4. RESULTS AND DISCUSSION

4.1. The relation between physical properties of cotton fibers

The objective of this section of the present study is to throw the light on the nature of interrelations between the various physical properties of cotton fibers within each of LS, ELS and the combined LS and ELS categories. This is deliberately done for two reasons, firstly, these relationships contributed directly or indirectly (in the form of individual properties or their interactions) to the relationships between fiber and yarn physical properties; secondly, the full understanding of these interrelations may be useful for the physical interpretation of the prediction equations of yarn properties from properties of cotton fibers from which those yarns were spun, which will be dealt with later.

The coefficient of simple correlations between cotton fibers physical properties

Table (1) includes the mean values for the various physical properties tested in this study for both LS and ELS cotton varieties.

Simple correlation coefficients between fiber physical properties of each of LS and ELS and combined LS + ELS categories are shown in Tables (2, 3 and 4).

4.1.1. The relationships between fiber length parameters

As shown in Table (2) in case of LS category 2.5% span length exhibited highly significant and positive correlation with the 50% span length. The uniformity ratio % correlated positively and significantly and positively and highly significantly with each of 2.5% and 50% span lengths, respectively. Meanwhile, the floating fiber index % showed highly significant and negative correlations with each of 2.5% and 50% span lengths and uniformity ratio %.

The above mentioned results indicated that as the 2.5% and 50% span lengths and uniformity ratio % increased the floating fiber index % is decreased.

Table 1. The fiber physical properties of Egyptian long-stapled (LS) and extra long-stapled (ELS) cotton varieties.

Cotton variety	Fiber length measurements by Fibrograph 530				Fineness/maturity measurements by F.M.T.					Tensile properties of fiber bundle by Stelometer 1/8" gauge			
	2.5% span length (m.m.) (X_1)	50% span length (m.m.) (X_2)	Uniformity ratio % (X_3)	Floating fiber index % (X_4)	Micronaire reading (X_5)	Linear density (millitex) (X_6)	Maturity % (X_7)	Maturity ratio (X_8)	Standard linear density (millitex) (X_9)	Bundle strength (g/Tex) (X_{10})	Bundle elongation % (X_{11})	Bundle stiffness (g/Tex) (X_{12})	Bundle toughness (g/Tex) (X_{13})
Long-stapled (LS)													
Giza 75	30.5	15.7	51.5	10.48	4.2	172	88	0.98	175	31.3	5.2	601	0.82
Giza 83	29.5	14.8	50.1	14.57	3.7	165	82	0.92	178	25.4	6.2	409	0.79
Giza 85	30.9	16.0	51.8	7.87	4.0	169	83	0.94	180	28.3	7.0	406	1.01
Extra long-stapled (ELS)													
Giza 70	35.7	18.2	51.2	9.41	3.8	158	85	0.97	163	35.4	5.7	618	1.00
Giza 77	34.6	18.1	52.3	6.79	3.6	142	79	0.88	162	34.3	5.6	612	0.96
Giza 84	33.5	17.1	51.1	9.33	3.4	136	81	0.91	148	36.6	6.3	579	1.16

Table 2. Coefficient of simple correlations (r) between various physical fiber properties of long-stapled cotton category (LS).

Fiber properties		50% span length (m.m.) X_2	Uniformity ratio % X_3	Floating fiber index X_4	Micronaire reading X_5	Linear density (millitex) X_6	Maturity % X_7	Maturity ratio X_8	Standard linear density (millitex) X_9	Bundle strength (g/Tex) X_{10}	Bundle elongation % X_{11}	Stiffness (g/Tex) X_{12}	Toughness (g/Tex) X_{13}
2.5% Span length (mm)	X_1	0.91**	0.70*	-0.90**	0.50	0.54	-0.23	0.48	0.45	0.50	0.41	0.02	0.79**
50% Span length (mm)	X_2		0.86**	-0.99**	0.39	0.43	-0.27	0.45	0.39	0.44	0.44	0.01	0.72**
Length uniformity ratio %	X_3			-0.88**	0.47	0.48	-0.03	0.53	0.11	0.56	0.26	0.15	0.65*
Floating fiber index %	X_4				-0.39	-0.43	0.27	-0.46	-0.38	-0.44	-0.45	-0.01	-0.72**
Micronaire reading	X_5					0.91**	0.53	0.86**	-0.39	0.92**	-0.45	0.68*	0.28
Linear density (millitex)	X_6						0.59*	0.96**	-0.45	0.92**	-0.50	0.68**	0.29
Maturity (%)	X_7							0.63*	-0.86**	0.52	-0.92**	0.75**	-0.47
Maturity ratio	X_8								-0.54	0.86**	-0.54	0.66*	0.22
Standard linear density (millitex)	X_9									-0.44	0.91**	-0.68*	0.54
Fiber bundle strength (g/tex)	X_{10}										-0.45	-0.78**	0.27
Fiber bundle elongation (%)	X_{11}											-0.78**	0.62*
Fiber bundle stiffness (g/tex)	X_{12}												-0.36

In case of ELS category, as shown in Table (3), the 2.5% span length showed highly significant and positive correlation only with 50% span length. Meanwhile the floating fiber index % exhibited highly significant and negative correlation with uniformity ratio % and insignificant negative correlations with the other length parameters.

The combined LS + ELS categories correlations in Table (4) showed highly significant and positive correlation between 2.5% and 50% span lengths. Moreover, significant and positive correlations exists between the 50% span length and the uniformity ratio %. The floating fiber index % exhibited highly significantly and negative correlations with each of the 2.5% and 50% span lengths and uniformity ratio %.

In conclusion, the longer the fibers the more uniformity the length distribution is the lower the floating fiber index %.

4.1.2. The relationships between fiber fineness/maturity parameters

Regarding fineness/maturity parameters, viz.; micronaire reading, linear density, maturity %, maturity ratio and standard linear density, it is shown in Table (2) in case of LS category that the micronaire reading exhibited highly significant and positive correlations with each of linear density and maturity ratio. However, insignificant negative correlation existed between the micronaire reading and each of maturity ratio and standard linear density, respectively. The linear density showed positive significant and highly significant correlations with each of maturity % and maturity ratio, respectively. However, insignificant negative correlation showed between linear density and the standard linear density. The maturity % showed highly significant positive and negative correlations with each of maturity ratio and standard linear density, respectively. Whereas, maturity ratio showed negative and insignificant correlation with the standard linear density.

Table 3. Coefficient of simple correlations (r) between various physical fiber properties of extra long-stapled cotton category (ELS).

Fiber properties		50% span length (m.m.) X_2	Uniformity ratio % X_3	Floating fiber index X_4	Micronaire reading X_5	Linear density (millitex) X_6	Maturity % X_7	Maturity ratio X_8	Standard linear density (millitex) X_9	Bundle strength (g/Tex) X_{10}	Bundle elongation % X_{11}	Stiffness (g/Tex) X_{12}	Toughness (g/Tex) X_{13}
2.5% Span length (mm)	X_1	0.93**	0.28	-0.16	0.97**	0.94**	0.27	0.43	0.86**	-0.40	-0.51	0.62*	-0.46
50% Span length (mm)	X_2		0.53	-0.40	0.91**	0.88**	0.05	0.18	0.90**	-0.53	-0.64*	0.66*	-0.59*
Length uniformity ratio %	X_3			-0.87**	0.24	0.18	-0.78**	-0.66*	0.47	-0.71**	-0.81**	0.60*	-0.76**
Floating fiber index %	X_4				-0.15	-0.10	0.68*	0.66*	-0.31	0.69*	0.69*	-0.42	0.66*
Micronaire reading	X_5					0.98**	0.31	0.46	0.83**	-0.46	-0.45	0.61*	-0.51
Linear density (millitex)	X_6						0.36	0.48	0.80**	-0.48	-0.50	0.54	-0.49
Maturity (%)	X_7							0.92**	-0.01	0.50	0.49	-0.23	0.52
Maturity ratio	X_8								0.05	0.44	0.33	0.06	0.38
Standard linear density (millitex)	X_9									-0.59*	-0.65*	0.57*	-0.65*
Fiber bundle strength (g/tex)	X_{10}										0.86**	-0.51	0.94**
Fiber bundle elongation (%)	X_{11}											-0.83**	0.97**
Fiber bundle stiffness (g/tex)	X_{12}												-0.72**

Table.4. Coefficient of simple correlations (r) between various physical fiber properties of both long-stapled and extra long stapled cotton categories.

Fiber properties		50% span length (m.m.) X_2	Uniformity ratio % X_3	Floating fiber index X_4	Micronaire reading X_5	Linear density (millitex) X_6	Maturity % X_7	Maturity ratio X_8	Standard linear density (millitex) X_9	Bundle strength (g/Tex) X_{10}	Bundle elongation % X_{11}	Stiffness (g/Tex) X_{12}	Toughness (g/Tex) X_{13}
2.5% Span length (mm)	X_1	0.98**	0.39	-0.63**	-0.29	-0.57**	-0.47*	-0.14	-0.59**	0.76**	-0.01	0.67**	0.56**
50% Span length (mm)	X_2		0.48*	-0.69**	-0.33	-0.59**	-0.54*	-0.20	-0.60**	0.74**	-0.01	0.68**	0.54*
Length uniformity ratio %	X_3			-0.83**	0.14	-0.01	-0.48*	-0.18	-0.050	0.12	-0.12	0.37	0.15
Floating fiber index %	X_4				0.15	0.32	0.70**	0.37	0.17	-0.30	-0.24	-0.29	-0.49*
Micronaire reading	X_5					0.92**	0.59**	0.78**	0.68**	-0.48*	-0.27	-0.06	-0.39
Linear density (millitex)	X_6						0.66**	0.72**	0.80**	-0.70**	-0.22	-0.30	-0.54*
Maturity (%)	X_7							0.78**	0.29	-0.28	-0.36	-0.14	-0.46*
Maturity ratio	X_8								0.34	-0.16	-0.26	0.07	-0.21
Standard linear density (millitex)	X_9									-0.87**	0.20	-0.60**	-0.43*
Fiber bundle strength (g/tex)	X_{10}										-0.04	0.62**	0.67**
Fiber bundle elongation (%)	X_{11}											-0.63**	0.60**
Fiber bundle stiffness (g/tex)	X_{12}												-0.01

From the above discussion, it is clear that with the exception of the standard linear density, all the fiber fineness / maturity parameters showed positive relationships between each other even in case of the insignificant values of (r). The standard linear density showed highly significant and negative correlation with maturity %, whereas, the correlations with other fineness / maturity parameters were insignificant and negative.

Considering ELS category, as in Table (3), the micronaire reading correlated highly significantly and positively with linear density. The same trend was found between linear density and standard linear density. Meanwhile, linear density did not correlated significantly with either maturity % or maturity ratio as in case of LS category. The maturity % correlated highly significantly and positively with maturity ratio.

Regarding the combined LS + ELS categories, as shown in Table (4), the fineness / maturity parameters, i.e. micronaire reading, linear density, maturity % and maturity ratio showed highly significantly and positively correlation with each other. The standard linear density exhibited highly significantly and positively correlations with each other. The standard linear density exhibited highly significantly and positively correlations with each of micronaire reading, linear density and insignificant positive correlations with other fineness / maturity parameters.

From the above relationships, it could be concluded that the trend of the relationships between the fineness / maturity parameters differ from LS to ELS to LS + ELS categories.

4.1.3. The relationships between fiber tensile parameters

Considering the tensile parameters, i.e. the bundle strength, elongation, stiffness and toughness of LS categories as shown in Table (2), the strength showed insignificant negative correlation with elongation %. While highly significant and positive correlations existed between the strength and each of the stiffness and the toughness. Meanwhile, the elongation % exhibited highly significant and negative and positive correlations with each of stiffness and toughness, respectively, Nevertheless, the stiffness showed insignificant negative correlation with toughness.

In case of ELS category as in Table (3) highly significant and positive correlation existed between strength and elongation %. The stiffness exhibited highly significant and negative and insignificant and negative correlations with each of elongation % and strength, respectively. Meanwhile, the toughness showed highly significant and positive correlations with each of strength and elongation %. Highly significant and negative correlation was found between stiffness and toughness.

In case of combined LS + ELS categories, no correlation exists between fiber strength and elongation % as shown in Table (4). The strength exhibited highly significant and positive correlations with each stiffness and toughness. Meanwhile, elongation % showed highly significant and negative and highly significant and positive with each of stiffness and toughness, respectively. The stiffness did not correlated significantly with stiffness.

From the above results, the correlation between fiber bundle strength and elongation % differ from LS and combined LS + ELS categories to ELS category. The stiffness and toughness did not show definite trends for r's.

4.1.4. The relationships between fiber length and fineness/maturity parameters

With respect to LS categories, as shown in Table (2), no significant correlations could be detected between any of length and fineness/ maturity parameters. However, it is observed, in general, that there are trends for positive relationships between the 2.5% and 50% span lengths as well as the uniformity ratio % and each of micronaire reading. Linear density, maturity ratio and each of micronaire reading. Linear density, maturity ratio and standard linear density. On the other hand, the floating fiber index exhibited negative insignificant relationships with each of micronaire reading, linear density, standard linear density and maturity ratio. The maturity % showed relatively lower insignificant correlation and positive.

It could be stated that the longer the fiber lengths, the uniform the length distribution and the less the floating fiber index %, the higher the maturity of fibers.

Considering ELS categore, as shown in Table (3), The 2.5% and 50% span lengths exhibited highly significantly and positive correlations with each of micronaire reading and linear density as well as the standard linear density of cotton fibers. Meanwhile, the length uniformity ratio % showed highly significantly and significantly negative correlations with maturity % and maturity ratio, respectively. The floating fiber index % showed significant and positive correlations with each of maturity % and maturity ratio.

From the above results for ELS category, it could be concluded that the associations between fiber length and fineness / maturity parameters were stronger than that found in LS category. The floating fiber index showed different trends in the two categories, where it was correlated insignificantly and negatively with fineness / maturity parameters in LS category, while it correlated significantly and positively in case of ELS category. In general, the longer the fibers the higher the fineness / maturity of these fibers. The relationships between fiber length and fineness / maturity parameters of ELS was stronger than that observed in LS category.

As shown, in Table (4), in case of estimating r's for both LS + ELS categories together, the results greatly differed from that estimated from each of LS and ELS categories separately. The 2.5% and 50% span lengths of the LS + ELS categories showed highly significantly and negative correlations with either linear density or standard linear density. Meanwhile, they correlated highly significantly and positively in case of ELS category. The micronaire reading showed insignificant and negative correlations with each of 2.5% and 50% span lengths, while the same correlations for LS or ELS categories gave different trends. The uniformity ratio exhibited significant and negative correlation with maturity %. The floating fiber index % showed insignificant and positive trends with all parameters of fineness / maturity with the exception of maturity %, where they correlated positively and highly significantly.

From the above results of LS, ELS and combined LS + ELS categories it could be concluded that results were mostly different from each of LS to ELS to combined LS + ELS categories.

4.1.5. The relationships between fiber length and bundle tensile parameters

As shown in Table (2), in case of LS category, only the toughness showed highly significant and positive, significant and positive, highly significant and negative correlations with 2.5% span length, 50% span length, uniformity ratio % and floating fiber index, respectively. Insignificant positive correlations were found between 2.5% and 50% span lengths and uniformity ratio between 2.5% and 50% span length and uniformity ratio and the other tensile parameters namely; bundle strength, elongation %, and stiffness. On the other hand, floating fiber index showed insignificant negative correlations with the above tensile parameters.

In general, as the 2.5% and 50% span lengths and uniformity ratio increased, the bundle strength, elongation % and toughness increased, too. Meanwhile, the increase in floating fiber index was associated by the reduction in bundle strength, elongation, stiffness and toughness.

However, in case of ELS category, Table (3), 2.5% span length correlated significantly and positively only with stiffness, meanwhile, it showed insignificant negative correlation with bundle strength, elongation and toughness.

The above relationships of the 2.5% span length gave an opposite trend to the relationships which were found in case of LS category.

The 50% span length showed significant negative correlations with each of elongation % and toughness, significant positive correlation with stiffness and insignificant negative trend with bundle strength.

Uniformity ratio % correlated highly significantly and negatively with each of bundle strength, elongation % and toughness, moreover, it correlated significantly and positively with stiffness.

From these results of ELS category, it is clear that the fiber length parameters did not show the same trends as in LS category of their correlations with fiber bundle tensile parameters, also, the most of these relationships were highly significant or significant.

Considering the combined LS + ELS categories, as in Table (4), highly significant and positive correlations were shown between the 2.5% and 50% span lengths and each of bundle strength and stiffness. Meanwhile, highly significant and positive and significant and positive correlations were detected between toughness and each of 2.5% span length and 50% span length, respectively. The uniformity ratio % did not show significant correlations with any of the fiber tensile parameters. Meanwhile, floating fiber index % exhibited significant and negative correlation with bundle toughness and insignificant and negative correlations with the other tensile parameters.

Obviously, the correlation coefficients between fiber length parameters and fiber tensile parameters differed from LS and ELS to combined LS + ELS.

4.1.6. The relationships between fiber fineness/maturity and fiber tensile parameters

With respect to LS category, as shown in Table (2), the fiber bundle strength showed highly significant and positive correlations with each of micronaire reading, linear density and maturity ratio %. Meanwhile, the bundle strength exhibited insignificant positive and negative correlations with each of maturity % and standard linear density, respectively. The fiber bundle elongation % correlated highly significantly and negatively and positively with each of maturity % and standard linear density, respectively. Meanwhile, tensile parameters exhibited insignificant and negative correlations with the other fineness / maturity parameters. Fiber bundle stiffness showed highly significant and positive correlation with maturity % and significant positive correlations with each of micronaire reading, linear density and maturity ratio. Moreover, significant and negative correlation was found between fiber bundle stiffness and standard linear density. Toughness showed insignificant positive correlations with fineness / maturity parameters and with the exception of maturity % which showed negative correlation.

In general, the above results proved that the more the mature the stronger, the less extensible and the stiffer the fibers in this category.

As far as ELS category is concerned, as in Table (3), standard linear density exhibited negative and significant correlations with each of bundle strength, elongation % and toughness. On the other hand, the bundle strength exhibited significant and positive correlation with stiffness. The micronaire reading revealed significant and positive correlation with stiffness and also showed insignificant and negative correlations with each of strength and elongation %. Linear density exhibited insignificant and negative correlations with each of strength and elongation %. Maturity % and maturity ratio showed insignificant positive correlations between each other and each of strength and elongation %. Stiffness and toughness exhibited different trends in the correlation between each other and each of fineness / maturity parameters.

From the above results, it is clear that general negative trend exists in the relationships between micronaire reading and each of strength and elongation %. The same trend was found, too, between linear density and each of strength and elongation %. On the other hand, each of maturity % and maturity ratio exhibited positive trends in their relationships with each of strength and elongation %. These results indicated that most of differences between the studied samples in this category may be due to the fineness in case of fineness / maturity parameters and the finer fiber is more stronger and extensible.

Considering the combined LS + ELS categories, as shown in Table (4), fiber bundle strength showed significant and negative correlation with micronaire reading and highly significant and negative correlation with linear density. The toughness exhibited significant and negative correlations with each of micronaire reading and linear density. The remained correlations between fineness . maturity parameters and fiber tensile parameters showed insignificant and negative r's. The results differed from LS to ELS to combined LS + ELS categories.

At the end of this argument, it could be seen that the longer the fibers the more the uniform the length distribution, the lower the floating fiber index %. However, the relationships between fiber fineness / maturity parameters as well as between the fiber bundle tensile parameters differ from LS to ELS to combined LS + ELS categories. Furthermore, the relationships between fiber length and fineness / maturity parameters, fiber length and bundle tensile parameters and fiber fineness / maturity and bundle tensile parameters differed from LS to ELS to combined EL + ELS categories.

In this respect, **Berkley (1945)** showed that the fiber physical properties are determined by its length. **Pillay and Shankaranaryana (1961)** showed that within variety, strength increased with increasing length. They added that increasing length decreased the elongation per unit load. **Kemp (1980)** reported that mature fiber are stronger than immature fibers. These results are in agreement with the results achieved in this study.

Based on the results of r's obtained in this section it was decided to sort out the physical fiber properties into two groups to be used in deriving of equations for predicting of yarn physical properties.

4.2. The relationships between physical properties of cotton spun yarns

Similar to the last section, the objective of this section is to study the nature of relationships between various physical properties of the cotton spun yarn, which will also help in the interpretation of the prediction equation of yarn from fiber properties which will be dealt with in the next section (4.3.).

As shown in Tables (5, 6 and 7), the physical properties of spun yarn of carded LS and ELS categories as well as ELS combed category are classified into three main groups; i.e. tensile properties (yarn strength, strength variation, elongation, elongation variation, stiffness and toughness), yarn evenness and yarn imperfections (i.e. number of thin places, thick places and neps/100 meters of the spun yarns).

Table 5. The means of the physical properties of carded yarns spun from long-stapled (LS) varieties into different counts at two levels of twist multiplier.

Varieties	Count	Twist multiplier	Yarn tensile properties: Strength (g/Tex)	Breaking load (CV%)	Elongation %	Elongation CV%	Stiffness (g/Tex)	Toughness (g/Tex)	Evenness (CV%)	Number of yarn imperfection /100 meters: Thin places	Thick places	Neps
Giza 75	30^S	3.6	16.57	10.73	8.40	9.03	197	0.70	18.57	33	50	33
		4.4	16.60	10.10	8.60	9.03	227	0.71	18.60	37	50	31
	40^S	3.6	14.87	11.70	6.50	10.37	229	0.48	20.70	49	59	36
		4.4	15.00	11.40	6.10	9.80	244	0.46	20.20	57	69	33
	60^S	3.6	13.03	14.37	4.93	11.33	264	0.34	22.37	116	156	105
		4.4	13.13	14.60	5.23	11.30	252	0.35	22.43	116	148	97
	80^S	3.6	11.00	15.77	4.47	11.83	250	0.24	27.93	190	327	257
		4.4	11.10	15.10	4.73	11.50	239	0.26	27.33	175	276	275
Giza 83	30^S	3.6	13.17	17.57	8.17	12.30	162	0.54	19.87	38	70	50
		4.4	13.53	17.37	8.47	12.57	158	0.56	19.73	39	56	35
	40^S	3.6	11.85	19.73	8.00	14.03	147	0.45	24.53	163	154	141
		4.4	11.97	20.07	7.73	13.50	155	0.47	24.80	224	344	281
	60^S	3.6	10.83	23.73	7.73	15.60	140	0.42	30.60	313	340	385
		4.4	10.27	23.23	8.00	15.43	126	0.41	31.33	344	441	275
	80^S	3.6	7.63	25.33	6.17	16.80	124	0.23	32.87	362	426	507
		4.4	8.37	25.27	6.30	16.40	132	0.26	33.40	432	465	409
Giza 85	30^S	3.6	15.13	11.10	9.87	10.03	154	0.72	18.20	35	50	34
		4.4	16.03	10.13	9.73	9.93	164	0.84	18.23	48	34	32
	40^S	3.6	13.60	12.07	9.33	11.63	147	0.64	20.03	49	99	70
		4.4	14.93	11.63	9.50	11.07	157	0.71	20.70	67	81	67
	60^S	3.6	11.83	14.03	8.43	12.27	140	0.50	24.57	93	217	101
		4.4	13.07	13.27	8.67	11.70	150	0.57	24.70	112	212	96
	80^S	3.6	8.93	17.03	7.47	13.17	120	0.34	27.00	111	268	200
		4.4	9.80	15.97	7.53	12.03	130	0.37	27.40	146	245	172

Table 6. The means of the physical properties of carded yarns spun from extra long-stapled (ELS) varieties into different counts at two levels of twist multiplier.

Varieties	Count	Twist multiplier	Yarn tensile properties						Evenness (CV%)	Number of yarn imperfection /100 meters		
			Strength (g/Tex)	Breaking load (CV%)	Elongation %	Elongation CV%	Stiffness (g/Tex)	Toughness (g/Tex)		Thin places	Thick places	Neps
Giza 70	40^S	3.6	18.07	11.13	8.40	8.17	215	0.76	20.07	93	114	188
		4.4	18.27	11.40	8.57	8.47	213	0.79	20.73	111	163	176
	60^S	3.6	15.67	11.93	8.30	10.20	188	0.65	21.83	121	201	230
		4.4	16.00	11.80	8.57	9.47	187	0.69	22.43	140	202	242
	80^S	3.6	13.83	14.17	6.37	13.30	216	0.44	26.10	241	211	320
		4.4	13.83	13.67	6.60	13.60	209	0.46	26.60	240	194	365
	100^S	3.6	12.33	15.70	5.10	15.37	248	0.32	28.90	310	431	434
		4.4	12.27	15.33	5.53	12.13	221	0.34	31.00	331	374	462
Giza 77	40^S	3.6	18.00	11.43	8.50	8.30	212	0.76	18.67	34	106	120
		4.4	17.13	10.93	8.60	8.83	199	0.74	20.23	97	85	105
	60^S	3.6	15.63	13.13	8.13	10.00	193	0.63	21.33	50	127	156
		4.4	14.37	14.03	7.20	10.93	200	0.52	23.47	172	300	166
	80^S	3.6	13.47	15.03	6.27	13.77	214	0.42	24.23	93	193	192
		4.4	12.97	17.80	5.03	15.50	259	0.32	25.97	180	229	239
	100^S	3.6	12.20	17.67	5.03	15.37	243	0.31	27.57	181	300	373
		4.4	11.10	19.73	4.60	17.13	277	0.26	29.73	228	301	337
Giza 84	40^S	3.6	18.87	12.30	9.07	8.63	208	0.85	18.37	48	84	75
		4.4	18.70	12.47	9.37	9.17	200	0.88	19.03	97	66	89
	60^S	3.6	16.83	13.60	8.77	9.40	192	0.74	21.20	59	137	93
		4.4	16.43	14.60	8.63	10.10	189	0.71	22.97	108	180	162
	80^S	3.6	14.33	14.57	6.93	13.43	207	0.47	24.20	75	170	172
		4.4	13.73	15.80	6.97	13.80	197	0.48	24.77	105	184	164
	100^S	3.6	13.13	17.60	6.37	15.53	207	0.42	25.77	131	234	212
		4.4	11.73	18.33	6.40	16.80	196	0.37	27.60	198	276	252

Table 7. The means of the physical properties of combed yarns spun from extra long-stapled (ELS) varieties into different counts at two levels of twist multiplier.

Varieties	Count	Twist multiplier	Yarn tensile properties: Strength (g/Tex)	Breaking load (CV%)	Elongation %	Elongation CV%	Stiffness (g/Tex)	Toughness (g/Tex)	Evenness (CV%)	Number of yarn imperfection /100 meters: Thin places	Thick places	Neps
Giza 70	60^s	3.6	18.87	10.03	8.87	7.77	207	0.83	20.10	54	152	151
		4.4	17.70	10.73	8.47	8.67	208	0.75	20.13	65	144	153
	80^s	3.6	17.47	10.23	8.33	12.13	210	0.73	24.00	162	210	254
		4.4	16.17	11.90	7.80	12.37	204	0.63	24.07	194	248	252
	100^s	3.6	16.57	11.80	7.83	12.30	217	0.65	26.97	216	283	355
		4.4	15.33	12.57	6.73	13.67	229	0.54	27.13	264	282	358
	120^s	3.6	15.20	14.20	5.73	14.97	267	0.44	29.53	260	323	403
		4.4	14.35	15.07	5.53	15.93	244	0.40	29.67	325	355	425
	140^s	3.6	14.43	14.70	5.23	16.03	276	0.38	32.03	334	385	458
		4.4	12.60	17.70	4.70	17.43	269	0.30	32.27	381	390	471
Giza 77	60^s	3.6	17.93	11.93	8.73	7.93	205	0.78	19.83	77	118	125
		4.4	17.20	12.23	8.50	8.10	203	0.73	20.03	36	114	133
	80^s	3.6	16.30	12.83	7.97	12.63	204	0.65	23.03	94	169	163
		4.4	15.63	12.73	7.67	13.00	206	0.60	23.07	182	166	168
	100^s	3.6	15.67	13.27	7.17	13.77	219	0.56	24.10	118	203	262
		4.4	15.23	13.17	6.43	14.30	238	0.49	24.20	208	218	278
	120^s	3.6	14.97	14.27	6.30	14.50	240	0.47	25.90	173	240	321
		4.4	14.83	14.87	6.03	14.77	237	0.46	26.20	252	233	344
	140^s	3.6	13.53	17.73	5.30	15.73	258	0.40	26.97	213	275	388
		4.4	13.33	17.60	5.40	16.60	246	0.37	27.10	368	266	391
Giza 84	60^s	3.6	19.47	9.30	9.77	7.50	199	0.90	19.70	22	57	65
		4.4	18.80	10.63	8.97	7.73	210	0.85	19.87	31	61	67
	80^s	3.6	19.33	10.33	9.07	8.93	214	0.88	21.17	54	100	122
		4.4	17.07	10.93	8.20	10.30	213	0.71	21.23	93	96	117
	100^s	3.6	17.30	11.40	8.87	13.23	195	0.77	24.13	118	139	154
		4.4	16.53	12.93	7.57	13.50	210	0.63	24.17	149	157	160
	120^s	3.6	15.80	13.10	7.40	14.20	213	0.59	25.10	135	180	227
		4.4	15.90	14.33	6.60	14.60	240	0.53	24.97	166	200	226
	140^s	3.6	13.87	15.80	5.80	15.03	244	0.40	25.90	165	206	322
		4.4	14.10	17.47	5.27	15.57	268	0.37	25.87	169	211	338

The coefficient of simple correlations between various physical properties of the cotton spun yarn

The values of r between various yarn properties are presented in Tables (8, 9, 10 and 11) for carded LS, ELS, combined LS + ELS and combed ELS categories, respectively. Each group of yarn properties are discussed for all the above categories as follows:

4.2.1. Yarn tensile properties and evenness

For LS carded yarns (Table, 8), ELS carded yarn (Table, 9), for LS+ELS carded yarns (Table, 10) and for ELS combed yarns (Table, 11), it could be stated that; the yarn evenness (C.V.%) correlated negatively and highly significantly with yarn strength, yarn elongation, yarn stiffness and yarn toughness in all carded and combed yarns spun from all categories with the exception of stiffness in case of combing LS and ELS carded yarns together where it was insignificant and in case of combed ELS yarns, where the evenness showed positively and highly significant correlation with the yarn stiffness. On the other hand, the yarn evenness showed positively and highly significant correlation with each of strength variation and elongation variation in all categories of carded and combed yarns. This implies that the more even, the stronger, more extensible, more stiffer and more toughness the yarn. On the other hand, there is a strong relation between mass variation and each of strength and extension varieties of the yarn. The results are in agreement with those of **Garawin (1971)** who found that the coefficient of correlation between yarn unevenness (C.V.%) and strength variations (C.V.%) was 0.96 between varieties. **Zaher *et al.* (1975)** found that as the yarn become finer, the yarn evenness decreased, elongation decreased while elongation (C.V.%) increased. **Abd El-Mohsen (1978)** also reported that there is association between yarn unevenness and strength variation.

Table 8. Coefficient of simple correlations (r) between various physical properties of carded yarns spun from long-stapled cotton varieties (LS).

Yarn properties	Breaking load (CV%)	Elongation %	Elongation (CV%)	Stiffness (g/Tex)	Toughness (g/Tex)	Evenness (CV%)	No. of thin places /100 meters	No. of thick places /100 meters	No. of neps /100 meters
Strength (g/Tex)	-0.85**	0.49**	-0.85**	0.61**	0.81**	-0.92**	-0.84**	-0.91**	-0.92**
Breaking load (CV%)		-0.40**	0.93**	-0.57**	-0.66**	0.79**	0.76**	0.80**	0.85**
Elongation (%)			-0.25*	-0.28*	0.89**	-0.57**	-0.54**	-0.51**	-0.51**
Elongation (CV%)				-0.68**	-0.56**	0.78**	0.76**	0.80**	0.82**
Stiffness (g/Tex)					0.11	-0.48**	-0.42**	-0.50**	-0.78**
Toughness (g/Tex)						-0.82**	-0.77**	-0.77**	-0.48**
Evenness (CV%)							0.93**	0.96**	0.93**
Number of thin places/100 meters								0.93**	0.92**
Number of thick places/100 meters									0.95**

Table 9. Coefficient of simple correlations (r) between various physical properties of carded yarns spun from extra long-stapled cotton varieties (ELS).

Yarn properties	Breaking load (CV%)	Elongation %	Elongation (CV%)	Stiffness (g/Tex)	Toughness (g/Tex)	Evenness (CV%)	No. of thin places /100 meters	No. of thick places /100 meters	No. of neps /100 meters
Strength (g/Tex)	-0.88**	0.91**	-0.92**	-0.36**	0.97**	-0.95**	-0.72**	-0.83**	-0.77**
Breaking load (CV%)		-0.80**	0.92**	0.37**	-0.86**	0.83**	0.54**	0.72**	0.53**
Elongation (%)			-0.85**	-0.65**	0.97**	-0.88**	-0.67**	-0.78**	-0.76**
Elongation (CV%)				0.36**	-0.90**	0.88**	0.63**	0.73**	0.66**
Stiffness (g/Tex)					-0.50**	-0.40**	0.34**	0.34**	0.42**
Toughness (g/Tex)						-0.93**	-0.70**	-0.82**	-0.78**
Evenness (CV%)							0.83**	0.86**	0.85**
Number of thin places/100 meters								0.77**	0.86**
Number of thick places/100 meters									0.78**

Table 10. Coefficient of simple correlations (r) between various physical properties of carded yarns spun from long-stapled and extra long-stapled cotton varieties.

Yarn properties	Breaking load (CV%)	Elongation %	Elongation (CV%)	Stiffness (g/Tex)	Toughness (g/Tex)	Evenness (CV%)	No. of thin places /100 meters	No. of thick places /100 meters	No. of neps /100 meters
Strength (g/Tex)	-0.83**	0.60**	-0.83**	0.27**	0.88**	-0.83**	-0.66**	-0.73**	-0.57**
Breaking load (CV%)		-0.56**	0.86**	-0.21*	-0.75**	0.79**	0.67**	0.73**	0.63**
Elongation (%)			-0.60**	-0.52**	0.89**	-0.69**	-0.59**	-0.59**	-0.59**
Elongation (CV%)				-0.14	-0.79**	0.80**	0.67**	0.68**	0.63**
Stiffness (g/Tex)					-0.16	-0.07	-0.01	-0.08	0.06
Toughness (g/Tex)						-0.84**	-0.69**	-0.73**	-0.64**
Evenness (CV%)							0.89**	0.92**	0.86**
Number of thin places/100 meters								0.88**	0.89**
Number of thick places/100 meters									0.88**

Table 11. Coefficient of simple correlations (r) between various physical properties of combed yarns spun from long-stapled and extra long-stapled cotton varieties.

Yarn properties	Breaking load (CV%)	Elongation %	Elongation (CV%)	Stiffness (g/Tex)	Toughness (g/Tex)	Evenness (CV%)	No. of thin places /100 meters	No. of thick places /100 meters	No. of neps /100 meters
Strength (g/Tex)	-0.93	0.91**	-0.91**	-0.63**	0.96**	-0.78**	-0.70**	-0.75**	-0.81**
Breaking load (CV%)		-0.91**	0.89**	0.70**	-0.93**	0.76**	0.64**	0.66**	0.75**
Elongation (%)			-0.93**	-0.85**	0.98**	-0.83**	-0.73**	-0.78**	-0.85**
Elongation (CV%)				0.76**	-0.94**	0.85**	0.76**	0.76**	0.83**
Stiffness (g/Tex)					-0.79**	0.69**	0.58**	0.59**	0.68**
Toughness (g/Tex)						-0.83**	-0.73**	-0.78**	-0.85**
Evenness (CV%)							0.90**	0.90**	0.92**
Number of thin places/100 meters								0.90**	0.90**
Number of thick places/100 meters									0.94**

4.2.2. Yarn tensile properties and imperfections

As shown in Tables (8, 9, and 11), there are negative and highly significant correlations between the number of imperfections i.e. number of thin places, thick places and nep/100 meters of the carded and combed spun from the two categories individually or together with yarn strength, elongation and toughness. However, the relationships between yarn imperfections and stiffness were insignificant in case of carded yarn spun from LS and ELS categories, and were positively and highly significant in case of combed yarn spun from the ELS category. On the other hand, positively and highly significant correlations existed between the number of imperfection and each of strength variation and elongation variation. The results signify that the higher number of imperfections the lower the strength, elongation, stiffness and toughness and the higher the variation in yarn strength and elongation. However, in case of ELS combed yarns the stiffness showed different behaviour which could be attributed to the effect of combing in improving the yarn strength and strength variation.

The results confirmed those of others such as **Patel *et al.* (1967)** who found that the single yarn strength was directly dependent on the yarn imperfections.

4.2.3. Yarn imperfections and evenness

As shown in Tables (8, 9, 10 and 11), the number of imperfections showed positive and highly significant correlations with evenness of carded yarns spun from LS, ELS and LS + ELS categories together, as well as combed yarns spun from ELS category. The results implied that the higher the number of imperfections the higher the unevenness of the yarn spun from LS, ELS, LS + ELS corded or ELS combed categories. The results are in agreement with **Patel (1967)** who found that the unevenness measured by Uster index of the combed cotton bore a close relationship to the count of the thick and thin places measured on the Uster imperfection indicator. **Nawar (1979)** found that the more even the yarn the lower the number of imperfections in this yarn and vice-versa. **Kemp (1980)** reported that the presence of the neps in the yarn caused by immature fibers contributes to yarn unevenness and giving poor appearance. **Abd El-Mohsen (1983)** also, showed that nep count increased yarn unevenness.

Briefly speaking, the more the even, the less imperfected and less variation in strengthen elongation, the stronger, more extensible and the toughier the carded yarns spun from LS, ELS, LS+ELS categories or combed yarn spun from ELS varieties. However, the stiffness behaved differently from LS to ELS to LS+ELS carded yarns and from ELS carded to combed yarns.

Based on the above discussion, three yarn properties were chosen as important with respect to various end uses namely; yarn strength (g/tex), yarn evenness (CV%) and number of neps/100 meters of spun yarn to be predicted from the two groups of fiber properties selected on the bases of the values of r's between various fiber properties as mentioned in the last section of the results and discussion.

4.3. The relationships between cotton fiber and yarn physical properties

The physical properties of the cotton spun yarns are determined by the physical properties of the cotton fibers from which these yarns are spun, the mechanical processing through successive spinning machinery and the interactions between the physical properties of the cotton fibers and the spinning mechanical processes.

Therefore, in this section of the results and discussion, in order to find the best equations to predict yarn physical properties from fiber physical properties, the coefficients of multiple correlations (R^2) were estimated for two groups of fiber properties i.e. G_1 and G_2 based on selecting the various measurements for testing each fiber property mentioned in the materials and methods with single yarn strength (g/tex), yarn evenness (CV%) and yarn neps/100 meters. These yarns were spun into two 40^s and 60^s in case of carded LS category and 60^s and 100s in case of ELS category. In all cases, the twist factor was fixed at 3.6. Other statistical parameters, namely, MSE mean squares of error, Cp, indicate the suitable number of X's or fiber properties in the model) were used in addition to R^2 to select the best model.

4.3.1. Single yarn strength (g/tex)

As shown in Table (12), regarding group No. 1 of fiber properties and 40s yarn, eight equations (1 to 8) representing different combinations of G_1 fiber properties were indicated in this table. It is clear that the fiber bundle strength (X_{10}) alone, equation 1, showed a value of 0.9057 for R^2 and the highest values of 0.192 and 141.68 for MSE and Cp, respectively. Adding the micronaire reading (X_5) variable to the multiple regression estimation, equation 2, the R^2 slightly increased by 0.0348 whereas the MSE and Cp substantially decreased by 0.058 and 53.58 , respectively. Adding to the multiple regression estimation the fiber length uniformity (X_3) variable in equation 3, a slight increase of 0.0094 in R^2 was shown, meanwhile MSE and Cp decreased slight by 0.007 and 12.92, respectively. In equation No. 4 including fiber length uniformity (X_3) fiber bundle strength (X_{10}) and fiber elongation % (X_{11}), resulted in a slight increase in R^2 of 0.0062, and and fiber elongation % (X_{11}), resulted in a slight increase in R^2 of 0.0062, and slight decrease in both MSE and Cp of 0.015 and 9.79, respectively. In case of equation No. 5 which combined 2.5% span length (X_1), fiber length uniformity ratio (X_3) and fiber bundle elongation % (X_{11}), the R^2 value increased by 0.0139, whereas the MSE and Cp decreased by 0.036 and 22.02, respectively. As far as these three equations namely; 3, 4, and 5 which included three fiber variables, are concerned, equation No. 5 seems to be the best based on the R^2, MSE and Cp values.

Table 12. Forward selection procedure for depended variable yarn strength for 40^S and 60^S counts of LS category from G_1 of physical fiber properties.

	Variable entered	Number in	R^2	MSE	Cp	B0	Fiber 2.5% span length X_1	Fiber uniformity X_3	Fiber floating index X_4	Micronaire reading X_5	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability >F	No.
							40^S Count (Y_1A)							
1	X_{10}	1	0.9057	0.192	141.68	-1.99					0.51		0.0001	1
2	X_5 X_{10}	2	0.9405	0.134	88.40	4.72				-3.88	0.85		0.0001	2
3	X_3, X_5, X_{10}	3	0.9499	0.127	75.48	-5.77		0.21		-3.18	0.74		0.0001	3
4	X_3, X_{10}, X_{11}	3	0.9561	0.112	65.69	-31.99		0.81			0.26	-0.51	0.0001	4
5	X_1, X_3, X_{11}	3	0.9700	0.076	43.67	-55.43	0.82	0.99				-1.08	0.0001	5
6	X_1, X_3, X_4, X_{11}	4	0.9846	0.045	22.49	-133.26	1.75	1.83	0.45			-0.82	0.0001	6
7	X_1, X_3, X_4, X_5, X_{11}	5	0.9968	0.011	5.04	-151.38	2.34	2.02	0.50	-1.93		-1.17	0.0001	7
8	X_1, X_3, X_4, X_5, X_{10}, X_{11}	6	0.9968	0.013	7.00	-155.09	2.39	2.07	0.51	-1.85	-0.02	-1.19	0.0001	8
							60^S Count (Y_1B)							
1	X_{10}	1	0.9336	0.084	13.96	0.13					0.41		0.0001	9
2	X_5, X_{10}	2	0.9407	0.083	13.60	2.24				-1.38	0.53		0.0001	10
3	X_1,X_5,X_{10}	3	0.9476	0.082	13.33	7.19	-0.19			-1.45	0.57		0.0001	11
4	X_1, X_{10}, X_{11}	3	0.9726	0.043	5.07	20.78	-1.03				0.66	0.57	0.0001	12
5	X_1, X_3, X_{10}, X_{11}	4	0.9789	0.038	5.05	33.88	-1.22	-0.25			0.79	0.85	0.0001	13
6	X_1, X_3, X_5, X_{10}, X_{11}	5	0.9838	0.034	5.36	38.08	-1.19	-0.32		-1.26	0.91	0.86	0.0001	14
7	X_1, X_3, X_4, X_5, X_{10}, X_{11}	6	0.9849	0.038	7.00	63.38	-1.54	-0.60	-0.12	-1.47	0.98	0..89	0.0001	15

In case of equation 6 in which the 2.5% span length (X_1), fiber uniformity ratio (X_3), floating fiber index (X_4) and fiber bundle elongation (X_{11}) were combined in the multiple regression estimation, the magnitude of increase and decrease with respect to equation No. 5 in R^2, MSE and Cp were 0.0122, -0.31 and -21.18, respectively. Equation No. 7 in which the micronaire reading was added to the variables in equation No. 6, the R^2 increased and MSE and Cp decreased with respect to their corresponding in case of equation No. 6 by 0.0122, -0.034 and -17.45, respectively. In case of equation No. 8 which combined the total six fiber properties of G_1, no change exist in R^2 while MSE slightly decreased by 0.003 and Cp increased by 1.96. Based on the above discussion, equation No. 7 is the best one according to the three statistical parameters i.e.; R^2, MSE and Cp.

$$Y_1A = -151.38 + 2.34X_1 + 2.02X_3 + 0.50X_4 + (-1.94X_5) + (-1.17X_{11}) \quad (7)$$

With respect to 60^s carded yarn and G_1 fiber properties, it is quite clear that in case of one variable namely, the bundle strength (X_{10}), R^2 showed relatively higher value compared with that in case of 40^s yarn count (equation No. 1). In all equations (9 to 15) the MSE and Cp values exhibited sharp decrease compared with their corresponding in equations (1 to 8) of 40^s count. This implies that the prediction of yarn strength from G_1 fiber properties is more precise in case of 60^s than 40^s yarn count.

Discussing the seven equations (9 to 15), it is noticed that substituting the fiber length uniformity (X_3) in equation No. 3 and No. 4 which contains three variables by 2.5% span length (X_1) in equations No. 11 and 12 increased R^2 and decreased MSE and Cp values which imply the relative higher importance of (X_1) than (X_3) in case of 60^s yarn count.

Equation No. 14 in which the fiber variables X_1, X_3, X_5, X_{10} and X_{11} were combined seems to be the best one.

$$Y_1B = 38.08 + (-1.19X_1) + (-0.32X_3) + (-1.26X_5 + 0.91X_{10} + 0.86X_{11}) \quad \textbf{(14)}$$

Considering the prediction equation for yarn strength of 40^s (equation No 16 to No. 23) and 60^s (equations No. 24 to No. 30) from G_2 of fiber properties, Table (13), the fiber bundle strength (X_{10}) came first also in case of the two 40^s and 60^s similar to the case of G_1 fiber properties. The yarn strength could be predicted from fiber strength alone but with much less precision. As in case of G_1, the R^2 increased in 60^s count than 40^s count in case of one variable (X_{10}) or two variables. The MSE and Cp decreased sharply in case of 60^s count than their corresponding in case of 40^s count. This implies that the two fiber groups G_1 and G_2 followed the same trend in the two yarn counts. Moreover, The yarn count is more effective in determining the precision of the equation for predicting the strength of the yarn spun from LS category.

The best equations for predicting yarn strength from G_2 fiber properties were equation No. 20 and equation No. 29 for the 40^s and 60^s yarn counts, respectively.

$$Y_1C = -61.23 + 0.99X_3 + 0.16X_6 + (-0.62X_{11}) \quad \textbf{(20)}$$

$$Y_1D = -50.42 + (-3.93X_2) + 1.66\,X_3 + 0.26X_6 + (-0.27X_7) + 0.58X_{10} \quad \textbf{(29)}$$

As far as the extra long-stapled (ELS) category are considered, Table (14), showed relatively higher R^2 values in case of 60^s compared with 100^s particularly in case of the first four equations of 60^s and 100^s counts. On the other hand, the MSE and Cp values were lower in case of 60^s than 100^s counts. The best equations for predicting the strength of 60s and 100s yarn counts from the G1 fiber properties based on the values of R^2, MSE and Cp are the equation No. 32 and the equation No. 45, respectively. It is noticed that fiber strength variable came first in case of 60^s count while fiber elongation % variable came first in case of 100^s

Table 13. Forward selection procedure for depended variable yarn strength for 40^S and 60^S counts of LS category from G_2 of physical fiber properties.

	Variable entered	Number in	R^2	MSE	Cp	B0	Fiber 50% span length X_2	Fiber uniformity X_3	Fiber linear density (millitex) X_6	Maturity % X_7	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability > F	No.
							40^S Count (Y_1C)							
1	X_{10}	1	0.9057	0.192	10.89	-1.20					0.51		0.0001	16
2	X_3, X_{10}	2	0.9289	0.160	8.24	-15.22		0.32			0.44		0.0001	17
3	X_3, X_7, X_{10}	3	0.9573	0.108	4.54	-32.38		0.56		0.11	0.27		0.0001	18
4	X_3, X_6, X_7	3	0.9642	0.091	3.16	-62.67		0.72	0.16	0.14			0.0001	19
5	X_3, X_6, X_{11}	3	0.9726	0.069	1.48	-61.23		0.99	0.16			-0.62	0.0001	20
6	X_3, X_6, X_{10}, X_{11}	4	0.9736	0.077	3.28	-70.95		1.10	0.21		-0.09	-0.69	0.0001	21
7	X_3, X_6, X_7, X_{10}, X_{11}	5	0.9749	0.085	5.02	-77.05		1.31	0.24	-0.08	-0.15	-1.06	0.0001	22
8	X_2, X_3, X_6, X_7, X_{10}, X_{11}	6	0.9750	0.101	7.00	-83.70	-0.31	1.45	0.28	-0.09	-0.16	-1.06	0.0007	23
							60^S Count (Y_1D)							
1	X_{10}	1	0.9336	0.084	31.65	0.13					0.41		0.0001	24
2	X_6, X_{10}	2	0.9576	0.059	19.31	21.73			-0.16		0.61		0.0001	25
3	X_3, X_6, X_{10}	3	0.9597	0.063	20.06	27.84		-0.08	-0.18		0.65		0.0001	26
4	X_3, X_6, X_7, X_{10}	4	0.9645	0.064	19.19	35.97		-0.17	-0.20	-0.04	0.73		0.0001	27
5	X_2, X_3, X_7, X_{10}	4	0.9840	0.029	7.56	-1.51	-2.00	0.73		-0.16	0.71		0.0001	28
6	X_2, X_3, X_6, X_7, X_{11}	5	0.9916	0.018	5.03	-50.42	-3.93	1.66	0.26	-0.27	0.58		0.0001	29
7	X_2, X_3, X_6, X_7, X_{10}, X_{11}	6	0.9916	0.021	7.00	-49.34	-3.94	1.63	0.26	-0.26	0.60	0.06	0.0001	30

Table 14. Forward selection procedure for depended variable yarn strength for 60^S and 100^S counts of ELS category from G_1 of physical fiber properties.

	Variable entered	Number in	R^2	MSE	Cp	B0	Fiber 2.5% span length X_1	Fiber uniformity X_3	Fiber floating index X_4	Micronaire reading X_5	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability > F	No.
	60^S Count (Y_1E)													
1	X_{10}	1	0.6987	0.1344	5.46	-2.84					0.53		0.0007	31
2	X_1 X_{10}	2	0.8787	0.0601	-0.58	14.23	-0.33				0.38		0.0001	32
3	X_1, X_5, X_{10}	3	0.8849	0.0642	1.14	16.53	-0.49			0.75	0.39		0.0004	33
4	X_1, X_5, X_{10}, X_{11}	4	0.8874	0.0717	3.03	18.01	-0.61			1.20	0.46	-0.25	0.0020	34
5	X_1, X_4, X_5, X_{10}, X_{11}	5	0.8881	0.0832	5.00	15.04	-0.53		-0.03	1.00	0.48	-0.18	0.0081	35
6	X_1, X_3, X_4, X_5, X_{10}, X_{11}	6	0.8881	0.0998	7.00	14.13	-0.55	0.02	-0.02	1.06	0.49	-0.20	0.0279	36
	100^S Count (Y_1F)													
1	X_{11}	1	0.5832	0.1312	13.16	6.10						1.10	0.0038	37
2	X_5, X_{11}	2	0.6391	0.1263	12.33	9.96				-0.72		0.88	0.0102	38
3	X_3, X_5	2	0.6896	0.1086	9.76	44.04		-0.52		-1.36			0.0052	39
4	X_1, X_3	2	0.7687	0.0809	5.74	51.39	-0.34	-0.52					0.0014	40
5	X_1, X_3, X_{10}	3	0.8051	0.0767	5.89	80.19	-0.45	-0.84			-0.25		0.0033	41
6	X_1, X_4, X_{10}	3	0.8230	0.0697	4.99	41.62	-0.57		0.44		-0.37		0.0022	42
7	X_1, X_4, X_5, X_{10}	4	0.8790	0.5443	4.14	51.89	-1.02		0.51	1.98	-0.43		0.0025	43
8	X_1, X_4, X_5, X_{10}, X_{11}	5	0.8905	0.5744	5.56	59.44	-1.34		0.57	3.04	-0.37	-0.52	0.0076	44
9	X_1, X_3, X_4, X_5, X_{10}, X_{11}	6	0.9000	0.0620	7.00	39.38	-1.76	0.55	0.87	4.42	-0.34	-0.94	0.0207	45

count, also, the prediction of the strength of the coarser yarn 60^s was more precise than the finer 100^s yarn count.

In case of the ELS, 60^s and 100^s yarn count and G1 of physical properties the two equations for predicting yarn strength were:

$$Y_1E = 14.23 + (-0.33X_1) + 0.38X_{10}) \quad \textbf{(32)}$$

$$Y_1F = 39.38 + (-1.76X_1) + 0.55X_3 + 0.87X_4 + 4.42X_5 + (-0.34X_{10} + (-0.94X_{11}) \quad \textbf{(45)}$$

Also, in case of the ELS, 60^s and 100^s yarn counts and G2 physical properties the two equations for predicting yarn strength were equation No. 51 (Table, 15), the two equations for predicting yarn strength were equation No. 51 and equation No. 62 as follows:

$$Y_1H = -129.46 + (-3.89X_2) + 2.91X_3 + 0.14X_6 + 0.37X_7 + 0.44X_{10}) \quad \textbf{(52)}$$

$$Y_1L = 79.31 + 2.77X_2 + (-2.03X_5) + (-0.20X_6) + 0.32X_7 + (-0.17X_{10}) + (-0.47X_{11}) \quad \textbf{(62)}$$

The coarser yarn count 60^s is predicted precisely than the finer count 100^s.

In examining all the prediction equations for yarn strength of LS category 40s and 60^s counts and ELS category 60^s and 100^s counts from G1 and G2 of physical fiber properties, the fiber length, finesse/maturity and bundle tensile measurements were included in most of these equations, whatever the differences from one count to another or from LS to ELS categories. The results are in agreement with those stated by several authors such as **Balls (1928), El-Didi (1962), Samra (1970),** who showed strong and positive correlations between fiber strength and yarn strength. On the other hand, **Salama (1962)** and **Samra (1970)** found strong correlation between half-fall length and 2.5% span length respectively with yarn strength, the same two authors, too, found negative and strong correlation between each of linear density and micronaire reading, respectively with yarn strength.

Table 15. Forward selection procedure for depended variable yarn strength for 60^S and 100^S counts of ELS category from G_2 of physical fiber properties.

	Variable entered	Number in	R^2	MSE	Cp	B0	Fiber 50% span length X_2	Fiber uniformity X_3	Fiber linear density (millitex) X_6	Maturity % X_7	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability > F	No.
	60^S Count (Y_1H)													
1	X_2	1	0.8025	0.09	25.63	35.43	-1.08						0.0001	46
2	X_2, X_{10}	2	0.8508	0.07	19.41	21.59	-0.75				0.22		0.0002	47
3	X_6, X_{10}	2	0.8638	0.06	17.19	4.11			-0.03		0.45		0.0001	48
4	X_6, X_7, X_{10}	3	0.8952	0.06	13.85	0.10			-0.04	0.16	0.28		0.0003	49
5	X_3, X_6, X_7, X_{10}	4	0.9231	0.05	11.09	-51.74		0.63	-0.04	0.31	0.45		0.0002	50
6	X_2, X_3, X_7, X_{10}	4	0.9413	0.04	7.99	-70.96	-0.97	1.20		0.34	0.43		0.0002	51
7	X_2, X_3, X_6, X_7, X_{10}	5	0.9657	0.02	5.83	-129.46	-3.89	2.91	0.14	0.37	0.44		0.0003	52
8	X_2, X_3, X_6, X_7, X_{10}, X_{11}	6	0.9706	0.03	7.00	-127.60	-3.24	2.63	0.10	0.43	0.52	-0.37	0.0011	53
	100^S Count (Y_1L)													
1	X_2	1	0.6827	0.10	8.92	27.54	-0.84						0.0009	54
2	X_2, X_7	2	0.7938	0.07	4.83	16.25	-0.78			0.13			0.0008	55
3	X_6, X_7	2	0.8343	0.06	2.83	-6.19			-0.05	0.32			0.0003	56
4	X_6, X_7, X_{11}	3	0.8550	0.06	3.73	-9.50			-0.06	0.42		-0.48	0.0010	57
5	X_6, X_7, X_{10}, X_{11}	4	0.8598	0.06	5.47	-8.95			-0.06	0.44	-0.09	-0.36	0.0041	58
6	X_3, X_6, X_7, X_{10}	4	0.8798	0.05	4.40	38.19		-0.55	-0.06	0.26	-0.28		0.0025	59
7	X_2, X_3, X_6, X_7, X_{10}	5	0.8948	0.06	5.60	76.93	1.94	-1.68	-0.15	0.23	-0.27		0.0067	60
8	X_2, X_3, X_6, X_7, X_{11}	5	0.8957	0.05	5.56	67.42	3.29	-2.08	-0.22	0.37		-0.74	0.0066	61
9	X_2, X_3, X_6, X_7, X_{10}, X_{11}	6	0.9062	0.06	7.00	79.31	2.77	-2.03	-0.20	0.32	-0.17	-0.47	0.0185	62

Berkly and Barker (1947) as well as **Webb and Richerdson (1947)** gave evidence of the relative importance of fiber length to the strength of 60s count.

Durest (1956) showed the importance of micronaire reading and pressly index to the strength of the yarn, whereas, in **1962, El-Didi and Salama** showed that M.F.L./ Mic. Rd. and Half-fall length/linear density, respectively, correlated significantly with yarn strength.

Webb (1965) found that the fiber properties contributing to yarn strength differ from one length category to another, moreover, the fiber properties differ when bundle strength was assessed at 0" or 1/8" bundle.

Louis *et al.* (1968) reported that 50% span length was better in explaining the effect of length on yarn strength, nevertheless, they concluded that 2.5% or 50% span lengths with fiber tenacity, micronaire reading, length uniformity ratio and elongation in a descending order are the most important fiber properties contributing to yarn strength. **Abdul Sattar and Hussain (1985)** found that fiber length, fineness and strength contributed the best in a descending order to yarn strength.

Almashouly (1981) and **El-Tabbakh *et al.* (1985)** showed that the interaction between strength and length or strength x elongation of fiber had contributed to yarn strength, on the other hand, **Almashouly and Abed (1987)** showed that MFL and length variation explained 0.94 of the variation of yarn strength.

El-Tabbakh *et al.* (1985) and **Sawires *et al.* (1990)** showed that fiber properties contribution to yarn strength differ from LS to ELS categories.

4.3.2. Yarn evenness (CV%)

With respect to G1 fiber properties and 40^s yarn, Table (16), the 2.5% span length (X_1) equation No. 63 showed relatively lower R^2 and higher MSE and Cp values. Including the bundle strength with 2.5% span length in the multiple regression estimation resulted in an increase of 0.0415 in R^2 and substantial decrease in MSE of 0.163 and Cp of 18.66 as in equation No. 64. Substitution of X_1 by X_{11} in equation 65 resulted in an increase of R^2 of 0.0121 and decrease in MSE of 0.061 and Cp of 6.05. Comparing these two equations namely 64 and 65 which included only two fiber variables, the latter seems to be more reliable.

Equation 66 which combined the 2.5% span length (X_1), fiber bundle strength (X_{10}) and fiber bundle elongation (X_{11}) showed relatively higher R^2 and lower MSE and Cp.

Equation No. 66, 67 and 68 were nearly similar with respect to R^2, MSE and Cp. Equations 69 and 70 were approximately similar on the base of R^2, MSE and Cp values and both of them are the best for predicting safely the evenness of LS 40s carded yarn from G_1 fiber properties.

$$Y_7A = 251.21 + (-2.99X_1) + (-1.84X_3) + (-0.70X_4) + (-3.15X_5) + (-0.69X_{11}) \quad \textbf{(69)}$$

In case of LS 60^s carded yarn and G_1 fiber properties, Table (16), equation No. 71, the fiber elongation (X_{11}) came first instead of 2.5% span length, the fiber elongation (X_{11}) in case of LS 40^s carded yarn and showed relatively lower R^2 and higher MSE and Cp compared with the other equation (72 to 77). Including fiber bundle strength (X_{10}) and fiber bundle elongation (X_{11}), (equation No. 72), resulted in higher value of R^2 and sharply decrease in the value of MSE and Cp. Including the 2.5% span length (X_1) with fiber bundle strength (X_{10}) in equation No. 73 showed values approximately similar to those in equation No. 72 for R^2 and MSE and relatively lower value of Cp. Therefore, equation No. 73 is better than No. 72 as each of them including two fiber variables.

Table 16. Forward selection procedure for depended variable yarn evenness for 40^S and 60^S counts of LS category from G_1 of physical fiber properties.

	Variable entered	Number in	R^2	MSE	Cp	B0	Fiber 2.5% span length X_1	Fiber uniformity X_3	Fiber floating index X_4	Micronaire reading X_5	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability > F	No.
							40^S Count (Y_7A)							
1	X_1	1	0.9065	0.426	38.60	113.24	-3.02						0.0001	63
2	X_1, X_{10}	2	0.9480	0.263	19.94	100.94	-2.40				-0.23		0.0001	64
3	X_{10}, X_{11}	2	0.9601	0.202	13.89	54.26					-0.83	-1.48	0.0001	65
4	X_1, X_{10}, X_{11}	3	0.9711	0.164	10.40	75.29	-1.04				-0.58	-0.91	0.0001	66
5	X_1, X_5, X_{10}, X_{11}	4	0.9747	0.164	10.60	75.97	-0.92			-1.93	-0.44	-1.01	0.0001	67
6	X_1, X_3, X_5, X_{10}, X_{11}	5	0.9767	0.177	11.61	91.01	-1.11	-0.28		-2.38	-0.27	-0.72	0.0001	68
7	X_1, X_3, X_4, X_5, X_{11}	5	0.9894	0.081	5.29	251.21	-2.99	-1.84	-0.70	-3.15		-0.69	0.0001	69
8	X_1, X_3, X_4, X_5, X_{10}, X_{11}	6	0.9900	0.091	7.00	258.30	-3.40	-2.17	-0.80	-3.74	0.15	-0.53	0.0001	70
							60^S Count (Y_7B)							
1	X_{11}	1	0.7741	5.74	26.44	-2.53						5.14	0.0002	71
2	X_{10}, X_{11}	2	0.9384	1.74	3.38	26.75					-0.83	4.21	0.0001	72
3	X_1, X_{10}	2	0.9416	1.65	2.91	-110.33	7.00				-2.57		0.0001	73
4	X_1, X_{10}, X_{11}	3	0.9647	1.12	1.39	-49.84	3.80				-1.75	2.16	0.0001	74
5	X_1, X_5, X_{10}, X_{11}	4	0.9667	1.21	3.08	-48.64	4.02			-3.42	-1.51	1.99	0.0001	75
6	X_1, X_4, X_5, X_{10}, X_{11}	5	0.9669	1.40	5.05	-54.75	4.12		0.07	-3.58	-1.44	2.16	0.0002	76
7	X_1, X_3, X_4, X_5, X_{10}, X_{11}	6	0.9672	1.67	7.00	-119.96	5.00	0.78	0.36	-2.93	-1.66	1.99	0.0015	77

Equation No. 74 which combined 2.5% span length (X_1), fiber bundle strength (X_{10}) and elongation (X_{11}) showed an increase in R^2 and decrease in MSE and Cp compared with their corresponding values in equation No. 73.

Adding to the above fiber variables included in equation No. 74, the micronaire reading (X_5), in equation No. 75, the only difference was Cp value which increased than its corresponding in equation No. 74.

Adding the fiber floating index (X_4) to the above variables of equation No. 75 as in equation No. 76 resulted in a relatively higher MSE and Cp values.

Including all the six fiber properties as in equation 77 showed also slight increase in MSE compared with equation No. 76.

Equation No. 74 is the best one for predicting evenness of LS 60^S carded yarn from G_1 fiber properties.

$$Y_7B = -49.84 + 3.80X_1 + (-1.75X_{10}) + 2.16X_{11}) \quad \textbf{(74)}$$

The two equations for predicting evenness of 40^S count from G_1 fiber properties (No. 69 and 70) are more precise than equation No. 74 for predicting the evenness of LS 60s carded yarn.

Considering the prediction of evenness for LS 40^S and ^{60S} carded yarns from G_2 fiber properties, Table (17), the value of R^2 are in general higher in case of 40^S count when compared with the case of 60^S count, and in particular when comparing equations No. 78, 79, 80 of 40^S count with equations No. 86, 87, 88 of 60^S count. The SME was much lower in case of 40^S than in case of 60^S counts, Cp only, in case of equations No. 86 and 87 of 60^S count, its values were higher than in case of equations No. 78 and 79, however, in the remaining equations of 40^S and 60^S counts the values were comparable.

Table 17. Forward selection procedure for depended variable yarn evenness for 40^S and 60^S counts of LS category from G_2 of physical fiber properties.

	Variable entered	Number in	R^2	MSE	Cp	B0	Fiber 50% span length X_2	Fiber uniformity X_3	Fiber linear density (millitex) X_6	Maturity % X_7	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability > F	No.
	40^S Count (Y_1C)													
1	X_2	1	0.9307	0.316	7.75	75.51	-3.47						0.0001	78
2	X_2, X_6	2	0.9577	0.214	3.61	90.62	-2.92		-0.14				0.0001	79
3	X_2, X_6, X_{11}	3	0.9613	0.220	4.79	101.01	-2.33		-0.24			-0.35	0.0001	80
4	X_6, X_{10}, X_{11}	3	0.9694	0.174	2.96	80.14			-0.19		-0.60	-1.50	0.0001	81
5	X_2, X_6, X_{10}, X_{11}	4	0.9719	0.182	4.39	82.26	-0.89		-0.17		-0.43	-1.07	0.0001	82
6	X_2, X_6, X_7, X_{10}, X_{11}	5	0.9725	0.209	6.25	86.51	-0.64		-0.18	-0.05	-0.44	-1.35	0.0001	83
7	X_2, X_3, X_7, X_{10}, X_{11}	5	0.9764	0.179	5.36	50.56	-2.04	0.86		-0.19	-0.54	-1.64	0.0001	84
8	X_2, X_3, X_6, X_7, X_{10}, X_{11}	6	0.9780	0.200	7.00	6.11	-3.65	1.74	0.24	-0.31	-0.69	-1.81	0.0005	85
	60^S Count (Y_1D)													
1	X_7	1	0.8904	2.784	9.41	137.77				-1.30			0.0001	86
2	X_7, X_{11}	2	0.9093	2.561	8.42	101.86				-0.98		1.56	0.0001	87
3	X_{10}, X_{11}	2	0.9384	1.737	3.78	26.75					-0.83	4.21	0.0001	88
4	X_6, X_{10}, X_{11}	3	0.9520	1.523	3.62	-47.05			0.55		-1.50	4.28	0.0001	89
5	X_6, X_7, X_{10}, X_{11}	4	0.9560	1.597	4.99	-21.55			0.54	-0.29	-1.31	3.42	0.0001	90
6	X_2, X_6, X_7, X_{10}	4	0.9677	1.171	3.13	-8.70	5.27		0.38	-0.58	-2.10		0.0001	91
7	X_2, X_3, X_7, X_{10}	4	0.9684	1.147	3.02	64.13	8.35	-1.49		-0.40	-1.94		0.0001	92
8	X_2, X_3, X_7, X_{10}, X_{11}	5	0.9685	1.332	5.00	64.51	8.00	-1.58		-0.34	-1.87	0.44	0.0002	93
9	X_2, X_3, X_6, X_7, X_{10}, X_{11}	6	0.9685	1.599	7.00	63.54	7.96	-1.56	0.01	-0.34	-1.87	0.43	0.0003	94

Comparing equation No. 80 and 81 of the 40^s which included three fiber variables, the best of them is the later one (equation No. 81) in which fiber bundle strength (X_{10}) substituted the 50% span length (X_2) in equation No. 80. Preferring equation No. 81 was based on both lower MSE and Cp values.

Comparing, also, equations No. 83 and 84 which include the five fiber variables for predicting the evenness of 40^s carded yarn, the latter No. 84 is the best based on MSE and Cp values, in which the linear density was replaced by the length uniformity ratio (X_3).

In case of 60^s carded yarn the two equations including two fiber variables i.e. equations No. 87 and 88, the latter is the best of them in which bundle strength replaced the fiber maturity %, based also on the R^2, MSE and Cp values.

Considering the three equations No. 90, 91 and 92 including four fiber variables equation No. 92 is the best of the three in which 50% span length (X_2), length uniformity ratio (X_3), maturity % (X_7) and fiber bundle strength (X_{10}) were included.

In general, equations No. 81 and 92 are the best for predicting the evenness of 40^s and 60^s carded yarns from G_2 fiber properties, respectively.

$$Y_7C = 80.14 + (-0.19X_6) + (-0.60X_{10}) + (-1.50X_{11}) \quad \textbf{(81)}$$

$$Y_7D = 64.13 + 8.35X_2 + (-1.49X_3) + (-0.40X_7) + (-1.94X_{10}) \quad \textbf{(92)}$$

Examining the prediction equations of evenness for ELS category, 60^s and 100^s counts of carded yarns from G_1 of physical fiber properties, Table (18), it is quite clear that R^2, MSE and Cp values are higher in case of the finer 100^s yarn than their corresponding values in case of the coarser 60^s yarn. This implies that the role of fiber properties in determining the yarn evenness is more pronounced in case of coarser 60^s than finer 100^s yarns. The best single fiber variable for predicting

Table 18. Forward selection procedure for depended variable yarn evenness for 60^S and 100^S counts of ELS category from G_1 of physical fiber properties.

	Variable entered	Number in	R^2	MSE	Cp	B0	Fiber 2.5% span length X_1	Fiber uniformity X_3	Fiber floating index X_4	Micronaire reading X_5	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability > F	No.
							60^S Count (Y_7E)							
1	X_1	1	0.4908	0.07	12.92	12.56	0.26						0.0112	95
2	X_1, X_3	2	0.6181	0.06	9.69	22.75	0.27	-0.21					0.0131	96
3	X_3, X_{10}	2	0.7576	0.04	3.96	80.89		-0.82			-0.48		0.0017	97
4	X_1, X_3, X_{10}	3	0.8042	0.03	4.04	64.62	0.11	-0.66			-0.36		0.0033	98
5	X_1, X_3, X_4, X_{10}	4	0.8673	0.02	3.45	86.06	0.21	-1.18	-0.30		-0.24		0.0034	99
6	$X_1, X_3, X_4, X_5, X_{10}$	5	0.8760	0.03	5.09	88.63	0.35	-1.28	-0.36	-0.55	-0.22		0.0108	100
7	$X_1, X_3, X_4, X_5, X_{10}, X_{11}$	6	0.8783	0.03	7.00	90.70	0.50	-1.39	-0.44	-1.05	-0.24	0.19	0.0340	101
							100^S Count (Y_7F)							
1	X_1	1	0.8958	0.22	30.76	-21.40	1.41						0.0001	102
2	X_1, X_{10}	2	0.9208	0.19	23.44	-7.64	1.27				-0.26		0.0001	103
3	X_1, X_3, X_{10}	3	0.9581	0.11	11.60	69.64	1.04	-0.95			-0.83		0.0001	104
4	X_1, X_3, X_4, X_{10}	4	0.9782	0.07	6.10	118.70	1.26	-2.12	-0.69		-0.56		0.0001	105
5	$X_1, X_3, X_4, X_5, X_{10}$,	5	0.9821	0.06	6.66	125.66	1.63	-2.40	-0.86	-1.50	-0.50		0.0001	106
6	$X_1, X_3, X_4, X_5, X_{10}, X_{11}$	6	0.9866	0.06	7.00	137.36	2.47	-2.99	-1.26	-4.28	-0.61	1.09	0.0002	107

evenness was 2.5% span length (X_1) in case of 60s and 100^S carded yarns. Length uniformity ratio (X_3) with 2.5% span length (X_1) in case of equation No. 96 or with fiber bundle strength (X_{10}) in case of equation No. 97, the latter is the best of them based on R^2, MSE and Cp values.

In general, the best equation for predicting the evenness of ELS 60^S and 100^S carded yarns from G_1 fiber properties are equation No. 99 in case of 60^S yarn or equation No. 105 and 106 in case of 100^S yarn.

$$Y_7E = 86.06 + 0.21X_1 + (-1.18X_3) + (-0.30X_4) + (-0.24X_{10}) \quad \textbf{(99)}$$

$$Y_7F = 125.66 + 1.63X_1 + (-2.40X_3) + (-0.86X_4) + (-1.50X_5) + (-0.50X_{10}) \quad \textbf{(106)}$$

With respect to prediction of evenness of 60^S and 100^S ELS carded yarns from G_2 fiber properties, Table (19), it was shown in general that R^2 and MSE values of 100^S yarn count were higher than those of 60^S yarn. Meanwhile, with the exception of equations No. 108 and 114 of 60^S and 100^S yarns, respectively, the Cp values tend to be higher in case of 60^S yarn equations than those in case of 100^S yarn equations.

In both 60^S and 100^S yarns the fiber linear density (X_6) was the best fiber property for predicting evenness from single variable.

The best equations for predicting evenness of 60^S and 100^S ELS carded yarns from G_2 fiber properties are equations No. 112 and 116, respectively.

$$Y_7H = 72.86 + (-1.93X_2) + 0.12X_6 + (-0.26X_7) + (-0.47X_{10}) + 0.48X_{11} \quad \textbf{(112)}$$

$$Y_7L = 2.57 + (-3.04X_2) + 1.33X_3 + 0.25X_6 + (-0.72X_{10}) \quad \textbf{(117)}$$

In conclusion, the physical fiber properties included in the multiple regression estimation for prediction of yarn evenness differed from one count to another and from LS to ELS length categories. In this connection, **Foster (1958), Zaher *et al.* (1975)** and **Abd-El-Mohsen (1978)** showed that the finer the count the uneven the yarn. Moreover, **Foster (1958)** also, showed that for the same count, the finer the fibers the even the yarn.

Almashouly (1981), Abdul-Sattar and Hussain (1985), El-Tabbakh *et al.* (1985), Almashouly and Abed (1987) and **Sawires *et al.* (1990)** proved that fiber length parameters were the most important contributors to yarn evenness followed by the fiber physical properties such as strength, linear density and micronaire reading. However, **Almasouley (1981)** showed that the total contribution of fiber properties to yarn evenness was 65% implying that the mechanical processing conditions through spinning are also important in determining the evenness of the spun yarn. **El-Tabbakh *et al.* (1985)** showed that fiber properties contributed to yarn evenness differ from LS and US Upland to ELS.

Abd-El-Salam *et al.* (1972) and **Kemp (1980)** concluded that the higher the fiber immaturity the lower the evenness of the yarn. However, **Garawin (1971)** showed that the evenness of the yarn do not depend only on the variation in micronaire reading between varieties (fineness) or within variety (maturity) alone, but, also, dependent on other fiber properties.

Keeping in mind the above results achieved on the relationships between yarn evenness and the physical properties of cotton fibers and the review cited above, it could be reported that agreements exist between the present results and the results of the several authors in the above review in that the yarn evenness depended on fiber properties which differ from one count to another and from LS to ELS cotton length categories, as well the mechanical processing condition through yarn spinning.

4.3.3. Neps/100 meters of spun yarns

Considering the equations (120 to 126) and (127 to 133) for predicting nep count in LS carded 40^s and 60^s from G_1 of physical fiber properties as presented in Table (20), it is shown that a part of the lower values of R^2 in case of equation No. 127 of 60^s count compared with its values in case of equation No. 120 of 40^s, the remaining equations in both 40^s and 60^s were nearly similar in R^2 values. However, the MSE and Cp values were always higher in case of finer 60^s yarn compared with the values in case of coarser 40^s yarns.

Considering equations No. 123 and 124 where 2.5% span length (X_1) and fiber length uniformity ratio % (X_3) were included with either bundle strength (X_{10}) or elongation (X_{11}), respectively, the latter was the best of the two, indicating a better role of elongation than strength in nep formation in spun yarn.

In case of 60^s carded yarn the two equations No. 129 and 130 including 2.5% span length (X_1) and fiber length uniformity ratio (X_3) with either bundle strength (X_{10}) or fiber floating index (X4), respectively, the equation No. 130 was the best based on R^2, MSE and Cp. This signifies that the short fiber content expressed in terms of F.F.I. is more effective in nep formation than the fiber bundle strength.

The best equation for predicting nep count in 40^s and 60^s yarns from G_1 fiber properties were No. 125 and 131, respectively, and the prediction equation in case of coarser yarn is more precise based on MSE and Cp values. As long as prediction equation of nep count of 40^s and 60^s yarns from G_2 fiber properties are concerned, Table (21), with the exception of the higher R^2 in equation No. 134 of 40^s yarn compared wit its corresponding lower value in equation No. 146 in which one fiber variable was included (either bundle strength or 50% span length, respectively), in all equations the values of R^2 were comparable for 40^s and 60^s yarns. However, the MSE values in case of 60^s count equations were very high compared with 40S count equations which are in favour of 40^s, whatever, the values of Cp. This means

Table 20. Forward selection procedure for depended variable nep count/100 meters for 40^S and 60^S counts of LS category from G_1 of physical fiber properties.

	Variable entered	Number in	R^2	MSE	Cp	B0	Fiber 2.5% span length X_1	Fiber uniformity X_3	Fiber floating index X_4	Micronaire reading X_5	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability > F	No.
	40^S Count ($Y_{10}A$)													
1	X_{10}	1	0.9602	90.72	90.06	586.48					-17.74		0.0001	120
2	X_1, X_{10}	2	0.9866	33.85	26.93	990.79	-15.99				-14.92		0.0001	121
3	X_1, X_3, X_{10}	3	0.9873	36.07	27.19	1042.6	-13.89	-2.38			-14.71		0.0001	122
4	X_1, X_3, X_4, X_{10}	4	0.9917	27.01	18.43	2919.08	-39.71	-23.20	-9.54		-12.06		0.0001	123
5	X_1, X_3, X_4, X_{11}	4	0.9937	20.55	13.55	4957.75	-80.22	-47.42	-15.04			23.92	0.0001	124
6	X_1, X_3, X_4, X_5, X_{11}	5	0.9978	8.49	5.50	4607.60	-68.97	-43.71	-14.18	-37.38		17.10	0.0001	125
7	X_1, X_3, X_4, X_5, X_{10}, X_{11}	6	0.9980	9.25	7.00	4250.12	-63.51	-39.46	-12.92	-29.65	-2.10	15.01	0.0001	126
	60^S Count ($Y_{10}B$)													
1	X_1	1	0.8745	2680.14	167.90	6332.52	-203.10						0.0001	127
2	X_1, X_{10}	2	0.9744	607.99	29.91	5045.46	-137.20				-24.29		0.0001	128
3	X_1, X_3, X_{10}	3	0.9889	296.65	11.58	5766.78	-108.11	-32.97			-21.39		0.0001	129
4	X_1, X_3, X_4	3	0.9908	245.85	8.91	18832.29	-289.83	-178.69	-65.22				0.0001	130
5	X_1, X_3, X_4, X_{10}	4	0.9962	114.22	3.25	13227.35	-210.77	-115.76	-37.92		-10.85		0.0001	131
6	X_1, X_3, X_4, X_{10}, X_{11}	5	0.9964	129.54	5.10	12849.57	-202.32	-111.16	-37.25		-13.74	-6.35	0.0001	132
7	X_1, X_3, X_4, X_5, X_{10}, X_{11}	6	0.9964	152.37	7.00	12509.18	-198.89	-106.97	-35.92	20.77	-16.25	-6.92	0.0001	133

Table 21. Forward selection procedure for depended variable nep counts/100 meters for 40^S and 60^S counts of LS category from G_2 of physical fiber properties.

	Variable entered	Number in	R^2	MSE	Cp	B0	Fiber 50% span length X_2	Fiber uniformity X_3	Fiber linear density (millitex) X_6	Maturity % X_7	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability > F	No.
	40^S Count ($Y_{10}C$)													
1	X_{10}	1	0.9602	90.72	13.52	586.48					-17.74		0.0001	134
2	X_2, X_{10}	2	0.9855	36.75	1.84	787.97	-18.53				-14.75		0.0001	135
3	X_2, X_6, X_{10}	3	0.9887	32.14	2.10	1125.32	-18.57		-2.52		-11.61		0.0001	136
4	X_2, X_6, X_{10}, X_{11}	4	0.9899	32.82	3.45	1145.84	-31.75		-2.10		-9.14	7.06	0.0001	137
5	X_2, X_3, X_6, X_{10}, X_{11}	5	0.9901	37.78	5.38	957.20	-39.63	3.26	-1.25		-9.52	8.71	0.0001	138
6	X_2, X_3, X_6, X_7, X_{10}	5	0.9907	35.24	5.02	436.46	-56.40	16.01	1.60	-2.81	-11.12		0.0001	139
7	X_2, X_3, X_6, X_7, X_{10}, X_{11}	6	0.9907	42.16	7.00	473.60	-56.56	14.92	1.42	-2.45	-11.31	1.91	0.0001	140
	60^S Count ($Y_{10}D$)													
1	X_2	1	0.9113	1895.76	34.39	3841.98	-235.17						0.0001	141
2	X_2, X_{10}	2	0.9833	397.13	1.99	3381.33	-165.96				-21.54		0.0001	142
3	X_2, X_3, X_{10}	3	0.9870	334.42	1.98	2556.93	-208.98	29.24			-21.67		0.0001	143
4	X_2, X_3, X_7, X_{10}	4	0.9884	339.96	3.32	2368.76	-175.09	20.08		3.99	-28.83		0.0043	144
5	X_2, X_6, X_7, X_{10}	4	0.9893	324.94	3.09	3483.62	-133.21		-6.14	6.42	-25.55		0.0001	145
6	X_2, X_3, X_6, X_7, X_{10}	5	0.9894	376.36	5.05	4111.07	-106.42	-12.96	-9.37	7.94	-24.24		0.0001	146
7	X_2, X_3, X_6, X_7, X_{10}, X_{11}	6	0.9895	447.18	7.00	4328.20	-107.33	-19.33	-10.48	10.03	-21.86	11.19	0.0001	147

that the prediction of nep in case of coarse 40^s yarn in more reliable than in case of 60^s yarns.

Considering equations No. 138 and 139 for predicting nep count of 40^s yarn in which the 50% span length (X_2), uniformity ratio (X_3), fiber linear density (X_6) and fiber bundle strength (X_{10}) were included with either bundle elongation (X_{11}) or maturity % (X_7), respectively, the maturity % is important (equation No. 139) in predicting the nep count than the fiber bundle elongation.

Considering equations No. 144 and 145 for predicting nep count in 60^s in which 50% span length (X_2), maturity % (X_7) and bundle strength (X_4) were included with either fiber length uniformity ratio (X_3) or fiber linear density (X_6), respectively, the equation No. 145 is the best with all respects indicating the more important role of fiber linear density than that of the length uniformity ratio (X_3) with respect to nep formation in the yarn.

The best equation for predicting nep count for 40^s and 60^s from G_1 fiber properties are No. 125 and 131 and from G_2 fiber properties are No. 139 and 145, respectively.

$$Y_{10}A = 4607.60 + (-68.97X_1) + (-43.71X_3) + (-14.18X_4) + (-37.38X_5) + 17.10X_{11} \quad (125)$$

$$Y_{10}B = 13227.35 + (-210.77X_1) + (-115.76X_3) + (-37.92X_4) + (-10.85X_{10}) \quad (131)$$

$$Y_{10}C = 436.46 + (-56.40X_2) + 16.01X_3 + 1.60X_6 + (-2.81X_7) + (-11.12X_{10}) \quad (139)$$

$$Y_{10}D = 3483.62 + (-133.21X_2) + (-6.14X_6) + 6.42X_7 + (-25.55X_{10}) \quad (145)$$

Considering ELS category equations (148 to 154) and (155 to 160) for predicting nep count in 60^s and 100^s yarns from G_1 physical fiber properties, Table (22), it is clear that the R^2s were higher and MSE values were much lower in case of 60^s count compared with the 100^s yarn count. Therefore, no matter the

Table 22. Forward selection procedure for depended variable nep counts/100 meters for 60^S and 100^S counts of ELS category from G_1 of physical fiber properties.

	Variable entered	Number in	R^2	MSE	Cp	B0	Fiber 2.5% span length X_1	Fiber uniformity X_3	Fiber floating index X_4	Micronaire reading X_5	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability > F	No.
							60^S Count ($Y_{10}E$)							
1	X_1	1	0.9616	149.01	15.87	-1995.57	62.30						0.0001	148
2	X_1, X_5	2	0.9718	121.66	11.54	-2320.09	81.02			-89.62			0.0001	149
3	X_1, X_5, X_{10}	3	0.9749	121.65	1.59	-2504.95	81.67			-82.85	3.89		0.0001	150
4	X_1, X_{10}, X_{11}	3	0.9898	49.35	2.32	-2228.60	58.84				18.69	-52.56	0.0001	151
5	X_1, X_4, X_{10}, X_{11}	4	0.9901	55.01	4.17	-2344.29	60.24		-1.70		20.84	-51.61	0.0001	152
6	$X_1, X_3, X_4, X_{10}, X_{11}$	5	0.9913	55.95	5.38	-1583.39	61.46	-14.63	-8.11		20.91	-51.02	0.0001	153
7	$X_1, X_3, X_4, X_5, X_{10}, X_{11}$	6	0.9920	62.42	7.00	-1365.30	76.02	-24.97	-14.98	-50.54	19.91	-36.20	0.0001	154
							100^S Count ($Y_{10}F$)							
1	X_1	1	0.8348	1868.96	8.12	-3088.52	99.08						0.0001	155
2	X_1, X_{10}	2	0.9228	970.28	1.53	-1212.46	80.57				-34.86		0.0001	156
3	X_1, X_3, X_{10}	3	0.9370	890.80	2.14	2259.95	69.87	-42.54			-60.50		0.0001	157
4	X_1, X_3, X_4, X_{10}	4	0.9433	916.05	3.53	4257.92	79.12	-90.35	-28.15		-49.58		0.0002	158
5	$X_1, X_3, X_4, X_5, X_{10}$	5	0.9487	966.53	5.00	4857.22	110.36	-114.68	-42.80	-129.25	-44.92		0.0008	159
6	$X_1, X_3, X_4, X_5, X_{10}, X_{11}$	6	0.9487	1159.75	7.00	4881.39	112.11	-115.89	-43.62	-134.10	-45.14	2.25	0.0043	160

differences in Cp values, the prediction equations are more reliable in case of courser 60^s yarns than 100^s finer yarns.

Considering equations No. 150 and 151 in case of 60^s yarn count which including 2.5% span length (X_1) and fiber bundle strength (X_{10}) with either micronaire reading (X_5) or fiber bundle elongation (X_{11}), respectively, equation No. 151 is the best of the two indicating a better role of elongation than micronaire reading in nep formation in the yarn.

The best equations are No. 151 and 157 for prediction of nep count in case of 60^s and 100^s yarns, respectively. It is worth to note that in these two equations only three fiber variables were combined and the fiber length uniformity ratio (X_3) play better role in 100^s yarn count while in case of 60^s yarn the fiber bundle elongation play better role for predicting nep formation.

$$Y_{10}E = -2228.60 + 58.84X_1 + 18.69X_{10} + (-52.56X_{11}) \quad (151)$$

$$Y_{10}F = 2259.95 + 69.87X_1 + (-42.54X_3) + (-60.50X_{10}) \quad (157)$$

Considering equations No. 161 to 168 and 169 to 176 for predicting nep count in case of 60^s and 100^s yarns from G_2 of physical fiber properties, Table (23), respectively, it is shown that R^2, MSE and Cp values in case of 60^s yarns are lower than in case of 100^s yarns implying the more reliability of prediction equations of neps in case of 60^s than in case of 100^s yarns.

Considering equations No. 164, 165 and 166 for prediction of nep count in case of 60^s yarn in which fiber linear density (X_6), fiber bundle strength (X_{10}) and fiber bundle elongation (X_{11}) were combined with either maturity % (X_7), 50% span length (X_2) or fiber length uniformity (X_3), equation No. 166 was the best due to the role of fiber length uniformity ratio (X_3) in predicting nep

Table 23. Forward selection procedure for depended variable nep count/100 meters for 60^S and 100^S counts of ELS category from G_2 of physical fiber properties.

	Variable entered	Number in	R^2	MSF	Cp	B0	Fiber 50% span length X_2	Fiber uniformity X_3	Fiber linear density (millitex) X_6	Maturity % X_7	Fiber bundle strength X_{10}	Fiber bundle elongation X_{11}	Probability > F	No.
							60^S Count ($Y_{10}H$)							
1	X_6	1	0.9144	331.96	44.80	-683.33			5.80				0.0001	161
2	X_6, X_7	2	0.9713	123.96	11.74	91.84			6.52	-10.92			0.0001	162
3	X_6, X_7, X_{10}	3	0.9794	99.78	8.70	124.16			7.23	-17.06	10.12		0.0001	163
4	X_6, X_7, X_{10}, X_{11}	4	0.9831	93.70	8.43	-38.76			6.64	-13.65	13.52	-25.18	0.0001	164
5	X_2, X_6, X_{10}, X_{11}	4	0.9835	91.50	8.19	-1895.61	58.37		3.15		24.42	-52.27	0.0001	165
6	X_2, X_3, X_{10}, X_{11}	4	0.9872	71.23	5.93	-493.28	122.60	-39.72			24.35	-58.87	0.0001	166
7	X_2, X_3, X_7, X_{10}, X_{11}	5	0.9914	55.30	5.28	1453.99	136.11	-65.95		-9.76	20.33	-43.13	0.0001	167
8	X_2, X_3, X_6, X_7, X_{10}, X_{11}	6	0.9919	62.87	7.00	2108.26	177.17	-88.37	-2.04	-9.01	21.44	-48.69	0.0001	168
							100^S Count ($Y_{10}L$)							
1	X_2	1	0.8564	1624.54	70.84	-2841.13	198.45						0.0001	169
2	X_2, X_6	2	0.9030	1219.06	47.24	-2445.32	127.40		3.54				0.0001	170
3	X_6 X_{10}	2	0.9563	548.98	17.98	1089.15			7.27		-50.98		0.0001	171
4	X_6, X_7, X_{10}	3	0.9618	539.83	16.96	1356.92			8.31	-10.38	-39.23		0.0001	172
5	X_2, X_6, X_7, X_{10}	4	0.9748	406.65	11.81	4458.74	-111.41		13.35	-25.15	-57.80		0.0001	173
6	X_2, X_3, X_6, X_{10}	4	0.9772	367.72	10.49	-6403.82	-425.94	237.38	27.14		-52.19		0.0001	174
7	X_2, X_3, X_6, X_7, X_{10}	5	0.9838	306.23	8.92	-2412.68	-379.42	175.15	25.71	-16.92	-53.35		0.0001	175
8	X_2, X_3, X_6, X_7, X_{10}, X_{11}	6	0.9909	206.06	7.00	-2769.34	-504.56	227.71	33.10	-30.08	-69.07	71.10	0.0001	176

formation in the spun yarn compared with maturity % (X_7) and 50% span length (X_2).

In case of 100^s yarn count, considering equation No. 170 and 171 including fiber linear density (X_6) with 50% span length (X_2) or fiber bundle strength (X_{10}), respectively, the No. 171 equation was the best of the two, indicating the best role of bundle strength (X_{10}) in predicting nep formation than the 50% span length (X_2).

Similarly, considering equations No. 173 and 174 in case of 100^s yarn, in which 50% span length (X_2), fiber linear density (X_6) and bundle strength (X_{10}) were combined with either maturity % (X_7) or fiber length uniformity ratio (X_3), respectively, the 174 equation was the best of the two indicating the more effectiveness of fiber length uniformity ratio (X_3) than maturity % (X_7) in predicting nep formation in the spun yarn. The best equations for predicting the nep count in case of 60^s and 100S yarns from G_2 fiber properties are equations No. 167 and 176, respectively.

$$Y_{10}H = 1453.99 + 136.11X_2 + (-65.95X_3) + (-9.76X_7) + 20.33X_{10} + (-43.13X_{11}) \quad \textbf{(167)}$$

$$Y_{10}L = -2769.34 + (-504.56X_2) + 227.71X_3 + 33.10X_6 + (-30.08X_7) + -69.07X_{10}) + 71.10X_{11}) \quad \textbf{(176)}$$

In conclusion, prediction of nep count/100 meters of LS 40^s and 60^s yarns as well as 60^s and 100^s yarns from either G_1 or G_2 of physical fiber properties differ from one count to another and from LS to ELS cotton length categories. Revising the literature review with respect to the nep formation in the yarn due to fiber properties, **Abd-El-Salam (1972)** stated that within cotton variety no close relation exists between fiber maturity and nep count in the spun yarn. Furthermore, between varieties neither fiber maturity alone, nor maturity, length and fineness taken together could completely explain the differences in nep potential.

On the other hand, **Almashouly (1977)**, **Kemp (1980)** and **Ahmed *et al.* (1984)** had given evidences to significant relations between micronaire reading and neps in the yarn. **El-Tabbak *et al.* (1985)** indicated that fiber linear density was the most important contributor to nep count in LS yarns. **El-Hariry *et al.* (1990)** showed that the length parameters and micronaire value exerted the greatest influence on yarn nep count and that fiber properties contributing to nep count in the yarn differ from one count to another and from carded to combed yarns. **Almashouly (1981)** stated that the contribution of fiber properties to nep count in yarn were as low as 16% indicating the role of mechanical as well as its interaction, with fiber properties in nep formation. On the other hand, **Almashouly and Abed (1987)** reported that the total trash content with short fiber content, mean fiber length and length variation explained 72% of the variation in the number of neps in the spun yarn.

The results achieved are in agreement with the results found by the above authors. Therefore, fiber properties needed to predict nep count in yarn differed according to yarn count and cotton length category. The magnitude of contribution of mechanical processing conditions and their interactions with fiber physical properties should not be underestimated. From the above arguments, should not be underestimated prediction of yarn strength, evenness and neps count/100 meters of spun yarn from the two selected groups of fiber properties differ from count to another and from LS to ELS length categories.

4.4. The effect of the spinning mechanical processing on the physical properties of the cotton spun yarns

The physical properties of the spun yarns are determined by the physical properties of the cotton fibers from which these yarns are assembled, the spinning mechanical processing variables and the interactions between fiber physical properties and spinning mechanical processing variables, or in other words, the successive spinning mechanical processes. The structural features of the cotton spun yarns such as count and twist contribute, also, to the physical properties of these yarns. Moreover, the interrelations amongst various fiber physical properties, as well as, the interrelations amongst various physical properties of the spun yarns have also, their influence on the final picture of the yarn properties. In this section of the present investigation, the effects of cotton varieties, yarn count and yarn twist, as well as, their first and second order of interactions on the various physical properties of carded yarns spun from LS and ELS varieties, as well as combed yarns spun from ELS varieties were studies. The statistical analysis of variance had been conducted for each of ten physical properties i.e. tensile properties (strength, breaking load CV%, elongation %, elongation CV%, stiffness and toughness), yarn evenness and yarn imperfections i.e. (number of thin and thick places as well neps/100 meters of the spun yarn). However, the results are going to be discussed for each source of variation i.e. variety, count, twist, variety x count, variety x twist, count x twist and variety x count x twist interactions as below:

4.4.1. The effect of cotton variety

The results of the analysis of variance with respect to the effect of cotton variety on the physical properties of the carded yarns spun from LS and ELS and combed yarns spun from the ELS varieties are presented in Tables (24, 25 and 26), respectively. The following facts could be stated:

4.4.1.1. Yarn tensile properties

As shown in Tables (24, 25 and 26), the yarn tensile properties more or less showed significant differences between cotton varieties. For LS carded yarn, Table (24), significant differences existed between LS Giza 75, Giza 83 and Giza 85 cotton varieties in yarn strength, breaking load CV%, elongation and elongation CV%. The values could be arranged in a descending order for

Table 24. Effect of varieties on each of carded yarn tensile properties, evenness and yarn imperfection in long-staple category (LS).

Yarn properties	Variety			L.S.D. at 0.05
	Giza 75	Giza 83	Giza 85	
Strength g/Tex	13.91 A	10.95 C	12.92 B	0.23
Breaking load C.V.%	12.97 C	21.54 A	13.25 B	0.26
Elongation %	6.12 C	7.57 B	8.82 A	0.22
Elongation C.V. %	10.52 C	14.58 A	11.48 B	0.32
Stiffness g/Tex	237	14.30 A	145 A	10.01
Toughness g/Tex	0.44 B	0.42 C	0.58 A	0.02
Evenness C.V.%	22.27 C	27.14 A	22.60 B	0.16
No. of thin places/100 meters	96.00 B	239 A	82 C	6
No, of thick places/100 meters	141 C	287 A	151 B	9
No. of neps/100 meters	108 B	260 A	96 C	6

Means followed by the same letter for the same property are not significantly different at 0.05 level.

Table 25. Effect of varieties on each of carded yarn tensile properties, evenness and yarn imperfection in extra long-staple category (LS).

Yarn properties	Variety			L.S.D. at 0.05
	Giza 70	Giza 77	Giza 84	
Strength g/Tex	15.03 B	14.36 C	15.47 A	0.23
Breaking load C.V.%	13.14 B	14.98 A	14.91 A	0.28
Elongation %	7.18 B	6.67 C	7.81 A	0.19
Elongation C.V. %	11.34 C	12.48 A	12.11 B	0.24
Stiffness g/Tex	212 B	225 A	200 C	11.00
Toughness g/Tex	0.56 B	0.50 C	0.62 A	0.02
Evenness C.V.%	24.71 A	23.90 B	22.99 C	0.19
No. of thin places/100 meters	198 A	129 B	103 C	11.00
No, of thick places/100 meters	237 A	206 B	166 C	16.00
No. of neps/100 meters	302 A	211 B	154 C	13.00

Means followed by the same letter for the same property are not significantly different at 0.05 level.

Table 26. Effect of varieties on each of combed yarn tensile properties, evenness and yarn imperfection in extra long-stapled category (ELS).

Yarn properties	Variety			L.S.D. at 0.05
	Giza 70	Giza 77	Giza 84	
Strength g/Tex	15.87 B	15.46 C	16.82 A	0..36
Breaking load C.V.%	12.89 B	14.06 A	12.62 B	0.32
Elongation %	6.92 B	6.95 B	7.75 A	0.27
Elongation C.V. %	13.13 A	13.13 A	12.06 B	0.38
Stiffness g/Tex	232 A	225 AB	221 B	9
Toughness g/Tex	0.56 A	0.55 A	0.67	0.03
Evenness C.V.%	26.59 A	24.04 B	23.21 C	0.28
No. of thin places/100 meters	226 A	167 B	110 C	13
No, of thick places/100 meters	277 A	200 B	141 C	14
No. of neps/100 meters	328 A	258 B	180 C	17

Means followed by the same letter for the same property are not significantly different at 0.05 level.

each of these properties as follows (Giza 75, Giza 85 and Giza 83); (Giza 83, Giza 85 and Giza 75); (Giza 85, Giza 83 and Giza 75); (Giza 83, Giza 85 and Giza 75). However, in case of yarn stiffness, Giza 75 was significantly stiffer than other two varieties Giza 83 and Giza 85 which did not significantly differ in this yarn tensile properties. On the other hand, Giza 85 was significantly higher than Giza 75 and Giza 83 which did not differ from each other in toughness.

For ELS carded yarn, Table (25), strength, elongation, elongation CV%, stiffness and toughness of the yarn differed significantly from one ELS variety to another (Giza 70, Giza 77 and Giza 84), the descending order of the varieties for each of these yarn properties were as follows: (Giza 84, Giza 70 and Giza 77); (Giza 84, Giza 70 and Giza 77); (Giza 77, Giza 70 and Giza 84); (Giza 84, Giza 70 and Giza 77), respectively. For breaking load CV% only Giza a70 was significantly lower than the other two varieties Giza 77 and Giza 84 which did not differ from each other.

For combed yarns, Table (26), Giza 70, Giza 77 and Giza 84 differed significantly from each other in yarn strength, in a descending as Giza 84, Giza 70 and Giza 77. For breaking load CV%, Giza 77 was significantly higher than Giza 70 and Giza 84 which did not differ significantly from each other. For yarn elongation, Giza 70 and Giza 77 were similar in elongation and significantly lower than the new established variety Giza 84. For elongation CV%, Giza 70 and Giza 77 varieties were similar and significantly higher than Giza 84 in this property. Yarn stiffness of Giza 84 was significantly lower than the similar two varieties Giza 70 and Giza 77 which did not differ significantly. For yarn toughness, Giza 84 was significantly higher than Giza 70 and Giza 77 yarns which did not differ significantly from each other.

The LS varieties showed a descending order with respect to yarn strength and uniformity of breaking load as Giza 75, Giza 85 and Giza 83. Elongation and elongation CV% showed different trends for the three varieties. However, Giza 85 produced more extensible and moderate variation in extensibility and this reflected in a strength trend for the varieties in the variation of the breaking load which is physically logical. Giza 75 yarns was stiffer than the other two varieties Giza 83 and Giza 85 which did not differ significantly. However, Giza 83 was significantly higher in toughness than the two other varieties Giza 75 and Giza 85 which were similar.

For extra long-stapled category, the strength and elongation showed similar trends in yarn spun from the three ELS varieties in a descending order as Giza 84, Giza 70 and Giza 77. However, Giza 70 produced yarn of the lowest variation in strength and elongation, despite the fact that its strength and elongation occupied a position which lied between Giza 84 and Giza 77.

Based on the strength and elongation trends the stiffness and toughness showed two reversal descending orders as follows (Giza 77, Giza 70 and Giza 84) and (Giza 84, Giza 70 and Giza 77), respectively.

Giza 84 produced stronger and more extensible carded or combed yarns followed by Giza 70 and Giza 77. Similarly, Giza 84 and Giza 70 showed the lowest variation in strength. Giza 84 alone showed the lowest variation in elongation, and was lower in stiffness, higher in toughness compared with the other two varieties.

4.4.1.2. Yarn evenness and imperfections

Significant differences existed in the evenness of the carded yarns spun from LS and ELS varieties, Tables (24 and 25), as well as the combed yarn spun from ELS varieties, Table (26).

However, in case of carded LS, the varieties were arranged in a descending order in evenness as Giza 75, Giza 85 and Giza 83. Whereas, in case of carded or combed yarns spun from ELS varieties the descending order was Giza 84, Giza 77 and Giza 70. The number of imperfections/100 meters (thin and thick places and neps) of carded yarns spun from LS and ELS varieties or combed yarns from ELS varieties showed significant differences between varieties. However, in case of LS carded yarns the ascending order values were (Giza 85, Giza 75 and Giza 83), (Giza 75, Giza 85 and Giza 83) and (Giza 85, Giza 75 and Giza 83) for the number of thin places, the number of thick places and the number of neps/100 meters, respectively.

Nevertheless, in case of ELS carded or combed yarns, the ascending order of the varieties for each of imperfections/100 meters was always Giza 84, Giza 77 and Giza 70.

4.4.2. The effect of yarn count

The results of the analysis of variance concerning the effect of yarn count on the physical properties of carded yarns spun from LS and ELS categories and combed yarns spun from ELS category are presented in Tables (27, 28 and 29), respectively.

4.4.2.1. Yarn tensile properties

As shown from the above mentioned tables with the exception of yarn stiffness in case of LS carded yarns, for the other yarn tensile properties significant influences were shown in the tensile properties of carded yarns spun from LS and ELS categories and combed yarns spun from ELS category. The strength, elongation and toughness of the yarn showed a general trend to decrease as the yarn fineness increased i.e. from (30^s, 40^s, 60^s and 80^s), (40^s, 60^s, 80^s and 100^s) and (60^s, 80^s, 100^s, 120^s and 140^s) for LS carded, ELS carded and ELS combed, respectively.

Table 27. Effect of counts on each of carded yarn tensile properties, evenness and yarn imperfection in long-staple category (LS).

Yarn properties	Count				L.S.D. at 0.05
	30^s	40^s	60^s	80^s	
Strength g/Tex	15.17 A	13.70 B	12.03 C	9.47 D	0.28
Breaking load C.V.%	12.83 D	14.43 C	17.34 B	19.08 A	0.29
Elongation %	8.87 A	7.86 B	7.17 C	6.11 D	0.25
Elongation C.V. %	10.48 D	11.73 C	12.49 B	13.62 A	0.38
Stiffness g/Tex	177	180	179	166	N.S.
Toughness g/Tex	0.68 A	0.53 B	0.43 C	0.28 D	0.02
Evenness C.V.%	18.87 D	21.83 C	26.00 B	29.32 A	0.19
No. of thin places/100 meters	38 D	101 C	182 B	236 A	7
No, of thick places/100 meters	52 D	134 C	252 B	334 A	9
No. of neps/100 meters	36 D	104 C	176 B	303 A	7

Means followed by the same letter for the same property are not significantly different at 0.05 level.

Table 28. Effect of count on each of carded yarn tensile properties, evenness and yarn imperfection in extra long-staple category (ELS).

Yarn properties	Count				L.S.D. at 0.05
	40^s	60^s	80^s	100^s	
Strength g/Tex	18.18 A	15.82 B	13.69 C	12.13 D	0.26
Breaking load C.V.%	11.61 D	13.18 C	15.17 B	17.41 A	0.32
Elongation %	8.75 A	8.27 B	6.36 C	5.51 D	0.22
Elongation C.V. %	8.59 D	10.02 C	13.90 B	15.39 A	0.28
Stiffness g/Tex	208 B	192 C	217 B	232 A	12
Toughness g/Tex	0.80 A	0.66 B	0.43 C	0.34 D	0.02
Evenness C.V.%	19.52 D	22.21 C	25.31 B	28.43 A	0.22
No. of thin places/100 meters	80 D	108 C	155 B	230 A	12
No, of thick places/100 meters	103 C	191 B	197 B	321 A	18
No. of neps/100 meters	127 D	175 C	242 B	345 A	16

Means followed by the same letter for the same property are not significantly different at 0.05 level.

Table 29. Effect of count on each of combed yarn tensile properties, evenness and yarn imperfection in extra long-staple category (ELS).

Yarn properties	Count					L.S.D. at 0.05
	60^{s}	80^{s}	100^{s}	120^{s}	140^{s}	
Strength g/Tex	18.33 A	16.99 B	16.11 C	15.17 D	13.64 E	0.47
Breaking load C.V.%	10.81 E	11.49 D	12.52 C	14.31 B	16.83 A	0.41
Elongation %	8.88 A	8.17 B	7.43 C	6.27 D	5.28 E	0.35
Elongation C.V. %	7.95 E	11.56 D	13.46 C	14.83 B	16.07 A	0.49
Stiffness g/Tex	205 B	208 AB	218 A	240 B	260 D	11
Toughness g/Tex	0.81 A	0.70 B	0.61 C	0.48 D	0.37 E	0.04
Evenness C.V.%	19.94 E	22.76 D	25.12 C	26.89 B	28.36 A	0.36
No. of thin places/100 meters	39 E	130 D	179 C	218 B	272 A	16
No, of thick places/100 meters	108 E	164 D	214 C	256 B	289 A	18
No. of neps/100 meters	116 E	179 D	262 C	324 B	395 A	22

Means followed by the same letter for the same property are not significantly different at 0.05 level.

On the other hand, the variation in the yarn breaking load (CV%) and elongation CV% showed ascending trend with yarn fineness in the case of the carded LS, carded LS, carded ELS ad combed ELS yarns.

However, the stiffness of ELS carded yarn tends to increase with increasing yarn finesses. The 120^s and 140^s combed yarns were significantly stiffer than the other combed yarns.

4.4.2.2. Yarn evenness and imperfections

As shown in Tables (27, 28 and 29) significant differences were shown in yarn evenness due to count in case of LS and ELS carded yarn, as well as, ELS combed yarns. There was a general trend for the evenness of LS and ELS carded, as well as, ELS combed yarns to decrease with increasing the fineness of the yarn.

For the number of yarn imperfections, i.e. thin and thick places and number of neps/100 meters of yarns spun from LS and ELS carded and ELS combed varieties, there were always significant differences in these imperfections due to count. There was a general trend for yarn imperfections to increase as yarn fineness increased.

Summarizing the above findings, it could be stated that for the tensile properties of LS and ELS carded and ELS combed yarns, the count exerted significant effect on the strength elongation and toughness of the spun yarn in such a manner that these properties decreased with increasing the yarn fineness. Nevertheless, the variation in the breaking load and elongation showed a reversal trend to increase with increasing the yarn fineness. However, the stiffness did no show significant effect for the count in case of LS carded yarn, although it tends to increase with increasing counts in the same cases of ELS carded and combed yarns. These results agreed with those found by **Zaher *et al.* (1975). Abd El-Mohsen (1978), Hegab (1975) and Nawar (1979).**

There was a general trend for the evenness of LS and ELS carded, as well as, ELS combed yarns to decrease with the increasing of yarn fineness. The results favoured those recorded by **Nawar (1979)** and **Abd El-Mohsen (1983).**

In all cases the number of imperfection in the spun yarns increases with increasing the yarn fineness which are confirmed by **Zaher *et al.* (1975)** and **Nawar (1979).**

4.4.3. The effect of yarn twist

The results of the analysis of variance with respect to the effect of the twist on the physical properties of carded yarns spun from LS and ELS varieties, as well as, combed yarns spun from ELS varieties are presented in Tables (30, 31 and 32, respectively).

4.4.3.1. Yarn tensile properties

With the exception of yarn elongation % and stiffness in case of carded LS and ELS yarns, as well as, stiffness in case of ELS combed yarns which were not influenced significantly by twist, all other yarn tensile properties were significantly affected by the two twist multiplier inserted in these yarns. However, in case of LS carded yarn, the strength showed a trend to increase with increasing twist from 3.6 to 4.4 implying that the optimum twist multiplier for maximum strength of LS carded yarns may be at similar or higher than 4.4 twist multiplier.

In case of ELS carded yarns and combed yarns, there is as trend for the strength to decrease when twist multiplier is increased from 3.6 to 4.4

Table 30. Effect of twist multiplier on each of carded yarn tensile properties, evenness and yarn imperfection in long-staple category (LS).

Yarn properties	Twist multiplier		L.S.D. at 0.05
	3.6	4.4	
Strength g/Tex	12.37 B	12.82 A	0.19
Breaking load C.V.%	16.16 A	15.68 B	0.21
Elongation %	7.55	7.46	N.S.
Elongation C.V. %	12.37 A	12.02 B	0.26
Stiffness g/Tex	173	178	N.S.
Toughness g/Tex	0.47 B	0.50 A	0.02
Evenness C.V.%	23.92 B	24.07 A	0.13
No. of thin places/100 meters	129 B	150 A	5
No, of thick places/100 meters	185 B	202 A	6
No. of neps/100 meters	160 A	150 B	5

Means followed by the same letter for the same property are not significantly different at 0.05 level.

Table 31. Effect of twist multiplier on each of carded yarn tensile properties, evenness and yarn imperfection in extra long-staple category (ELS).

Yarn properties	Twist multiplier 3.6	Twist multiplier 4.4	L.S.D. at 0.05
Strength g/Tex	15.20 A	14.71 B	0.19
Breaking load C.V.%	14.03 B	14.66 A	0.23
Elongation %	7.27	7.17	N.S.
Elongation C.V. %	11.79 B	12.16 A	0.20
Stiffness g/Tex	212	212	N.S.
Toughness g/Tex	0.56 A	0.54 B	0.01
Evenness C.V.%	23.19 B	24.54 A	0.16
No. of thin places/100 meters	120 B	167 A	9
No, of thick places/100 meters	192 B	214 A	13
No. of neps/100 meters	214 B	231 A	11

Means followed by the same letter for the same property are not significantly different at 0.05 level.

Table 32. Effect of twist multiplier on each of combed yarn tensile properties, evenness and yarn imperfection in extra long-staple category (ELS).

Yarn properties	Twist multiplier 3.6	Twist multiplier 4.4	L.S.D. at 0.05
Strength g/Tex	16.45 A	15.65 B	0.30
Breaking load C.V.%	12.73 B	13.66 A	0.26
Elongation %	7.49 A	6.92 B	0.22
Elongation C.V. %	12.44	13.10	0.31
Stiffness g/Tex	224	229	N.S.
Toughness g/Tex	0.63 A	0.56 B	0.02
Evenness C.V.%	24.56	24.66	N.S
No. of thin places/100 meters	143 B	192 A	10
No, of thick places/100 meters	202	209	N.S.
No. of neps/100 meters	251	259	N.S.

Means followed by the same letter for the same property are not significantly different at 0.05 level.

indicating that the optimum twist multiplier for maximum strength may be at or below 3.6 or lower twist multiplier.

There was a general trend for toughness to increase with increasing twist from 3.6 to 4.4 twist multiplier in case of LS carded yarn. On the contrary in case of ELS carded or combed yarn the trend of toughness with twist multiplier was reversed. The breaking load CV% and elongation CV% showed a trend to decrease with increasing twist in case of LS carded yarn. A reverse trend was found in case of ELS carded yarns. This is possibly the result of different optimum twists for maximum strength for LS and ELS yarns. Meanwhile, in case of ELS combed yarn the effect of twist on the elongation CV% was insignificant.

4.4.3.2. Yarn evenness and imperfections

The effect of twist multiplier on the yarn evenness for carded LS and ELS yarns, as well as combed ELS are presented in Tables (30, 31 and 32), respectively. For LS and ELS carded yarns there were significant differences in yarn evenness between 3.6 and 4.4 twist multiplier. There was a trend in the two cases for yarn evenness to increase with increasing twist from 3.6 to 4.4 twist multiplier. However, in case of ELS combed yarns no significant differences could be detected in yarn evenness with changing the twist multiplier from 3.6 to 4.4. The number of thin places showed significant differences due to twist in case of LS and ELS carded yarns, as well as, ELS combed yarn the trend was that the number of thin places increased with increasing of twist multiplier from 3.6 to 4.4. The number of thick places increased with increasing twist multiplier from 3.6 to 4.4 in case of LS and ELS carded yarn. Whereas the effect of twist on the number of thick places in ELS combed yarn was insignificant.

Considering the number of neps, the effect was significant in case of both LS and ELS carded yarns. However, the trend of neps was to decrease with increasing the twist in case of LS carded yarn, meanwhile the opposite trend was shown in case of ELS carded yarn, where, the nep count was increased as twist was increased. For ELS combed yarn, the effect of twist on nep count was insignificant.

The above results could be summarized as:

Strength of LS carded yarn increased as the twist multiplier was increased from 3.6 to 4.4 indicating that the optimum twist multiplier for maximum yarn strength is lower or similar or higher than 4.4. However, in case of ELS carded and combed yarn increasing twist multiplier from 3.6 to 4.4 resulted in a decrease in yarn strength indicating that the optimum twist for maximum strength could be attained at either below or at 3.6 or at below than 4.4. This is in favour of **Morton (1931)** and **Gregory (1950),** who showed that strength of yarn increase with increasing twist where strength of more and more fibers are used and contributed to yarn strength after optimum twist for maximum strength is attained, further increase of twist leads to a decrease in the yarn strength due to fiber obliquity or inclination. Therefore, attaining optimum twist depends on the balance between fiber cohesion with increase the strength and fiber inclination with respect to yarn axis which decrease the strength. These trends were also confirmed by the results obtained by **Abd El-Mohsen (1983), Mansour (1984)** and **Kamal *et al.* (1985).**

Flori and Brown (1951), Leitgeb and Wakeham (1956) and **Louis *et al.* (1960)** showed that shorter and coarser fibers require higher twist multiplier for maximum strength than longer and finer fibers. These results were confirmed by **Sadek *et al.* (1972), Abd El-Salam *et al.* (1972)** and **Zaher *et al.* (1975).**

Sullivan (1942), Landstreet (1954) and **Campell (1959)** introduced different equations for predicting optimum twist multiplier for maximum yarn strength from various fiber properties and classer's staple length.

There was a trend for the toughness of LS carded yarns to increase with increasing twist multiplier from 3.6 to 4.4. However, this trend was reversed in case of ELS carded and combed yarns.

The strength and elongation CV% of LS carded yarns showed a trend to decrease with increasing the twist multiplier from 3.6 to 4.4. However, in case of ELS carded yarn the trend was reversed due to the different levels of optimum twist multiplier for LS and ELS yarns. In case of ELS combed yarns, the effect of twist multiplier on both strength and elongation CV% was insignificant.

The evenness of LS and ELS carded yarns decreased with increasing twist multiplier. The effect of twist multiplier on evenness of ELS combed yarns was insignificant. In this concern **Nanjundayayya (1966)** showed that the evenness of the yarn is very important because the yarn break at the thinnest place of the test length and the thinnest place is over-twisted. **Hegab (1975)**, also showed that the yarn unevenness increased with increasing twist multiplier.

The number of thin places in LS and ELS carded yarns was decreased when twist multiplier was increased from 3.6 to 4.4. However, in case of the ELS combed yarn no significant effect for the twist multiplier was found. For twist multiplier effect on the number of thick places of LS and ELS carded yarns, the number of thick places increased as twist multiplier was increased from 3.6 to 4.4, while no significant effect was shown in case of ELS combed yarns.

The nep count decreased in LS carded yarns as twist multiplier was increased from 3.6 to 4.4. However, for ELS carded yarn the trend was reversed. Furthermore, the nep count in ELS combed yarns was not affected significantly by the twist. In this concern, **Zaher *et al.* (1975)** found that number of yarn imperfections was not affected significantly by twist. The results agreed with those found by **Abd El-Mohsen (1978)** and **Bragg *et al.* (1992)** with respect to the effect of combing on the quality of the spun yarns.

4.4.4. The effect of variety x count interaction:

The results of the analysis of variance with respect to the effect of variety x count first order interaction on the physical properties of yarns spun from LS and ELS carded varieties as well as combed yarns spun from ELS varieties are presented in Tables (33, 34 and 35), respectively.

4.4.4.1. Yarn tensile properties

In all cases the tensile properties of spun yarns showed significant effect with the exception of yarn strength and elongation of LS and ELS carded yarns, as well as the stiffness of ELS combed. These tensile properties showed various trends with counts due to the effect of the interaction between variety x count which differ from one variety to another indicating that the response to different counts is different for each variety.

4.4.4.2. The yarn evenness and number of imperfections/100 meters

Imperfection showed significant differences due to the interaction between variety x count in any of LS and ELS carded yarns or ELS combed yarns. In all cases the number of imperfections increased with increasing yarn fineness but with different trends for each variety particularly in case of the finennest counts.

Table 33. Effect of the interaction between varieties and count on each of carded yarn tensile properties, evenness and yarn imperfections in long-staple category (LS).

Yarn properties	Variety	Count				L.S.D. at 0.05
		30^s	40^s	60^s	80^s	
Strength g/Tex	Giza 75	16.58	14.93	13.08	11.05	
	Giza 83	13.35	11.90	10.55	8.00	0.46
	Giza 85	15.58	14.27	12.45	9.37	
Breaking load C.V.%	Giza 75	10.42	11.55	14.48	15.43	
	Giza 83	17.47	19.90	23.48	25.30	0.51
	Giza 85	10.62	11.85	14.05	16.50	
Elongation %	Giza 75	8.50	6.30	5.08	4.60	
	Giza 83	8.32	7.87	7.87	6.23	0.43
	Giza 85	9.80	9.42	8.55	7.50	
Elongation C.V. %	Giza 75	9.03	10.09	11.32	11.67	
	Giza 83	12.43	13.77	15.52	16.60	0.65
	Giza 85	9.98	11.35	11.98	12.60	
Stiffness g/Tex	Giza 75	212	237	258	244	
	Giza 83	160	151	133	128	20
	Giza 85	159	152	145	125	
Toughness g/Tex	Giza 75	0.70	0.47	0.34	0.25	
	Giza 83	0.55	0.46	0.41	0.25	0.04
	Giza 85	0.78	0.67	0.53	0.35	
Evenness C.V.%	Giza 75	18.58	20.45	22.40	27.63	
	Giza 83	19.80	24.67	30.97	33.13	0.33
	Giza 85	18.22	20.37	24.63	27.20	
No. of thin places/100 meters	Giza 75	35	52	116	182	
	Giza 83	38	194	329	397	11
	Giza 85	42	58	102	128	
No, of thick places/100 meters	Giza 75	50	64	152	301	
	Giza 83	63	249	391	445	16
	Giza 85	42	90	214	256	
No. of neps/100 meters	Giza 75	32	34	101	266	
	Giza 83	42	210	330	458	12
	Giza 85	33	69	98	186	

Table 34. Effect of the interaction between varieties and count on each of carded yarn tensile properties, evenness and yarn imperfections in extra long-staple category (ELS).

Yarn properties	Variety	Count				L.S.D. at 0.05
		30^S	40^S	60^S	80^S	
Strength g/Tex	Giza 70	18.17	15.83	13.83	12.30	
	Giza 77	17.57	15.00	13.22	11.65	N.S.
	Giza 84	18.78	16.63	14.03	12.43	
Breaking load C.V.%	Giza 70	11.27	11.87	13.92	15.52	
	Giza 77	11.18	13.58	16.42	18.75	0.56
	Giza 84	12.38	14.10	15.18	17.97	
Elongation %	Giza 70	8.48	8.43	6.48	5.32	
	Giza 77	8.55	7.67	5.65	4.82	N.S.
	Giza 84	9.22	8.70	6.95	6.38	
Elongation C.V. %	Giza 70	8.32	9.83	13.45	13.75	
	Giza 77	8.57	10.47	14.63	16.25	0.48
	Giza 84	8.90	9.75	13.62	16.17	
Stiffness g/Tex	Giza 70	214	187	213	235	
	Giza 77	206	197	237	260	21
	Giza 84	204	191	202	202	
Toughness g/Tex	Giza 70	0.78	0.67	0.45	0.33	
	Giza 77	0.75	0.58	0.37	0.28	0.03
	Giza 84	0.86	0.72	0.48	0.40	
Evenness C.V.%	Giza 70	20.40	22.13	26.35	29.95	
	Giza 77	19.45	22.40	25.10	28.65	0.38
	Giza 84	18.70	22.08	24.48	26.68	
No. of thin places/100 meters	Giza 70	102	130	240	321	
	Giza 77	65	111	136	204	21
	Giza 84	73	84	90	164	
No, of thick places/100 meters	Giza 70	138	202	202	405	
	Giza 77	96	213	211	302	32
	Giza 84	75	159	177	255	
No. of neps/100 meters	Giza 70	182	236	343	448	
	Giza 77	112	161	216	355	27
	Giza 84	87	128	168	232	

Table 35. Effect of the interaction between varieties and count on each of combed yarn tensile properties, evenness and yarn imperfections in extra long-staple category (ELS).

Yarn properties	Variety	Count 60^S	80^S	100^S	120^S	140^S	L.S.D. at 0.05
Strength g/Tex	Giza 70	18.28	16.82	15.95	14.77	13.52	
	Giza 77	17.57	15.97	15.45	14.90	13.43	N.S.
	Giza 84	19.13	18.20	16.91	15.85	13.98	
Breaking load C.V.%	Giza 70	10.38	11.07	12.18	14.63	16.20	
	Giza 77	12.08	12.78	13.22	14.57	17.67	0.72
	Giza 84	9.97	10.63	12.17	13.72	16.63	
Elongation %	Giza 70	8.67	8.07	7.28	5.63	4.97	
	Giza 77	8.62	7.82	6.80	6.17	5.35	N.S.
	Giza 84	9.37	8.63	8.22	7.00	5.53	
Elongation C.V. %	Giza 70	8.22	12.25	12.98	15.45	16.73	
	Giza 77	8.02	12.82	14.03	14.63	16.17	0.85
	Giza 84	7.62	9.62	13.37	14.46	15.30	
Stiffness g/Tex	Giza 70	208	207	220	256	272	
	Giza 77	204	205	228	238	252	N.S.
	Giza 84	204	213	208	227	255	
Toughness g/Tex	Giza 70	0.79	0.68	0.60	0.42	0.34	
	Giza 77	0.76	0.62	0.53	0.47	0.38	0.06
	Giza 84	0.90	0.79	0.70	0.56	0.39	
Evenness C.V.%	Giza 70	20.12	24.03	27.05	29.60	32.15	
	Giza 77	19.93	23.05	24.15	26.05	27.03	0.61
	Giza 84	19.78	21.20	24.15	25.03	25.88	
No. of thin places/100 meters	Giza 70	60	178	240	293	358	
	Giza 77	32	138	163	212	290	29
	Giza 84	26	74	133	150	167	
No, of thick places/100 meters	Giza 70	148	226	283	341	388	
	Giza 77	116	168	210	236	271	20
	Giza 84	59	98	148	191	208	
No. of neps/100 meters	Giza 70	153	253	357	414	465	
	Giza 77	130	166	271	333	390	24
	Giza 84	66	120	157	226	330	

4.4.5. The effect of variety x twist multiplier interaction

The results of the analysis of variance concerning the effect of this interaction on the physical properties of the carded yarns spun from LS and ELS and ELS combed varieties are presented in Tables (36, 37 and 38), respectively.

4.4.5.1. Yarn tensile properties

As shown in Table (36), the variety x twist multiplier interaction exerted significant effect on yarn strength, breaking load CV% and toughness of LS carded yarns.

Considering yarn strength of LS carded varieties, Table (36), significant differences existed between the two levels of twist multiplier 3.6 and 4.4 in case of Giza 85 yarns only, implying that this variety showed best response to the effect of twist compared with the other two varieties. The breaking load CV% of LS carded yarns followed similar trend in that Giza 85 responded better to twist resulting in an improvement of strength variation by increasing the twist to 4.4 which is reflected on the improvement of strength, too, compared with Giza 75 and Giza 83. Although in case of Giza 75 and Giza 83 the differences in strength or strength CV% was insignificant between the two levels of twist multiplier 3.6 and 4.4, there is a tendency in either cases of yarn strength and breaking load CV% to be improved, possibly due to the differences between varieties in optimum twist for maximum strength.

The toughness of LS yarn showed a similar trend as strength and strength variation, where Giza 85 showed improvement in yarn toughness with increasing the twist multiplier to 4.4. The other two varieties showed insignificant effect on toughness due to the increasing of twist.

With respect to ELS carded yarns as shown in Table (37), the variety x twist multiplier interaction exerted significant effect on all the six tensile

Table 36. Effect of the interaction between varieties and twist multiplier on each of carded yarn tensile properties, evenness and yarn imperfections in long-staple category (LS).

Yarn properties	Variety	Twist multiplier		L.S.D. at 0.05
		3.6	4.4	
Strength g/Tex	Giza 75	13.87	13.96	
	Giza 83	10.87	11.03	0.32
	Giza 85	12.38	13.46	
Breaking load C.V.%	Giza 75	13.14	12.80	
	Giza 83	21.59	21.48	0.36
	Giza 85	13.76	12.75	
Elongation %	Giza 75	6.08	6.17	
	Giza 83	7.52	7.62	N.S.
	Giza 85	8.78	8.86	
Elongation C.V. %	Giza 75	10.64	10.41	
	Giza 83	14.68	14.48	N.S.
	Giza 85	11.78	11.18	
Stiffness g/Tex	Giza 75	235	240	
	Giza 83	143	143	N.S.
	Giza 85	140	150	
Toughness g/Tex	Giza 75	0.44	0.44	
	Giza 83	0.41	0.42	0.03
	Giza 85	0.55	0.62	
Evenness C.V.%	Giza 75	22.39	22.14	
	Giza 83	26.97	27.32	0.23
	Giza 85	22.45	22.86	
No. of thin places/100 meters	Giza 75	97	96	
	Giza 83	219	290	8
	Giza 85	72	93	
No, of thick places/100 meters	Giza 75	148	135	
	Giza 83	247	326	11
	Giza 85	159	143	
No. of neps/100 meters	Giza 75	108	109	
	Giza 83	271	250	8
	Giza 85	101	92	

Table 37. Effect of the interaction between varieties and twist multiplier on each of carded yarn tensile properties, evenness and yarn imperfections in extra long-staple category (ELS).

Yarn properties	Variety	Twist multiplier 3.6	Twist multiplier 4.4	L.S.D. at 0.05
Strength g/Tex	Giza 70	14.98	15.09	
	Giza 77	14.82	13.89	0.52
	Giza 84	15.79	15.15	
Breaking load C.V.%	Giza 70	13.23	13.05	
	Giza 77	14.34	15.62	0.34
	Giza 84	14.52	15.30	
Elongation %	Giza 70	7.04	7.32	
	Giza 77	6.98	6.36	0.27
	Giza 84	7.78	7.84	
Elongation C.V. %	Giza 70	11.76	10.92	
	Giza 77	11.86	13.10	0.34
	Giza 84	11.75	12.47	
Stiffness g/Tex	Giza 70	217	208	
	Giza 77	216	234	15
	Giza 84	204	196	
Toughness g/Tex	Giza 70	0.54	0.57	
	Giza 77	0.53	0.46	0.02
	Giza 84	0.62	0.61	
Evenness C.V.%	Giza 70	24.22	25.19	
	Giza 77	22.95	24.85	0.27
	Giza 84	22.38	23.59	
No. of thin places/100 meters	Giza 70	191	205	
	Giza 77	89	169	15
	Giza 84	78	127	
No, of thick places/100 meters	Giza 70	239	234	
	Giza 77	182	230	23
	Giza 84	156	176	
No. of neps/100 meters	Giza 70	293	311	
	Giza 77	210	211	N.S.
	Giza 84	138	169	

Table 38. Effect of the interaction between varieties and twist multiplier on each of combed yarn tensile properties, evenness and yarn imperfections in extra long-staple category (ELS).

Yarn properties	Variety	Twist multiplier 3.6	Twist multiplier 4.4	L.S.D. at 0.05
Strength g/Tex	Giza 70	16.50	15.23	
	Giza 77	15.69	15.25	N.S.
	Giza 84	17.51	16.48	
Breaking load C.V.%	Giza 70	12.19	13.59	
	Giza 77	14.01	14.12	0.45
	Giza 84	11.99	13.26	
Elongation %	Giza 70	7.20	6.65	
	Giza 77	7.09	6.81	N.S.
	Giza 84	8.18	7.32	
Elongation C.V. %	Giza 70	12.64	13.61	
	Giza 77	12.91	13.35	N.S.
	Giza 84	11.78	12.34	
Stiffness g/Tex	Giza 70	234	230	
	Giza 77	224	226	N.S.
	Giza 84	213	230	
Toughness g/Tex	Giza 70	0.61	0.52	
	Giza 77	0.57	0.53	N.S.
	Giza 84	0.72	0.62	
Evenness C.V.%	Giza 70	26.53	26.65	
	Giza 77	23.97	24.12	N.S.
	Giza 84	23.20	23.22	
No. of thin places/100 meters	Giza 70	205	246	
	Giza 77	125	209	18
	Giza 84	98	121	
No, of thick places/100 meters	Giza 70	270	284	
	Giza 77	201	200	N.S.
	Giza 84	137	145	
No. of neps/100 meters	Giza 70	325	332	
	Giza 77	352	263	N.S.
	Giza 84	178	182	

properties of the spun yarns. The strength and breaking load CV% showed significant decreasing and increasing effects, respectively, in case of Giza 77 and Giza 84, which give impression that the optimum twist to be at 3.6 twist multiplier or below.

The elongation showed significant differences between 3.6 and 4.4 twist multiplier in case of Giza 70 and Giza 77 varieties. However, there is no constant trend for elongation with changing twist multiplier. The variation in elongation showed decreasing effect in case of Giza 70 and increasing effect in case of Giza 77 and Giza 84 which is possibly due to the effect of twist distribution according to mass variation.

The stiffness of the yarn showed significant differences due to twist multiplier in case of Giza 77 only, where the twist multiplier increase leads to stiffness increase. Meanwhile, the toughness differs significantly as the twist multiplier increased from 3.6 to 4.4 in case of Giza 70 and Giza 77. It seems that stiffness and toughness were reflecting the trends of both strength and elongation of the yarns.

In case of ELS combed yarns the interaction between variety x twist exerted significant effect only on the breaking load variation of the yarn, Table (38). In case of Giza 70 and Giza 84 there was a significant increasing effect for the twist on the yarn breaking load variation. This may be due to the fact that combing plays a role in response to twist.

4.4.5.2. The yarn evenness and number of imperfections/100 meters

The variety x twist multiplier interaction showed significant effect on evenness of LS carded yarns. However, changes of twist multiplier from 3.6 to 4.4 resulted in a significant increase in evenness in case of Giza 75 while decreased the evenness of both Giza 83 and Giza 85. For ELS three varieties

Giza 70, Giza 77 and Giza 84, the increase of twist multiplier from 3.6 to 4.4 decreased the yarn evenness. The evenness of ELS combed yarns was not affected significantly by the varieties x twist interaction.

Considering the effect of variety x twist multiplier interaction on the number of imperfections for LS and ELS carded yarns, as well as combed yarns. In case of LS and ELS carded, there were significant increases in thin place of Giza 83 and Giza 85 LS carded yarns, Giza 77 and Giza 84 ELS carded yarns with increasing twist multiplier. The same trend was found in case of Giza 70, Giza 77 and Giza 84 combed yarns.

The interaction between variety x twist multiplier showed significant effect in case of LS and ELS carded yarns and insignificant effect in case of combed ELS yarns on thick places/100 meters. There was a decreasing effect in number of thick places in case of Giza 85 and Giza 75 LS carded yarns. However, the effect was reversed in case of Giza 83 carded yarns. Meanwhile, increasing twist increased significantly the number of thick places of Giza 77 and Giza 84 ELS carded yarns.

For nep count/100 meters, the interaction showed only significant effect in case of Giza 83 and Giza 85 LS carded yarns, the number of neps decreased significantly with increasing twist multiplier from 3.6 to 4.4. In other cases the effect of interaction was insignificant.

4.4.6. The effect of count x twist multiplier interaction

The results of the analysis of variance with respect to the count x twist multiplier interaction on the physical properties of LS and ELS carded yarns, as well as ELS combed yarns are presented in Table (39, 40 and 41), respectively.

Table 39. Effect of the interaction between count and twist multiplier on each of carded yarn tensile properties, evenness and yarn imperfections in long-staple category (LS).

Yarn properties	Twist multiplier T.M.	Count 30^S	40^S	60^S	80^S	L.S.D. at 0.05
Strength g/Tex	3.6	14.96	13.43	11.90	9.19	N.S.
	4.4	15.39	13.97	12.16	9.76	
Breaking load C.V.%	3.6	13.13	14.50	17.64	19.30	N.S.
	4.4	12.53	14.37	17.03	18.78	
Elongation %	3.6	8.81	7.94	7.03	6.03	N.S.
	4.4	8.93	7.78	7.30	6.19	
Elongation C.V. %	3.6	10.46	12.01	13.07	13.93	N.S.
	4.4	10.51	11.46	12.81	13.31	
Stiffness g/Tex	3.6	171	174	181	165	N.S.
	4.4	183	186	176	167	
Toughness g/Tex	3.6	0.65	0.52	0.41	0.27	N.S.
	4.4	0.70	0.54	0.44	0.30	
Evenness C.V.%	3.6	18.88	21.76	25.84	29.27	N.S.
	4.4	18.86	21.90	26.16	29.38	
No. of thin places/100 meters	3.6	36	87	174	221	9
	4.4	41	116	191	251	
No, of thick places/100 meters	3.6	56	104	237	340	13
	4.4	47	164	267	328	
No. of neps/100 meters	3.6	39	82	197	321	10
	4.4	32	127	156	285	

Table 40. Effect of the interaction between count and twist multiplier on each of carded yarn tensile properties, evenness and yarn imperfections in extra long-staple category (ELS).

Yarn properties	Twist multiplier T.M.	Count				L.S.D. at 0.05
		30^S	40^S	60^S	80^S	
Strength g/Tex	3.6	18.31	16.04	13.88	12.56	N.S.
	4.4	18.03	15.60	13.51	11.70	
Breaking load C.V.%	3.6	11.62	12.89	14.459	17.02	0.46
	4.4	11.60	13.48	15.76	17.80	
Elongation %	3.6	8.66	8.40	6.52	5.50	N.S.
	4.4	8.84	8.13	6.20	5.51	
Elongation C.V. %	3.6	8.37	9.87	13.50	15.42	0.39
	4.4	8.82	10.17	14.30	15.36	
Stiffness g/Tex	3.6	212	191	212	232	N.S.
	4.4	204	192	222	231	
Toughness g/Tex	3.6	0.79	0.67	0.44	0.35	N.S.
	4.4	0.80	0.64	0.42	0.32	
Evenness C.V.%	3.6	19.03	21.46	24.84	27.41	0.31
	4.4	20.00	22.96	25.78	29.44	
No. of thin places/100 meters	3.6	58	76	136	207	N.S.
	4.4	102	140	175	252	
No, of thick places/100 meters	3.6	101	155	191	322	26
	4.4	105	227	202	320	
No. of neps/100 meters	3.6	128	160	228	340	N.S.
	4.4	126	190	256	351	

Table 41. Effect of the interaction between count and twist multiplier on each of combed yarn tensile properties, evenness and yarn imperfections in extra long-staple category (ELS).

Yarn properties	Twist multiplier T.M.	Count					L.S.D. at 0.05
		60^S	80^S	100^S	120^S	140^S	
Strength g/Tex	3.6	18.76	17.70	16.51	15.32	13.94	N.S.
	4.4	17.90	16.29	15.70	15.02	13.34	
Breaking load C.V.%	3.6	10.42	11.13	12.16	13.85	16.08	N.S.
	4.4	11.20	11.86	12.89	14.76	17.59	
Elongation %	3.6	9.12	8.45	7.96	6.48	5.44	N.S.
	4.4	8.64	7.89	6.91	6.06	5.12	
Elongation C.V. %	3.6	7.73	11.23	13.10	14.56	15.60	N.S.
	4.4	8.17	11.89	13.82	15.10	16.33	
Stiffness g/Tex	3.6	204	209	209	239	259	N.S.
	4.4	206	208	228	241	261	
Toughness g/Tex	3.6	0.86	0.75	0.65	0.50	0.39	N.S.
	4.4	0.78	0.64	0.55	0.46	0.35	
Evenness C.V.%	3.6	19.88	22.73	25.07	26.84	28.30	N.S.
	4.4	20.01	22.79	25.17	26.94	28.41	
No. of thin places/100 meters	3.6	34	103	151	189	237	23
	4.4	44	156	207	248	306	
No, of thick places/100 meters	3.6	109	159	208	248	289	N.S.
	4.4	106	168	219	264	289	
No. of neps/100 meters	3.6	114	180	258	317	390	N.S.
	4.4	118	179	266	332	400	

4.4.6.1. Yarn tensile properties

As shown in the above mentioned tables, the effect of count twist multiplier interaction was only significant in case of breaking load CV% and elongation CV% of ELS carded yarns, the strength and elongation variations were increased as a result of increasing twist.

4.4.6.2. The yarn evenness and number of imperfections and neps count/100 meter

The yarn evenness was significantly affected by count twist multiplier interaction in ELS carded only, the evenness decreased with increasing yarn fineness. However, the magnitude of evenness and the rate of decrease differed from 3.6 to 4.4 twist multiplier.

All the number of imperfections i.e. thin and thick places and neps were significantly affected by count x twist multiplier interaction in case of LS carded yarns. In case of ELS carded and combed yarns only the number of thick places exhibited significant differences due to the interaction. The magnitude and rate of change differed from 3.6 to 4.4 twist multiplier.

4.4.7. The effect of variety x count x twist multiplier interaction

The results of the analysis of variance concerning the effect of variety x counts x twist multiplier interaction on the physical properties of LS and ELS carded and combed ELS yarns are presented in Tables (42, 43 and 44), respectively.

4.4.7.1. Yarn tensile properties

Only breaking load CV% and elongation CV% of ELS carded yarns were affected significantly by this second order interaction.

4.4.7.2. The yarn evenness and number of imperfections and nep count/100 meters

Evenness, thin and thick places and neps formation were affected significant by this second order interaction in LS category only. Meanwhile

Table 42. Effect of the interaction between varieties, count and twist multiplier on each of carded yarn tensile properties, evenness and yarn imperfections in long-staple category (LS).

Yarn properties	Variety	Count 30^S, Twist multiplier 3.6	30^S 4.4	40^S 3.6	40^S 4.4	60^S 3.6	60^S 4.4	80^S 3.6	80^S 4.4	L.S.D. at 0.05
Strength g/Tex	Giza 75	16.57	16.60	14.87	15.00	13.03	13.13	11.00	11.10	
	Giza 83	13.17	13.53	11.83	11.97	10.83	10.27	7.63	8.37	N.S.
	Giza 85	15.13	16.03	13.60	14.93	11.83	13.07	8.93	9.80	
Breaking load C.V.%	Giza 75	10.73	10.10	11.70	11.40	14.37	14.60	15.77	15.10	
	Giza 83	17.57	17.37	19.73	20.07	23.73	23.23	25.33	25.27	N.S.
	Giza 85	11.10	10.13	12.07	11.63	14.83	13.27	17.03	15..97	
Elongation %	Giza 75	8.40	8.60	6.50	6.10	4.93	5.23	4.47	4.73	
	Giza 83	8.17	8.47	8.00	7.73	7.73	8.00	6.17	6.30	N.S.
	Giza 85	9.87	9.73	9.33	9.50	8.43	8.67	7.47	7.53	
Elongation C.V. %	Giza 75	9.03	9.03	10.37	9.80	11.33	11.30	11.83	11.50	
	Giza 83	12.30	12.57	14.03	13.50	15.60	15.43	16.80	16.40	N.S.
	Giza 85	10.03	9.93	11.63	11.07	12.27	11.70	13.17	12.03	
Stiffness g/Tex	Giza 75	197	227	229	244	264	252	250	239	
	Giza 83	162	158	147	155	140	126	124	132	N.S.
	Giza 85	154	164	147	157	140	150	120	130	
Toughness g/Tex	Giza 75	0.70	0.71	0.48	0.46	0.34	0.35	0.24	0.26	
	Giza 83	0.54	0.56	0.45	0.47	0.42	0.41	0.23	0.26	N.S.
	Giza 85	0.72	0.84	0.64	0.71	0.50	0.57	0.34	0.37	
Evenness C.V.%	Giza 75	18.57	18.60	20.70	20.20	22.37	22.43	27.93	27.33	
	Giza 83	19.87	19.73	24.53	24.80	30.60	31.33	32.87	33.40	0.46
	Giza 85	18.20	18.23	20.03	20.70	24.57	24.70	27.00	27.40	
No. of thin places/100 meters	Giza 75	33	37	49	57	116	116	190	175	
	Giza 83	38	39	163	224	313	344	362	432	16
	Giza 85	35	48	49	67	93	112	111	146	
No, of thick places/100 meters	Giza 75	50	50	59	69	156	148	327	276	
	Giza 83	70	56	154	344	340	441	426	465	22
	Giza 85	50	34	99	80	217	212	268	245	
No. of neps/100 meters	Giza 75	33	31	36	33	105	97	257	275	
	Giza 83	50	35	141	281	385	275	507	408	16
	Giza 85	34	32	70	67	101	96	200	172	

Table 43. Effect of the interaction between varieties, count and twist multiplier on each of carded yarn tensile properties, evenness and yarn imperfections in extra long-staple category (ELS).

Yarn properties	Variety	Count: 40^S		60^S		80^S		100^S		L.S.D. at 0.05
		Twist multiplier: 3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	
Strength g/Tex	Giza 70	18.07	18.27	15.67	16.00	13.83	13.83	12.33	12.27	
	Giza 77	18.00	17.13	15.63	14.37	13.47	12.97	12.20	11.10	N.S.
	Giza 84	18.87	18.70	16.83	16.43	14.33	13.73	13.13	11.73	
Breaking load C.V.%	Giza 70	11.13	11.40	11.93	11.80	14.17	13.67	15.70	15.35	
	Giza 77	11.43	10.93	13.13	14.03	15.03	17.80	17.67	19.73	0.79
	Giza 84	12.30	12.47	13.60	14.60	14.57	15.80	17.60	18.53	
Elongation %	Giza 70	8.40	8.57	8.30	8.57	6.37	6.60	5.10	5.53	
	Giza 77	8.50	8.60	8.13	7.20	6.27	5.03	5.03	4.60	N.S.
	Giza 84	9.07	9.37	8.77	8.63	6.93	6.97	6.37	6.40	
Elongation C.V. %	Giza 70	8.17	8.47	10.20	9.47	13.30	13.60	15.37	12.13	
	Giza 77	8.30	8.83	10.00	10.93	13.77	15.50	15.37	17.13	0.68
	Giza 84	8.63	9.17	9.40	10.10	13.43	13.80	15.53	16.80	
Stiffness g/Tex	Giza 70	215	213	188	187	216	209	248	221	
	Giza 77	212	199	193	200	214	259	243	277	N.S.
	Giza 84	208	200	192	189	207	197	207	196	
Toughness g/Tex	Giza 70	0.76	0.79	0.65	0.69	0.44	0.46	0.32	0.34	
	Giza 77	0.76	0.74	0.63	0.52	0.42	0.32	0.31	0.26	N.S.
	Giza 84	0.85	0.88	0.74	0.71	0.47	0.48	0.42	0.37	
Evenness C.V.%	Giza 70	20.07	20.73	21.83	22.43	26.10	26.60	28.90	31.00	
	Giza 77	18.67	20.23	21.33	23.47	24.23	25.97	27.57	29.73	N.S.
	Giza 84	18.37	19.03	21.20	22.97	24.20	24.77	25.77	27.60	
No. of thin places/100 meters	Giza 70	93	111	121	140	241	240	310	331	
	Giza 77	34	97	50	172	93	180	181	228	N.S.
	Giza 84	48	97	59	108	75	105	131	198	
No, of thick places/100 meters	Giza 70	114	163	201	202	211	194	431	379	
	Giza 77	106	85	127	300	193	229	300	304	45
	Giza 84	84	66	137	180	170	184	234	276	
No. of neps/100 meters	Giza 70	188	176	230	242	320	365	434	462	
	Giza 77	120	105	156	166	192	239	373	337	38
	Giza 84	75	98	93	162	172	164	212	252	

Table 44. Effect of the interaction between varieties, count and twist multiplier on each of combed yarn tensile properties, evenness and yarn imperfections in extra long-staple category (ELS).

Yarn properties	Variety	60^S 3.6	60^S 4.4	80^S 3.6	80^S 4.4	100^S 3.6	100^S 4.4	120^S 3.6	120^S 4.4	140^S 3.6	140^S 4.4	L.S.D. at 0.05
Strength g/Tex	Giza 70	18.87	17.70	17.47	16.17	16.57	15.33	15.20	14.33	14.43	12.60	
	Giza 77	17.93	17.20	16.30	15.63	15.67	15.23	14.97	14.83	13.53	13.33	N.S.
	Giza 84	19.47	18.80	19.33	17.07	17.30	16.53	15.80	15.90	13.87	14.10	
Breaking load C.V.%	Giza 70	10.03	10.73	10.23	11.90	11.80	12.57	14.20	15.07	14.70	17.70	
	Giza 77	11.93	12.23	12.83	12.73	13.27	13.17	14.27	14.87	17.73	17.60	N.S.
	Giza 84	9.30	10.63	10.33	10.93	11.40	12.93	13.10	14.33	15.80	17.47	
Elongation %	Giza 70	8.87	8.47	8.33	7.80	7.83	6.73	5.73	5.53	5.23	4.70	
	Giza 77	8.73	8.50	7.97	7.67	7.17	6.43	6.30	6.03	5.30	5.40	N.S.
	Giza 84	9.77	8.97	9.07	8.20	8.87	7.57	7.40	6.60	5.80	5.27	
Elongation C.V. %	Giza 70	7.77	8.67	12.13	12.37	12.30	13.67	14.97	15.93	16.03	17.43	
	Giza 77	7.93	8.10	12.63	13.00	13.77	14.30	14.50	14.77	15.73	16.60	N.S.
	Giza 84	7.50	7.73	8.93	10.30	13.23	13.50	14.20	14.60	15.03	15.57	
Stiffness g/Tex	Giza 70	207	208	210	204	217	229	267	244	276	269	
	Giza 77	205	203	204	206	219	238	240	237	258	246	N.S.
	Giza 84	199	210	214	213	195	210	213	240	244	268	
Toughness g/Tex	Giza 70	0.83	0.75	0.73	0.63	0.65	0.54	0.44	0.40	0.38	0.30	
	Giza 77	0.78	0.73	0.65	0.60	0.56	0.49	0.47	0.46	0.40	0.37	N.S.
	Giza 84	0.90	0.85	0.88	0.71	0.77	0.63	0.59	0.53	0.40	0.37	
Evenness C.V.%	Giza 70	20.10	20.13	24.00	24.07	26.97	27.13	29.53	29.67	32.03	32.27	
	Giza 77	19.83	20.03	23.03	23.07	24.10	24.20	25.90	26.20	26.97	27.10	N.S.
	Giza 84	19.70	19.87	21.17	21.23	24.13	24.17	25.10	24.97	25.90	25.87	
No. of thin places/100 meters	Giza 70	54	65	162	194	216	264	260	325	334	381	
	Giza 77	27	36	64	182	118	208	173	252	213	368	N.S.
	Giza 84	22	31	54	93	118	149	135	166	165	169	
No, of thick places/100 meters	Giza 70	152	144	210	242	283	282	323	359	385	390	
	Giza 77	118	114	169	166	203	218	240	233	275	266	N.S.
	Giza 84	57	61	100	96	139	157	180	200	206	211	
No. of neps/100 meters	Giza 70	151	153	254	252	355	358	403	425	458	471	
	Giza 77	125	133	163	168	262	278	321	344	388	391	N.S.
	Giza 84	65	67	122	117	154	160	227	226	322	338	

Column headings: Count (60^S, 80^S, 100^S, 120^S, 140^S); Twist multiplier (3.6, 4.4).

ELS carded yarns exhibited significant effect for this interaction in case of thick places and neps count only.

At the end of the above argument, the effect of the cotton variety and spinning processing variables namely; count and twist multiplier as well as their first and second order interactions on the physical properties of the cotton yarn spun from LS and ELS carded and ELS combed varieties might be summarized as follows:

For LS category, the Giza 75 variety was stronger, more uniform in strength, stiffer, more even in thickness and lower in thick places, followed by Giza 85 and Giza 83 varieties.

For ELS category, the varieties take the above descending order as Giza 84, Giza 70 and Giza 77.

The strength, elongation, evenness decreased with increasing the fineness of the yarn. Nevertheless, the strength and elongation variation as well as the number of imperfections increased with the increasing of yarn fineness.

The trend of twist with strength, elongation, strength and elongation variations, and imperfections differ from LS to ELS carded or combed yarns possibly due to differences in optimum twist from one category to another and carded to combed yarns.

The variety x count interaction exerted significant effects on all tensile properties except the strength and elongation of LS and ELS carded yarns and the stiffness of ELS combed yarns. However, the trend differ from one variety to another. On the other hand, the unevenness and imperfections increased with increasing the count of LS and ELS carded yarns and ELS combed yarns.

However, the trend differ from one variety to another particularly in case of the finest counts.

The variety x twist multiplier interaction exerted significant effects on strength, strength variation and toughness of LS carded yarn, Giza 85 shows the best response to twist and and was tougher and more even than Giza 75 and Giza 83 possibly due to the differences between these three varieties in optimum twist multiplier. For ELS carded yarns, the trend differ from one yarn property to another. For ELS combed yarns, the effects was only significant on the strength variations.

The count x twist interaction exerted significant effects on strength and elongation variation and evenness of ELS carded yarn and on imperfections of LS and ELS carded and ELS combed yarns.

The second order variety x count x twist multiplier interaction exerted significant effects on strength and elongation variations as well as thick places and neps of ELS yarns. However, the effect was only significant on the imperfections and evenness of LS yarns.

4.5. Improvements achieved in the quality of Egyptian cotton

In view to determine the magnitude of the improvements achieved in the quality of Egyptian cotton and to appreciate the role played by the cotton technologist and breeder in this affair, the following procedures had been used in this section of the results and discussion:

(i) Measuring the variation in physical properties of fiber and yarns within each length category alone and within the two categories together, so as to define the possibility, or otherwise, of further improvement in the quality of Egyptian cotton.

(ii) Comparing the physical properties of the spun yarns with levels of the percentage of world production to check the precision of the results and the validity of the micro spinning technique at CRI, ARC, Giza.

(iii) Finding out the percentage increase or decrease in the physical properties of the new introduced varieties with respect to the relatively older commercial varieties in each cotton category.

4.5.1. Variation of fiber and yarn physical properties within each length category and within combined categories.

Table (45), includes the medium, the mean, the standard deviation (S.D.), the coefficient of variation (CV%), the minimum and maximum for each of the fiber physical properties of long-stapled category LS. As shown in the above table, comparing the values of the statistical parameters, the value of CV% for the FFI is noticeably higher, also, for fiber bundle stiffness, fiber bundle elongation and fiber bundle toughness in a descending order. On the other hand, the high values of FFI (CV%) and the mean implying that breeder does not give much care for this important fiber length parameter. The values of stiffness and toughness (CV%) reflect the relation between fiber bundle strength and fiber bundle elongation in this category. Considering the ELS category as shown in Table (46), the statistical parameters were higher in medium, mean minimum and maximum in the most of the physical fiber properties than that of LS category. For FFI in this category, too, the (CV%) was high and that confirm the same fact of LS category, that the breeder did not give attention to this important length parameter.

Dealing with the combined LS and ELS categories together as shown in Table (47), results indicated that within category the variation of each character was low, but within the two categories it was high, and that gives a broad scale for the

Table 45. Median, mean, standard deviation and coefficient of variation for each of the studied physical fiber properties of long-staple category (LS).

Fiber properties	Statistical parameters					
	Median	Mean	S.D.	C.V.%	Minimum	Maximum
2.5% Span length (mm)	30.55	30.31	0.64	2.11	29.40	31.10
50% Span length (mm)	15.70	15.50	0.65	3.61	14.50	16.10
Length uniformity ratio %	51.55	51.13	0.90	1.76	49.20	52.00
Floating fiber index %	10.48	10.97	3.01	27.44	7.36	16.97
Micronaire reading	4.00	3.98	0.23	5.78	3.60	4.30
Linear density (millitex)	169.00	168.00	3.30	1.96	163.00	173.00
Maturity (%)	82.50	83.80	3.50	4.18	80.0	90.00
Maturity ratio	0.94	0.95	0.03	3.15	0.92	0.99
Standard linear density (millitex)	178.00	177.00	2.28	1.29	174.00	180.00
Fiber bundle strength (g/tex)	28.50	28.40	2.50	8.80	25.10	31.60
Fiber bundle elongation (%)	6.10	6.10	0.80	13.11	5.00	7.30
Fiber bundle stiffness (g/tex)	415.00	472.00	0.96	20.34	387.00	616.00
Fiber bundle toughness (g/tex)	0.83	0.87	0.11	12.64	0.77	1.04

Table 46. Median, mean, standard deviation and coefficient of variation for each of the studied physical fiber properties of extra long-staple category (ELS).

Fiber properties	Statistical parameters					
	Median	Mean	S.D.	C.V.%	Minimum	Maximum
2.5% Span length (mm)	34.65	34.60	0.94	2.72	33.40	35.80
50% Span length (mm)	18.10	17.82	0.52	2.92	17.10	18.30
Length uniformity ratio %	51.25	51.57	0.60	1.16	51.00	52.60
Floating fiber index %	9.23	8.51	1.34	15.75	6.20	9.79
Micronaire reading	3.60	3.61	0.21	5.82	3.20	3.90
Linear density (millitex)	142.00	145.00	9.80	6.76	135.00	159.00
Maturity (%)	81.00	80.50	1.40	1.74	78.00	82.00
Maturity ratio	0.91	0.92	0.04	4.35	0.87	0.99
Standard linear density (millitex)	160.00	158.00	7.20	4.56	148.00	166.00
Fiber bundle strength (g/tex)	35.40	35.40	1.00	2.82	34.20	37.00
Fiber bundle elongation (%)	5.80	5.70	0.40	7.02	5.40	6.70
Fiber bundle stiffness (g/tex)	608.00	603.00	24.00	3.98	551.00	633.00
Fiber bundle toughness (g/tex)	1.00	1.04	0.09	9.00	0.93	1.24

breeder for crossing and selecting the best combinations to introduce new varieties. The FFI showed the same trend as in the above two categories.

The values of the statistical parameters of the various physical properties of carded yarns spun from LS, ELS and combined LS+ELS categories and combed yarns spun from ELS category are presented in Table (48, 49, 50 and 51), respectively. The SD, CV%, minimum and maximum showed higher values in case of evenness and yarn imperfections and that differed from LS to ELS carded yarns as well as to ELS combed yarns. The above results indicated that both cotton breeder and technologist should give more attention to decrease the short fiber content and improve most yarn properties through fiber properties in both LS and ELS length categories.

4.5.2. Comparison of yarn properties with those of the world levels

The evenness of thickness (CV%), strength, and neps/100 meters of LS and ELS carded yarns were compared with the world production in Table (52). Similarly, the above three characteristics of ELS combed yarns were compared with their corresponding of world yarns as shown in Table (53).

For LS carded yarns spun from Giza 75, Giza 83 and Giza 85 into 30^S count at 3.6 or 4.4 twist multiplier, evenness of yarns spun from Giza 75 or Giza 85 at the two levels of twist 3.6 and 4.4 lied between 50% and 75% of world production, implying that the evenness of these yarns are within more than 75% of the world yarns. On the other hand, carded yarns spun from Giza 83 LS variety into 30^S count at both 3.6 and 4.4 twist multipliers lied between 75% and 95% of the world production. With respect to the evenness of 40^S count corded yarns spun from LS varieties, the evenness of the yarns spun from Giza 75 at 3.6 twist multiplier lies between 75% and 95% of the world production while that spun into 40^S carded yarn at 4.4 twist multiplier lies between 50% and 75% of the world production.

Table 48. Median, mean, standard deviation (S.D.) and coefficient of variation (C.V.%) for various physical properties of yarns spun from carded long-staple category (LS) varieties.

Yarn properties	Statistical parameters					
	Median	Mean	S.D.	C.V.%	Minimum	Maximum
Strength (g/Tex)	12.95	12.59	2.52	20.02	7.30	17.30
Breaking load(C.V. %)	15.10	15.92	4.75	29.84	9.70	26.20
Elongation (%)	7.90	7.50	1.61	21.47	3.80	10.10
Elongation (C.V. %)	11.90	12.19	2.20	18.04	8.90	17.10
Stiffness (g/Tex)	154.00	175.00	49.00	28.00	114.00	283.00
Toughness (g/Tex)	.47	0.48	0.17	35.42	0.21	0.97
Evenness (C.V. %)	23.35	24.00	4.74	19.75	17.90	33.60
Number of thin places/100 meter	107.00	139.00	115.00	82.73	30.00	460.00
Number of thick places/100 meter	158.00	193.00	138.00	71.50	28.00	480.00
Number of neps/100 meter	100.00	155.00	137.00	88.39	29.00	511.00

Table 49. Median, mean, standard deviation (S.D.) and coefficient of variation (C.V.%) for various physical properties of yarns spun from carded extra long-staple category (ELS) varieties.

Yarn properties	Statistical parameters					
	Median	Mean	S.D.	C.V.%	Minimum	Maximum
Strength (g/Tex)	14.35	14.95	2.39	15.99	10.90	19.20
Breaking load(C.V. %)	14.15	14.34	2.52	17.57	10.70	20.30
Elongation (%)	7.30	7.22	1.48	20.50	4.20	9.80
Elongation (C.V. %)	11.40	11.89	2.96	24.89	8.00	17.60
Stiffness (g/Tex)	205.00	212.00	27.26	12.86	181.00	356.00
Toughness (g/Tex)	0.51	0.56	0.19	33.93	0.24	0.91
Evenness (C.V. %)	23.90	23.86	3.56	14.92	18.10	31.10
Number of thin places/100 meter	120.00	143.00	81.30	56.85	26.00	352.00
Number of thick places/100 meter	184.00	202.00	94.02	46.54	59.00	479.00
Number of neps/100 meter	195.00	222.00	108.00	48.65	66.00	490.00

Table 50. Median, mean, standard deviation (S.D.) and coefficient of variation (C.V.%) for various physical properties of yarns spun from carded long-staple and extra long stapled varieties.

Yarn properties	Statistical parameters					
	Median	Mean	S.D.	C.V.%	Minimum	Maximum
Strength (g/Tex)	13.60	13.77	2.72	19.75	7.30	19.20
Breaking load(C.V. %)	14.40	15.13	3.87	25.58	9.70	26.00
Elongation (%)	7.85	7.36	1.55	21.06	3.80	10.10
Elongation (C.V. %)	11.90	12.08	2.60	21.52	8.00	17.60
Stiffness (g/Tex)	198.00	194.00	44.00	22.68	114.00	356.00
Toughness (g/Tex)	0.47	0.52	0.19	36.54	0.21	0.97
Evenness (C.V. %)	23.90	23.93	4.18	17.47	17.90	33.60
Number of thin places/100 meter	115.00	141.00	99.00	70.21	26.00	460.00
Number of thick places/100 meter	179.00	198.00	118.00	59.60	28.00	480.00
Number of neps/100 meter	173.00	188.00	128.00	68.08	29.00	511.00

Table 51. Median, mean, standard deviation (S.D.) and coefficient of variation (C.V.%) for various physical properties of yarns spun from combed extra long stapled varieties.

Yarn properties	Statistical parameters					
	Median	Mean	S.D.	C.V.%	Minimum	Maximum
Strength (g/Tex)	15.90	16.05	1.88	11.71	11.90	19.90
Breaking load(C.V. %)	13.15	13.19	2.43	18.42	9.10	18.60
Elongation (%)	7.45	7.21	1.48	20.52	4.10	9.80
Elongation (C.V. %)	13.65	12.77	3.04	23.80	6.80	18.10
Stiffness (g/Tex)	223.00	226.00	27.23	12.05	185.00	307.00
Toughness (g/Tex)	0.61	0.59	0.18	0.31	0.24	0.96
Evenness (C.V. %)	24.30	24.61	3.49	14.18	19.10	32.60
Number of thin places/100 meter	160.00	168.00	103.00	61.31	17.00	411.00
Number of thick places/100 meter	202.00	206.00	90.00	43.69	44.00	420.00
Number of neps/100 meter	251.00	255.00	121.00	47.45	54.00	516.00

Table 52. Comparison of evenness, strength and nep count/100 meters of LS and ELS carded yarns with the world levels.

World proportion %	Yarn count: 30^S						40^S						40^S					
	Variety: Giza 75		Giza 83		Giza 85		Giza 75		Giza 83		Giza 85		Giza 70		Giza 77		Giza 84	
	Twist multiplier: 3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4
Yarn evenness (CV %)																		
									*	*								
95																		
			*	*			*					*	*	*		*		
75																		
	*	*			*	*		*			*				*		*	*
50																		
25																		
5																		
Yarn strength (g/Tex)																		
95																		
									*	*								
75																		
			*	*							*							
50																		
25																		
					*	*	*	*				*						
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	*	*											*	*	*	*	*	*
Yarn nep count/100 meters																		
										*			*	*				
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50																		
			*	*	*						*	*						
25																		
		*				*	*	*										
5																		

Table 53. Comparison of evenness, strength and nep count/100 meters of ELS combed yarns with the world levels.

World proportion %	Yarn count 60^S						80^S						100^S					
	Variety: Giza 70		Giza 77		Giza 84		Giza 70		Giza 77		Giza 84		Giza 70		Giza 77		Giza 84	
	Twist multiplier: 3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4	3.6	4.4
Yarn evenness (CV%)																		
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
95																		
75																		
50																		
25																		
5																		
Yarn strength (g/Tex)																		
95																		
									*	*				*	*	*		
75																		
			*					*				*	*					*
50																		
	*	*	*			*	*										*	
25																		
					*						*							
5																		
Nep count/100 meters																		
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
95																		
75																		
50																		
25																		
5																		

For Giza 85 carded 40^S count yarn spun at 3.6 twist multiplier the evenness lies between 50% and 75% of the world production, while the other level of twist 4.4 showed evenness which lies between 75% and 95% of the world production. However, the evenness of 40^S yarn spun from Giza 83 at the two levels of twist 3.6 and 4.4 lied above than 95% of the production.

As far as the strength of 30^S carded yarns are concerned, spun at 3.6 or 4.4 twist multiplier, in case of Giza 75 variety the strength lies below 5%, while the strength of the yarns spun from Giza 85 variety lies between 5% and 25% of the world production. Whereas in case of Giza 83 variety the yarn strength lies between 50% and 75%.

Meanwhile, the strength of 40^S carded yarn count spun from Giza 75 variety at both 3.6 and 4.4 twist multiplier lies between 5% and 25%. The strength of Giza 85 40^S yarn count spun at 3.6 twist multiplier lies between 50% and 75%, while that spun at 4.4 twist multiplier lies between 5 and 25%. The strength of 40^S carded yarn count spun from Giza 83 variety at the two levels of twist lies between 75% and 95% of the world production.

As long as the nep count is considered, the LS carded yarn spun from Giza 75 into 30^S count at 3.6 twist multiplier lies between 50% and 75% and that spun at 4.4 twist multiplier lies between 5% and 25%. Meanwhile, the 30^S count spun from Giza 85 variety at 3.6 twist multiplier lies between 25% and 50%, whereas that spun at 4.4 twist multiplier lies between 5% and 25%. However, the nep count of 30^S carded yarn count spun from Giza 83 variety at both 3.6 and 4.4 twist multiplier lied between 25% and 50% of the world production.

Considering, 40^S carded yarn count spun from Giza 75 at the two levels of twist 3.6 and 4.4, it lied between 5% and 25% and the yarns spun from Giza 85 at the same count and twist multiplier lied between 5% and 25% of the world production. The nep count of 40s carded yarn count spun from Giza 83 variety at 3.6 and 4.4 twist multiplier lied between 50% and 75% and above 95% of the world production, respectively.

Dealing with ELS 40^S carded yarns count, the evenness of Giza 70 carded yarns spun at 3.6 or 4.4 twist multiplier lied between 75% and 95%. Whereas yarns spun from Giza 77 at the same count and the two levels of twist 3.6 and 4.4 the evenness lied between 50% and 75% and 75% and 95% of the world production, respectively. the evenness of Giza 84 carded yarns at 40^S count and both 3.6 and 4.4 twist multiplier lied between 50% and 75%.

The strength of 40^S ELS carded yarns spun for Giza 70, Giza 77 and Giza 84 at 3.6 or 4.4 twist multiplier lied below 5% of the world production.

As far as the nep count is considered from yarns spun into 40^S count and 3.6 and 4.4 twist multiplier from Giza 70, Giza 77 and Giza 84, in case of Giza 70 the nep count lied above 95% in all yarns and in case of Giza 77 lied between 75% and 95% in all yarns. Meanwhile, the yarns spun from Giza 84 at 3.6 and 4.4 twist multiplier into 40^S count lied between 50% and 75% and between 75% and 95%, respectively, of the world production.

Considering the ELS combed yarns spun from Giza 70, Giza 77 and Giza 84 it is shown evenness and nep count always lied above the 95% of the world production in case of 60^S, 80^S and 100^S yarn count and at 3.6 or 4.4 twist multiplier.

However, the strengths of these ELS combed yarns behaved in a different manner. In case of 60^S yarns count spun at 3.6 and 4.4 twist multiplied from Giza 70 or 3.6 from Giza 77 or at 4.4 twist multiplier from Giza 84 the strength lied between 25% and 50% of the world production. Meanwhile, the 60^S yarn count spun from Giza 77 and Giza 84 at 4.4 and 3.6 twist multiplier, respectively, showed strength lied between 50% and 75% of the world production.

In case of 80^S combed yarn count spun from Giza 70 and Giza 84 at 4.4 twist multiplier, the strength lied between 50% and 75% of the world production. Whereas the strength of 80^S combed yarn spun at 3.6 twist multiplier from Giza 70 and Giza 84 lied between 5% and 25% and between 25% and 50%, respectively. The strength of 60^S combed yarn count spun from Giza 77 at both 3.6 and 4.4 twist multiplier lied between 75% and 95% of the world production.

The 100^S combed yarn count strength of yarns spun from Giza 70 and Giza 84 at 4.4 and 3.6 twist multiplier lied between 75% and 95% and between 25% and 50%, respectively. The strength of 100^S combed yarn count spun from Giza 70 and Giza 84 at 3.6 and 4.4 twist multiplier, respectively lied between 50% and 75% of the world production. the strength of 100^S combed yarn count spun from Giza 77 at both 3.6 and 4.4 twist multiplier lied between 75% and 95% of the world production.

For carded 30s and 40s count of LS yarns at each of 3.6 and 4.4 twist multiplier and carded ELS 40^S carded yarn count of 3.6 and 4.4 twist multiplier, the evenness, strength and nep count lied within the range of the world yarn production. Meanwhile the 60^S, 80^S and 100^S combed yarn counts at 3.6 and 4.4 twist multiplier, the strength lied within the range of the world production. However, there are many facts which should be taken into account when concluding such comparison which are:

1. The micro spinning technique is dealing with very small size sample of 40 or 60 grams in case of carded yarns and 1 kg in case of combed yarns which differ from commercial spinning mills. However, the technique is

valid for comparison of the results of different samples, grades and varieties or strains for the breeder and spinner.

2. The ambient temperature and relative humidity suffer fluctuation at present due to out of control reasons.
3. The technique applied since 1934 and 1963 used very old technology with respect to drafting systems, speeds and technology control.
4. Nevertheless the results ensure the need for new technology for the microspinning test so as to go side by side with the modern mills.

4.5.3. Comparison of new introduced to relatively older commercial cotton varieties

In view to asses the improvement achieved in cotton quality, and to appreciate the role played by both cotton technologist and breeder in this matter, the recently introduced varieties were compared with relatively older commercial varieties with respect to both fiber and yarn physical properties.

4.5.3.1. Physical fiber properties

In case of LS category both new introduced varieties Giza 83 and Giza 85 were compared with the relatively older commercial variety Giza 75. Meanwhile, in case of ELS category the new introduced Giza 84 variety was compared with the relatively older two commercial varieties namely Giza 70 and Giza 77. The comparison was based always on the percentage increase and decrease in the fiber and yarn physical properties of the new introduced variety with respect to relatively older commercial variety.

As shown in Table (54), for the comparison of fiber physical properties of LS category varieties, for fiber length measurements Giza 85 was slightly higher in 2.5%, 50% span lengths and length uniformity than Giza 75. On the other hand, Giza 75 was noticeably higher in FFI value than Giza 85. Giza 83 showed somewhat lower values of 2.5% and 50% span lengths and uniformity ratio than Giza 75, but FFI was higher in Giza 83 than in case of Giza 75.

With respect to fiber fineness/maturity measurements the Giza 85 showed lower micronaire reading, lower linear density, lower maturity % and lower maturity ratio. However, Giza 83 showed relatively pronounced lower values of fineness/maturity parameters than Giza 75. For standard linear density, Giza 85 and Giza 83 were higher than Giza 75 with 2.86% and 1.71%, respectively. For the bundle tensile properties, Giza 85 and Giza 83 were less in fiber bundle strength by 8.63% and 18.85% than Giza 75, respectively. On the other hand, Giza 85 and Giza 83 were higher in elongation than Giza 75 by 36.54% and 19.23%, respectively. The fiber bundle stiffness and toughness behaved according to the trend of strength and elongation.

In general, Giza 75 showed superiority over Giza 85 which in turn was better than Giza 83.

Considering the fiber physical properties of ELS category as shown in Table (55), with respect to fiber length measurements Giza 84 showed lower values in 2.5% and 50% span lengths than Giza 70, whereas the length uniformity ratio and FFI show valueless differences.

Comparing Giza 84 with Giza 77, the Giza 84 was about 5.52% lower and 37.41% higher in 50% span length and FFI, respectively, than Giza 77.

As far as the fiber fineness/maturity is considered, the fineness of Giza 84 in terms of micronaire value and linear density was lower by 10.53%. 5.56% and 13.92%, 4.22% than Giza 70 and Giza 77, respectively. On the other hand, Giza 84 was lower than Giza 70 by 6% expressed as maturity ratio. Nevertheless the standard linear density showed lower value of Giza 84 by 9.2% and 8.64 than Giza 70 and Giza 77, respectively.

Table 54. Comparison between the commercial Giza 75 variety with the new Giza 83 and Giza 85 varieties in fiber physical properties.

Fiber properties	Giza 75	Giza 83			Giza 85		
		Value	Difference	Differ. %	Value	Difference	Differ. %
2.5% Span length (mm)	30.50	29.50	-1.0	-3.28	30.90	0.40	1.31
50% Span length (mm)	15.70	14.80	-0.9	-5.73	16.00	0.30	1.91
Length uniformity ratio %	51.50	50.10	-1.4	-2.72	51.80	0.30	0.58
Floating fiber index %	10.48	14.57	4.09	39.03	7.87	-2.61	-24.90
Micronaire reading	4.20	3.70	-0.50	-11.90	4.00	-0.20	-4.76
Linear density (millitex)	172.00	165.00	-7.00	-4.07	169.00	-3.00	-17.44
Maturity (%)	88.00	82.00	-6.00	-6.82	81.00	-7.00	-7.96
Maturity ratio	98.00	92.00	-6.00	-6.12	94.00	-4.00	-4.08
Standard linear density (millitex)	175.00	178.00	3.00	1.71	180.00	5.00	2.86
Fiber bundle strength (g/tex)	31.30	25.40	-5.90	-18.85	28.60	-2.70	-8.63
Fiber bundle elongation (%)	5.20	6.20	1.00	19.23	7.10	1.90	36.54
Fiber bundle stiffness (g/tex)	601.00	409.00	-192.00	-31.95	406.00	-195.00	-32.45
Fiber bundle toughness (g/tex)	0.82	0.79	-0.03	-3.66	1.01	0.19	23.17

Table 55. Comparison between the commercial Giza 70 and Giza 77 varieties with the new variety Giza 84 in fiber physical properties.

Fiber properties	Giza 84	Giza 70	Difference	Difference %	Giza 77	Differences	Difference %
2.5% Span length (mm)	33.50	35.70	-2.20	-6.16	34.60	-1.10	-3.18
50% Span length (mm)	17.10	18.20	-1.10	-6.04	18.10	-1.00	-5.52
Length uniformity ratio %	51.10	51.20	-0.10	-0.20	52.30	-1.20	-2.30
Floating fiber index %	9.33	9.41	-0.08	-0.85	6.79	2.54	37.41
Micronaire reading	3.40	3.80	-0.40	-10.53	3.60	-0.20	-5.56
Linear density (millitex)	136.00	158.00	-22.00	-13.92	142.00	-6.00	-4.22
Maturity (%)	81.00	82.00	-1.00	-1.22	79.00	2.00	2.53
Maturity ratio	91.00	97.00	-6.00	-6.19	88.00	3.00	3.41
Standard linear density (millitex)	148.00	163.00	-15.00	-9.20	162.00	-14.00	-8.64
Fiber bundle strength (g/tex)	36.60	35.40	1.20	3.39	34.30	2.30	6.71
Fiber bundle elongation (%)	6.30	5.70	0.60	10.53	5.60	0.70	12.50
Fiber bundle stiffness (g/tex)	579.00	618.00	-0.39	-6.31	612.00	-33.00	-5.93
Fiber bundle toughness (g/tex)	1.16	1.00	0.16	16.00	0.96	0.20	20.23

Comparing the fiber bundle, tensile properties revealed that Giza 84 is stronger and more extensible than Giza 77 by 6.71% and 12.5%, respectively. The results showed also that Giza 84 was lower in stiffness by 6.3% and 5.9% than Giza 70 and Giza 77 respectively. Nevertheless Giza 84 was tougher by 16.0% and 20.83% than Giza 70 and Giza 77, respectively.

4.5.3.2. Physical properties of LS and ELS carded yarns

Considering the yarn tensile properties of LS category as shown in Table (56), there was pronouncing decrease in yarn strength of Giza 83 than Giza 75 in the strength for various 30^S, 40^S, 60^S and 80^S counts of yarn spun at 3.6 or 4.4 twist multiplier which ranged from 16.86% to 24.60%. On the other hand, Giza 85 showed lower strength lower than Giza 75 for the above different counts and twist, however, the percentage decrease was relatively lower and ranged from 0.46% to 18.82%. On the other hand, the breaking load CV% showed higher values in case of Giza 83 than Giza 75 and ranged from 59.11% to 76.05% for the various counts and twist multiplies. Nevertheless the breaking load CV% of Giza 85 was slightly higher in case of 80^S count than Giza 75.

Giza 85 was higher in extension than Giza 75 by 13.14% to 70.99% for the various yarn counts and twist. Giza 83 was more extensible than Giza 75 by 23.08% to 56.80% in case of 40^S, 60^S and 80^S counts at the two levels of twist, whereas in case of 30^S yarn count at both 3.6 and 4.4 twist multiplier the extension of the two varieties showed valueless difference for each other. The variation of extension was higher in Giza 83 than Giza 75 and ranged between 35.29% to 42.61%. Whereas in case of Giza 85 the percentage of the increasing of extension variation ranged between 3.54% to 12.96% for various counts and twist multiplies. Giza 83 and Giza 85 yarns were less stiffer than

Table 56. Comparison between the commercial Giza 75 variety with the new Giza 83 and Giza 85 varieties in yarn tensile properties, evenness and yarn imperfections.

Count	Twist multiplier	Giza 75	Giza 83			Giza 85			Giza 75	Giza 83			Giza 85		
			Value	Differ.	Differ. %	Value	Differ.	Differ. %		Value	Differ.	Differ. %	Value	Differ.	Dffer. %
		1. Yarn strength							**2. Yarn breaking load CV%**						
30^S	3.6	16.57	13.17	-3.40	-20.52	15.13	-1.44	-8.69	10.73	17.57	6.84	63.75	11.10	0.37	3.45
	4.4	16.60	13.53	-3.07	-18.49	16.03	-0.57	-3.43	10.10	17.37	7.27	71.98	10.13	0.03	0.30
40^S	3.6	14.87	11.83	-3.04	-20.44	13.60	-1.27	-8.54	11.70	19.73	8.03	68.63	12.07	0.37	3.16
	4.4	15.00	11.97	-3.03	-20.20	14.93	-0.07	-0.47	11.40	20.07	8.67	76.05	11.63	0.23	2.02
60^S	3.6	13.03	10.83	-2.20	-16.88	11.83	-1.20	-9.21	14.37	23.73	9.36	65.14	14.83	0.46	3.20
	4.4	13.13	10.27	-2.86	-21.78	13.07	-0.06	-0.47	14.60	23.23	8.63	59.11	13.27	-1.33	-9.11
80^S	3.6	11.00	7.63	-2.37	-21.54	8.93	-2.07	-18.82	15.77	25.33	9.56	60.62	17.03	1.26	7.99
	4.4	11.10	8.37	-2.73	-24.60	9.80	-1.30	-11.71	15.10	25.27	9.17	60.73	15.97	0.87	5.76
		3. Yarn elongation %							**4. Yarn elongation CV%**						
30^S	3.6	8.40	8.17	-0.23	-2.74	9.87	1.47	17.50	9.03	12.30	3.27	36.21	10.03	1.00	11.07
	4.4	8.60	8.47	-0.13	-1.51	9.73	1.13	13.14	9.03	12.57	3.54	39.20	9.93	0.90	9.97
40^S	3.6	6.50	8.00	1.50	23.08	9.33	2.83	43.54	10.37	14.03	3.66	35.29	11.63	1.26	12.15
	4.4	6.10	7.73	1.63	26.72	9.50	3.40	55.74	9.80	13.50	3.70	37.76	11.07	1.27	12.96
60^S	3.6	4.93	7.73	2.80	56.80	8.43	3.50	70.99	11.33	15.60	4.27	37.69	12.27	0.94	8.30
	4.4	5.23	8.00	2.77	52.96	8.67	3.44	65.77	11.30	15.43	4.13	36.55	11.70	0.40	3.54
80^S	3.6	4.47	6.17	1.76	38.03	7.47	3.00	67.71	11.83	16.80	4.97	42.01	13.17	1.24	10.48
	4.4	4.73	6.30	1.57	33.19	7.53	2.80	59.20	11.50	16.40	4.90	42.61	12.03	0.53	4.61
		5. Yarn stiffness							**6. Yarn toughness**						
30^S	3.6	197	162	-35	-17.37	154	-43	-21.83	0.70	0.54	-0.16	-22.86	0.72	0.02	2.86
	4.4	227	158	-69	-30.40	164	-63	-27.75	0.71	0.56	-0.15	-21.13	0.84	0.13	18.31
40^S	3.6	229	147	-82	-35.81	147	-82	-35.81	0.48	0.45	-0.03	-6.25	0.64	0.16	33.33
	4.4	244	155	-89	-36.48	157	-87	-35.66	0.46	0.47	0.01	-2.17	0.71	0.25	54.35
60^S	3.6	264	140	-124	-46.97	140	-124	-46.97	0.34	0.42	0.08	23.53	0.50	0.16	47.06
	4.4	252	126	-126	-50.00	150	-102	-40.48	0.35	0.41	0.06	17.14	0.57	0.22	62.86
80^S	3.6	250	124	-126	-50.40	120	-130	-52.00	0.24	0.23	-0.01	-4.17	0.34	0.10	41.67
	4.4	239	132	-107	-44.77	130	-109	-45.61	0.26	0.26	0.00	0.00	0.37	0.11	42.31
		7. Evenness CV%							**8. Number of thin places/100 meters**						
30^S	3.6	18.57	19.87	1.30	7.00	18.20	-0.37	-1.99	33	38	5	18.15	35	2	6.06
	4.4	18.60	19.73	1.13	6.08	18.23	-0.37	-1.99	37	39	2	5.40	48	11	29.73
40^S	3.6	20.70	24.53	3.83	18.50	20.03	-0.67	-3.24	49	163	114	232.65	49	0	0
	4.4	20.20	24.80	4.60	22.77	20.70	0.50	2.48	57	224	167	292.98	67	10	17.54
60^S	3.6	22.37	30.60	8.23	36.79	24.57	2.20	9.83	116	313	197	169.83	93	-23	-19.86
	4.4	22.43	31.33	8.90	39.68	24.70	2.27	10.12	116	344	228	196.55	112	-4	-3.45
80^S	3.6	27.93	32.87	4.94	17.69	27.00	-0.93	-3.33	190	362	172	90.53	111	-79	-41.58
	4.4	27.33	33.40	6.07	22.21	27.40	0.07	-0.26	175	432	257	146.86	146	-29	-16.57
		9. Number of thick places/100 meters							**10. Number of neps/100 meters**						
30^S	3.6	50	70	20	40.00	50	0	0.00	33	50	17	51.52	34	1	3.03
	4.4	50	56	6	12.00	34	-16	-32.00	31	35	4	12.90	32	1	3.23
40^S	3.6	59	154	95	161.02	99	40	67.80	36	141	105	291.67	70	34	94.44
	4.4	69	344	275	398.55	80	11	15.94	33	281	248	751.52	67	34	103.03
60^S	3.6	156	340	184	117.95	217	61	39.10	105	385	280	226.67	101	-4	-3.81
	4.4	148	441	293	197.97	212	64	43.24	97	275	178	183.50	96	-1	-1.03
80^S	3.6	327	426	99	30.28	268	-59	-18.04	257	507	250	97.28	200	-57	-22.18
	4.4	276	465	189	68.48	245	-31	-11.23	275	408	133	48.36	172	-103	-37.45

Giza 75 yarns by 17.77% to 50.0% and 21.83% to 52.00%, respectively. Giza 83 yarns were less in toughness than Giza 75 yarns by 2.17% to 23.53%. Nevertheless, Giza 85 yarns were higher in toughness than Giza 75 yarns by 2.86 to 62.86%.

As long as evenness of the yarns is considered, Giza 83 yarns were more uneven than Giza 75 yarns by 6.08% to 39.68% for the various counts and twist multipliers. Meanwhile Giza 85 yarns were uneven by 9.83% and 10.12% than Giza 75 yarns for 60^S at 3.6 and 4.4 twist multiplier, respectively. Giza 85 exhibited lower thin places/100 meters than that of Giza 75 yarns in case of 60^S and 80^S yarn counts in the range of 3.45 to 41.58%. However, in case of 30^S at 3.6 and 4.4 twist multiplier and 40^S at 4.4 twist multiplier the number of thin places of Giza 85 was higher than Giza 75 by 6.06% to 29.73%. Whereas at 40^S count and 3.6 twist multiplier no difference was shown between the two varieties in the number of thin places.

The thick places in Giza 85 yarns were lower by 11.25% to 82% than those in Giza 75. Whereas, at 30^S yarn spun at 3.6 no difference existed between Giza 75 and Giza 85 yarns. Nevertheless, at 40s and 60^S yarns spun at 3.6 and 4.4 twist multiplier the thick places in Giza 85 yarns were higher than in Giza 75 by 15.94% to 67.80%. Whereas Giza 83 yarn showed very high thick places than Giza 75 yarns by 12.00% to 398.55%.

The nep count of Giza 85 yarns were lower in 80^S yarn count by 22.18% and 37.45% than the corresponding Giza 75 yarns, respectively. Whereas at 40 count the Giza 85 yarns exceeded their corresponding values of Giza 75 by 94.44% and 103.02%. Meanwhile, the nep count in Giza 83 exceeded their corresponding values in Giza 75 yarns by 12.90% to 751.52%.

In conclusion, Giza 75 yarns spun at 3.6 and 4.4 twist multiplier into 30^S, 40^S, 60^S and 80^S carded yarn counts showed superiority of yarn physical properties than Giza 85 yarns which in turn were better than Giza 83 yarns.

Dealing with ELS carded yarns as shown in Table (57) Giza 84 yarns were stronger than their corresponding values of Giza 77 yarns by 4.83% to 14.33% for the various yarn counts at 3.6 and 4.4 twist multiplier. Meanwhile, Giza 84 yarns were stronger than Giza 70 yarns except in case of 80s count at 4.4 twist multiplier and 100^S count at 4.4 twist multiplier, Giza 70 was stronger by 0.72% and 4.40%, respectively.

For breaking load variation, Giza 84 yarns were higher in strength variation than Giza 70 yarns by 2.82% to 19.57% for different counts and twist. Meanwhile, Giza 84 was higher in breaking load variation than Giza 77 at 40^S and 60^S yarn counts at 3.6 and 4.4 twist multiplier. On the other hand, Giza 84 was lower in breaking load variation at 80^S and 100^S yarn counts.

The elongation % values of Giza 84 yarns were higher by 0.70% to 24.90% and by 6.71% to 38.57% than Giza 70 and Giza 77 yarns, respectively.

The elongation variation of Giza 84 yarns were higher by 5.63% to 38.50% than those of Giza 70 yarns, except in case of 60^S yarn count of 3.6 twist multiplier, Giza 70 yarn was higher in elongation variation than Giza 84 yarn by 7.84%. The elongation variations of Giza 77 yarns at 60^S, 80^S and 100^S counts at both 3.6 and 4.4 twist multiplier were higher than the corresponding yarns of Giza 84 by 1.05% to 10.97%, in case of 40^S count at 3.6 or 4.4 twist multiplier and 100^S count at 3.6 twist multiplier Giza 77 yarns were lower in yarn elongation variation than that of Giza 84 yarns.

Table 57. Comparison between the commercial Giza 70 and Giza 77 varieties with the new Giza 84 in carded yarn tensile properties, evenness and yarn imperfections.

Count	Twist multiplier	Giza 84	Giza 70	Differe-nce	%	Giza 77	Differe-nce	Differ. %	Giza 84	Giza 70	Differe-nce	Differ. %	Giza 77	Differe-nce	Differ. %
				1. Yarn strength							**2. Yarn breaking load CV%**				
40^{S}	3.6	18.87	18.07	0.80	4.43	18.00	0.87	4.83	12.30	11.13	1.17	10.51	11.43	0.87	7.61
	4.4	18.70	18.27	0.43	2.35	17.13	1.57	9.16	12.47	11.40	1.07	9.39	10.93	1.54	14.09
60^{S}	3.6	16.83	15.67	1.16	7.40	15.63	1.20	7.68	13.60	11.93	1.67	14.00	13.13	0.47	3.58
	4.4	16.43	16.00	0.43	2.69	14.37	2.06	14.33	14.60	11.80	2.80	23.73	14.03	0.57	4.06
80^{S}	3.6	14.33	13.83	0.50	3.62	13.47	0.86	6.39	14.57	14.17	0.40	2.82	15.03	-0.46	3.06
	4.4	13.73	13.83	-0.10	-0.72	12.97	0.76	5.86	15.80	13.67	2.13	15.58	17.80	-2.00	-11.24
100^{S}	3.6	13.13	12.33	0.80	6.49	12.20	0.93	7.62	17.60	15.70	1.90	12.10	17.67	-0.07	-0.40
	4.4	11.73	12.27	-0.54	-4.40	11.10	0.63	5.68	18.33	15.33	3.00	19.57	19.73	-1.40	-7.10
				3. Yarn elongation %							**4. Yarn elongation CV%**				
40^{S}	3.6	9.07	8.40	0.67	7.98	8.50	0.57	6.71	8.63	8.17	0.46	5.63	8.30	0.33	3.98
	4.4	9.37	8.57	0.80	9.34	8.60	0.77	8.95	9.17	8.47	0.70	8.26	8.83	0.34	3.85
60^{S}	3.6	8.77	8.30	0.47	5.66	8.13	0.64	7.87	9.40	10.20	-0.80	-7.84	10.00	-0.60	-6.00
	4.4	8.63	8.57	0.06	0.70	7.20	1.43	19.86	10.10	9.47	0.63	6.65	10.93	-0.83	-7.59
80^{S}	3.6	6.93	6.37	0.56	8.79	6.27	0.66	10.53	13.43	13.30	0.13	0.98	13.77	-0.34	-2.47
	4.4	6.97	6.60	0.37	5.61	5.03	1.94	38.57	13.80	13.60	0.20	1.47	15.50	-1.70	-10.97
100^{S}	3.6	6.37	5.10	1.27	24.90	5.03	1.34	26.64	15.53	15.37	0.16	1.04	15.37	0.16	1.05
	4.4	6.40	5.53	0.87	15.73	6.40	0.00	0.00	16.80	12.13	4.67	38.50	17.13	-0.33	-1.93
				5. Yarn stiffness							**6. Yarn toughness**				
40^{S}	3.6	208	215	-7	-3.26	212	-4	-1.89	0.85	0.76	0.09	11.84	0.76	0.09	11.84
	4.4	200	213	-13	-6.10	199	1	0.50	0.88	0.79	0.09	11.39	0.74	0.14	18.92
60^{S}	3.6	192	188	4	2.13	193	-1	-0.52	0.74	0.65	0.09	13.85	0.63	0.11	17.46
	4.4	189	187	2	1.07	200	-11	-5.58	0.71	0.69	0.02	2.90	0.52	0.19	36.54
80^{S}	3.6	207	216	-9	-4.17	214	-7	-3.27	0.47	0.44	0.03	6.82	0.42	0.05	11.90
	4.4	197	209	-12	-5.74	259	-62	-23.94	0.48	0.46	0.02	4.35	0.32	0.16	50.00
100^{S}	3.6	207	248	-41	-16.53	243	-36	-14.82	0.42	0.32	0.10	31.25	0.31	0.11	35.48
	4.4	196	221	-25	-11.31	277	-81	-29.24	0.37	0.34	0.03	8.82	0.26	0.11	42.31
				7. Evenness CV%							**8. Number of thin places/100 meters**				
40^{S}	3.6	18.37	20.07	-1.70	-8.47	18.67	-0.30	-1.61	48	93	-45	-48.34	34	14	41.18
	4.4	19.03	20.75	-1.72	-8.29	20.23	-1.20	-6.03	97	111	-14	-12.61	97	0	0
60^{S}	3.6	21.20	21.83	-0.63	-2.89	21.33	-0.13	-0.61	59	121	-62	-51.24	50	9	18.00
	4.4	22.97	22.43	0.54	2.41	23.47	-0.50	-2.13	108	140	-32	-22.86	172	-64	-37.21
80^{S}	3.6	24.20	26.10	-1.90	-7.28	24.23	-0.03	-0.12	75	241	-166	-68.88	93	-18	-19.36
	4.4	24.77	26.60	-1.83	-6.88	25.97	-1.20	-4.62	105	240	-135	-56.25	180	-75	-41.67
100^{S}	3.6	25.77	28.90	-3.13	-10.83	27.57	-1.80	-6.53	131	310	-179	-57.74	181	-50	-27.62
	4.4	27.60	31.00	-3.40	-10.97	29.73	-2.13	-7.16	198	331	-133	-40.18	228	-30	-13.16
				9. Number of thick places/100 meters							**10. Number of neps/100 meters**				
40^{S}	3.6	84	114	-30	-26.32	106	-22	-20.76	75	188	-113	-60.11	120	-45	-37.50
	4.4	6	163	-97	-59.51	85	-19	-22.35	98	176	-78	-44.32	105	-7	-6.67
60^{S}	3.6	137	201	-64	-31.84	127	10	7.87	93	230	-137	-59.56	156	-63	-40.38
	4.4	180	202	-22	-10.89	300	-120	-40.00	162	242	-80	-33.06	166	-4	-2.41
80^{S}	3.6	170	211	-41	-19.43	193	-23	-11.92	172	320	-148	-46.25	192	-20	-10.42
	4.4	184	194	-10	-5.16	229	-45	-19.65	164	365	-201	-55.07	239	-75	-31.38
100^{S}	3.6	234	431	-197	-45.71	300	-66	-22.00	212	434	-222	-51.15	373	-161	-43.16
	4.4	276	379	-103	-27.18	304	-28	-9.21	252	462	-210	-45.45	337	-85	-25.22

Giza 84 yarns were less stiffer than each of Giza 70 and Giza 77 yarns, except in case of Giza 70 60^S yarn count at 3.6 or 4.4 twist multiplier and Giza 77 40^S yarn count at 4.4 twist multiplier.

Also, Giza 84 yarns were tougher than each of Giza 70 and Giza 77 yarns by 2.9% to 31.25% and by 11.84% to 50.02%, respectively.

For evenness Giza 70 yarns were lower than Giza 84 yarns by 2.89% to 10.97 except in case of Giza 70 60^S yarn count at 4.4 twist multiplier which was more even than corresponding yarn of Giza 84. Meanwhile, Giza 77 yarns were lower in uniformity than Giza 84 yarns by 0.12% to 7.16% for different counts and twist.

The thin places of Giza 70 yarns were higher by 12.61% to 68.88% than their corresponding of Giza 84 yarns. Whereas Giza 77 60^S count and 4.4 twist multiplier and 80^S and 100^S yarns at both 3.6 and 4.4 twist multiplier were higher in thin places than their corresponding yarns of Giza 84 by 13.16% to 41.67%. Nevertheless, Giza 77 40^S count at both 3.6 and 4.4 twist multiplier and 60^S count at 3.6 twist multiplier were lower in yarn thin places than their corresponding Giza 84 yarns.

For thick places of Giza 84 yarns were lower by 5.16% to 59.51% and 7.87% to 40.00% than their corresponding yarns of Giza 70 and Giza 77, respectively.

The nep counts of Giza 70 and Giza 77 yarns were higher by 33.06% to 60.11% and by 2.41 to 43.16% than their corresponding values of Giza 84 yarns, respectively.

4.5.3.3 Physical properties of ELS combed yarn.

As shown in Table (58), all Giza 84 combed yarns spun into 60^S to 140^S counts at two twist multiplier 3.6 or 4.4 were stronger than the corresponding combed yarns of Giza 70 and Giza 77 by 0.40% to 1.67 and 0.47% to 1.70%, respectively, with one exception in case of Giza 70 140^S combed yarn at 3.6 twist multiplier which was stronger than Giza 84 combed yarn by 0.56%.

The breaking load (CV%) of Giza 84 combed yarns were more even by 0.93% to 8.15% and 0.74% to 22.04% than that of Giza 70 and Giza 77 combed yarns, respectively, except in case of 140^S count at 3.6 twist multiplier Giza 70 was more even.

Giza 84 combed yarns were more extensible by 5.90% to 29.14% and 5.53% to 17.33% than Giza 70 and Giza 77 combed yarns, respectively, with the exception of 140^S counts at 4.4 twist multiplier in which Giza 77 was more extensible than Giza 84 by 9.14%.

The combed yarns of Giza 84 at different counts and twist were more even in elongation variation by 0.65% to 26.38% and 0.18% to 29.30% than their corresponding combed yarn counts of Giza 70 and Giza 77, respectively, except in case of 60^S count at 4.4 twist multiplier Giza 70 yarn was more even than Giza 84 combed yarn by 0.65%.

The Giza 84 combed yarns were less in stiffness than Giza 70 yarns in case of 60^S count at 3.6 twist multiplier by 3.86%, also less in stiffness at 100^S, 120^S and 140^S counts of 3.6 and 4.4 twist multiplier. In case of 60^S count at 4.4 twist multiplier and 80^S count at 3.6 or 4.4 twist multiplier, Giza 84 combed yarns were stiffer than that of Giza 70 combed yarns. Giza 77 combed yarns were lower in stiffness than Giza 84 combed yarns in case of 60^S count at 4.4 twist multiplier, 80^S count at the two levels of twist, 120^S count at 4.4. twist multiplier and 140^S count at 4.4 twist

Table 58. Comparison between the commercial Giza 70 and Giza 77 varieties with the new Giza 84 in combed yarn tensile properties, evenness and yarn imperfections.

Count	Twist multiplier	Giza 84	Giza 70	Difference	Differ. %	Giza 77	Difference	Differ. %	Giza 84	Giza 70	Difference	Differ. %	Giza 77	Difference	Differ. %
		1. Yarn strength							**2. Yarn breaking load CV%**						
60^S	3.6	19.47	18.87	0.60	3.18	17.93	1.54	8.59	9.30	10.03	-0.73	-7.28	11.93	-2.63	-22.04
	4.4	18.80	17.10	1.10	5.65	17.20	1.60	9.30	10.63	10.73	-0.10	-0.93	12.23	-1.60	-13.08
80^S	3.6	19.33	17.47	1.86	10.65	16.30	3.03	18.59	10.33	10.23	0.10	0.98	12.83	-2.50	-19.49
	4.4	17.07	16.17	0.90	5.56	15.63	1.44	9.21	10.95	11.90	-0.97	-8.15	12.73	-1.80	-14.14
100^S	3.6	17.30	16.57	0.73	4.41	15.67	1.63	10.40	11.40	11.80	-0.40	-3.39	13.27	-1.87	-14.09
	4.4	16.53	15.33	1.20	7.83	15.23	1.30	8.54	12.93	12.57	0.36	2.86	13.17	-0.24	-1.82
120^S	3.6	15.80	15.20	0.60	3.95	14.97	0.83	5.54	13.10	14.20	-1.10	-7.25	14.27	-1.17	-8.20
	4.4	15.90	14.33	1.57	10.96	14.83	1.07	7.22	14.33	15.07	-0.74	-4.91	14.87	-0.54	-3.63
140^S	3.6	13.87	14.43	-0.56	-3.88	13.53	0.34	2.51	15.80	14.70	1.10	7.48	17.73	-1.93	-10.89
	4.4	14.10	12.60	1.50	11.90	13.33	0.77	5.78	17.47	17.70	-0.23	-0.13	17.60	-0.13	-0.74
		3. Yarn elongation %							**4. Yarn elongation CV%**						
60^S	3.6	9.77	8.87	0.90	16.15	8.73	1.04	11.91	7.50	7.77	-0.27	-3.48	7.93	-0.43	-5.42
	4.4	8.97	8.47	0.50	5.90	8.50	0.47	5.53	7.73	7.68	0.05	0.65	8.10	-0.37	-4.57
80^S	3.6	9.07	8.33	0.74	8.88	7.97	1.10	13.80	8.93	12.13	-3.20	-26.38	12.63	-3.70	-29.30
	4.4	8.20	7.80	0.40	5.13	7.67	0.53	6.91	10.30	12.37	-2.07	-16.73	13.00	-2.70	-20.77
100^S	3.6	8.87	7.83	1.04	13.28	7.17	1.70	23.71	13.23	12.30	-0.93	-0.57	13.00	-0.54	-3.90
	4.4	7.57	6.73	0.84	12.48	6.43	1.14	17.73	13.50	13.67	-0.17	-1.24	14.30	-0.80	-5.59
120^S	3.6	7.40	5.73	1.67	29.14	6.30	1.10	17.46	14.20	14.97	-0.77	-5.14	14.50	-0.30	-2.07
	4.4	6.60	5.53	1.07	19.35	6.03	0.57	9.45	14.60	15.93	-1.33	-8.35	14.77	-0.17	-1.15
140^S	3.6	5.80	5.23	0.57	10.90	5.30	0.50	9.43	15.03	16.03	-1.00	-6.24	15.73	-0.70	-4.45
	4.4	5.27	4.70	0.57	12.13	5.80	-0.53	-9.14	15.57	17.43	-1.86	-10.67	16.60	-0.03	-0.18
		5. Yarn stiffness							**6. Yarn toughness**						
60^S	3.6	199	207	-8	-3.96	205	-6	-2.93	0.90	0.83	0.07	8.43	0.78	0.12	15.38
	4.4	210	208	2	1.92	203	7	3.45	0.85	0.75	0.10	13.33	0.73	0.12	16.44
80^S	3.6	214	210	4	1.90	204	10	4.90	0.88	0.73	0.15	20.55	0.65	0.13	20.06
	4.4	213	204	9	4.41	206	7	3.40	0.71	0.63	0.08	12.70	0.60	0.11	18.33
100^S	3.6	195	217	-22	-10.14	219	-24	-10.96	0.77	0.65	0.12	18.46	0.56	0.21	37.50
	4.4	210	229	-19	-8.30	238	-28	-11.76	0.63	0.54	0.09	16.67	0.49	0.14	28.57
120^S	3.6	213	267	-54	-20.22	240	-27	-11.25	0.59	0.44	0.15	3.41	0.47	0.12	25.53
	4.4	240	244	-4	-1.64	237	3	1.27	0.53	0.40	0.13	32.50	0.46	0.07	15.22
140^S	3.6	244	276	-32	-11.59	258	-14	-5.43	0.40	0.38	0.02	5.26	0.40	0.00	0.00
	4.4	268	269	-1	-0.37	246	22	8.94	0.37	0.30	0.07	23.33	0.37	0.00	0.00
		7. Evenness CV%							**8. Number of thin places/100 meters**						
60^S	3.6	19.90	20.10	-0.40	-1.99	19.83	-0.13	-0.66	22	54	-32	-59.26	27	-5	-18.52
	4.4	19.87	20.13	-0.26	-1.29	20.02	-0.16	-0.80	31	65	-34	-53.31	36	-5	-13.89
80^S	3.6	21.17	24.00	-2.83	-11.79	23.03	-1.86	-8.08	54	162	-108	-66.67	94	-40	-42.55
	4.4	21.23	24.07	-2.84	-11.80	23.07	-1.84	-7.98	93	194	-101	-52.06	182	-89	-48.90
100^S	3.6	24.13	26.97	-2.84	-10.53	24.10	0.03	0.12	118	216	-98	-45.37	118	0	0
	4.4	24.17	27.13	-2.96	-10.91	24.20	-0.03	-0.12	149	264	-115	-43.56	208	-59	-28.36
120^S	3.6	25.10	29.53	-4.43	-15.00	25.90	-0.80	-3.09	135	260	-125	-48.08	173	-38	-21.96
	4.4	24.97	29.67	-4.70	-15.84	26.20	-1.23	-4.70	166	325	-159	-48.92	252	-86	-34.13
140^S	3.6	25.90	32.03	-6.13	-19.14	26.97	-1.07	3.97	165	334	-169	-50.60	213	-48	-22.54
	4.4	25.87	32.27	-6.40	-19.83	27.10	-1.23	-4.54	169	381	-212	-55.64	368	-199	-54.08
		9. Number of thick places/100 meters							**10. Number of neps/100 meters**						
60^S	3.6	57	152	-95	-62.50	118	-61	-51.70	65	151	-86	-36.95	125	-60	-48.00
	4.4	61	144	-83	-57.64	114	-53	-46.49	67	153	-86	-56.21	133	-66	-49.62
80^S	3.6	100	210	-110	-52.38	169	-69	-40.83	122	254	-132	-51.97	163	-41	-25.15
	4.4	96	242	-146	-60.33	166	-70	-42.17	117	252	-135	-53.57	168	-51	-30.36
100^S	3.6	139	283	-144	-50.88	203	-64	-31.53	154	355	-201	-56.62	262	-108	-41.22
	4.4	157	282	-125	-44.33	218	-61	-27.98	160	358	-198	-55.31	278	-118	-42.45
120^S	3.6	180	323	-143	-44.27	240	-60	-25.00	227	403	-276	-68.49	321	-94	-29.28
	4.4	200	359	-159	-44.24	233	-33	-14.16	226	425	-199	-46.82	344	-118	-34.30
140^S	3.6	206	385	-179	-46.44	275	-69	-25.09	322	458	-136	-29.69	388	-66	-17.01
	4.4	211	390	-179	-45.90	266	-55	-20.68	338	471	-133	-28.24	391	-53	-13.56

multiplier, but higher in stiffness in case of 100^S count at the two levels of twist, 120^S at 3.6 twist multiplier and 140^S count.

Giza 84 yarns were mostly more tougher than their corresponding Giza 70 and Giza 77 combed yarns by 8.43% to 32.5% and 15.22% to 37.50%, respectively.

Regarding evenness and yarn imperfection, i.e. thin and thick places and number of neps/100 meters, Giza 84 combed yarns were more even, less in yarn imperfections/100 meters than all combed yarns of Giza 70 and Giza 77 combed yarns at different counts and levels of twist.

Going through literature review cited on this matter by **El-Didi (1985), Abd El-Salam (1994), Sawires *et al.* (1990), Seif (1994a, b and c)** and in the light of the results obtained in this section, it could be concluded that in the LS category the relatively older commercial variety Giza 75 by all means proved to be superior to Giza 83 and Giza 85 new introduced varieties.

On the other hand, Giza 84 showed superiority in most fiber physical properties and yarn physical properties over those of Giza 70 and Giza 77 relatively older commercial varieties which is a credit for cotton technologist and breeder for ELS category. Unfortunately, this new Giza 84 variety was suddenly stopped in 1995 season without explaining the reasons for this.

4.6. Proposed end uses for raw cotton and cotton spun yarns

Based on the most important physical properties of raw cotton fibers and cotton yarns spun from LS and ELS varieties used in the present investigation, as well as the various end uses of cotton fibers, yarns and fabrics and recent technologies available as shown in the literature review, the end uses proposed, here, could be as under:

4.6.1. Raw cotton fibers

Table (59) shows the most important physical properties namely; 2.5% spun length, length uniformity (%), fiber bundle strength (g/tex) and elongation (%) for the raw cotton of LS and ELS varieties used in the present research work, arranged in a descending order with respect to most of the above mentioned physical fiber properties. The following end uses are proposed as under:

4.6.1.1. To produce apparel for men and women and for boys and misses (trousers, shirts, underwear, hosiery, overall and coverall, dresses, blouses and waists and washable service apparel), **Rodney, (1961).**

4.6.1.2. Intimate blending of ELS cotton fibers with 38 mm and 1.5 denier polyester, viscose rayon and other man-made fibers. Meanwhile the LS cotton fibers could be intimately blended with the same man made fibers but of 32 mm length and 1.7 denier. Egyptian cotton could be also blended with other imported foreign cotton such as U.S. Upland cottons. This needs the development of best blending techniques (**Robert *et al.*, 1990**).

4.6.1.3. The LS and ELS cottons could be used for the production of the sewing threads due to the fact that these cottons meet the requirements of this type of yarns from the stand-point of length, fineness and strength. Similarly, and for the same reasons, LS and ELS cotton could be used for producing combed handicraft yarns which are used for, crocheting, knitting, darny, embroidery, ring making .... etc. **(Sparting, 1965).**

4.6.1.4. The superiority of Egyptian cotton in the physical properties of fibers enables them for strategic uses in military and industrial uses.

Table 59. The most important physical properties of new cotton fibers.

Variety	2.5% span length (mm)	Variety	Length uniformity ratio (%)	Variety	Micronaire reading	Variety	Fiber bundle strength (g/Tex)	Variety	Fiber bundle elongation (%)
				ELS					
Giza 70	35.7	Giza 77	52.3	Giza 84	3.4	Giza 84	36.6	Giza 84	6.3
Giza 77	34.6	Giza 70	51.2	Giza 77	3.6	Giza 70	35.4	Giza 70	5.7
Giza 84	33.5	Giza 84	51.1	Giza 70	3.8	Giza 77	34.3	Giza 77	5.6
				LS					
Giza 85	30.9	Giza 85	51.8	Giza 75	4.2	Giza 75	31.3	Giza 85	7.0
Giza 75	30.5	Giza 75	51.5	Giza 85	4.0	Giza 85	28.3	Giza 83	6.2
Giza 83	29.5	Giza 83	50.1	Giza 83	3.7	Giza 83	25.4	Giza 75	5.2

4.6.1.5. For electrostatic spinning as a promising candidate with respect to yarn structure and quality (**Robert *et al.*, 1984**).

4.6.1.6. Egyptian cotton could be blended with wool on the ring spinning to make blended fabrics for ladies underwear (**Louis and Bel, 1985**).

4.6.1.7. To produce air-jet textured cotton filament spun yarns to satisfy the requirements of the thermal comfort and softness (**Kothari, 1988**).

4.6.1.8. To produce a novel Pseudo composite cotton-rich staple blend yarn with improved tensile properties to made stronger fabrics which could be useful for the combination of durable press and flame retardant finishing where the fabric strength in critical. These yarns may have several textile-military application (**Sawhney *et al.*, 1988**).

4.6.1.9. To produce staple-core/cotton-warp yarns consisting of core of suitable high tenacity man-made staple fibers which are covered with a sheath of cotton fibers. The core provided high strength, durability, easy-care, and so-called functional characteristics to the fabrics produced from the core yarns, while the exterior wrap provides the look, handle and comfort of King cotton. This core yarn fabrics may be used in Egyptian military purposes due to good flame retardancy, high strength and durability (**Sawhney *et al.*, 1989**).

4.6.1.10. To produce stronger, more durable fabrics from cotton yarns reinforced with high tenacity polyester or nylon filaments which benefit military fabrics. The fabrics hand breathibility and other desirable inherent properties of cotton are preserved, (**Ruppenicker *et al.*, 1989**).

4.6.1.11. To produce twistless yarn fabrics woven from twistless yarn produced by wrap spinning which had better abrasion resistance and lower air permeability, (**Ruppenicker *et al.*, 1990**).

4.6.1.12. To produce cotton derived for the manufacture of jeans (**Textiles, 1990**).

4.6.1.13. To produce non-women fabrics.

4.6.2. Cotton spun yarns

The most important physical properties namely strength, evennes and nep count of LS and ELS carded as well as ELS combed yarns are shown in Tables (60, 61 and 62), respectively. In the light of results obtained for these yarns it could be used as follows:

4.6.2.1. The regular carded or combed yarns could be plied and used in the manufacture of households, and industrial purposes. Whereas the regular yarns could be used for apparel (**Rodney, 1961**).

4.6.2.2. Yarns could be plied and used as sewing and handicraft threads (**Sparling, 1965**).

4.6.2.3. Yarns could be twisted with themselves or with others to obtain a strand that is more uniform, stronger and has greater tenacity, more resistant to abrasion, flexing or has a novelty appearance (**Truslow, 1965**).

Table 60. The most important physical properties of LS carded yarns.

Count	Twist multiplier	Yarn strength (g/Tex)						Yarn evenness (CV%)						Nep count/100 meters					
		Giza 75		Giza 83		Giza 85		Giza 75		Giza 83		Giza 85		Giza 75		Giza 83		Giza 85	
		Value	order	Value	order	Value	order	Value	order	Value	order	Value	order	Value	order	Value	order	Value	order
30^S	3.6	16.57	2	13.17	2	15.13	2	18.57	1	19.87	2	18.20	1	33	2	50	2	34	2
	4.4	16.60	1	13.53	1	16.03	1	18.60	2	19.73	1	18.23	2	31	1	35	1	32	1
40^S	3.6	14.87	4	11.85	4	13.60	4	20.70	4	24.53	3	20.03	3	36	4	141	3	70	4
	4.4	15.00	3	11.97	3	14.93	3	20.20	3	24.80	4	20.70	4	33	3	281	5	67	3
60^S	3.6	13.03	5	10.83	5	11.83	6	22.37	5	30.60	5	24.57	5	105	6	385	6	101	6
	4.4	13.00	6	10.27	6	13.07	5	22.43	6	31.33	6	24.70	6	97	5	275	4	96	5
80^S	3.6	11.00	8	7.63	8	8.93	8	27.93	8	32.87	7	27.00	7	257	7	507	8	200	8
	4.4	11.10	7	8.37	7	9.80	7	27.33	7	33.40	8	27.40	8	275	8	408	7	172	7

Table 61. The most important physical properties of ELS carded yarns.

Count	Twist multiplier	Strength (g/Tex)						Evenness (CV%)						Nep count/100 meters					
		Giza 84		Giza 70		Giza 77		Giza 84		Giza 70		Giza 77		Giza 84		Giza 70		Giza 77	
		Value	order	Value	order	Value	order	Value	order	Value	order	Value	order	Value	order	Value	order	Value	order
40^S	3.6	18.87	1	18.07	2	18.00	1	18.37	1	20.07	1	18.67	1	75	1	188	2	120	2
	4.4	18.70	2	18.27	1	17.13	2	19.03	2	20.75	2	20.23	2	89	2	176	1	105	1
60^S	3.6	16.83	3	15.67	4	15.63	3	21.20	3	21.83	3	21.33	3	93	3	230	3	156	3
	4.4	16.43	4	16.00	3	14.37	4	22.97	4	22.43	4	23.47	4	162	4	242	4	166	4
80^S	3.6	14.33	5	13.83	5	13.47	5	24.20	5	26.10	5	24.23	5	172	6	320	5	192	5
	4.4	13.73	6	13.83	6	12.97	6	24.77	6	26.60	6	25.97	6	164	5	365	6	239	6
100^S	3.6	13.13	7	12.33	7	12.20	7	25.77	7	28.90	7	27.57	7	212	7	434	7	373	7
	4.4	11.73	8	12.27	8	11.10	8	27.60	8	31.00	8	29.73	8	252	8	462	8	337	8

Table 62. The most important physical properties of ELS combed yarns.

Count	Twist multiplier	Yarn strength (g/Tex)						Yarn evenness (CV%)						Nep count/100 meters					
		Giza 84		Giza 70		Giza 77		Giza 84		Giza 70		Giza 77		Giza 84		Giza 70		Giza 77	
		Value	order	Value	order	Value	order	Value	order	Value	order	Value	order	Value	order	Value	order	Value	order
60^S	3.6	19.47	1	18.87	1	17.93	1	19.20	1	20.10	1	19.83	1	65	1	151	1	125	1
	4.4	18.80	3	17.70	2	17.20	2	19.87	2	20.13	2	20.03	2	67	2	153	2	133	2
80^S	3.6	19.33	2	17.47	3	16.36	3	21.17	3	24.00	3	23.03	3	122	4	254	4	163	3
	4.4	17.07	5	16.17	5	15.63	5	21.23	4	24.07	4	23.07	4	117	3	252	3	168	4
100^S	3.6	17.30	4	16.57	4	15.67	4	24.13	5	26.97	5	24.10	5	154	5	355	6	262	5
	4.4	16.53	6	15.33	6	15.23	6	24.17	6	27.13	6	24.20	6	160	6	358	7	278	6
120^S	3.6	15.80	8	15.20	7	14.97	7	25.10	8	29.53	7	25.90	7	227	8	403	8	321	7
	4.4	15.90	7	14.33	9	14.83	8	24.97	7	29.67	8	26.20	8	226	7	425	9	344	8
140^S	3.6	13.87	10	14.43	8	13.53	9	25.90	10	32.03	9	26.97	9	322	9	258	5	388	9
	4.4	14.10	9	12.60	10	13.33	10	25.87	9	32.27	10	27.10	10	338	10	471	10	391	10