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Evaluating the performance attributes of single jersey conventional and organic cotton

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Abstract
The performance attributes of knitted T-shirts made from conventional cotton and organic cotton yarns were tested. Physical and mechanical tests like abrasion resistance, bursting strength, pilling resistance, dimensional stability and elasticity tests were carried out on the two samples and comparisons made. For testing abrasion resistance ISO 12947-2:1998 test was employed. Bursting strength was tested using ASTM- D 3786 / D 3786 M-13, which is a diaphragm bursting strength test. ISO 12945-2:2000 test was applied for calculating resistance to pilling. To find out the dimensional stability of the two T-shirts, shrinkage /growth and spirality of the garments were tested by making marks before and after laundering. The elasticity was tested using BS 4294:1968 test and the results of all tests were statistically analyzed. The results revealed that conventional cotton had better mechanical properties like abrasion resistance and bursting strength than conventionally grown cotton. While comparing physical properties, there was no significant difference found in resistance to pilling up to 2000 cycles. The tests conducted for comparing dimensional stability indicated that organic cotton is more stable in lengthwise direction but tends to elongate in width wise direction. The spirality tests revealed that convention cotton has less spirality than organic. The extension and recovery tests for testing elasticity revealed that organic samples were more elastic than conventional cotton samples.

Keywords: Physical and Mechanical properties, Single Jersey, Resistance to Abrasion, Bursting Strength, Resistance to Pilling, Dimensional stability

Introduction
Cotton is the most popular natural fiber in the knitting industry. It can be used in any kind of machine and can be used for all kinds of knitted goods [1]. It is known for its qualities like good strength, heat conductivity, and high resistance to degradation by heat. It is also characterized by excellent properties like absorbency, comfort, drape, high wet strength, softness and water retaining capacity and non-allergic properties [2]. Conventional cotton is the cotton grown using conventional agricultural methods utilizing agrochemicals and water. Approximately 25 million tons of conventional cotton is produced every year which takes 29,000 litres of water per kg. Conventionally grown cotton uses 25% of the world's insecticides and more than 10% of all pesticides while the cultivation of cotton accounts for only 2.4% of agriculturally used areas [3]. Organic cotton is the cotton grown without the use of any synthetic chemicals i.e., pesticides, plant growth regulators, defoliants and fertilizers. Organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil's biological activity. It is based on minimal use of off-farm inputs and on management practices that restores, maintains and enhances ecological harmony [4].
The durability and serviceability of a fabric are mainly judged by its mechanical, physical and aesthetic parameters, and the services it has to cater for, with a progressive decrease in overall quality during wear. The strength parameters are the key deciding factors in ensuring the durability and serviceability of the final product [5]. The tensile properties of textile materials comprises of their resistance to stretching or pulling forces. The amount of force required to break a textile material and the amount it extends before breaking is used to calculate the tensile strength of a fabric. Abrasion is the mechanical deterioration of fabric components by rubbing against another surface. It ultimately results in the loss of performance characteristics of a fabric by reducing its strength. Pilling is a fabric surface fault characterized by little balls or "pills" of entangled fibres clinging to the fabric surface.

It is caused due to friction experienced by garments during wear and care over the time. The dimensional stability refers to shrinkage and growth of fabrics after it has gone through recommended care procedure.

The present study tested selected performance attributes of knitted T-shirts made from conventional and organic cotton yarns. Conventional and organic cotton yarns were weft knitted to produce single jersey fabric, and later stitched into a T-shirt. Both the T-shirts were made of the same size, colour, weight, count and construction. The T-shirts were later subjected to objective evaluation for its physical and mechanical properties and the results were statistically analysed.

Objectives

The following are the objectives of the study to

- Selection and optimization of conventional cotton and organic cotton yarn, knitting technique and T-shirt production
- To evaluate the physical and mechanical properties of conventional and organic cotton T-shirts.
- Consolidation and statistical analysis.

Methodology

Fabric was knitted using conventional and organic cotton yarn. A plain knit structure, also called single jersey, was produced using 30^S combed yarns of both cotton varieties on a circular weft knitting machine (Model- Mayer and Cie). The following machine settings were selected for the formation of fabric from yarn: gauge- 24, cylinder diameter-30", speed- 30 rpm, feeders- 90, number of needles- 2256 and needle size- 7 mm. Both fabrics were produced having a medium loop length of- 2.8mm. Constant machine and room settings with relative humidity of the knitting room at 65 $\pm$ 2% and temperature 30$\pm$2^{o}C was kept. After the fabric was produced, simple round neck T-shirts, half sleeves were cut and stitched, size- large (chest 40"). The T-shirts were then tested and compared for their physical and mechanical properties which included abrasion resistance, bursting strength, resistance to pilling, dimensional stability, spirality and elasticity. The results of the various laboratory tests performed on conventional and organic cotton T-shirt samples were statistically analyzed by using T-test wherever necessary.

Evaluation of mechanical properties

The mechanical property test includes abrasion resistance and bursting strength tests.

I. Abrasion Resistance

ISO 12947-2:1998 test was employed in this study to test resistance to abrasion. The instrument used for the test was Martindale Abrasion Tester. Circular samples of 38mm diameter cloth were cut and fixed on the circular specimen holders. A modified specimen holder, with a flattened rubber ball to stretch the knitted fabric was used for the test. A force of 9 kPa was applied on top of the specimen to hold it against the abradant. The brass plate was then subjected to multidirectional motion. The abradant paper was fastened to each of the four tables beneath, such that the fabric mounted on the specimen holder rub uniformly against the abradant surfaces. Resistance to abrasion was established by testing hole formation and weight loss in percentage. The end point was determined by loss in weight of the sample. The abrasion test was carried out for both conventional and organic cotton T-shirt fabrics. This test was carried out 5 times and the readings were noted, tabulated, and the mean was calculated from the results.

II. Bursting Strength

For the present study ASTM- D 3786/ D 3786 M-13 which is the standard test method for calculating bursting strength of textile fabrics with diaphragm bursting strength tester method was used. Eureka hydraulic bursting strength tester was used for the study. The instrument consists of a device for holding a rubber diaphragm and a ring clamp mechanism for holding the sample. The internal diameter of the clamp ring was 31$\pm$ 0.75 mm in diameter. The liquid used in the compressing medium was glycerine. The pressure in the liquid was increased by means of screwdriver piston. The specimens were clamped over a rubber diaphragm and hydraulic pressure was applied until the specimen ruptures. At the point where the fabric ruptures, the pressure is indicated in Kg/cm^2 by the pressure gauge. The difference between the total pressure required to rupture the specimen and the pressure required to inflate the diaphragm is reported as the bursting strength. The readings were noted for 5 samples each for conventional and organic cotton and the means calculated.

Evaluation of physical properties

The physical property test includes tests for resistance to pilling, shrinkage, spirality and extension and recovery.

III. Resistance to Pilling

For the present study ISO 12945-2:2000 method was used, to calculate the resistance to pilling for both conventional and organic cotton T-shirt samples. The specimens cut from the T-shirt samples were mounted on the large bottom and small top specimen holder and then rubbed against each other. A 2.5 cN/cm pressure is used for knitted fabrics. In the place of standard abradant, the fabric sample was placed on the lower holder. The machine was rotated for 125 cycles, 500 cycles, 1000 cycles and 2000 cycles and the fabric on the upper holder was accessed at the end of each set of cycle. The specimen's resistance to pilling was accessed according to the following grading scheme:

- **Grade 5:** No change
- **Grade 4:** Slight surface fuzzing and/or partially formed pilling
- **Grade 3:** Moderate surface fuzzing and/or moderate pilling. Pills of varying size and density partially covering the specimen surface.
- **Grade 2:** Distinct surface fuzzing and/or distinct pilling. Pills of varying size and density covering a large proportion of the specimen surface.
- **Grade 1:** Dense surface fuzzing and/or severe pilling. Pills of varying size and density covering the whole of the specimen surface.

IV. Shrinkage

For the present study, the T-shirts were tested for shrinkage/growth in length and width. Specimens were conditioned according to ASTM Standard D 1776 before each measurement. Each specimen was conditioned at 21$\pm$1 ^{o}C and 65$\pm$2% RH, 4 hours prior to the test. Benchmarks were drawn with indelible ink, 25 cm apart at a distance of 3 cm from the edge, in both length and width direction. The marked samples were then given a dynamic wash at 40 ^{o}C using a standard detergent and tumble dried. The marks were re-measured and shrinkage was calculated by:

$$\% \text{ Shrinkage} = \frac{100\ (B - A)}{A}$$

Where, A= original length/ breadth and B= length/ breadth after treatment Length and width changes were calculated separately for 5 garments each of conventional and organic cotton. A mean was calculated from the readings for both the samples respectively. Growth was reported as a positive percentage, while shrinkage was reported as a negative number.

V. Spirality

For the present study the spirality test was conducted on both conventional and organic cotton T-shirt. The samples were conditioned for the test according to ASTM Practice D 1776 Standard Practice for conditioning and textile testing. Each specimen was conditioned at 21±1 ºC and 65±2% RH, for 4 hours prior to the test. To measure the angle of spirality in the specimen, 5 different places were chosen for each sample where the wale was marked with indelible ink, and later course linked wale was marked, like an inverted T, before laundering the garment. The marked samples were then given a dynamic wash at 40 ºC using a standard detergent and tumble dried. By using a protractor, the angle different from the normal of the wale was then measured and percentage difference calculated. 5 readings were taken and a mean calculated.

VI. Extension and recovery

For the present study 5 samples each of conventional and organic cotton were tested as per BS 4294:1968 method (withdrawn) and the load applied was 3 Kg. The fabric samples were cut with the template provided in the extensometer and were fixed to the sample support platform in the movable jaw and tightened from both sides. While mounting and tightening, it was ensured that the needle of the movable jaw coincides with the '0' of the elongation scale when using the sample size of 3" X 3.5" for knitted garments. The hook and the cord were attached to the movable guide through a roller. 3 Kg weights were suspended to apply force at the hook provided at the other end of the cord.

With the handle provided on the screw rod, the force was released, the movable jaw moved as the fabric extended. The fabric was extended for a period for 1 minute and then relaxed. The extension and recovery percentages were calculated separately by taking mean of 5 readings respectively.

Results and discussions

The results and discussions for evaluating the mechanical and physical properties of Single Jersey Conventional and Organic Cotton T-shirts are given below.

I. Abrasion Resistance: Resistance to abrasion for the samples was tested by examining hole formation and weight loss in percentage of the two T-shirt samples.

- **Hole formation:** The following Figure A indicate hole formation of the two T-shirt samples.

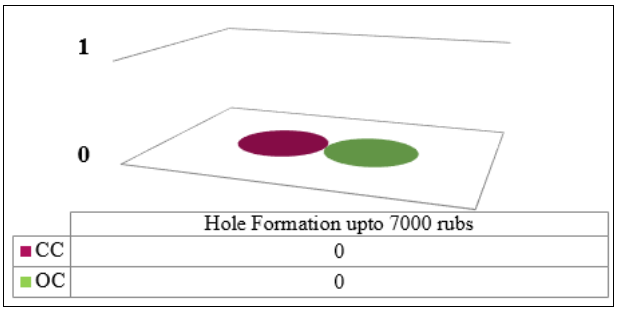

Fig A: Resistance to Abrasion- Hole Formation
*CC= Conventional Cotton; OC= Organic Cotton

Figure A showed hole formation in CC and OC T-shirt samples. It was observed that there was no hole formation upto 7000 rubs for both the CC and OC. According to the T-value of the two samples compared, there was no significant difference in hole formation for CC and OC samples.

- **Weight loss in percentage:** The following Table 1 and Figure B indicate weight loss in percentage of the two T-shirt samples.

Table 1: Weight Loss

Variable	100% CC	100% OC	T value
Weight Loss	4.47±0.12	6.55±0.05	22.627**

Values are mean ± SD of five samples in each group
** - Significant at 1% level

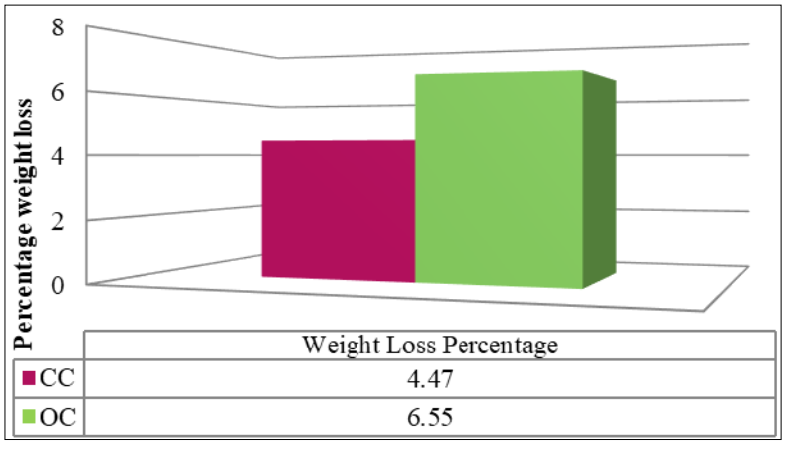

Fig B: Resistance to Abrasion-Weight Loss in Percentage.
*CC= Conventional Cotton; OC= Organic Cotton

Table 1 and Figure B showed the weight loss in percentage for CC and OC samples. It was observed that weight loss in percentage for CC was low as compared to that of OC. The percentage loss in weight for CC was 4.47% whereas that for

OC was 6.55%. According to the T-value of the two samples compared, there was a significant difference in weight loss percentage of CC and OC samples.

II. Bursting strength: The following Table 2 and Figure C indicate bursting strength of the two T-shirt samples.

Table 2: Bursting Strength

Variable	100% CC	100% OC	T value
Bursting Strength	5.26±0.13	4.29±0.12	-7.844**

Values are mean ± SD of five samples in each group
** - Significant at 1% level

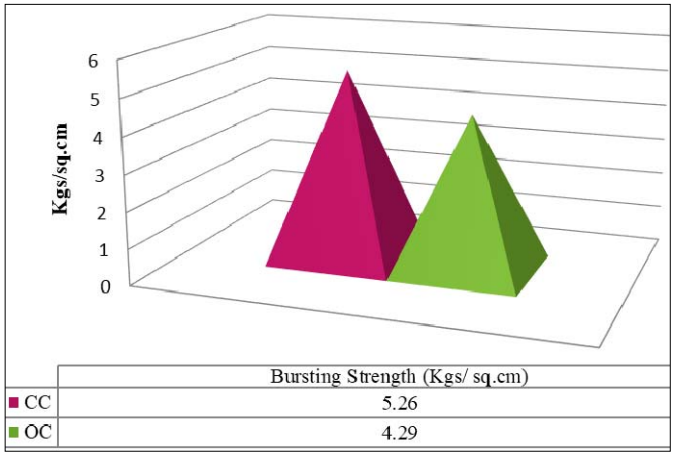

Fig C: Bursting Strength (Kgs/sq.cm.)
*CC= Conventional Cotton; OC= Organic Cotton

Table 2 and Figure C showed the bursting strength of CC and OC samples. It was observed that the bursting strength of CC was more when compared to the bursting strength of OC. The bursting strength of CC was 5.26 Kg/sq.cm whereas that of OC was 4.29 Kg/sq.cm. According to the T-value of the two samples compared, there was a significant difference in the bursting strength of CC and OC samples.

III. Resistance to pilling: The following Table 3 and Figure D indicate resistance to pilling of the two T-shirt samples.

Table 3: Resistance to Pilling

Variable	100% CC	100% OC	T value
125 Cycles	3	3	ns
500 Cycles	3	3	ns
1000 Cycles	2	2	ns
2000 Cycles	1	1	ns

Values are mean ± SD of five samples in each group
ns – Not Significant

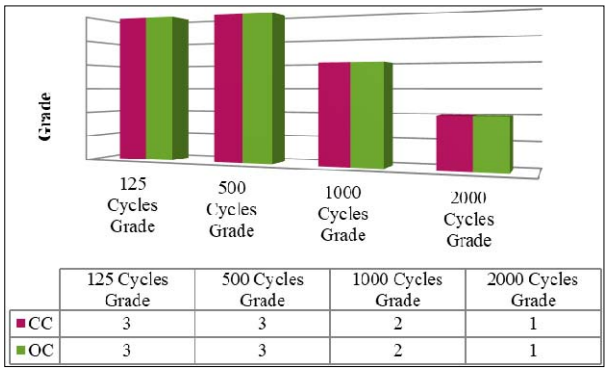

Fig D: Resistance to Pilling
*CC= Conventional Cotton; OC= Organic Cotton

Table 3 and Figure D showed the resistance to pilling for CC and OC samples. It was observed from the test that both CC and OC showed same grades for resistance to pilling after 125 cycles, 500 cycles, 100 cycles and 2000 cycles. CC and OC both showed Grade 3 resistance to pilling after 125 and 500 cycles. Resistance to pilling decreased to Grade 2 for both the samples after 1000 cycles. Further, Grade 1 was observed for both CC and OC samples after 2000 cycles. According to the T-value of the two samples compared, there was no significant difference in resistance to pilling of CC and OC samples.

IV. Shrinkage: The following Table 4 and Figure E indicate the shrinkage percentage of the two T-shirt samples.

Table 4: Shrinkage

Variable	100% CC	100% OC	T value
Lengthwise Shrinkage	2.56±0.23	1.52±0.15	-5.356**
Width wise Shrinkage	2.8±0.03	1.36±0.09	-22.66**

Values are mean ± SD of five samples in each group
** - Significant at 1% level

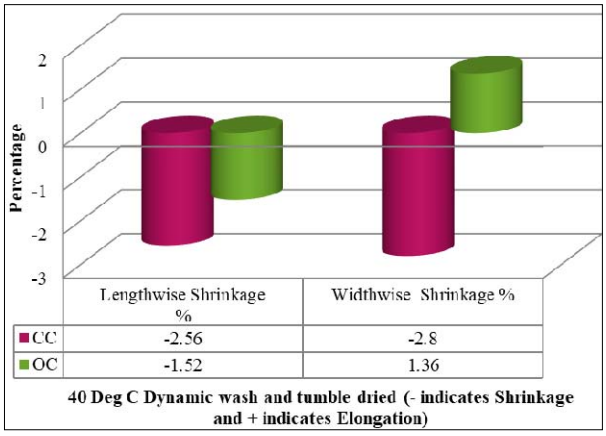

Fig E: Shrinkage in Percentage
*CC= Conventional Cotton; OC= Organic Cotton

Table 4 and Figure E showed the percentage shrinkage in length wise and width wise direction of CC and OC samples. After wash, the CC samples showed shrinkage of 2.56% and OC showed shrinkage of 1.52% in the length direction. In the width wise direction CC showed shrinkage of 2.8% whereas OC showed an extension of 1.36%. According to the T-value of the two samples compared, there was a significant difference in shrinkage percentage of CC and OC samples.

V. Spirality: The following Table 5 and Figure F indicate the spirality of the two T-shirt samples.

Table 5: Spirality

Variable	100% CC	100% OC	T value
Spirality	0	2.5	-

Values are mean ± SD of five samples in each group
** - Significant at 1% level

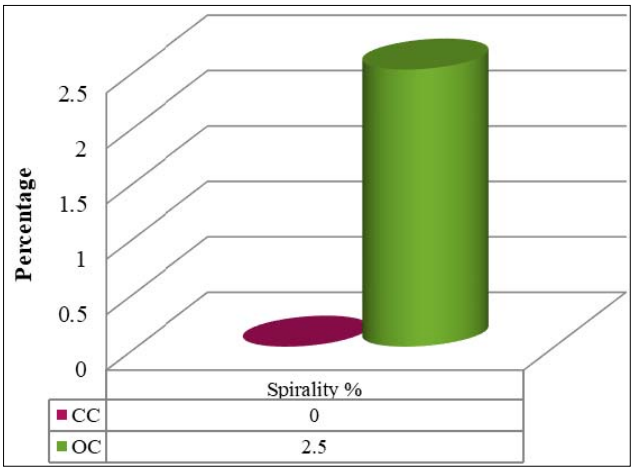

Fig F: Spirality in Percentage
***CC= Conventional Cotton; OC= Organic Cotton

Table 5 and Figure F showed the spirality in percentage of the CC and OC samples. The CC samples showed nil spirality whereas the OC T-shirt reported a spirality of 2.5% after wash. According to the T-value of the two samples compared, there was a significant difference in spirality percentage of CC and OC samples.

VI. Extension and recovery: The Extension and recovery of the samples are measured by calculating extension percentage and residual extension percentage.

- **Extension percentage:** The following Table 6 and Figure G indicate the extension percentage of the two T-shirt samples.

Table 6: Extension Percentage

Variable	100% CC	100% OC	T value
Lengthwise Extension	29±0.95	41±1.18	11.234**
Width wise Extension	72±0.43	120±0.95	65.584**

Values are mean ± SD of five samples in each group
** - Significant at 1% level

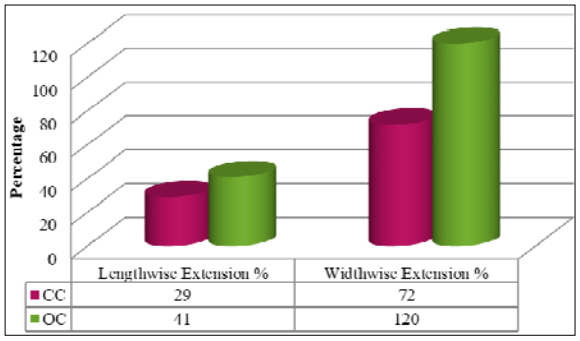

Fig G: Extension in Percentage
***CC= Conventional Cotton; OC= Organic Cotton

Table 6 and Figure G showed the extension percentage of the CC and OC samples. CC showed a 29% extension in length which was less as compared to OC which showed an extension of 41%. In the width wise direction the extension of CC was 72% which was again less as than that OC which showed a 120% extension. According to the T-value of the two samples compared, there was a significant difference in extension percentage of CC and OC samples.

- **Residual extension:** The following Table 7 and Figure H indicate the residual extension percentage of the two T-shirt samples.

Table 7: Residual Extension Percentage

Variable	100% CC	100% OC	T value
Lengthwise Extension	6.67±0.32	9.3±0.03	11.643**
Width wise Extension	20±0.94	34±0.08	20.746**

Values are mean ± SD of five samples in each group
** - Significant at 1% level

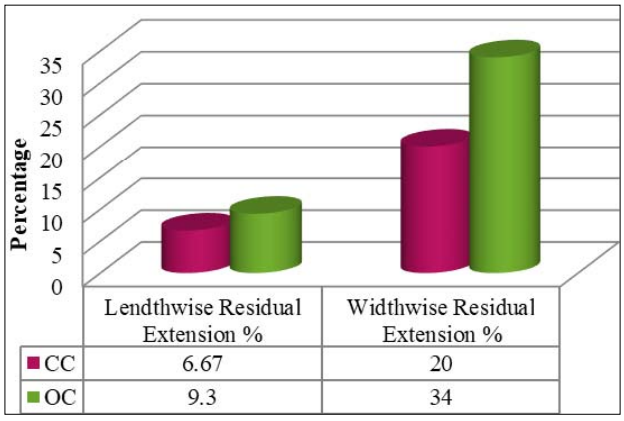

Fig H: Residual Extension in Percentage
***CC= Conventional Cotton; OC= Organic Cotton

Table 7 and Figure H showed the residual extension of the CC and OC samples. The residual extension for CC was recorded less in both length and width wise direction. The residual extension percentage after one minute of relaxation for CC was 6.67% in the length direction and that for OC was 9.3%. In the width wise direction the residual extension percentage after one minute of relaxation for CC was 20% which was less than the relaxation of OC which was 34% after one minute of relaxation. According to the T-value of the two samples compared, there was a significant difference in residual extension percentage for CC and OC samples.

Conclusion

The study compared the selected physical and mechanical properties of conventional and organic cotton knitted t-shirts. Abrasion resistance, bursting strength, resistance to pilling, dimensional stability and elasticity tests were performed on the two fabrics by standard testing methods. Abrasion resistance test was carried out by ISO 12947-2:1998 test method, using Martindale Abrasion Tester. Bursting strength test was conducted by ASTM-D 3786/ D 3786 M-13 test method using diaphragm bursting strength tester. The pilling tests were performed according to ISO 12945-2:2000 test method. Shrinkage and spirality tests were conducted to evaluate the dimensional stability of the knitted T-shirts and specimens conditioned before the tests according to ASTM Standard D 1776. The elasticity of the garments was measured by carrying out extension and recovery tests according to BS 4294:1968 method (withdrawn), which was replaced by BS 4952: 1992.

The study compared conventional and organic cotton, knitted T-shirts with exactly same attributes like size, colour, weight, count and construction. The statistical analysis revealed that even though both the T-shirts were made using 100% cotton yarns, 150 GSM, 30’s count and same knitting construction, there was a significant difference in their physical and mechanical attributes. Conventional cotton showed better mechanical properties like abrasion resistance and bursting strength than Organic cotton. While studying the physical properties, there was no significant difference in resistance to pilling up to 2000 cycles. The shrinkage test for testing dimensional stability indicated that Organic cotton is more stable in lengthwise direction but tends to elongate in the width wise direction. The spirality tests revealed that conventional cotton is better in spirality performance than organic cotton. Organic cotton was found to establish more elasticity than conventional cotton in extension and recovery tests.

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