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# Analysis of the performance of an improved *G. arboreum* L. cotton under mill conditions

MATISH CHANDRA*, S. SREENIVASAN AND ASHOK K. AKADE
*ICAR-Indian Institute of Soil and Water Conservation, Dehradun - 248 195*
** Email: matishchandra@gmail.com*

**ABSTRACT :** A study was conducted on the processing efficiency and behaviour of improved *G. arboreum* cotton under mill conditions. It was found that the improved *G. arboreum* cotton can be processed successfully on high speed modern textile processing machines. The qualitative analysis of the yarn, fabric and other relevant characters revealed that the improved *arboreum* cotton is a potent and viable alternative to the medium long *G. hirsutum* cotton.

**Key words :** Fibre quality, *G. hirsutum*, improved *G. arboreum*, processing efficiency

*Gossiypium arboreum* cotton cultivars, which are often categorised as those producing short and coarse fibres suitable for production of rough, coarse fabric only and regarded as lower in quality in general, have shown tremendous improvement with regards to the fibre quality parameters (Chandra and Sreenivasan, 2011). Also, under the laboratory conditions, the improved *G. arboreum* cotton strains are reported to performed *at par* with the *G. hirsutum* cotton strains of comparable fibre quality traits, as far as the quality of yarn and fabric is concerned (Chandra and Sreenivasan, 2011). The performance was of utmost significance with regards to the neps, which are universally considered as a major flaw in yarn, at both medium and coarse counts and fabric dye uptake. However, as the processing conditions in a laboratory and that in a commercial textile unit differ significantly, the efficacy, real worth and test of true potential of any cotton to bear the stress and strain of high speed processing can only be adjudged by performing a full scale processing in a commercial textile unit under the operating conditions, generally encountered in the industry. Also the fabric produced cannot be considered to be possessing required quality for the market unless and until the fibres are processed on high speed productive spinning systems and the yarn subjected to modern knitting, weaving machines and chemical finishes. This paper describes an evaluation of the performance of improved *G. arboreum* cotton under mill conditions with respect to the following target areas.

- Use of improved *G. arboreum* cotton for the commercial production of yarn with an average count.
- Commercial production of knitted fabrics and finished garments making use of the above yarns.

The prime objective of the present work is to explore the possibility of using improved *G. arboreum* cotton for the production of textiles, the demand for which, usually, is being fulfilled by *G. hirsutum* cotton.

## MATERIALS AND METHODS

Improved *G. arboreum* cotton (PA 255) and *G. hirsutum* cotton (LRA 5166) were procured from farmers field grown under direct supervision of agricultural scientists, employing recommended agricultural practices. The seed cotton was ginned and converted in to bales. The criterion for selection of the improved *G. arboreum* strain PA 255 was fibre quality and yarn properties (Chandra and Sreenivasan, 2011(a), 2011(b). Two bales each, of both PA 255 and LRA 5166 was processed along with the regular mill run material (*G. hirsutum* cotton mix) of comparable fibre quality traits at M/s. Maral Over Seas Ltd. Maral Sarovar, Agra -Mumbai Road, Dhamnod, Madhya Pradesh, an 100 per cent export oriented unit. Detail of lint samples used and their respective identifiers are given in the Table 1.

**Table 1.** Details of yarn and fabric constructional parameters and their codes

| Cotton | Count | Type of yarn | Wales | Courses | Knitted | Fibre, yarn and fabric sample identifier |
|---|---|---|---|---|---|---|
| PA 255 (Improved *G. arboreum* L) | 30s | Combed | 20 | 13 | Single Jersey | PA |
| LRA 5166 (*G. hirsutum* L) | 30s | Combed | 20 | 12 | Single Jersey | LR |
| Regular mill run material (*G. hirsutum* L) | 30s | Combed | 20 | 13 | Single Jersey | RM |

**Physical quality parameters:** The identified cottons, were processed simultaneously without making any change in the mechanical set up and at each stage of processing (carding, drawing etc), samples were collected and evaluated for fibre properties. Measurements were made with commercially available HVI (High Volume Instrument) and AFIS (Advanced Fibre Information System). The experimentation work was conducted and data was collected at each of the following processing stages as per the set norms of the mill.

- Raw cotton (mixing)
- Carding
- Drawing
- Combing

Also, apart from the regular observations and tests conducted as per the norms followed at textile unit, the material (sliver) was collected along the processing line and subjected to thorough investigations for various fibre parameters (primarily AFIS fibre properties). The results thus obtained are reported and analysed separately.

**Yarn preparation :** All the 3 cottons were processed simultaneously with the same setting of machine parameters for the production of combed yarn of 30s. The details of machines and settings used in the commercial unit and other relevant parameters are outlined in Table 2.

**Fabric preparation :** The fabric samples prepared were of single jersey knitted type as per the constructional details presented in Table 1. The fabrics were prepared on a Fukara [Japan] make circular knitting machine with the specifications dia /gauge/ number of feeder: 21'/ 28'/64' adopting the same fabric variables with common processing parameters. The fabric samples were given various treatments such as scouring, bleaching and dyeing by using standard procedures followed at the commercial unit.

**Evaluation of yarn and fabric quality parameters :** The yarns samples were evaluated for their physical and mechanical characteristics. The comfort properties were evaluated in terms of air permeability, low stress mechanical properties of fabric (grey, bleached and dyed) such as tensile**,** shear, bending, compression and surface properties using standard procedures

**Table 2.** Machine and machine settings used for processing

| Process | Make | Process details |
|---|---|---|
| Blow room | Reiter | The process was accomplished at beater speed 680 rpm and feed roller speed 283 rpm with 3 beating points. |
| Carding | Reiter | The card of 'C 10' and flat top 'PT 52' were used with cylinder speed 450 rpm and lickering speed 1300 on cylinder wires graf 2040 x 0.4. All the settings between cylinder and flat top were placed at 0.2. |
| Breaker draw frame | Reiter | The draw frame (L Do/6) was used with top and bottom roller 3x3 with a sliver feed of 8. |
| Combing | Reiter | Comber (E 7/5A) was used with the number of doubling 8 needles/centimeter 26 and top comber penetration (+). |
| Draw frame | Reiter | Draw frame (RSB 1) with top roller diameter 40 mm and delivery speed 450 m/min. |
| Speed frame | Reiter | The speed frame (LF 1400A) was used with Twist Multiplier 1.31 and break draft of 1.03. |
| Ring frame | Reiter | The ring frame (G5/1) was used with spindle speed of 16800 rpm, traveler type bracker 3/0 and twist multiplier 3.68. |

**Yarn evaluation :** The yarn quality was evaluated by using standard test methods (Sundaram, *et al.,* 2004). The single yarn tensile tests were conducted at lower speed (Instron tensile tester) as well as at higher speed (Tensojet) following standard test procedures [Sundaram, *et al.,* 2004].

**Fabric evaluation**

**Appearance :** The appearance parameters were determined as per the standard methods practiced in the commercial textile unit.

**Low stress mechanical and comfort properties :** The low stress mechanical properties were evaluated using the Kawabata evaluation system (KES-FB) in terms of various parameters. Total Hand Value (THV) was estimated from Primary Hand Values (PHV), *i.e.* koshi (stiffness), numeri (smoothness), fukurami (fullness and softness) and hari (anti drape stiffness) using Kawabata hand evaluation regression equations for application as men's summer and winter wear. Air permeability of the fabrics was measured with the help of prolific air permeability measuring instrument as per ASTM-D737-96.

All the tests were conducted under standard atmospheric conditions of 65 ±2 per cent RH and 27 ±2°C temp.

**Statistical analysis :** The data obtained was statistically analysed using completely randomized design (CRD). Duncan's Multiple Range Test was also applied for individual comparison of mean values among various quality parameters using SPSS 11.5 statistical software programme.

## RESULTS AND DISCUSSION

**Fibre properties (Raw cotton and at intermediate processing stages) :** During the cotton processing there are a few stages, in which fibres are opened, blended and parallelised. At the same time, cleaning and removal of short fibres is an integral part of all the stages. The analysis of the data (Table 3) reveals that with respect to seed coat neps (cnts/g) the values recorded for the improved *arboreum* cotton (PA 255) were markedly low at mixing as well as at other stages of processing. Infact improved *arboreum* cotton (PA 255) cotton recorded zero values for SCN after carding and combing.

**Table 3.** Processing parameters recorded as per the norms followed at the textile unit

| Genotype | PA | LR | RM |
|---|---|---|---|
| **Mixing** | | | |
| 2.5 per cent span length (mm) | 28.16 | 26.94 | 29.50 |
| 50 per cent span length | 13.9 | 12.5 | 14.0 |
| UR (%) | 49 | 46 | 47 |
| Tenacity, g/tex | 21.9 | 22.3 | 21.8 |
| Fineness (MV) | 4.41 | 4.49 | 3.94 |
| Trash (%) | 3.47 | 4.49 | 3.94 |
| SFC | 9.60 | 9.30 | 8.38 |
| Neps | 131 | 121 | 82 |
| SCN | 2 | 10 | 9 |
| **Card** | | | |
| Sliver neps | 63 | 91 | 81 |
| SCN | 0 | 6 | 6 |
| Sliver SFC (%) | 12.06 | 8.60 | 10.31 |
| **Comber** | | | |
| Sliver neps | 18 | 44 | 33 |
| SCN | 0 | 4 | 3 |
| Sliver SFC (%) | 5.30 | 4.00 | 5.72 |
| Noil (%) | 17.53 | 19.11 | 17.10 |

It is quite remarkable, since the presence of seed coat neps is considered as one of the important factors that under value the textile material. With regards to the fibre neps (cnts/g) also the improved *arboreum* cotton (PA 255) recorded markedly lower values in comparison to the *hirsutum* cotton (LRA 5166) and regular mill run material at all the 3 stages of processing. It appears that fibre maturity has a definitive role to play in containing fibre neps during processing.

The noil (%) recorded for improved *arboreum* cotton was found to comparatively low; though the short fibre content (SFC) values recorded for improved *arboreum* cotton were seemingly higher as compared to the *hirsutum* cotton (LRA 5166) and regular mill run material. The higher flat waste recorded for improved *arboreum* cotton (1% higher) seems to be the reason for lower noil (%) even with higher SFC per cent.

**Comparative performance during important stages of processing *:*** Primarily, the

**Table 4.** Summary AFIS results from 3 cottons at various stages of processing

| Parameter | Fibre mean length L(w) (mm) | UQL (w) (mm) | SFC (w) (%) | Fibre mean length L(n) (mm) | SFC (n) (%) | Fineness (mtex) | Maturity ratio (%) | Neps (cnt/g) | SCN (cnt/g) |
|---|---|---|---|---|---|---|---|---|---|
| **Improved *G. arboreum* cotton (PA 255)** | | | | | | | | | |
| Carding | 23.1 | 28.7 | 12.2 | 16.8 | 37.2 | 167 | 0.86 | 51 | 3 |
| Drawing | 24.4 | 29.5 | 9.5 | 18.5 | 30.2 | 170 | 0.92 | 41 | 4 |
| Combing | 24.4 | 29.2 | 6.4 | 20.6 | 18.7 | 172 | 0.93 | 17 | 0.4 |
| CD (p=0.05) | 0.50 | 0.61 | 0.73 | 0.79 | 0.95 | 7.12 | 0.04 | 8.35 | 1.75 |
| Percentage change | +5.6 | +1.7 | -47.5 | +22.6 | -49.7 | +3.0 | +8.1 | -66.7 | -86-7 |
| ***G. hirsutum* cotton (LRA 5166)** | | | | | | | | | |
| Carding | 22.9 | 28.5 | 13.5 | 16.5 | 38.1 | 160 | 0.83 | 71 | 10 |
| Drawing | 23.9 | 29.3 | 10.9 | 18.0 | 31.9 | 159 | 0.85 | 76 | 6 |
| Combing | 25.4 | 30.2 | 5.2 | 21.8 | 14.1 | 162 | 0.88 | 30 | 1 |
| CD (p=0.05) | 0.52 | 1.29 | 0.62 | 0.76 | 1.05 | 8.12 | 0.04 | 7.88 | 4.95 |
| Percentage change | +10.9 | +6.0 | -61.5 | +32.1 | -62.9 | +1.25 | +6.0 | -57.8 | -90.0 |
| **Regular mill run material** | | | | | | | | | |
| Carding | 22.9 | 28.8 | 13.3 | 16.8 | 37.3 | 155 | 0.82 | 76 | 9 |
| Drawing | 23.7 | 29.5 | 12.4 | 17.5 | 35.6 | 157 | 0.85 | 71 | 7 |
| Combing | 25.1 | 30.2 | 7.3 | 20.9 | 19.0 | 159 | 0.87 | 31 | 2 |
| CD (p=0.05) | 0.56 | 0.69 | 0.64 | 0.78 | 1.20 | 9.05 | 0.04 | 8.87 | 2.65 |
| Percentage change | +9.6 | +4.9 | -45.1 | +24.4 | -49.1 | +2.6 | +6.1 | -59.3 | -77.8 |

* Percentage change (%) between carding and combing

**Table 5.** Summary AFIS results from 3 cottons for combed sliver

| Parameter | Fibre mean length L(w) (mm) | UQL (w) (mm) | SFC (w) (%) | Fibre mean length L(n) (mm) | SFC (n) (%) | Fineness (mtex) | Maturity ratio (%) | Neps (cnt/g) | SCN (cnt/g) |
|---|---|---|---|---|---|---|---|---|---|
| PA | 24.4[a] | 29.2[a] | 6.4[b] | 20.6[a] | 18.7[b] | 172[b] | 0.93[b] | 16.8[a] | 0.4[a] |
| LR | 25.4[b] | 30.2[b] | 5.2[a] | 21.8[b] | 14.1[a] | 162[a] | 0.88[a] | 30.2[b] | 1.4[b] |
| RM | 25.1[b] | 30.2[b] | 7.3[c] | 20.9[a] | 19.0[b] | 159[a] | 0.87[a] | 31.0[b] | 2.2[b] |

Mean values followed by different letters within column are significant at 0.05 level of probability (Duncan's Multiple Range Test)

present study was aimed at, to ascertain the suitability of improved *arboreum* cotton for high speed processing. The lint samples (slivers) were collected along the processing line at 3 stages namely carding, drawing and combing were evaluated for fibre quality parameters on AFIS. The data presented in Table 4 clearly indicates that the processing behaviour of improved *arboreum* cotton (PA 255) was found to be quite different in comparison to that of *hirsutum* cotton (LRA 5166) and regular mill run material. The analysis of data presented in Table 4 reveals that, in the case of improved *arboreum* cotton, the changes recorded, in length parameters *viz.,* L(w), L(n) and UQL (w), after successive processing stages were markedly less in comparison to other two cottons. The AFIS results (Table 4) indicated that between carding and combing stages the improved *arboreum* cotton recorded a markedly lower gain in fibre mean length by wt L(w) ( +5.6 % higher) as compared to *hirsutum* cotton (LRA-5166) (+10.9% higher ) and regular mill run material(+9.6% higher). Similarly, with regards to the UQL (w) also, the change (gain) noticed for improved *arboreum* cotton (+1.7% higher) was lower as compared to *hirsutum* cotton (+6.0% higher) and regular mill run material (+4.9% higher).

However the changes (gain) in fibre mean length by number L (n) recorded for improved *arboreum* cotton (+22.6% higher ) were comparable to those recorded for regular mill run material (+24.4% higher ) but found to be markedly lower as compared to *hirsutum* cotton (+32.1% higher). With regards to the impact of processing on SFC(w) and SFC(n) the effective

**Table 6.** Yarn parameters as per the norms followed at the textile unit

| Cotton | PA | LR | RM |
|---|---|---|---|
| **Structural and evenness** | | | |
| Count | 30.0 | 30.0 | 30.0 |
| Actual count | 31.7 (1.46) | 30.0 (0.97) | 30.0 (0.85) |
| Maximum count | 32.2 | 30.5 | 30.5 |
| Minimum count | 30.7 | 29.5 | 29.5 |
| Twist (/inch) | 20.2 | 20.2 | 20.2 |
| **Ring frame cops** | | | |
| U (%) | 10.1 | 9.1 | 9.0 |
| Thin (-50%) | 0 | 0 | 0 |
| Thick (+50%) | 19 | 16 | 15 |
| Neps (+200%) | 26 | 39 | 40 |
| Total imperfections | 45 | 55 | 55 |
| Hairiness index | 5.2 (3.5) | 4.8 (1.5) | 4.9 (6.8) |
| Breaking Strength (g) | 290 (9.4) | 330 (6.0) | 333 (6.8) |
| RKM | 14.7 | 16.7 | 16.9 |
| Elongation | 3.9 (8.2) | 4.5 (7.7) | 4.3 (6.7) |
| **Cones** | | | |
| U (%) | 10.6 | 9.7 | 9.1 |
| Thin (-50%) | 1 | 0 | 0 |
| Thick (+50%) | 26 | 25 | 16 |
| Neps (+200%) | 60 | 66 | 56 |
| Total imperfections | 87 | 91 | 72 |
| Breaking Strength (g) | 275 (9.8) | 290 (9.0) | 324 (7.5) |
| RKM | 13.8 | 14.5 | 16.5 |
| Elongation | 3.5 (9.9) | 3.8 (9.7) | 4.2 (9.0) |

Figures in parenthesis are CV values,

changes recorded for improved *arboreum* cotton (– 47.5% and –49.7% lower, respectively) and regular mill run material (–45.1% and –49.1% lower, respectively) were comparable, however the values recorded for *hirsutum* cotton (– 62.9% and – 61.5% lower respectively) were found to be noticeably higher.

The analysis of data (Table 4) clearly indicates that between carding and combing processing stages the percentage increase in fineness (m.tex) and maturity (measured in terms of maturity ratio) recorded for improved *arboreum* cotton was highest (+ 3% and +8% higher, respectively). Thus indicating that, during processing, improved *arboreum* cotton has greater tendency to drift towards resulting in coarser and stiffer fibres (high maturity). The changes recorded for SCN (cnt/g) and Neps (cnt/g) were comparable among the three cottons.

**Comparative status of fibre quality parameters after combing operation :** The analysis of the data presented in Table 5 indicates that in general the fibre quality parameters recorded for improved *arboreum* cotton (PA 255) after combing are significantly different from *hirsutum* cotton (LRA 5166) and the regular mill run material. The improved *arboreum* cotton (PA 255) material (sliver) obtained after combing was found to be short in length, coarse in fineness and high in maturity (leading to stiffness). These 2 parameters *i.e.* length and fineness, in association with maturity, play significant role in deciding mechanical properties of yarn.

**Yarn properties:**

**Structural and unevenness properties :** The geometrical properties of the yarns are presented in the Table 6**.** It is evident that, though the count CV (%) values are within the USTER specified limits, the improved *arboreum* cotton recorded highest CV (%) (1.46), and also the difference between lowest and highest values of yarn counts was noticeably high. The setting of machine seems to have played an important role in these variations in yarn count as raw material properties (fibre) for the 3 cottons were found to be comparable. The yarn evenness in terms of U(%) and imperfections in terms of thin places, thick places and neps are shown in the Table 6. The results reveal that the yarn produced from improved *arboreum* cotton (PA 255) performed noticeably well in comparison to the *hirsutum* cotton (LRA 255) and regular mill run material. The presence of imperfections in the yarn leads to localization of stress, whereby the rupture process gets initiated.

From the data presented in Table 6 it is

**Table 7.** Comparison with USTER statistics for 30s combed yarn

| Yarn characteristics | USTER values for 30s combed yarn | PA | LR | RM |
|---|---|---|---|---|
| Average count | 30s (29.6-30.4) | 31.7 | 30.0 | 30.0 |
| Count,CV (%) | < 1.5 | 1.5 | 1.0 | 0.9 |
| Twist multiplier | 3.5 to 3.6 | 3.7 | 3.7 | 3.7 |
| U (%) | 9.2 to 9.8 | 10.1 | 9.1 | 9.0 |
| -50 per cent thin place/1000 m | <4 | 0 | 0 | 0 |
| +50 per cent thick place /1000 m | <30 | 19 | 16 | 15 |
| +200 Neps/1000meter | <50 | 26 | 39 | 40 |
| Total imperfections /1000 m | <85 | 45 | 55 | 55 |
| RKM (tenacity), g/tex | > 16.5 | 14.7 | 16.7 | 16.9 |
| RKM, CV (%) | <7.5 (%) | 9.4 | 5.9 | 6.8 |
| Elongation (%) | > 5.5 | 3.9 | 4.5 | 4.3 |
| Hairiness 'H' | 4.0 to 4.5 | 5.2 | 4.8 | 4.9 |

evident that the improved *arboreum* cotton (PA 255) performed better than the *hirsutum* cotton (LRA 5166) and the regular mill run material as the values for number of thick (+50%) and thin (-50%) places recorded were lowest. The distribution of thick and thin places in a yarn encourages the probability of encountering lower strength. The irregularity and imperfections observed in yarn are influenced by the raw material parameters along with the setting of the processing machine. Despite the fact that the machine setting was not optimum for the improved *arboreum* cotton, as reflected by the actual count obtained (Table 6), the performance with respect to yarn irregularity was commendable. The neps values obtained for improved arboreum were the lowest and this may be due to higher maturity exhibited by the improved *arboreum* cotton, since apart from external mechanical reasons maturity plays a significant role in determining the occurrence of neps. Also the hairiness values recorded for the improved *arboreum* cotton were found to be on the higher side as compared to hose obtained for *hirsutum* cotton (LRA 5166) and the regular mill material. The improved *arboreum* cotton (PA 255) recorded lower values for breaking strength; RKM and elongation as compared to the *hirsutum* cotton (LRA 5166) and the regular mill run material at ring frame cops stage as well as at cone stage.

Improved *arboreum* cotton (PA 255) recorded comparatively lower values for U(%) and other imperfections. The presence of highly mature fibre in improved *arboreum* cotton helps in reducing neps and other deformities in fibres that arises during post harvest processing such as ginning. It appears that the higher uniformity ratio and low fibre neps not only compensate for coarseness of fibre (higher micronaire value) but also improve yarn evenness and other imperfection parameters.

From the data presented in Table 7 it is evident that the improved *arboreum* cotton (PA 255) accommodates itself perfectly within the USTER standards barring RKM, elongation and hairiness values. The values recorded for RKM and elongation are slightly lower than the USTER standard. The possible reason may be the higher micronaire and maturity value recorded for improved *arboreum* cotton (PA 255) as compared to the other 2 cottons processed.

**Table 8.** Single yarn physico mechanical properties

| Cotton | PA | LR | RM |
|---|---|---|---|
| **Low speed (Instron)** | | | |
| Breaking load (gf) | 170 | 210 | 220 |
| | (14) | (17) | (10) |
| Elongation (%) | 4.2 | 4.5 | 4.4 |
| | (10) | (14) | (9) |
| Energy to break(gf-mm) | 2000 | 2800 | 2700 |
| | (20) | (27) | (16) |
| Modulus (g/den) | 57221 | 76882 | 76786 |
| Tenacity (g/tex) | 9.3 | 11.2 | 11.4 |
| **High speed (Tensojet)** | | | |
| Elongation (%) | 3.9 | 4.5 | 4.3 |
| | (8.2) | (7.6) | (6.7) |
| Tenacity (g/tex) | 14.7 | 16.7 | 16.9 |
| | (9.4) | (6.0) | (4.3) |

Figures in parenthesis are CV values

**Table 9.** Fabric appearance parameters as per the norms followed at the textile unit

| Fabric appearance parameters | Fabric | | |
|---|---|---|---|
| | PA | LR | RM |
| Weight of roll (kg) | 38.6 | 20.3 | 20.1 |
| **Extremely serious faults** | | | |
| Long thick | 3.6 | 2.0 | 1.8 |
| Long thin | 2.1 | 2.9 | 2.3 |
| **Total** | **5.7** | **4.9** | **4.1** |
| **Serious faults** | | | |
| Short thick | 15.5 | 26.6 | 18.2 |
| Short thin | 5.2 | 3.9 | 2.2 |
| **Total** | **20.7** | **30.5** | **20.4** |
| Other parameters | | | |
| Grey contamination (kg) | 4.1 | 4.6 | 4.7 |
| Dead fibre neps/100 $cm^2$ | 1.0 | 1.2 | 2.4 |
| Spirality | 1.4 | 1.6 | 1.3 |
| Dye pick up | 15 (%) | Normal | Normal |
| Pilling grade | higher | | |
| Face | 3 | 3 | 3 |
| Back | 3 | 3 | 3 |

**Physico mechanical properties (Single yarn strand tensile properties) :** The breaking strength of yarn is usually taken as the index of yarn quality, although this parameter alone does not entirely represent the performance of the material during actual use or further processing. Other factors such as extensibility, elastic modulli are also important depending on the end use of the yarn. The decisive factors that control the behaviour of yarn in post spinning processes are the frequency of seldom occurring, extremely weak places that do not have a normal distribution. The properties of yarns in terms of tenacity, extension at break and modulus are shown in the Table 8. The data presented clearly reveals that at lower speed [Instron tensile tester], the tenacity, breaking load, elongation, energy to break and modulus values recorded for *hirsutum* cotton (LRA 5166) and regular mill run material were higher than the values obtained for the yarn produced from improved *arboreum* cotton (PA 255). Similarly, at higher speed [Tensojet] also, *hirsutum* cotton (LRA 5166) and regular mill run material recorded higher values for yarn elongation and tenacity as compared to the improved *arboreum* cotton (PA 255). The combination of lower fibre mean length, higher fineness and maturity values recorded for improved *arboreum* cotton (PA 255) seems to have resulted in markedly lower values for these important mechanical parameters as compared to *hirsutum* cotton (LRA 5166) and the regular mill run material. On similar lines, the improved *arboreum* cotton (PA 255) recorded noticeably lower values for the energy to break (gf-mm) and modulus (g/den) in comparison to the *hirsutum* cotton (LRA 5166) and the regular mill run material. Yarn mechanical properties in general are largely determined by the fibre fineness, fibre length and fibre strength. As evident from the data presented in Table 4, a noticeable change in fibre fineness (fmtex) was observed, after combing operation and the change was more prominently visible for improved *arboreum* cotton

**Table 10.** Low stress mechanical properties

| Fabric | Grey | | | Bleached | | | Finished | | |
|---|---|---|---|---|---|---|---|---|---|
| | PA | LR | RM | PA | LR | RM | PA | LR | RM |
| **Tensile properties** | | | | | | | | | |
| EMT (%) | 21.13 | 31.50 | 26.42 | 26.42 | 30.55 | 35.23 | 40.63 | 42.80 | 35.23 |
| LT | 0.752 | 0.713 | 0.718 | 0.762 | 0.789 | 0.801 | 0.713 | 0.839 | 0.796 |
| WT, gf.cm/cm$^2$ | 29.2 | 27.5 | 23.9 | 33.2 | 30.2 | 35.1 | 36.7 | 45.3 | 34.9 |
| RT (%) | 22.4 | 23.8 | 21.9 | 14.8 | 16.5 | 20.7 | 18.9 | 15.0 | 20.4 |
| **Shear properties** | | | | | | | | | |
| G , gf./cm.deg | 0.550 | 0.590 | 0.630 | 0.730 | 0.940 | 0.785 | 0.700 | 0.805 | 0.820 |
| 2HG, gf.cm | 1.78 | 1.64 | 2.15 | 3.11 | 4.82 | 3.56 | 2.76 | 3.89 | 3.99 |
| 2HG5, gf.cm | 1.64 | 1.60 | 2.07 | 3.14 | 4.80 | 3.61 | 2.79 | 3.87 | 4.00 |
| **Bending properties** | | | | | | | | | |
| B, gf.cm$^2$/cm | 0.0184 | 0.0197 | 0.0227 | 0.0172 | 0.0188 | 0.0193 | 0.0177 | 0.0203 | 0.0232 |
| 2HB, gf.cm/cm | 0.02 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 |
| **Construction and compression properties** | | | | | | | | | |
| LC | 0.305 | 0.303 | 0.326 | 0.313 | 0.326 | 0.352 | 0.436 | 0.371 | 0.384 |
| WC, gf.cm/cm$^2$ | 0.435 | 0.400 | 0.392 | 0.436 | 0.371 | 0.384 | 0.464 | 0.416 | 0.356 |
| RC (%) | 47.99 | 47.00 | 47.20 | 42.14 | 39.17 | 44.17 | 42.92 | 44.85 | 44.84 |
| T, mm | 1.050 | 0.984 | 0.973 | 1.050 | 0.977 | 0.966 | 1.063 | 1.008 | 0.960 |
| W, mg/cm$^2$ | 4.547 | 4.576 | 5.000 | 5.097 | 6.006 | 6.305 | 5.682 | 6.495 | 6.418 |
| **Surface properties** | | | | | | | | | |
| MIU | 0.198 | 0.214 | 0.216 | 0.215 | 0.217 | 0.216 | 0.222 | 0.220 | 0.220 |
| MMD | 0.011 | 0.013 | 0.015 | 0.011 | 0.015 | 0.016 | 0.011 | 0.016 | 0.017 |
| SMD, ëm | 5.4 | 8.0 | 9.0 | 3.2 | 2.9 | 2.9 | 3.0 | 3.6 | 3.6 |

(PA 255). This marked change in fibre fineness seems to have played a significant role in improved arboreum cotton (PA 255) recording low values for yarn tenacity.

**Fabric properties:**

**Fabric appearance :** The scrutiny of the fabric appearance parameters presented in the Table 9 reveals that the fabric obtained from improved *arboreum* cotton (PA 255) performed extremely well with respect to the appearance of extremely serious and serious faults in the fabric. Extremely serious faults were found to be lowest in improved *arboreum* cotton fabric as compared to the *hirsutum* and regular run material in the mill.

On the similar lines the serious faults were *at par* with those found in regular mill material. With respect to grey contaminations, dead fibre neps the values recorded for improved *arboreum* cotton (PA 255) fabric were lowest. Amongst all the 3 fabric test samples evaluated for dye pick up, the dye uptake was fifteen per cent higher for improved *arboreum* cotton (PA 255) fabric as compared to *hirsutum* and regular mill run material.

**Fabric low stress mechanical properties :** With regards to fabric quality requirements in modern times, comfort is one of the most important aspects of clothing. Evaluation of low stress mechanical properties and computation of handle there from has become an essential part of objective evaluation of fabric quality with regard to their use as garment. The low stress mechanical properties, of the fabric produced (grey, bleached and dyed fabric) were evaluated by employing the Kawabata Evaluation System (KES).

**Tensile properties :** The tensile properties determined in terms of EMT, LT, WT and RT are summarized in Table 10. The *hirsutum* cotton (LRA 5166) fabric showed higher extensibility and tensile energy than the improved *arboreum* cotton (PA 255) fabric. In respect of resilience behaviour of fabric, fabric from improved *arboreum* cotton recorded higher tensile resilience (RT) than *hirsutum* cotton fabric. The grey fabric produced from improved *arboreum* cotton recorded higher tensile energy (WT) and linearity (LT) values. This suggests that the grey fabric obtained from improved *arboreum* cotton is more rigid. The extensibility values recorded for the grey fabric produced from improved *arboreum* cotton were found to be on lower side as compared to that obtained from *hirsutum* cotton and regular mill run material. This may be attributed to the lower elongation percent recorded by raw fibres and yarn produced from improved *arboreum* cotton. With respect to bleached fabric, improved *arboreum* cotton (PA 255) fabric, again, recorded lower values for extensibility, linearity and resilience. However the value obtained for tensile energy was higher than *hirsutum* cotton (LRA 5166) fabric but lower than the regular mill run material. The performance of dyed fabric produced from improved *arboreum* cotton was found to be *at par* with the fabrics obtained from *hirsutum* cotton and regular mill run material.

**Bending properties :** Although, fabric bending properties are usually considered to be the function of the bending properties of its constituent yarns, the fibre fineness, yarn twist and structures of yarn and fabric also are known to influence the bending behaviour of fabric. The analysis of data (Table 10) indicated that in the case of finished fabric, bending rigidity and hysteresis values obtained for the improved *arboreum* cotton (PA 255) fabric were *at par* with the values obtained for the fabric produced from *hirsutum* (LRA 5166) cotton. Interestingly in the case of grey fabric, improved *arboreum* cotton fabric recorded higher values for bending rigidity. The bending rigidity obtained for grey, bleached and dyed fabric, clearly showed that the lowest values for bending rigidity were recorded for improved *arboreum* cotton (PA 255) fabric. These values, although numerically low, do not appear to be statistically different from those obtained for *hirsutum* cotton fabric. The data obtained for bending hysteresis also showed similar trends as the improved *arboreum* cotton fabric recorded lowest value. Thus underlining the fact that the fabric produced from improved *arboreum* cotton is supple *i.e.* less stiff (firm) but comparable to the fabric produced from *hirsutum* cotton (LRA 5166).

**Shear properties:** Shear parameters are of utmost importance during the process of garment manufacturing in order to allow the fabric to conform to the intended garment shape. It is evident from the results (Table 10) that the finished fabric produced from *hirsutum* cotton (LRA 5166) recorded numerically higher values for shear parameters. However, improved *arboreum* cotton (PA 255) fabric (grey and bleached), recorded markedly high shear stiffness, hysteresis, both at $0.5^0$ and $5^0$ shear angle. The shear rigidity for the fabric (grey, bleached and finished) obtained from improved *arboreum* cotton was found to be the lowest, this may be attributed to the lower values of young's modulus for yarn and fabric bending rigidity recorded by both yarn and fabric produced from improved *arboreum* cotton. The lower values of shear rigidity/ stiffness for improved *arboreum* cotton fabric imply less resistance to the shearing movement, resulting into softer fabric with better drape. The shear hysteresis for improved *arboreum* cotton fabric at $0.5^0$ and $5^0$ also recorded lower values except for grey fabric, which were higher than those obtained for the fabric produced from *hirsutum* cotton.

**Fabric surface properties:** The surface characteristics of a fabric influence its handle, comfort and aesthetic properties and usually reported in terms coefficient of friction (MIU), mean deviation of coefficient of friction (MMD), and surface smoothness (SMD). In general the values recorded for various surface parameters (Table 10) are on lower side in case of improved *arboreum* cotton fabric as compared to those recorded for *hirsutum* cotton fabric. Lower MIU and SMD values for the improved *arboreum* cotton (PA 255) fabric indicated that it has a fairly fault free smooth surface which is preserved even after finishing.

**Fabric compressional properties** : Fabric compression is considered as one of the most important factors while assessing fabric mechanical properties and it reflects the cumulative effect of the fabric structure as well

**Table 11.** Fabric hand and air permeability

| Type of fabric | | Primary handle value | | | THV | Air permeability |
|---|---|---|---|---|---|---|
| | | KOSHI | NUMERI | FUKURAMI | | ($m^3/m^2$/min |
| Grey | PA | * | 6.36 | 3.94 | * | 216 |
| | LR | * | 5.82 | 3.40 | * | 222 |
| | RM | 0.19 | 4.80 | 3.72 | 0.83 | 196 |
| Bleached | PA | * | 6.70 | 3.80 | 0.67 | —- |
| | LR | * | 6.44 | 3.81 | 1.33 | —- |
| | RM | * | 7.16 | 3.94 | 1.51 | —- |
| Finished | PA | * | 7.44 | 4.21 | 0.81 | 65 |
| | LR | * | 6.09 | 4.32 | 1.05 | 67 |
| | RM | * | 6.15 | 4.45 | 1.20 | 66 |

'*' below scale

as the constituent fibres and yarn surface properties. The analysis of data (Table 10) indicated that the compressional energy and linearity of *hirsutum* cotton (LRA 5166) fabric were higher than PA 255 cotton fabric. However the values recorded for compressional resilience (RC) were higher than the corresponding values recorded for the improved *arboreum* cotton (PA 255) fabric, thus suggesting a higher level of recovery from being compressed and thereby a more elastic fabric as for as this deformation is concerned. Usually compressional resilience is believed to have a direct bearing on the fabric aerial density.

**Air permeability:** The air permeability values, in terms of rate of flow of air ($m^3/s/m^2$), obtained for grey and finished fabrics are presented in Table 11. From the data in the table, it is evident that for the grey fabrics the fabric produced from *hirsutum* (LRA 5166) cotton recorded highest value followed by the fabric produced from improved *arboreum* cotton (PA 255). With regards to the grey fabric produced from regular mill run material, the air permeability was lowest at 196 $m^3/s/m^2$. However, with respect to the finished fabrics the values recorded for the fabric produced from improved *arboreum* cotton (PA 255) were comparable to those obtained for other 2 categories used in the investigation.

**Garment :** As per the mandate of the commercial unit [EOU (export oriented unit)] the defined garment range (knitted garments, which includes, T shirts, sportswear and other hosiery items) was produced and marketed with no discrimination on account of cotton species. The mill was successful in marketing the cotton textile goods (yarn and garment) prepared from the improved *arboreum* cotton along with those prepared from conventional *hirsutum* cotton and regular material being run in the unit.

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