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The Correlation Between Cotton Fibre Properties and Ring and Rotor Yarn Properties

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THE CORRELATION BETWEEN COTTON FIBRE PROPERTIES AND RING AND ROTOR YARN PROPERTIES

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ABSTRACT

The correlation between the properties of upland cottons and the physical properties of rotor and ring yarns processed on miniature and full-scale machinery has been investigated. For the miniature system, the tensile properties of the fibres tended to have the most significant effect on those of the yarns, followed by 50 per cent span length, whereas for full-scale processing, the 50 per cent span length assumed greater importance. Fibre fineness characteristics, micronaire in particular, generally had the most significant effect on the rotor yarn evenness characteristics, whereas the fibre length characteristics, particularly the 50 per cent span length, had the main effect on those of the ring yarns. Poor correlations were obtained between yarn evenness characteristics and fibre properties for the miniature system. Air-flow measured fineness (Mtex) was highly correlated with micronaire but the latter tended to have a more significant effect on the yarn properties. Air-flow measured maturity seldom had a significant effect on yarn properties.

INTRODUCTION

Numerous studies[1-15] have been directed towards determining the correlation between the various cotton fibre properties and ring-spun yarn strength the ultimate aim being the accurate prediction of yarn strength from the fibre properties. Fewer studies have been directed towards other ring yarn properties, for example irregularity[3, 16-20], and towards rotor-spun yarns[21-24]. Although considerable success has been achieved in quantifying the effects of many of the cotton fibre properties on yarn strength and, to a lesser extent, yarn irregularity, anomalies[8, 25] and gaps in our knowledge still exist and there is a need for further research, particularly in areas such as the effects of cotton growing season locality and type (independent of fibre properties), the correlation between rotor yarn properties and fibre properties and the effect of air-flow determined fineness and maturity on yarn properties.

This paper reports on some findings of a study started at the South African Wool and Textile Research Institute (SAWTRI) some five years ago, and which was aimed at determining the effect of fibre properties, and in particular, air-flow determined fineness and maturity, on the properties of ring- and rotor yarns processed along both miniature and full-scale routes. The work reported covers eight cultivars of Upland (Gossypium hirsutum) type cottons grown in different areas in South Africa over three growing seasons.

EXPERIMENTAL

Miniature Processing

Samples from various cottons, grown during the 1977, 1978 and 1979 seasons, were processed on a Shirley (Platt) miniature plant. Table I lists the correlations between the fibre properties and Table II the average values and standard deviations of the latter.

In each case, approximately 100 g of cotton was passed through a Shirley Analyser, miniature card and miniature draw frame (3 passages). Half of the draw-frame slivers were spun on a Shirley (Platt) miniature ring-frame into 25 and 50 tex yarns (38 tex twist factor) while the other half were spun into 25 and 50 tex yarns (48 tex twist factor) on a full-scale rotor spinning machine at a rotor speed of 45 000 rev/min and an opening roller speed of 6 000 rev/min and using smooth doffing tubes and a rotor diameter of 55 mm . Most of the lots were spun into both ring- and rotor yarns.

Full-Scale Processing

About 50 kg of cotton lint from each of more than 100 cotton lots was processed through a blow room having three cleaning points (porcupine, two-bladed and Kirschner beaters). The laps were processed at 7,5 kg/hr on a card fitted with a short-term autoleveller. The card slivers were passed twice through a drawframe running at 122 m/min, with six doublings at each passage. Two different linear densities were produced at the second passage, namely 2,5 ktex for spinning directly on a rotor machine and 4,5 ktex for processing into a 480 tex roving in preparation for ring spinning. Rotor spinning was carried out as before on a selection of the cottons, except that the yarn tex ranged from 25 to 30. Ring spinning was carried out using a double-apron drafting system at a spindle speed of 11 000 rev/min employing a tex twist factor of 38. Yarns of different linear densities (mostly between 15 and 50 tex) were spun. Table III gives the correlation between the various fibre properties and Table IV the average values and standard deviations for the latter.

Yarn Tests

Single thread strength and extension were measured on an Uster Automatic Strength tester (constant rate of load). Skein strength (CSP) was measured on a Heal tester. Yarn irregurality and frequencies of imperfections were measured on the Uster range of equipment, using standard settings and procedures. Hairiness was measured on a Shirley Yarn Hairiness Meter at the standard distance of 3 mm . The yarns were tested at 20°C and 65% RH.

Fibre Tests

Cotton was passed through the Shirley Analyser, after which micronaire, maturity ratio and fineness were determined on an IIC-Shirley Fineness/Maturity Tester. The zero-gauge tenacity, and in many cases also the ⅛″-gauge tenacity, were measured on a Stelometer using sliver prepared on a miniature card. All values were corrected to the Pressley levels by means of USDA standard samples prepared in the same way. Length characteristics were determined on a digital Fibrograph. Fibre tests were carried out under standard atmospheric conditions (20°C and 65% RH).

RESULTS AND DISCUSSIONS

Multiple regression analyses were carried out on the logarithmic transforms of the data. Such a log-log type of analysis was favoured above the normal multiple quadratic type because of its relative simplicity, both in computation and interpretation, and because, on balance, it was considered to yield physically more meaningful regression equations. The stepwise procedure was used and significance was tested at the 5% probability level. Because of the significant correlations between certain fibre properties (see Tables I and III), the results of the statistical analyses, and therefore the trends, in some cases depended upon the particular fibre properties selected for simultaneous inclusion in the statistical analyses. Various different combinations of independent variables were tried and the most significant (best fit) regression equations obtained are given in Tables V to X.

Analyses showed that, in most cases, the 50% span length results were slightly better correlated with both the ring- and rotor yarn properties than the 2,5% span length and only the analyses involving the 50% span length are discussed. Other workers[3, 7, 8] have reported similar findings for ring yarns.

Miniature Processing

Rotor Yarns

From Tables V and VI it can be seen that, of the three air-flow determined parameters (micronaire, maturity and fineness) maturity had, statistically, the least effect on the various rotor yarn properties. Furthermore, micronaire generally had a more significant effect than fineness, particularly for the 25 tex yarns. The additional information on the fineness of the cottons therefore did little to improve the correlation between fibre and yarn properties. It is important to note, however, that there was a high correlation ($r = 0,85$) between fineness and micronaire for these cottons (see Table I). An increase in micronaire tended to increase irregularity and the frequencies of thin and thick places and to decrease the strength of the yarns, although this depended to some extent upon the season and yarn tex. When significant, the effect of fibre fineness was similar to that of micronaire. Surprisingly, an increase in micronaire or fibre linear density (fineness), if anything, was associated with a slight increase in the frequency of yarn neps, which is the reverse of the general trend for card sliver neps. Fibre extension had the most significant effect on yarn extension at break while fibre tenacity generally had the most significant effect on single thread tenacity and CSP. An increase in fibre extension also tended to have an adverse effect on CSP.

The 50% span length had an important effect on the yarn properties, an increase in which generally improving the yarn tensile, hairiness and evenness properties, although the trends were generally absent or sometimes even opposite for the 1978 season. Ramey *et al*[21] found rotor yarn strength to be mainly dependent upon fibre tenacity and mean length, the fibre fineness characteristics having little effect.

Where an increase in uniformity ratio had an effect on the yarn properties it tended to be an adverse one.

Even though the yarns were spun to the same nominal linear density (tex), the small differences in actual tex between yarns spun from the different cotton had a significant effect on many of the yarn properties. This clearly illustrates that, in the case of such miniature spinning trials, it is important to measure the actual yarn linear density and to include this as an independent variable in any statistical analysis so as to improve accuracy.

From the results of the statistical analysis it is clear that the correlation coefficients, particularly those associated with the yarn evenness and hairiness characteristics, were too low to allow any of the equations to be used for predictive purposes, and at best they only serve to illustrate the various trends. The very low correlation coefficients associated with the yarn evenness characteristics indicate that the miniature system is not suitable for evaluating yarn evenness characteristics and their correlation with fibre properties. Previously[26] it was found that higher correlations were obtained between the tensile properties of rotor yarns processed along miniature and full-scale routes, respectively, than between their evenness properties.

Ring Yarns

From Tables VII and VIII it can be seen that, of the air-flow measured parameters, maturity had the least effect on the yarn properties, having no effect on the properties of the 50 tex yarns and affecting the 25 tex yarn properties only slightly in a few isolated cases. According to these results, therefore, information on maturity, as measured by the air-flow technique, was of little value when trying to predict the yarn properties from those of the fibres. Other workers[6, 7, 21] also found maturity to have little effect on ring yarn tenacity. Of the other two air-flow measured properties, micronaire was more important generally than fineness, particularly for the 50 tex yarns, which is in line with the trends observed for the rotor yarns. In only a few cases did fineness result in a better correlation than micronaire.

Although the trends were not always consistent, an increase in micronaire tended to have a slightly adverse effect on yarn strength and irregularity and a greater one on the frequencies of thin places. Other workers[7] reported similar trends for yarn strength and irregularity. If anything, an increase in micronaire reduced the frequency of neps in the ring yarn which contrasts with the rotor yarn results. Once again, the small variations in yarn linear density had a significant effect on a number of the yarn properties.

The 50% span length generally had an important effect on the properties of both yarns, an increase in span length significantly increasing yarn strength and decreasing irregularity and the frequencies of thin and thick places although, as in the case of the rotor yarns, its effect was notably smaller and sometimes non-existent for the 1978 seasons. El Sourady *et al*[8] have reported on the importance of environmental and genetic factors in determining the relationship between ring yarn strength and fibre properties. More recently Feaster *et al*[25] reported that, for Pima cottons grown in 1959, six fibre properties explained 59% of the variation in yarn tenacity whereas for similar cottons grown in 1979 the same six fibre properties could only explain 14% of the variation in yarn tenacity. As could be expected[1-15] yarn strength was largely affected by fibre tenacity and yarn extension by fibre extension. In certain cases, an increase in fibre extension decreased CSP, this also having been observed for the rotor yarns.

As in the case of the rotor yarns, the correlation coefficients, particularly those associated with the yarn evenness and hairiness properties, were far too low for prediction purposes and therefore the equations are, at best, only indicative of trends.

Full-Scale Processing

Rotor Yarns

According to Table IX fibre linear density did not improve the correlation between fibre and yarn properties, once micronaire, with which it was highly correlated (r = 0,9, see Table III), was taken into consideration. An increase in maturity ratio tended to increase the yarn irregularity and the frequencies of thin and thick places. This could be at least partly due to the positive correlation between maturity and micronaire (see Table III).

Taking on overall view of the results, it appears that the 50% span length had the most significant effect on the yarn tensile properties with an increase in the 50% span length increasing the yarn tenacity, CSP and extension and decreasing the yarn irregularity, hairiness, CV of Strength and frequencies of imperfections.

An increase in micronaire increased the number of neps in the yarn which was also observed for the rotor yarns processed along the miniature route. It also increased the CV of strength and decreased yarn extension.

An increase in fibre tenacity increased yarn strength but decreased yarn extension at break. The effect of 50% span length on the tensile properties of these yarns was more significant than for the yarns processed on the miniature system where the fibre tensile properties were of greater significance in the latter case. As in the case of the yarn processed along the miniature route, more of the variation in the yarn tensile properties could be explained in terms of fibre properties than was the case for the yarn evenness properties.

Ring Yarns

From Table X it is apparent that, of the fibre properties studied, the 50% span length generally had the most significant effect on the various yarn properties. An increase in the 50% span length increased the single thread tenacity and the CSP and decreased hairiness, irregularity and the frequencies of imperfections. The latter effect was particularly large, which was also the case for the rotor yarns.

After the 50% span length, micronaire was next most important, an increase in micronaire increasing the CV of strength, hairiness, irregularity and thin places and decreasing CSP and extension. Maturity ratio had no effect on the various yarn properties except that an increase in maturity decreased yarn irregularity. Once micronaire had been taken into consideration, fibre linear density (mtex) did not have a significant effect on the yarn properties, except in the case of yarn hairiness. The apparent lack of an effect of fibre linear density is due to the fact that it was highly correlated with micronaire and once micronaire was included in the analyses, fineness had little further effect.

An increase in fibre tenacity increased the single thread tenacity and CSP, as expected, but decreased the yarn extension at break. Fibre extension increased the yarn extension at break and the CSP. An increase in uniformity ratio had an adverse effect on yarn strength and the frequency of neps, but this unexpected result may be due to the correlation between uniformity ratio and 50% span length. The important effect of yarn tex is very apparent.

SUMMARY

The correlation between the properties of Upland cottons and the physical properties of rotor- and ring yarns processed on miniature and full-scale machinery has been investigated by means of multiple regression analyses. Because of significant correlations between certain fibre properties, the results of the statistical analyses, and therefore the trends, in some cases depended upon the fibre properties selected for simultaneous inclusion in the statistical analysis. In most cases the 50% span length results were slightly better correlated with both the ring- and rotor yarn properties than the 2,5% span length.

Certain of the trends observed between yarn- and fibre properties differed for the different growing seasons (years) and spinning systems, making it difficult to generalise. For the miniature system, the tensile properties of the fibres tended to have the most significant effect on those of the yarns, followed by 50% span length, whereas for full-scale processing, the 50% span length assumed greater importance. Fibre fineness characteristics, micronaire in particular, generally had the most significant effect on the rotor yarn evenness characteristics, whereas the fibre length characteristics, particularly the 50% span length, had the main effect on those of the ring yarns. Poor correlations were obtained between yarn evenness characteristics and fibre properties for the miniature system. Air-flow measured fineness (mtex) was highly correlated with micronaire but the latter tended to have a more significant effect on the yarn properties. Air-flow measured maturity seldom had a significant effect on yarn properties.

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TABLE I

CORRELATION BETWEEN FIBRE PROPERTIES FOR THE APPROXIMATELY 400 COTTONS PROCESSED ON THE MINIATURE SYSTEM

	⅛"-gauge Tenacity*	Zero-Gauge Tenacity	Micro-naire	Fine-ness	Matu-rity Ratio	2,5% Span Length	50% Span Length	Unifor-mity Ratio
⅛"-gauge Tenacity	1	0,82	−0,06	−0,19	0,25	0,72	0,43	−0,16
Zero-gauge Tenacity		1	−0,02	−0,25	0,34	0,64	0,48	−0,12
Micronaire			1	0,85	0,64	0,01	0,30	0,48
Fineness				1	0,15	−0,20	0,11	0,45
Maturity					1	0,35	0,43	0,22
2,5% Span Length						1	0,81	−0,07
50% Span Length							1	0,50
Uniformity Ratio								1

* Only 131 results available

TABLE II

MEANS AND STANDARD DEVIATIONS FOR THE PROPERTIES OF THE COTTONS USED IN THE MINIATURE TRIALS

Property	Mean	Standard Deviation
⅛"-gauge tenacity (cN/tex)	25,0	2,1
Zero-gauge tenacity (Pressley)	87	7,8
Micronaire	3,86	0,47
Fineness (Linear Density in mtex)	160	20
Maturity Ratio	0,89	0,08
2,5% Span Length (mm)	27,9	1,5
50% Span Length (mm)	12,9	0,84
Uniformity ratio (%)	46	1,8
Standard Fineness (H_s in mtex)*	182	30
Perimeter $= 3{,}8\sqrt{H_s}$ (μm)	51,1	3,8

* Calculated from: $H_s = \dfrac{\text{Linear density}}{\text{Maturity ratio}}$

TABLE III

CORRELATION BETWEEN PROPERTIES OF FIBRES USED IN FULL-SCALE TRIALS*

	⅛"-gauge Tenacity	Extension	Micro-naire	Fine-ness	Matu-rity Ratio	2,5% Span Length	50% Span Length	Unifor-mity Ratio
⅛"-gauge Tenacity	1	−0,24	−0,09	−0,32	0,42	0,81	0,68	0,27
Extension	−0,48	1	0,49	0,37	0,13	−0,15	0,02	0,21
Micronaire	0,21	−0,11	1	0,87	0,71	0,11	0,37	0,65
Fineness	0,10	−0,10	0,90	1	0,47	0,10	0,15	0,46
Maturity	0,16	−0,02	0,63	0,31	1	0,55	0,67	0,73
2,5% Span Length	0,43	−0,39	0,07	0,01	0,10	1	0,92	0,57
50% Span Length	0,53	−0,36	0,09	−0,04	0,24	0,88	1	0,81
Uniformity Ratio	0,17	−0,15	0,32	0,14	0,41	0,15	0,46	1

* Values above the diagonal pertain to the cottons ($\simeq 65$) spun into rotor yarns and those below the diagonal to the cottons ($\simeq 130$) spun into ring yarns

TABLE IV

MEANS AND STANDARD DEVIATIONS FOR THE PROPERTIES OF THE COTTONS USED IN THE FULL-SCALE TRIALS

Property	Mean	Standard Deviation
⅛"-gauge tenacity (cN/tex)	24,2	3,8
Zero-gauge tenacity (Pressley)	88	8,2
Extension (%)	6,8	1,0
Micronaire	4,1	0,5
Fineness (Linear Density in mtex)	169	15,6
Maturity Ratio	0,88	0,06
2,5% Span Length (mm)	27,7	1,7
50% Span Length (mm)	12,9	1,0
Uniformity (%)	46,4	1,8
Standard Fineness (H_S in mtex)*	193	21
Perimeter $= 3{,}8\sqrt{H_S}$ (μm)	52,8	2,8

* Calculated from: $H_S = \frac{\text{Linear density}}{\text{Maturity ratio}}$

TABLE V

SUMMARY OF THE STATISTICAL ANALYSIS OF THE RESULTS OF THE 25 TEX ROTOR YARNS (MINIATURE PROCESSING)

Yarn Property (Y) and Season	CONTRIBUTION OF INDEPENDENT VARIABLE TO OBSERVED FIT*(%)									Most Significant Regression Equations	Number of Lots	Multiple Correlation coefficient
	Zero-gauge Tenacity (X_1)	⅛"-Gauge (X_2)	Extension (X_3)	Micronaire (X_4)	Maturity (X_5)	Fineness (X_6)	50% Span (X_7)	Uniformity (X_8)	Yarn tex (X_9)		(n)	(r)
TENACITY												
1977	13	–	ns	11	ns	ns	18	ns	ns	$0{,}35\ X_1^{0.4}\ X_4^{-0.3}\ X_7^{0.7}$	89	0,65
1978	11	23	ns	ns	ns	ns	ns	ns	10	$1{,}2\ X_1^{0.3}\ X_2^{0.5}\ X_9^{-0.3}$	116	0,66
1977 + 1978	29	–	ns	ns	ns	ns	7	ns	ns	$0{,}27\ X_1^{0.5}\ X_7^{0.4}$	205	0,60
EXTENSION												
1977	ns	–	20	ns	ns	ns	ns	ns	4	$1{,}8\ X_3^{0.3}\ X_9^{0.2}$	89	0,49
1978	ns	ns	42	ns	ns	ns	ns	ns	2	$1{,}6\ X_3^{0.5}\ X_9^{0.2}$	116	0,66
1977 + 1978	4	–	3	ns	ns	ns	9	ns	5	$0{,}92\ X_1^{-0.4}\ X_3^{0.3}\ X_7^{0.7}\ X_9^{0.5}$	205	0,47
CSP												
1977	24	–	ns	13	ns	ns	15	ns	11	$175\ X_1^{0.6}\ X_4^{-0.3}\ X_7^{0.6}\ X_9^{-0{,}4}$	89	0,79
1978	7	6	5	ns	ns	7	ns	ns	42	$3120\ X_1^{0.3}\ X_2^{0{,}3}\ X_3^{-0{,}2}\ X_6^{-0{,}1}\ X_9^{-0.6}$	116	0,82
1978	–	16	7	3	4	–	ns	3	28	$2{,}3\text{x}10^4\ X_2^{0.5}\ X_3^{-0.2}\ X_4^{-0{,}2}\ X_5^{0.2}\ X_8^{-0.4}\ X_9^{-0.7}$	116	0,79
1977 + 1978	33	–	1	4	ns	ns	ns	ns	21	$798\ X_1^{0.7}\ X_3^{-0{,}1}\ X_4^{-0{,}1}\ X_9^{-0{,}6}$	205	0,77
HAIRINESS												
1977	ns	–	ns	ns	ns	ns	17	ns	ns	$173\ X_7^{-1{,}3}$	89	0,41
1978	26	ns	ns	ns	ns	ns	ns	ns	ns	$4381\ X_1^{-1{,}6}$	116	0,51
1978	–	–	–	ns	ns	ns	7	7	ns	$1{,}9\text{x}10^{-2}\ X_7^{-2{,}6}\ X_8^{3{,}1}$	116	0,37
1977 + 1978	–	–	–	ns	ns	ns	14	3	ns	$4{,}8\ X_7^{-3{,}4}\ X_8^{-2.2}$	205	0,40
IRREGULARITY												
1977	–	–	–	49	ns	ns	2	ns	ns	$18{,}4\ X_4^{0.3}\ X_7^{-0.1}$	89	0,72
1978	–	–	–	ns	ns	11	14	ns	ns	$4{,}2\ X_6^{0.1}\ X_7^{0.4}$	116	0,50
1977 + 1978	–	–	–	21	ns	ns	ns	ns	ns	$15{,}1\ X_4^{0.2}$	205	0,46
THIN PLACES												
1977	–	–	–	58	ns	ns	5	ns	ns	$3{,}6\text{x}10^4\ X_4^{4{,}5}\ X_7^{-2{,}4}$	89	0,81
1978	–	–	–	24	ns	ns	9	9	ns	$6.6\text{x}10^{-8}\ X_4^{1{,}8}\ X_7^{2{,}7}\ X_8^{3{,}3}$	116	0,65
1977 + 1978	–	–	–	39	ns	ns	ns	5	3	$7{,}6\text{x}10^{-3}\ X_4^{2{,}8}\ X_8^{2.8}\ X_9^{-1{,}3}$	205	0,68
THICK PLACES												
1977	–	–	–	43	ns	ns	ns	ns	ns	$17{,}8\ X_4^{1{,}8}$	89	0,66
1978	–	–	–	21	ns	ns	12	ns	ns	$0{,}026\ X_4^{1{,}5}\ X_7^{2{,}6}$	116	0,57
1977 + 1978	–	–	–	17	ns	ns	ns	ns	2	$403\ X_4^{1{,}5}\ X_9^{-0{,}9}$	205	0,43
NEPS												
1977	ns	–	ns	9	ns	ns	5	ns	ns	$7{,}3\text{x}10^3\ X_4^{1{,}1}\ X_7^{-1{,}4}$	89	0,37
1978	ns	ns	ns	8	ns	ns	ns	ns	ns	$279\ X_4^{0{,}6}$	116	0,27
1977 + 1978	ns	–	ns	5	ns	ns	2	ns	2	$2{,}5\text{x}10^4\ X_4^{0{,}7}\ X_7^{-0{,}8}\ X_9^{-0{,}7}$	205	0,30

* : observed fit = r^2x100

– : variable omitted from analysis

ns : not significant

TABLE VI

SUMMARY OF THE STATISTICAL ANALYSIS OF THE RESULTS OF THE 50 TEX ROTOR YARNS (MINIATURE PROCESSING)

Yarn Property (Y) and Season	CONTRIBUTION OF INDEPENDENT VARIABLE TO OBSERVED FIT*(%)									Most Significant Regression Equations	Number of Lots	Multiple Correlation coefficient
	Zero-gauge Tenacity (X_1)	⅛"-Gauge (X_2)	Extension (X_3)	Micronaire (X_4)	Maturity (X_5)	Fineness (X_6)	50% Span (X_7)	Uniformity (X_8)	Yarn tex (X_9)		(n)	(r)
TENACITY												
1977	19	–	ns	7	ns	–	28	ns	ns	$0{,}35\ X_1^{0.4}\ X_4^{-0.2}\ X_7^{0.7}$	89	0,73
1977	19	–	ns	–	ns	7	28	ns	ns	$0{,}71\ X_1^{0.4}\ X_6^{-0.2}\ X_7^{0.7}$	89	0,73
1978	21	22	ns	ns	ns	ns	ns	ns	ns	$0{,}75\ X_1^{0.3}\ X_2^{0.4}$	130	0,66
1978		35	8	ns	ns	ns	ns	ns	ns	$2{,}8\ X_2^{0.6}\ X_3^{-0.2}$	130	0,65
1977 + 1978	14	–	4	ns	ns	ns	21	7	ns	$4{,}6\ X_1^{0.3}\ X_3^{-0.1}\ X_7^{0.7}\ X_8^{-0.5}$	219	0,80
EXTENSION												
1977	ns	–	21	ns	ns	ns	5	ns	ns	$2{,}4\ X_3^{0.3}\ X_7^{0.2}$	89	0,51
1978	ns	4	35	ns	ns	ns	ns	ns	19	$1{,}57\ X_2^{-0.1}\ X_3^{0.3}\ X_9^{0.4}$	130	0,76
1977 + 1978	7	–	5	ns	ns	ns	6	ns	26	$0{,}28\ X_1^{-0.3}\ X_3^{0.3}\ X_7^{0.4}\ X_9^{0.9}$	219	0,66
CSP												
1977	28	–	ns	12	ns	ns	18	ns	11	$377\ X_1^{0.5}\ X_4^{-0.2}\ X_7^{0.7}\ X_9^{-0.6}$	89	0,83
1978	–	30	12	ns	ns	ns	ns	ns	26	$6{,}7\text{x}10^3\ X_2^{0.6}\ X_3^{-0.3}\ X_9^{-0.7}$	130	0,82
1977 + 1978	14	–	8	ns	na	ns	4	2	35	$1{,}5\text{x}10^4\ X_1^{0.4}\ X_3^{-0.2}\ X_7^{0.4}\ X_8^{-0.7}\ X_9^{-0.4}$	219	0,80
HAIRINESS												
1977	ns	ns	ns	ns	ns	ns	49	6	ns	$20.9\ X_7^{-3.4}\ X_8^{2.1}$	89	0,74
1978	19	ns	ns	ns	ns	ns	13	5	8	$5{,}8\text{x}10^5\ X_1^{-1.4}\ X_7^{-3.2}\ X_8^{2.3}\ X_9^{-1.5}$	130	0,67
1978	–	–	–	ns	ns	ns	19	14	8	$2{,}3\ X_7^{-5.1}\ X_8^{5.0}\ X_9^{-1.3}$	130	0,59
1977 + 1978	ns	–	ns	ns	ns	ns	23	3	16	$1{,}7\text{x}10^7\ X_7^{-4.4}\ X_8^{2.3}\ X_9^{-3.0}$	219	0,65
IRREGULARITY												
1977	–	–	–	17	ns	ns	3	ns	ns	$20{,}4\ X_4^{0.3}\ X_7^{-0.3}$	89	0,45
1978	–	–	–	ns	ns	9	ns	5	9	$8{,}8\ X_6^{0.1}\ X_8^{0.2}\ X_9^{-0.2}$	130	0,47
1978	–	–	–	12	3	–	ns	ns	5	$28{,}5\ X_4^{0.2}\ X_5^{-0.1}\ X_9^{-0.2}$	130	0,44
1977 + 1978	–	–	–	ns	ns	13	ns	ns	4	$15{,}8\ X_6^{0.2}\ X_9^{-0.2}$	219	0,41
1977 + 1978	–	–	–	11	ns	–	ns	ns	5	$31.7\ X_4^{0.2}\ X_9^{-0.3}$	219	0,40
THIN PLACES												
1977	–	–	–	ns	ns	ns	ns	9	10	$1{,}6\text{x}10^{-7}\ X_8^{25}\ X_9^{-21}$	89	0,44
1978	–	–	–	ns	ns	13	ns	ns	5	$1148\ X_6^{5.8}\ X_9^{-8.6}$	130	0,43
1978	–	–	–	11	3	–	ns	ns	4	$3{,}2\text{x}10^{11}\ X_4^{7.2}\ X_5^{5.7}\ X_9^{-8.8}$	130	0,42
1977 + 1978	–	–	–	ns	ns	5	2	6	3	$4{,}5\text{x}10^{-19}\ X_6^{4.2}\ X_7^{-7.0}\ X_8^{17}\ X_9^{-6.4}$	219	0,41
1977 + 1978	–	–	–	9	ns	–	ns	ns	4	$9{,}7\text{x}10^{13}\ X_4^{6.5}\ X_9^{-9.9}$	219	0,36
THICK PLACES												
1977	–	–	–	24	ns	ns	ns	6	ns	$5{,}0\text{x}10^{14}\ X_4^{6.1}\ X_8^{-10}$	89	0,55
1978	–	–	–	5	ns	ns	ns	ns	ns	$1{,}6\ X_4^{1.5}$	130	0,21
1977 + 1978	–	–	–	ns	ns	6	ns	1	3	$10^7\ X_6^{2.6}\ X_8^{-3.8}\ X_9^{-3.7}$	219	0,32
1977 + 1978	–	–	–	6	ns	–	ns	–	4	$1{,}2\text{x}10^6\ X_4^{2.2}\ X_9^{-3.7}$	219	0,31
NEPS												
1977	ns	–	7	ns	ns	ns	ns	ns	7	$1{,}9\text{x}10^6\ X_3^{1.6}\ X_9^{-3.0}$	89	0,38
1978	ns	ns	ns	5	ns	–	3	ns	5	$7{,}9\text{x}10^6\ X_4^{1.0}\ X_7^{-1.9}\ X_9^{-1.9}$	130	0,35
1977 + 1978	–	–	ns	ns	ns	2	7	ns	12	$1{,}6\text{x}10^9\ X_6^{0.6}\ X_7^{-2.5}\ X_9^{-3.3}$	219	0,46

* : observed fit = r^2x100

– : variable omitted from analysis

ns : not significant

TABLE VII

SUMMARY OF THE STATISTICAL ANALYSIS OF THE RESULTS OF THE 25 TEX RING YARNS (MINIATURE PROCESSING)

Yarn Property (Y) and Season	CONTRIBUTION OF INDEPENDENT VARIABLE TO OBSERVED FIT*(%)									Most Significant Regression Equations	Number of Lots (n)	Multiple Correlation coefficient (r)
	Zero-gauge Tenacity (X_1)	⅛"-Gauge (X_2)	Extension (X_3)	Micronaire (X_4)	Maturity (X_5)	Fineness (X_6)	50% Span (X_7)	Uniformity (X_8)	Yarn tex (X_9)			
TENACITY												
1977	18	–	ns	11	ns	ns	31	ns	ns	$0{,}29\ X_1^{0.4}\ X_4^{-0.2}\ X_7^{0.9}$	156	0,77
1978	–	47	ns	6	ns	ns	ns	ns	ns	$1{,}3\ X_2^{0.9}\ X_4^{-0.2}$	119	0,73
1979	16	–	–	ns	ns	11	20	ns	ns	$0{,}67\ X_1^{0.6}\ X_6^{-0.2}\ X_7^{0.5}$	118	0,68
1977 + 1978	11	–	3	4	ns	ns	33	5	ns	$4{,}0\ X_1^{0.3}\ X_3^{-0.1}\ X_4^{-01}\ X_7^{0.9}\ X_8^{-0.6}$	275	0,74
1977 + 1978	26	–	ns	8	ns	ns	19	–	ns	$0{,}32\ X_1^{0.50}\ X_4^{-0.22}\ X_7^{0.75}$	275	0,73
1977 + 1978 + 1979	30	–	–	ns	ns	6	23	2	ns	$1{,}7\ X_1^{0.6}\ X_6^{-0.2}\ X_7^{0.8}\ X_8^{0.4}$	393	0,78
EXTENSION												
1977	8	–	31	ns	ns	ns	ns	ns	13	$4{,}7\ X_1^{-0.2}\ X_3^{0.4}\ X_9^{0.3}$	156	0,72
1978	–	ns	45	ns	ns	ns	ns	ns	5	$0{,}73\ X_3^{0.7}\ X_9^{0.4}$	119	0,71
1979	13	–	–	3	10	ns	ns	13	17	$1{,}9\ X_1^{-0.3}\ X_4^{-0.1}\ X_5^{-0.4}\ X_8^{-0.4}\ X_9^{0.4}$	118	0,75
1977 + 1978	8	–	31	ns	ns	ns	ns	ns	14	$3{,}7\ X_1^{-0.2}\ X_3^{0.5}\ X_9^{0.3}$	275	0,72
1977 + 1978 + 1979	30	–	–	ns	7	ns	ns	ns	7	$27{,}5\ X_1^{-0.5}\ X_5^{-0.3}\ X_9^{0.4}$	393	0,67
CSP												
1977	5	–	ns	3	ns	ns	13	1	51	$7{,}1\text{x}10^3\ X_1^{0.3}\ X_4^{-0.2}\ X_7^{0.8}\ X_8^{-0.3}\ X_9^{-1.0}$	156	0,86
1978	–	22	2	1	ns	ns	ns	ns	57	$1{,}3\text{x}10^4\ X_2^{0.8}\ X_3^{-0.2}\ X_4^{-0.1}\ X_9^{-1.0}$	119	0,91
1979	7	–	ns	ns	ns	8	18	21	21	$2{,}6\text{x}10^3\ X_1^{0.4}\ X_6^{-0.2}\ X_7^{0.5}\ X_9^{-0.7}$	118	0,74
1977 + 1978	34	–	1	2	ns	ns	8	1	59	$1\text{x}10^4\ X_1^{0.3}\ X_3^{-0.1}\ X_4^{-0.1}\ X_7^{0.8}\ X_8^{-03}\ X_9^{-1.0}$	275	0,87
1977 + 1978 + 1979	18	–	–	ns	ns	5	11	ns	38	$3{,}2\text{x}10^3\ X_1^{0.6}\ X_6^{-0.2}\ X_7^{0.5}\ X_9^{-0.9}$	393	0,85
IRREGULARITY												
1977	–	–	–	2	ns	ns	17	ns	ns	$46{,}6\ X_4^{0.1}\ X_7^{-0.4}$	156	0,44
1978	–	–	–	3	ns	ns	7	ns	ns	$41\ X_4^{0.1}\ X_7^{-0.4}$	119	0,30
1979	–	–	–	ns	ns	ns	9	10	ns	$110\ X_7^{-0.2}\ X_8^{-0.4}$	118	0,44
1977 + 1978	–	–	–	3	ns	–	11	ns	ns	$42{,}7\ X_4^{0.1}\ X_7^{-0.4}$	275	0,37
1977 + 1978 + 1979	–	–	–	ns	ns	ns	16	ns	1	$57{,}1\ X_7^{-0.3}\ X_9^{-0.1}$	393	0,42
THIN PLACES												
1977	–	–	–	9	ns	ns	6	ns	5	$4{,}1\text{x}10^{14}\ X_4^{4.5}\ X_7^{-7.4}\ X_9^{-5.8}$	156	0,45
1978	–	–	–	6	ns	ns	4	ns	3	$3\text{x}10^{12}\ X_4^{3.8}\ X_7^{-8.4}\ X_9^{-4.7}$	119	0,36
1979	–	–	–	ns	ns	ns	11	ns	ns	$2{,}1\text{x}10^{12}\ X_7^{-10}$	118	0,33
1977 + 1978	–	–	–	10	ns	ns	5	ns	2	$9{,}3\text{x}10^{13}\ X_4^{4.2}\ X_7^{-7.1}\ X_9^{-5.4}$	275	0,41
1977 + 1978 + 1979	–	–	–	ns	ns	5	7	ns	3	$7{,}2\text{x}10^7\ X_6^{3.2}\ X_7^{-8.1}\ X_9^{-3.8}$	393	0,40
1977 + 1978 + 1979	–	–	–	4	ns	–	9	ns	2	$1{,}6\text{x}10^{15}\ X_4^{3.0}\ X_7^{-9.0}\ X_9^{-4.3}$	393	0,39
THICK PLACES												
1977	–	–	–	2	ns	ns	23	ns	ns	$1{,}4\text{x}10^5\ X_4^{0.4}\ X_7^{-2.9}$	156	0,50
1978	–	–	–	ns	ns	ns	ns	13	6	$9{,}7\text{x}10^8\ X_8^{-3.0}\ X_9^{-1.3}$	119	0,43
1979	–	–	–	ns	ns	ns	ns	8	7	$3{,}9\text{x}10^{11}\ X_8^{-3.5}\ X_9^{-2.8}$	118	0,39
1977 + 1978	–	–	–	ns	ns	ns	14	ns	2	$4{,}8\text{x}10^5\ X_7^{-2.2}\ X_9^{-0.7}$	275	0,40
1977 + 1978 + 1979	–	–	–	1	4	–	14	ns	3	$5{,}5\text{x}10^6\ X_4^{0.4}\ X_5^{-1.0}\ X_7^{-2.1}\ X_9^{-1.0}$	393	0,47
NEPS												
1977	ns	–	ns	13	ns	ns	ns	10	ns	$1{,}77\text{x}10^7\ X_4^{-0.9}\ X_8^{-2.8}$	156	0,49
1978	ns	ns	8	ns	ns	ns	ns	23	ns	$3{,}2\text{x}10^{10}\ X_3^{-0.9}\ X_8^{-4.3}$	119	0,56
1979	ns	–	–	ns	ns	ns	2	10	7	$8.2\text{x}10^{13}\ X_7^{1.4}\ X_8^{-5.4}\ X_9^{-3.0}$	118	0,43
1977 + 1978	ns	–	ns	5	ns	ns	ns	5	ns	$6{,}0\text{x}10^5\ X_4^{-0.6}\ X_8^{-1.7}$	275	0,31
1977 + 1978 + 1979	–	–	–	ns	3	ns	ns	8	1	$3\text{x}10^6\ X_5^{-0.8}\ X_8^{-3.0}\ X_9^{-0.8}$	393	0,34
1977 + 1978 + 1979	–	–	–	5	ns	–	4	–	1	$2{,}2\text{x}10^5\ X_4^{-0.7}\ X_7^{-1.2}\ X_9^{-0.8}$	393	0,31

* : observed fit = r^2x100

– : variable omitted from analysis

ns : not significant

TABLE VIII

SUMMARY OF THE STATISTICAL ANALYSIS OF THE RESULTS OF THE 50 TEX RING YARNS (MINIATURE PROCESSING)

Yarn Property (Y) and Season	CONTRIBUTION OF INDEPENDENT VARIABLE TO OBSERVED FIT*(%)									Most Significant Regression Equations	Number of Lots (n)	Multiple Correlation coefficient (r)
	Zero-gauge Tenacity (X_1)	⅛"-Gauge (X_2)	Extension (X_3)	Micronaire (X_4)	Maturity (X_5)	Fineness (X_6)	50% Span (X_7)	Uniformity (X_8)	Yarn tex (X_9)			
TENACITY												
1977	12	–	ns	11	ns	ns	21	ns	ns	$0,72\ X_1^{0,3}\ X_4^{-0,2}\ X_7^{0,7}$	156	0,66
1978	31	24	ns	ns	ns	ns	ns	ns	ns	$0,54\ X_1^{0,4}\ X_2^{0,4}$	118	0,74
1978	–	43	10	ns	ns	ns	ns	ns	ns	$2,9\ X_2^{0,7}\ X_3^{-0,2}$	118	0,73
1977 + 1978	33	–	ns	4	ns	ns	9	ns	ns	$0,50\ X_1^{0,5}\ X_4^{-0,1}\ X_7^{0,5}$	274	0,68
EXTENSION												
1977	4	–	26	ns	ns	ns	ns	ns	21	$2,3\ X_1^{-0,2}\ X_3^{0,4}\ X_9^{0,4}$	156	0,71
1978	7	ns	40	ns	ns	ns	ns	ns	ns	$10\ X_1^{-0.20}\ X_3^{0,4}$	118	0,69
1977 + 1978	4	–	35	ns	ns	ns	ns	ns	7	$3,8\ X_1^{-0,1}\ X_3^{0,4}\ X_9^{0,2}$	274	0,68
CSP												
1977	4	–	ns	5	ns	ns	13	ns	38	$6,4\text{x}10^3\ X_1^{0,3}\ X_4^{-0,2}\ X_7^{0,7}\ X_9^{-0,9}$	156	0,77
1978	5	7	5	ns	ns	ns	ns	ns	58	$1,3\text{x}10^4\ X_1^{0,2}\ X_2^{0,3}\ X_3^{-0,2}\ X_9^{-0.9}$	118	0,87
1977 + 1978	7	–	1	2	ns	ns	7	ns	52	$1,1\text{x}10^4\ X_1^{0,3}\ X_3^{-0,1}\ X_7^{0,5}\ X_9^{-0,9}$	274	0,83
HAIRINESS												
1978	ns	ns	ns	11	ns	ns	ns	ns	ns	$1,6\ X_4^{1,9}$	118	0,33
IRREGULARITY												
1977	–	–	–	ns	ns	ns	3	6	5	$142\ X_7^{-0.1}\ X_8^{-0.3}\ X_9^{-0,2}$	156	0,37
1978	–	–	–	ns	ns	10	11	6	3	$56,7\ X_6^{0.1}\ X_7^{-0,4}\ X_8^{-0,4}\ X_9^{0,1}$	118	0,55
1978	–	–	–	3	ns	–	17	–	2	$37,8\ X_4^{0,1}\ X_7^{-0,6}\ X_9^{0,2}$	118	0,47
1977 + 1978	–	–	–	4	ns	ns	6	8	ns	$155\ X_4^{0.1}\ X_7^{-0,2}\ X_8^{-0,5}$	274	0,42
THIN PLACES												
1977	1	–	–	3	ns	ns	3	ns	ns	$122\ X_1^{5,0}\ X_4^{6.5}\ X_7^{-14}$	156	0,27
1978	–	–	–	4	ns	ns	5	ns	ns	$9,9\text{x}10^{15}\ X_4^{6,7}\ X_7^{-19}$	118	0,30
1977 + 1978	–	–	–	2	ns	ns	4	ns	3	$6,9\text{x}10^{24}\ X_4^{4,2}\ X_7^{-12}\ X_9^{-8,2}$	274	0,31
THICK PLACES												
1977	–	–	–	ns	ns	ns	16	ns	ns	$2,2\text{x}10^5\ X_7^{-3,2}$	156	0,40
1978	–	–	–	ns	ns	ns	ns	11	4	$2,4\text{x}10^{12}\ X_8^{-4,5}\ X_9^{-1,8}$	118	0,39
1977 + 1978	–	–	–	ns	ns	ns	7	8	7	$10^{11}\ X_7^{-1,9}\ X_8^{-2,9}\ X_9^{-1,4}$	274	0,47
NEPS												
1977	ns	–	ns	18	ns	ns	ns	ns	ns	$1,9\text{x}10^3\ X_4^{-1,8}$	156	0,42
1978	–	ns	ns	ns	ns	ns	4	30	8	$1,8\text{x}10^{18}\ X_7^{2,8}\ X_8^{-8,7}\ X_9^{-2,6}$	118	0,65
1977 + 1978	–	–	ns	ns	ns	7	ns	14	ns	$4,5\text{x}10^{10}\ X_6^{-0,8}\ X_8^{-3,9}$	274	0,46
1977 + 1978	–	–	6	4	ns	–	ns	8	ns	$2,5\text{x}10^8\ X_3^{-0,8}\ X_4^{-0,7}\ X_8^{-3,1}$	274	0,42

* : observed fit = r^2x100

– : variable omitted from analysis

ns : not significant

TABLE IX

SUMMARY OF THE STATISTICAL ANALYSIS OF THE RESULTS OF THE ROTOR YARNS (FULL-SCALE TRIALS)

Yarn Property (Y)	CONTRIBUTION OF INDEPENDENT VARIABLE*(%) ⅛"-Gauge Tenacity (X_2)	Extension (X_3)	Micronaire (X_4)	Maturity (X_5)	Fineness (X_6)	50% Span Length (X_7)	Uniformity Ratio (X_8)	Yarn tex (X_9)	Most Significant Regression Equations	Number of yarns (n)	Multiple Correlation coefficient (r)
Single thread tenacity	30	ns	ns	7	ns	35	ns	12	$0,07\ X_2^{0,6}\ X_5^{-0,6}\ X_7^{1,0}\ X_9^{0,1}$	65	0,91
CV of single thread strength	ns	4	12	ns	ns	27	ns	9	$254\ X_3^{-0,38}\ X_4^{0,9}\ X_7^{-1,2}\ X_9^{-0,2}$	54	0,72
Single thread extension	4	10	15	ns	ns	26	ns	3	$1,02\ X_2^{-0,4}\ X_3^{0,5}\ X_4^{-1,0}\ X_7^{-1,4}\ X_9^{0,1}$	65	0,76
CSP	ns	ns	ns	ns	ns	51	14	11	$4,1\text{x}10^3\ X_7^{2,0}\ X_8^{-1,8}\ X_9^{0,2}$	55	0,87
Hairiness	ns	11	ns	ns	ns	17	10	ns	$3,9\text{x}10^{-5}\ X_3^{-1,0}\ X_7^{-2,8}\ X_8^{5,5}$	32	0,61
Irregularity	ns	ns	ns	14	ns	5	7	23	$2,7\text{x}10^3\ X_5^{0,8}\ X_7^{-0,4}\ X_8^{-0,9}\ X_9^{-0,2}$	65	0,69
Thin Places	ns	ns	ns	13	ns	5	5	27	$1,1\text{x}10^{36}\ X_5^{15}\ X_7^{-7,3}\ X_8^{-13}\ X_9^{-3,6}$	64	0,72
Thick Places	ns	14	ns	15	ns	13	ns	6	$1,1\text{x}10^{16}\ X_3^{-4,6}\ X_5^{12,1}\ X_7^{-7,5}\ X_{10}^{-1,5}$	64	0,69
Neps	ns	10	14	ns	ns	8	ns	17	$6,4\text{x}10^6\ X_3^{-2,6}\ X_4^{4,9}\ X_7^{-2,8}\ X_9^{-1,5}$	65	0,70

TABLE X

SUMMARY OF THE STATISTICAL ANALYSIS OF THE RESULTS OF THE RING YARNS (FULL-SCALE TRIALS)

Yarn Property (Y)	CONTRIBUTION OF INDEPENDENT VARIABLE TO OBSERVED FIT*(%) ⅛"-Gauge Tenacity (X_2)	Extension (X_3)	Micronaire (X_4)	Maturity (X_5)	Fineness (X_6)	50% Span length (X_7)	Uniformity Ratio (X_8)	Yarn tex (X_9)	Most Significant Regression Equations	Number of yarns (n)	Multiple Correlation coefficient (r)
Single thread tenacity	5	ns	ns	ns	ns	36	16	9	$81,5\ X_2^{0,2}\ X_7^{1,4}\ X_8^{-1,6}\ X_9^{0,1}$	117	0,81
CV of single thread strength	ns	ns	2	ns	ns	ns	ns	45	$17,9\ X_4^{0,2}\ X_9^{-0,3}$	117	0,70
Single thread extension	4	6	6	ns	ns	ns	ns	36	$6,7\ X_2^{-0,1}\ X_4^{-0,3}\ X_9^{0,2}$	131	0,72
CSP	10	3	4	ns	ns	38	4	13	$526\ X_2^{0,3}\ X_3^{0,1}\ X_4^{-0,2}\ X_7^{1,3}\ X_8^{-0,8}\ X_9^{0,1}$	117	0,85
Hairiness	ns	ns	15	ns	19	4	ns	8	$7,9\text{x}10^{21}\ X_4^{8,6}\ X_6^{-10,9}\ X_7^{-2,3}\ X_9^{0,6}$	52	0,68
Irregularity	ns	ns	3	2	ns	10	ns	65	$195\ X_4^{0,3}\ X_5^{-0,4}\ X_7^{-0,7}\ X_9^{-0,4}$	140	0,89
Thin Places	ns	ns	1	ns	ns	9	ns	63	$6,6\text{x}10^{18}\ X_4^{2,7}\ X_7^{-11,0}\ X_9^{-5,2}$	109	0,86
Thick Places	ns	ns	ns	ns	ns	16	ns	58	$2,3\text{x}10^{12}\ X_7^{-6,4}\ X_9^{-2,2}$	112	0,86
Neps	ns	ns	ns	ns	ns	16	2	35	$5,5\text{x}10^3\ X_7^{-5,2}\ X_8^{3,8}\ X_9^{-1,3}$	148	0,72

ns : not significant

* : observed fit = r^2x100

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