtained by Egyptian cotton Giza-88, Giza-86 and Giza-70 with RKM of 24.707, 24.637 and 24.585 g per tex, respectively, followed by CIS cotton varieties Sultop, Elisa and Surex with RKM of 17.757, 17.648 and 17.529 g, respectively.

Different researchers have commented breaking length (RKM) value of yarns in different ways but they mainly correlate this character with the nature of cotton being used. Yarn tensile response i.e., rupture per kilometer is based mainly on physical properties of fibre such as strength, fineness, maturity etc. (Liu *et al*., 2001).

Individual comparison of means for breaking length (RKM) due to the machines M_1 and M_2 presented in Table 3(a) shows that the difference between both the machines is significant. The best value is obtained at modified machine (M_2) as 22.561 g per tex followed by conventional machine (M_1) as 19.727 g per tex; since stronger yarn is produced on modified machine, so its RKM value is also high as compared to the conventional machine.

Table 3. Analysis of variance for breaking length (RKM)

Source of variance	Degree of freedom	Sum of squares	Mean square	F. value	Prob.
M	1	1083.655	1083.655	4529.4575	0.0000*
C	5	6615.461	1323.092	5530.2543	0.0000*
MXC	5	2.397	0.479	2.0041	0.0769 NS
T	2	85.348	42.674	178.3678	0.0000*
MXT	2	0.031	0.016	0.0655	-
CXT	10	0.136	0.014	0.0567	-
MXCXT	10	0.273	0.027	0.1140	-
S	2	0.422	0.211	0.8817	-
MXS	2	0.014	0.007	0.0298	-
CXS	10	0.121	0.012	0.0507	-
MXCXS	10	0.093	0.009	0.0389	-
TXS	4	0.012	0.003	0.0124	-
MXTXS	4	0.054	0.013	0.0563	-
CXTXS	20	0.142	0.007	0.0296	-
MXCXTXS	20	0.310	0.015	0.0647	-
Error	432	103.354	0.239	-	-
Total	539	7891.823	-	-	-

CV = 2.31%; NS = non-significant; * = highly significant; (Ref: Freed, 1992).

Table 3(a). Comparison of individual treatment means for breaking length (RKM)

Cotton variety (C)		Twist multiplier	Spindle speed	Spinning system
Egyptian cotton	CIS cotton	(T)	(S)	(M)
C_1 24.585[a]	C_4=17.648[bc]	T_1=20.656[c]	S_1=21.108	M_1=19.727[b]
C_2 24.637[a]	C_5=17.757[b]	T_2=21.146[b]	S_2=21.149	M_2=22.561[a]
C_3 24.707[a]	C_6=17.529[c]	T_3 =21.630[a]	S_3=21.175	-

Mean values having different letter differ significantly at 5% level of significance.

It has been observed that tenacity of compact yarn produced on the Zinser spinning machine surpasses the conventional yarn by 17%, while this value is higher up to 23.24% in the yarn spun on the Suessen spinning machine (Nikolic *et al*., 2003).

The comparison of individual means for yarn breaking length (RKM) due to twist multipliers 3.6, 3.7 and 3.8 shows that all these values differ significantly from each another. The best value is observed at T_3 as 21.630 g per tex followed by T_2 and T_1 with their respective mean values of 21.146 and

20.656 g per tex. From the above result, it can be inferred that by decreasing the twist, yarn breaking length (RKM) decreases.

These results are in line with the findings of Ozguney *et al*. (2008) that as the twist multipliers of the yarn increase, U%, CV%, neps, count variation and hairiness values decreased whereas breaking force, elongation at break (%)and breaking resistance increased.

Comparison of individual means concerning the breaking length (RKM) due to spindle speed (S) is represented in Table 3(a). The highest value of RKM, 21.175 g per tex, was recorded for S_3 (22000 rpm) followed by 21.149 and 21.108 g per tex for S_2 (21000 rpm) and S_1 (20000 rpm), respectively. The results have non-significant differences with respect to each other.

Yarn elongation. The statistical analysis of variance and comparison of individual means for yarn elongation are given in Table 4 and 4(a), respectively. The results indicate that the cotton variety (C), twist multiplier (T), spinning system (M) and interaction MXC were highly significant while spindle speed (S) and all other interactions were non significant.

Individual comparison of mean values given in Table 4(a) regarding the yarn elongation for Egyptian cotton varieties Giza-70, Giza-86 and Giza-88 and CIS cotton varieties Elisa, Sultop and Surex showed significant differences with respect to each other. More elongation percentage was obtained by CIS cotton varieties Sultop, Elisa and Surex as 5.021, 4.918 and 4.899%, respectively, followed by Egyptian cotton, Giza-86, Giza-88 and Giza-70 as 3.722, 3.070 and 2.978%, respectively. From the point of view of yarn quality, it is observed that higher yarn elongation is a desirable feature because increase in elongation reduces yarn hairiness.

Mean values relating to yarn elongation due to spinning systems M_1 and M_2 are shown in Table 4(a) which reveal that both the values are significant with respect to one another. The highest value is obtained at modified compact spinning frame (M_2) as 4.587% followed by conventional ring spinning frame (M_1) with mean value of 3.616%.

These results agree with the findings that elongation at break of compact yarns is 4 to 11% higher as compared to conventional yarns. The tenacity of compact yarn produced on the Zinser spinning machine surpasses the conventional yarn by 15.90%, while this value is higher up to 28.87% in yarns spun on the Suessen spinning machine (Nikolic *et al*., 2003).

Duncan's multiple range test indicates the highest value of yarn elongation as 4.271% recorded for T3 (3.8), followed by 4.130 and 3.904% recorded for T2 (3.7) and T1 (3.6), respectively. All the three values showed significant differences among each other. The present results show that by increasing twist multiplier, yarn elongation increases i.e. the twist factor affects the yarn elongation.

These results are in line with the findings of Ureyen (2006) that breaking elongation was highly influenced by yarn count, twist and roving count. The elongation increased with higher twist and decreased with finer roving. Coars yarns have more elongation values than fine yarns.

Comparison of individual means concerning yarn elongation due to spindle speed (S) is represented in Table 4(a). The highest value of yarn elongation, 4.110%, was recorded for S_3 (22000 rpm) followed by 4.102 and 4.092% for S_2 (21000 rpm) and S_1 (20000 rpm), respectively. The results have non significant differences with respect to each other.

Table 4. Analysis of variance for yarn elongation (%)

Source of variance	Degree of freedom	Sum of squares	Mean square	F. value	Prob.
M	1	127.264	127.264	3173.2438	0.0000*
C	5	415.517	83.103	2072.1247	0.0000*
MXC	5	4.938	0.988	24.6252	0.0000*
T	2	12.308	6.154	153.4497	0.0000*
MXT	2	0.168	0.084	2.0969	0.1241 NS
CXT	10	0.302	0.030	0.7531	-
MXCXT	10	0.203	0.020	0.5051	-
S	2	0.028	0.014	0.3469	-
MXS	2	0.000	0.000	0.0024	-
CXS	10	0.007	0.001	0.0163	-
MXCXS	10	0.004	0.000	0.0093	-
TXS	4	0.000	0.000	0.0030	-
MXTXS	4	0.000	0.000	0.0027	-
CXTXS	20	0.001	0.000	0.0016	-
MXCXTXS	20	0.002	0.000	0.0020	-
Error	432	17.326	0.040	-	-
Total	539	578.067	-	-	-

CV = 4.88%; NS = non significant; * = highly significant; (Ref: Freed, 1992).

Table 4(a). Comparison of individual treatment means for yarn elongation (%)

Cotton variety (C)		Twist multiplier	Spindle speed	Spinning system
Egyptian cotton	CIS cotton	(T)	(S)	(M)
C_1=2.978[e]	C_4=4.918[b]	T_1=3.904[c]	S_1=4.092	M_1=3.616[b]
C_2=3.722[c]	C_5= 5.021[a]	T_2=4.130[b]	S_2=4.102	M_2=4.587[a]
C_3=3.070[d]	C_6=4.899[b]	T_3 =4.271[a]	S_3=4.110	

Mean values having different letters differ significantly at 5% level of significance.

Conclusion

The study revealed that Egyptian cotton varieties generated better results for yarn rupture per kilometer, strength and tensile properties as compared to CIS cotton yarn. The Egyptian cotton variety Giza-88 and CIS cotton variety Sultop overall performed better.

Compact yarn possessed better strength and elongation as compared to the conventional ring-spun yarn due to the better structure of the compact yarn which is mainly due to the elimination of spinning triangle when compared with ring spun yarn.

Similarly, maximum twist showed best results for yarn strength parameters, yarn elongation while spindle speed did not generate any significant effect on any of the yarn properties.

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