A COMPARATIVE STUDY ON DYEING CAPABILITY OF CONVENTIONAL AND ORGANIC COTTON FABRICS

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Abstract: *Cotton fiber, which is the most widely used natural fiber in the textile and paper industries, has a crucial environmental impact. Cultivation of conventional cotton consumes a lot of water and requires the usage of a higher amount of pesticides. Organic cotton is a more environmentally friendly alternative to its growing conditions. The characteristics of cotton change with the differences in growing conditions. In this study, the properties of yarns obtained from both conventionally and organically grown cotton were tested and analyzed. The properties of these yarns in the fabric structure were compared in terms of fabric performance. The produced fabrics were dyed in the cold-pad batch method with 5 different colors of reactive dyes, which are the most demanding colors in the ready-made garment industry. The physical properties and the fastness test results of the dyed organic and conventional cotton fabrics were investigated in detail to highlight the plant growing effects on the fabric behavior. Comparative color analysis and evaluation of the fabrics were made to discuss the performance of the fabrics. It is found that organically grown cotton is not only superior in quality but also has no negative effect on fabric properties.*

Keywords: Organic Cotton, Conventional Cotton, Reactive Dyeing, Sustainability, Textile Processing, Colorimetric Data.

KOMPARATIVNA STUDIJA SPOSOBNOSTI BOJENJA KONVENCIONALNIH I ORGANSKIH PAMUČNIH TKANINA

Apstrakt: *Pamučno vlakno, koje je najčešće korišćeno prirodno vlakno u tekstilnoj i papirnoj industriji, ima presudan uticaj na životnu sredinu. Uzgoj konvencionalnog pamuka troši mnogo vode i zahteva upotrebu veće količine pesticida. Organski pamuk je ekološki prihvatljivija alternativa uslovima njegovog uzgoja. Karakteristike pamuka se menjaju sa razlikama u uslovima gajenja. U ovoj studiji ispitana su i analizirana svojstva prediva dobijenih i od konvencionalno i od organski uzgojenog pamuka. Upoređena su svojstva ovih prediva u strukturi tkanine u pogledu performansi tkanine. Proizvedene tkanine su obojene metodom hladnog tampona sa 5 različitih boja reaktivnih boja, koje su najzahtevnije boje u konfekcijskoj industriji. Fizička svojstva i rezultati ispitivanja postojanosti obojenih organskih i konvencionalnih pamučnih tkanina su detaljno ispitani kako bi se istakli efekti uzgoja biljaka na ponašanje tkanine. Urađena je komparativna analiza boja i procena tkanina* *kako bi se razgovaralo o performansama tkanina. Utvrđeno je da je organski uzgojen pamuk ne samo superiorniji u kvalitetu, već i nema negativan uticaj na svojstva tkanine.*

Ključne reči: Organski pamuk, konvencionalni pamuk, reaktivno bojenje, održivost, obrada tekstila, kolorimetrijski podaci.

1. INTRODUCTION

The rapid progress of industrialization and urbanization has accelerated the decline of the world's valuable resources and is responsible for environmental disasters and ecological imbalances. Nowadays, the concept of recycling, reuse, sustainability, and waste prevention is crucial and inevitable for a sustainable and environmentally friendly planet. The COVID-19 pandemic first appeared in December 2019 in an animal market in Wuhan, China [47,41]. It is clear that the outbreak of the COVID-19 pandemic is due to climate change, urbanization, rigorous agriculture, capitalism, etc. [3, 49]. Due to COVID-19, there was shut down all over the world which had a positive impact on the environment. For example, air pollution decreased by 50% in 2020 compared to 2019 [41]. Water pollution was also curbed as a result. This pandemic unambiguously demonstrated the urgent need for a sustainable world. So, increasing the production of organic cotton can be an eco-friendly and supporting endeavor to fight these problems. Moreover, the cultivation of naturally colored organic cotton (NACOC) can be more beneficial for the environment as it can eliminate the dyeing process which pollutes the environment to a great extent [11]. Globally, 26,172,678 tons of cotton are produced per year (AtlasBig n.d.). To produce cotton of this quantity, a large number of pesticides and water are used which accelerates the problem of environmental pollution and water scarcity. Across the entire planting season of cotton, more than 148 types of pests survive on cotton plants [18, 48]. Various pests create major problems in cotton farming. Cotton plant bugs (Apolygus lucorum, Lygus pratensis L. and Adelphocoris suturalis Jakovlev), the cotton bollworm (Helicoverpa armigera Hübner), aphids (Aphis gossypii Glover), and whiteflies (Bemisia tabaci Gennadius) are the most remarkable ones. Remarkable cotton diseases are Verticillium and Fusarium wilts. The issues of these pests are not going to be solved just by using pesticides. Organic cotton farming by intercropping with different crops like wheat, sunflower, rape can allure the native helpful insects which can act as a solution against the problem of using insecticides [7]. Moreover, the higher use of fertilizer emancipates nitrous oxide, which is a greenhouse gas having 300 times higher warming power than CO_2 [34,16]. About 50% of global pesticide usage occurs during the farming of non-organic cotton [27]. Using pesticides for a longer period of time increases the resistance of the insects to pesticides and decreases the number of other helpful insects [7]. It also destroys the natural fertility of the soil. Moreover, these pesticides are carried with rainwater and get mixed with the water of ponds, canals, or rivers. Pesticides are not only liable for the problem of water pollution but also for the death of marine animals [19]. In the case of cotton textile, 95% of water is required for producing raw material and the rest of the 5% is utilized for the processing of cotton fabric. To process 1 kg of cotton textile, approximately 100-150L water is needed [36]. To produce just one kilogram of raw cotton an astonishing amount of 7,000-29,000 liters of water is required which is the most water requirement among all crops [30,50,12]. All these reasons lead to the urgent need to cultivate organic cotton, as it can not only reduce water consumption but also reduce the risk of environmental disasters by minimizing the use of pesticides in cotton production. Farming organic cotton can reduce water consumption by 91% [8]. For producing organic cotton, no harmful chemicals are used, develops good soil rather than harming it, has a reduced effect on the air. The cultivation of organic cotton uses 62% less power and 88% less energy than that of conventional cotton cultivation [30]. According to the 2021 Organic Cotton Market Report published by Textile Exchange, 249,153 tons of organic cotton fiber is produced by 229,280 farmers on 588,425 hectares of certified organic land in 21 nations [40]. A comprehensive life cycle assessment by the Textile Exchange indicated that the probability of global warming can be reduced by 46 percent by shifting from conventional cotton to organic cotton [34,10]. As per the Organic Cotton Life Cycle Assessment results, the organic cotton harvest of 2013-14 of 116,974 metric tons resulted in a saving of 236.9 billion liters of water, 300.6 million kilowatts of energy, 96.2 million kg of CO_2 [10]. Organic cotton production is expected to reach an approximate growth of 48%, with Turkey and India expect to be the largest contributors [40]. There are several certification systems to ensure the authenticity of organic cotton. International voluntary standards, the Global Organic Textile Standard (GOTS) and the Organic Content Standard (OCS) provide the affirmation starting from farm to the end product. Among them, GOTS and OCS are mostly used. In 2020, there was a significant increase in the number of GOTS-certified facilities. A growth rate of 34% was recorded from 7,765 in 2019 to 10,388 in 2020. OCS aims to accelerate the production of organic agriculture. Just like GOTS, OCS also recorded a significant growth of 40% from 6,181 in 2019 to 8,638 in 2020 [44]. Matured cotton fiber has multilayer cells. The outermost layer is known as the cuticle which comprises of non-cellulosic materials. The Primary wall is surrounded by cuticles. The Secondary wall starts just after the primary wall. Lumen, which is a hollow tube, is located in the central region of cotton fiber. The fineness of the cotton fiber depends on the thickness of the cell wall. The degree of crystallinity is different between primary and secondary cell walls. Cotton fiber is composed of 90% cellulose and 10% non-cellulosic polysaccharides [48].

Figure 1: Physical structure of cotton fiber

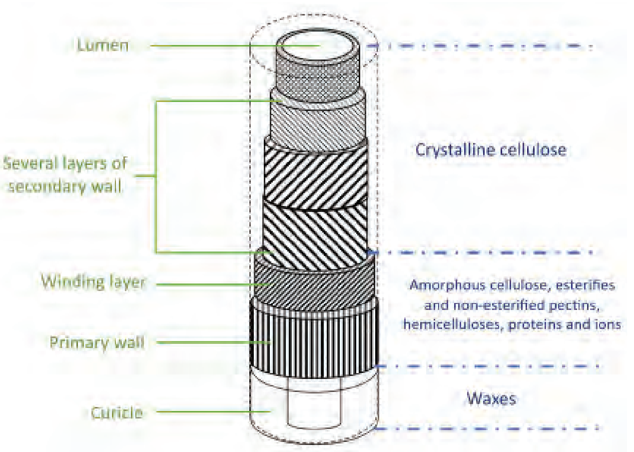

Table 1: Chemical composition of cotton fiber

Constituent	Composition (%Dry weight)	
	Typical %	Range %
Cellulose	95	88-96
Protein	1.3	1.1-1.9
Pectic substances	0.9	0.7-1.6
Ash	1.2	0.7-1.6
Total Sugar	0.3	0.1-1.0
Organic Acids	0.8	0.5-1.0
Pigments	Traces	
Others	1.5	

Data published by Textile Exchange in 2017 illustrates the difference between fiber length (upper half of mean length) and micronaire value of conventional cotton and organic cotton from different states in India. Temperature conditions, soil quality, etc. have an impact on fiber length. Fiber length affects the spinning process, as longer fibers are more likely to produce better yarn quality. The fibers collected from different regions of India, organic cotton had the highest fiber length of 39 mm, while the fiber length of conventional cotton was about 23 mm. Moreover, the micronaire value of cotton indicates the maturity and fineness of the fiber. It has a direct influence on the production of higher-quality yarns. Organic cotton from different Indian states had a fineness value of 3, while conventional cotton had a fineness value of 5, which means it is coarser than the organic cotton fiber. Moreover, the organic cotton fiber with a higher maturity level undoubtedly influences the dyeing process angel [2,44]. Organic fibers have more metal percentage than non-organic (conventional) cotton fibers. FTIR spectrum analysis showed that in organic cotton fibers, the representative groups are present in a higher percentage than in conventional cotton fibers. Both fibers show similar crystallinity. SEM analysis of organic and non-organic cotton fiber shows that both of them have the same cross-sectional structure [31].

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Element	Conventional cotton (ppm)	Organic Cotton (ppm)	Difference (%)
Ag	Not detected	Not detected	-
Cu	Not detected	Not detected	-
Cd	Not detected	Not detected	-
Co	Not detected	Not detected	-
Ni	Not detected	Not detected	-
Pb	Not detected	Not detected	-
Sb	Not detected	Not detected	-
Cr	Not detected	Not detected	-
Cr-ıv	Not detected	Not detected	-
Zn	Not detected	Not detected	-
As	Not detected	Not detected	-
Hg	Not detected	Not detected	-
Fe	22	89	75.28
Ca	933	796	-17.21
K	4527	4995	9.37
Al	38	65	41.54
Mg	560	670	16.42
P	259	285	9.12

The main goal of organic cotton cultivation defined as regenerative cotton is to preserve the richness of the soil and reduce water consumption. In the Aydın Söke region, which is one of the high-quality cotton-growing areas in Turkey, wheat is usually planted before cotton, and the production doubles every year. Before wheat is planted on the land reserved for organic cotton-oriented regenerative agriculture, clover-like plants are planted in the soil, which provides a lot of nitrogen. Growing plants are left in the soil, which acts as a natural fertilizer and protective layer for the plants. This reduces the need for and eliminates the need for expensive fertilizers. Minerals in the soil increase and molecules from old fertilizer applications are not released into the atmosphere. So, since more point use is sufficient, water consumption decreases by 70%, and labor costs decrease.

Reactive dyes are the most used dyes in the textile industry. They can produce excellent colors by using eco-friendly dyeing procedures. They have the ability to make covalent bonds easily between oxygen atoms of cotton hydroxyl groups and carbon atoms of dye reactive groups in an alkaline medium [35]. They are mainly used for cellulosic fibers such as cotton and viscose [6]. Along with the ability to have a reaction with fibers, reactive dyes have can also react with water. The prime drawback of reactive dyes is having low equilibrium dye exhaustion and poor fixation of dye which enables the usage of high amounts of salt and alkali in the dye bath [42].When these are released, they destroy the ecological stability of the water organism and marine life [35].

The general steps of organic fabric dyeing using basic dyestuffs are accountable for the decline of some properties of organic cotton [46]. However, the microwave radiation process is an eco-friendly dyeing technique that may enhance the strength and dyeing process of cotton. This sustainable dyeing process along with organic cotton might help to have a more sustainable and environment-friendly textile product [22]. Reproducible shades and even dyeing is possible on cotton fabric by the usage of reactive dyes [35,6,46]. For this research, 1/1 plain twill regular cotton and organic cotton fabric were used. These two fabrics are mainly used in the textile industry. This study aimed to investigate the effects and comparison of dyeing properties of conventional cotton and organic cotton. Also, the future possibilities for organic cotton dyeing are discussed.

2. MATERIALS AND METHODS

2.1 Fabric Structure Preparation

In the scope of this study, conventional and organic cotton-based fabrics were prepared and dying processes were kindly performed at Akın Textile, Kırklareli, Türkiye. The most used yarn count which is Ne 40 was selected to weave the fabrics. Conventional cotton yarns (COCOT) and organic cotton yarns (ORCOT) were spun as the combed yarns. It is known that combed yarns provide the best yarn properties in terms of physical strength and unevenness [26,17,13]. 1/1 plain fabrics were prepared with COCOT and ORCOT yarns. The plain-woven structure is one of the most used structures and the studies are often using this structure for the homogeneous distribution of the yarns and a clear examination of the applied tests. In this study, the woven structure was used to analyze the effect of dyeing processes in detail. The construction of the conventional cotton fabric and organic cotton fabric used was 61X36/40X40 and 62X36/40X40 respectively. It means the warp and weft count of both fabrics is Ne 40. For conventional cotton fabric, warp ends per inch (EPI) in warp direction was 61 and weft picks per inch (PPI) in weft direction was 36. For organic cotton fabric, warp ends per inch (EPI) in warp direction was 62 and weft picks per inch (PPI) in weft direction was 36. The areal density values of the samples were found in accordance with the ASTM D3776/D3776M-20 standard and it is given in Table 3.

Table 3: Structural properties of used fabric

Sample	*Fabric structure*	*Areal Density (g/m²)*
Conventional	Plain 1/1	146.8
Organic	Plain 1/1	144.0

2.2 Fabric Dyeing Process

Reactive dye is one of the most commonly used dyes for dyeing cotton-based products due to its extraordinary washing fastness and strong protection against chemical reactions. Reactive dyes are mostly used to dye cotton-based fabrics and it consumes more than 50% of the worldwide utilization [28,8,35] . When the cellulosic fibers come into contact with water, they generate a slight negative charge due to the ionization of the hydroxyl groups, and the reactive dyes also become anionic in the solution [28]. The negative charge that develops on the fibers causes anionic reactive dyes to be repelled, limiting their excretion. Therefore, when dyeing cotton with reactive dyes and other anionic dyes, numerous electrolytes such as sodium sulfate (Glauber's salt) or sodium chloride are required to reduce the charge repulsion between the negatively charged cotton and the reactive dyes [39,28].These salts are completely dissociated in water to lose ion pairs. The positive sodium ion migrates to the fiber-water interface and effectively cancels the zeta potential, destroying the barrier to initial dye-fiber interaction [24]. During this process, the main expectation from the test results is to highlight the differences between organic and conventional fibers' cellulosic structures. In the reactive dyeing of cellulose substrates, only about 70-80% of the reactive dye is consumed, and large amounts of electrolyte are required for the consumption. The electrolyte used in the dyeing process is disposed of as wastewater and increases the total dissolved solids (TDS) content. The wastewater must be further treated to remove them [38]. Researchers have made many attempts to improve the dye uptake of reactive dyes and reduce the use of salt in the reactive dyeing process. To reduce salt consumption, the substrate, i.e., the cotton that absorbs the dyes without the use of salt, has been changed [52]. Table 4 shows the recipe used for the bleaching process during this study. The chemicals used in the bleaching process meet GOTS 6 organic standards, the same process and parameters were used for both fabrics. The organic-based fabric can be classified as a sustainable product as its raw material and the dying process was done by GOTS standard.

To achieve a sustainable dyeing process with a good result, pre-treatment of the fabric needs to be well-applied and well-determined. The quality of the pre-treated fabrics directly affects the final products. The main tests were performed to determine the hydrophilicity, pH, whiteness, and capillarity of the fabric. It is found that the applied test shows the suitability of the pre-treatment of the fabrics [25]. The pre-treated fabrics test is given in Table 5, these results are effective to dye the fabrics and they mostly change with the industrial experience. The results are fit Akin Textiles dying process.

Table 4: Bleaching recipe

Chemicals	Gr/Lt
Peroxide Stabilizer	5
Bleach Soaker	3
Dispergator	3
Washer	3
Air Removal	3
50% Hydrogen Peroxide	30
48° Be Costic	30

* Be means Bome which is a unit of density. It is calculated using specific gravity scales.

The fabrics were dyed by using the cold pad-batch method at room temperature [52]. By performing the faster dyeing process, the dye penetration time into the fabric can vary from 6 to 24 hours. It is an advantageous and economical process as it is economically suitable for lab-scale dyeing and reduces the consumption of dyes and chemicals as compared to the other dyeing process [19,20,21]. Organic and conventional cotton fabrics were dyed with 5 different colors using the same recipes as given in Table 5. These selected colors are also chosen as the customer expectation and WGSN trend analyses. It is also important to mention that light and dark color dyes were used as these colors have the ability to determine the real effect of cellulose content in the structure [21].

Figure 2: Dyeing process of fabrics

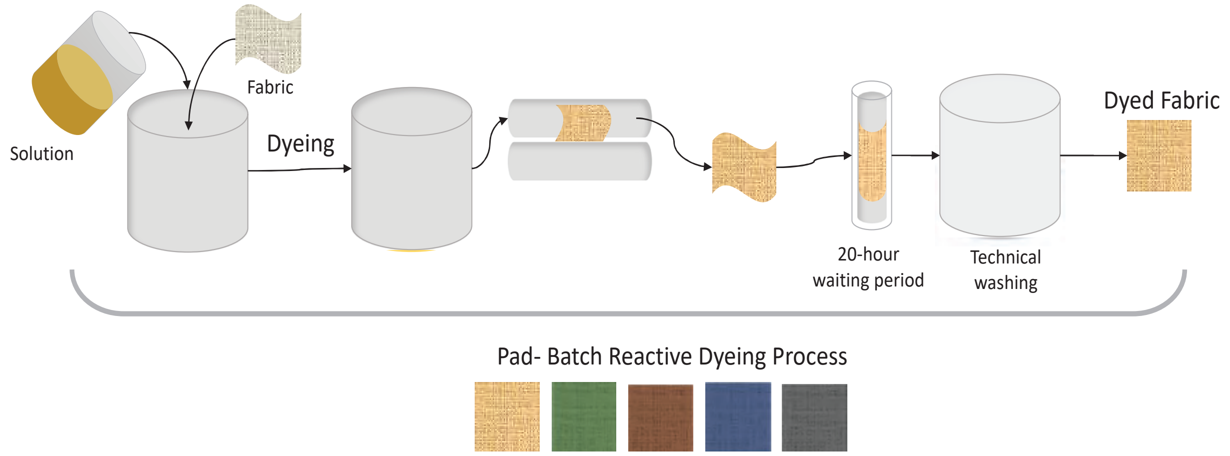


Table 5: Dyeing Recipes

	Gr/Lt	Trade Name of Dye		Gr/Lt	Trade Name of Dye
Beige			***Navy Blue***		
Reactive Yellow	4	Levafix Amber C-AN	Reactive Yellow	10	Remazol Ultra Yellow RGB
Reactive Red	1	Remazol Red FLM01	Reactive Red	12	Remazol Ultra Red RGB
Reactive Blue	1	Levafix Blue CA	Reactive Blue	50	Remazol Navy RGB %150
Green			***Black***		
Reactive Yellow	12	Levafix Amber C-AN	Reactive Yellow	5	Remazol Ultra Yellow RGB
Reactive Red	3	Remazol Red FLM01	Reactive Red	5	Remazol Ultra Red RGB
Reactive Blue	4	Levafix Blue CA	Reactive Black	95	Remazol Map Black NW
Brown					
Reactive Yellow	30	Remazol Ultra Yellow RGB			
Reactive Red	18	Remazol Ultra Red RGB			
Reactive Blue	25	Remazol Navy RGB %150			

The amount of dye in the recipe was weighed, and then 150 ml of water at a temperature of 60-65 degrees was added and mixed in a magnetic stirrer until the dye gets dissolved. A wetting agent was added to the dye, which was dissolved by adding urea. The amount of the solution was made up to 400 ml and the temperature was controlled during the process. When the temperature reached 22 degrees, lye and silicate were added. When the solution was homogenized, the solution weighed up to 500 ml. The dissolved dye was poured into the cloth tub and the fabric was dyed. The dyed fabric was first rolled on the roller and then prepared for the waiting process by keeping it in an airtight nylon bag. The dyes used were subjected to a 20-hour waiting period according to the instructions for the standard waiting time of dyes. The dyed fabrics had undergone a technical washing process of 5-minutes (Table 6).

Table 6: Washing Recipes

	Sodium Silicate (38° Be) Gr/Lt	Caustic (48° Be) Gr/Lt
Beige	68	3.45
Green	68	5.55
Brown	68	16.95
Navy Blue	68	16.95
Black	68	18.00

3. RESULT AND DISCUSSIONS

3.1 Tensile and Tearing Strength Properties of the Fabrics

Strength and elasticity are considered the two most important mechanical properties of fabrics. Tensile strength and elongation at break are the most common characteristics of these fabric properties. The tensile strength and elongation at the break of the fabric depend on the yarns used. When using plain and plied yarns, the tensile strength of fabrics made of plied yarns in the weft direction tends to be higher than that of plain yarns. The spinning and weaving parameters affect the surface and mechanical properties of the fabric. Greater crimp in load-bearing is the result of greater interlacing of the yarn. It is responsible for lower breaking strength. When the fiber length of the yarns is higher and the fibers are properly straightened and combed during the spinning process, the yarns are more compact and have higher tensile strength. This also gives the fabrics better tensile strength. In addition, fabric structure also affects the tensile strength of the fabric. For example, plain weave fabrics have higher tensile strength than twill weave fabrics because the number of interlaces per unit is higher [29,23]. Therefore, the tensile properties of the yarn directly affect the mechanical properties of the fabric. The detailed results of the yarn tests can be found in Table 7. As expected, the properties of the combined yarns are good, which can be attributed to the additional combing process to which the yarns were subjected and which reduces the proportion of short fibers. It is a well-known phenomenon that fiber length has a positive or negative effect on yarn and fabric properties. To exclude such effects on the tested fabrics, the yarns were first tested to highlight their properties of the yarns. It is also mentioned that the spinnability of the two fibers can be discussed and numerical data can be provided for further studies. The organic cotton fibers showed slightly higher torsion ("T") values compared to the conventional cotton fibers; however, the values for twists are almost the same. These are the most important parameters for observing the dye penetration rate of the material. The tightness value of the yarn determines the interaction between the dye and the fiber. The non-uniformity of the yarn is also similar.

The tensile properties of the fabrics were determined by the strip method (ISO 13934-1:2013 Part 1: Determination of maximum force and elongation at maximum force using the strip method). The values of organic and conventional fabrics are directly proportional to the values obtained from the yarns they were weaved. The results were better for all organic fabrics than for conventional cotton fabrics without being affected by dyeing. Tear properties of fabrics-Part 1: Determination of tear force using ballistic pendulum method (Elmendorf) test was performed on organic and conventional fabrics in accordance with ISO 13937-1:2000 standard. The tearing and elongation values of organic and conventional fabrics are directly proportional to the values obtained from their yarns. Results on all organic fabrics were better than conventional cotton fabrics without being affected by dyeing. It can be also said that apart from the effect of dying, the organic yarn had better test results as compared to the conventional yarn and it can positively influence the fabric's mechanical properties.

It is visible from Table 8 that the dyed organic fabrics have better maximum force, elongation and tearing strength in comparison to dyed conventional fabrics. Organic yarn properties are shown in Table 7 exhibits that organic cotton yarn possesses lesser yarn imperfections compared to conventional cotton yarn. The factor of having lesser yarn imperfection is due to better fiber fineness and density of organic cotton [15]. Hence, the tightness factor of organic fabric is higher which gives better maximum force. In table 8, the average test value of every parameter of organic fabric was more than the average test result of conventional fabric.

Table 7: The tested yarn properties

Sample	CV%	Twist (Z)	T"	%U	Thin Places (-50%)	Thick Places (+50%)	Neps (+200%)	RKM (Resistance/km)	ELONG %
COCOT	1.3	28.0	1.3	2.1	3	34	140	19.4	5.31
ORCOT	1.6	27.9	1.6	2.8	0	7	30	22.5	5.13

Table 8: Mechanical strength test comparison chart

Samples	**Maximum Force (N)**	**Elongation (%)**	**Tearing Strength Max. Force (N)**
Conventional (undyed fabric)	504	9.58	4.24
Conventional Dyed-Beige	545	11.67	3.70
Conventional Dyed-Green	606	11.70	3.51
Conventional Dyed-Brown	529	11.43	3.43
Conventional Dyed-Navy Blue	513	11.32	3.37
Conventional Dyed-Black	496	10.76	3.27
Organic (undyed fabric)	592	11.72	4.54
Organic Dyed-Beige	587	12.69	4.20
Organic Dyed-Green	606	12.63	4.17
Organic Dyed-Brown	578	12.45	4.03
Organic Dyed-Navy Blue	593	12.38	3.94
Organic Dyed-Black	581	11.28	3.94

3.3 Color fastness to artificial light

Textiles - Tests for color fastness - Part B02: Color fastness to artificial light: Xenon arc fading lamp test was carried out in accordance with ISO 105-B02:2014 standard. Lightfastness is an important property in dyed fabrics which indicates the fading resistance of the dyes under exposure to sunlight or artificial light source. Poor color fastness of the textile products is one of the major reasons for customer complaints. It varies according to the molecular structure and type of dyes used, how the dyeing process was conducted, and the depth of the color. The resistance to loss or changes of color is a result of the connection between the fiber and dye [37, 32]. After conducting the test, no noteworthy change was observed in the tones of the fabric samples. The values are found to be 4, the only difference was observed at the brown dye which is 3/4. It was the same for both conventional and organic fabrics. Overall, the test results indicated that the color fastness to light test gives good results for both organic and conventional fabrics. It can be interpreted that the fiber structures did not have any differences in terms of dye absorption.

3.4 Color fastness to domestic and commercial laundering

Test for color fastness- Part C06: Color fastness to domestic and commercial laundering test was carried out in accordance with TS EN ISO 105-C06 standard. Reactive dyes, unlike all other classes of dyes, are dyes that can react with fiber macromolecules and can bind to fibers with true covalent bonds [9,5]. Because of these properties, their wet fastness is outstanding. The test results were found to be similar for both fabrics. Here, the color fastness of the fabrics may be the same for home laundering, which is a reason for preference in fiber selection. The staining in the color of the fabrics was 5 which is the highest value as per the comparison chart given below. The test was applied in industrial conditions to make sure that the outcome

Table 9: Color fastness to artificial light comparison chart

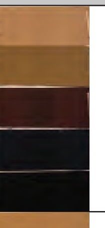
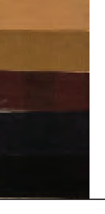
Samples		
Conventional Dyed-Beige	*4*	
Conventional Dyed-Green	*4*	
Conventional Dyed-Brown	*3/4*	
Conventional Dyed-Navy Blue	*4*	
Conventional Dyed-Black	*4*	
Organic Dyed-Beige	*4*	
Organic Dyed-Green	*4*	
Organic Dyed-Brown	*3*	
Organic Dyed-Navy Blue	*3/4*	
Organic Dyed-Black	*4*	

Table 10: Color fastness to domestic and commercial laundering comparison chart

Sample types	**Amount of solution**	**Change in Color**	**Staining in Color**					
			Acetate	**Cotton**	**Nylon**	**Polyester**	**Acrylic**	**wool**
Conventional Dyed-Beige	150 ml	4/5	5	5	5	5	5	5
Conventional Dyed-Green	150ml	4/5	5	5	5	5	5	5
Conventional Dyed-Brown	150ml	4/5	5	5	5	5	5	5
Conventional Dyed-Navy Blue	150ml	4/5	5	5	5	5	5	5
Conventional Dyed-Beige	150ml	4/5	5	5	5	5	5	5
Organic Dyed-Beige	150 ml	4/5	5	5	5	5	5	5
Organic Dyed-Green	150ml	4/5	5	5	5	5	5	5
Organic Dyed-Brown	150ml	4/5	5	5	5	5	5	5
Organic Dyed-Navy Blue	150ml	4/5	5	5	5	5	5	5
Organic Dyed-Black	150ml	4/5	5	5	5	5	5	5

can fit the industrial expectation. The organic agricultural activities did not have any side effects on the properties that are tested. There are some misunderstandings that the immature fiber content of organic cotton negatively affects the dyeing properties which causes a problem with the final fabric. This study clearly depicts that the dyeing ability of organic cotton is similar to conventional cotton. The temperature of the washing bath, ration of wash liquor to goods, type of the detergent used, additives used in the dyebath, and intensity of mechanical action influence the washing and laundering fastness test of fabric.

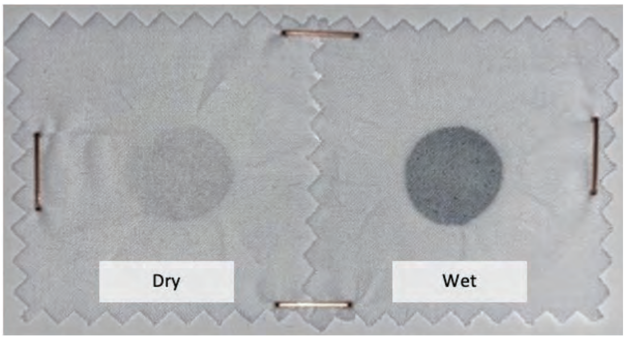
3.5 Color fastness to rubbing

Textiles - Tests for color fastness - Part X12: Color fastness to rubbing test was carried out in accordance with TS EN ISO 105-X12 standard. Rubbing fastness is the resistance of a fabric to transfer its color to another fabric with which it is in contact by rubbing [33]. It is one of the crucial tests as rubbing can cause a problem during the production of ready-garment and usage period. Generally, dark colors attain lower rub fastness in comparison to light colors. The fabrics are always within contact with different structures and the color changes should be at a limited value. The rubbing behavior is also a fiber-related property that can change the look of the fabric after a very short time of usage. The rubbing fastness mostly depends on the dye used and the interaction between fiber and dye. In reactive dyeing, it can leave more traces on the test fabric in friction fastness due to only physical bonding to cellulosic fibers. The wear properties of the fibers also affect the rubbing and it is seen from the test that both samples had similar look after testing. The black color had the lowest color fastness value after wet rubbing for both conventional and organic fabrics (Figure 3). In general, dark colors have the lowest color fastness after wet rubbings.

Table 11: Color fastness to dry and wet rubbing comparison chart

Samples	Dry Rubbing	Wet Rubbing
Conventional Dyed-Beige	5	4
Conventional Dyed-Green	5	3/4
Conventional Dyed-Brown	4/5	2/3
Conventional Dyed-Navy Blue	4	2
Conventional Dyed-Black	3	2
Organic Dyed-Beige	5	4/5
Organic Dyed-Green	5	4
Organic Dyed-Brown	4/5	2/3
Organic Dyed-Navy Blue	4	2
Organic Dyed-Black	3/4	1/2

Figure 3: Organic dyed sample wet and dry rubbed sample



3.6 Color fastness to water

Test for color fastness- Part E01: Color fastness to water test was carried out in accordance with ISO 105-E01:2013 standard. This test is done to measure the resistance to water of different printed, dyed textile products such as yarn, fabric, or finished garments. It determines the degree of resistance of textile colors to immersion in water. Generally, distilled or de-ionized water is used to conduct this test because of the composition variability of natural (tap) water. As per the test result, conventional and regular fabric dyed with Beige and Green colors has the same level of color fastness to water. In the case of Brown dye, conventional fabric has a rating of 4 whereas organic fabric has a slightly higher rating of 4/5 with Acetate. On the other hand, conventional fabric has a test rating of 4/5 with Nylon in comparison to the rating of 4 for organic fabric. Conventional fabric dyed with navy blue dye gives a test rating of 4 with Acetate and 4/5 with Nylon in comparison to the test rating of organic fabric of 4/5 and 4 respectively. For Black color dyed conventional fabric, the test rating of 4/5 with cotton is marginally higher than the rating of 4 for organic fabric. Overall, this study interprets that both conventional and organic fabric have a very closer level of color fastness to water test rating.

3.7 Color fastness to perspiration

Test for color fastness- Part E04: Color fastness to perspiration test was carried out in accordance with TS EN ISO 105-E04 standard. Perspiration is generally described as sweating from the human body. It is

Table 12: Color fastness to water comparison chart

Sample types	Amount of solution	Change in Color	Staining in Color					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Conventional Dyed-Beige	150 ml	4/5	5	5	5	5	5	5
Conventional Dyed-Green	91ml	4/5	5	5	5	5	5	5
Conventional Dyed-Brown	91ml	4/5	4	4	4/5	4/5	4/5	4/5
Conventional Dyed-Navy Blue	93ml	4/5	4	4	4/5	4/5	4/5	4/5
Conventional Dyed-Black	150ml	4/5	4/5	4/5	4	4/5	4/5	4/5
Organic Dyed-Beige	150 ml	4/5	5	5	5	5	5	5
Organic Dyed-Green	91ml	4/5	5	5	5	5	5	5
Organic Dyed-Brown	91ml	4/5	4/5	4	4	4/5	4/5	4/5
Organic Dyed-Navy Blue	93ml	4/5	4/5	4	4	4/5	4/5	4/5
Organic Dyed-Black	150ml	4/5	4/5	4	4	4/5	4/5	4/5

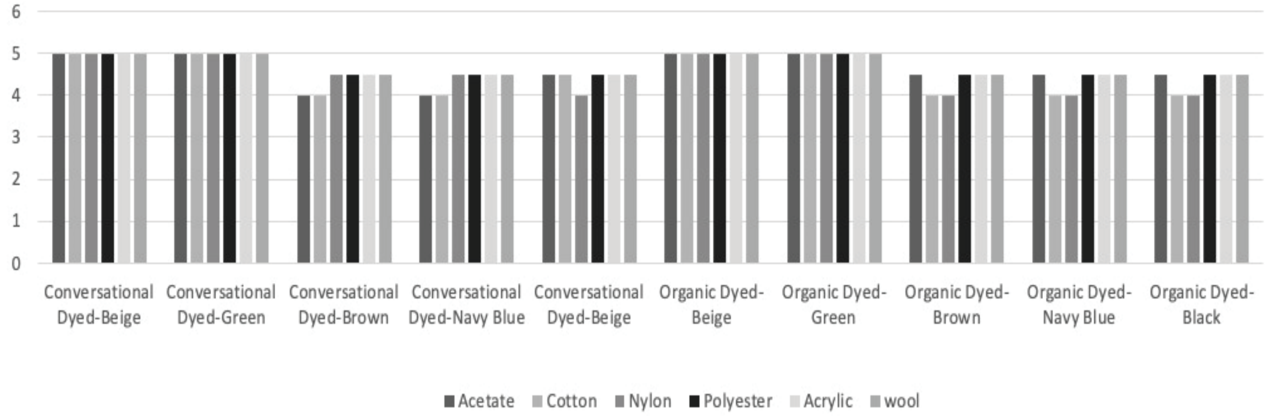


Figure 4: Comparison of color fastness to water test

a chemical that contains large amounts of salts. It can be both acidic and alkaline. Color fastness to perspiration test is used to find out the resistance of textile products against both acidic and alkaline perspiration. This test is done specially for sportswear and heavy dresses. From the tests conducted for color fastness to perspiration, it was observed that organic cotton fabric has somewhat the same level of color fastness rating as conventional fabric with very little change in a few cases for both acidic and alkaline

Table 13: Color Fastness to Perspiration (Alkaline)

Samples		Amount of solution (ml)	Sample Weight (gr)	Change in Color	Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Conventional Cotton	***Conventional Dyed-Beige***	92	184	4/5	5	5	5	5	5	5
	Conventional Dyed-Green	93	186	4/5	5	5	5	5	5	5
	Conventional Dyed-Brown	93	186	4/5	4	2/3	4	4	4	4/5
	Conventional Dyed-Navy Blue	93	186	4/5	4	3	4	4	4	4/5
	Conventional Dyed-Black	91	182	4/5	4	3/4	4/5	4/5	4/5	4/5
Organic Cotton	***Organic Dyed-Beige***	91	182	4/5	5	5	5	5	5	5
	Organic Dyed-Green	91	182	4/5	5	5	5	5	5	5
	Organic Dyed-Brown	91	182	4/5	4	3	4	4	3/4	4
	Organic Dyed-Navy Blue	93	186	4/5	4	3/4	4/5	4	4	4
	Organic Dyed-Black	94	188	4/5	4	3/4	4/5	4/5	4/5	4/5

Table 14: Color Fastness to Perspiration (Acid)

Samples		Amount of solution (ml)	Sample Weight	Change in Color	Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Conventional Cotton	***Conventional Dyed-Beige***	92	184	4/5	5	5	5	5	5	5
	Conventional Dyed-Green	93	186	4/5	5	5	5	5	5	5
	Conventional Dyed-Brown	93	186	4/5	4	3	4	4	4	4/5
	Conventional Dyed-Navy Blue	93	186	4/5	4/5	4	4/5	4/5	4/5	4/5
	Conventional Dyed-Black	91	182	4/5	4/5	4	4/5	4/5	4/5	4/5
Organic Cotton	***Organic Dyed-Beige***	91	182	4/5	5	5	5	5	5	5
	Organic Dyed-Green	91	182	4/5	5	5	5	5	5	5
	Organic Dyed-Brown	91	182	4/5	4	3/4	4	4/5	4/5	4
	Organic Dyed-Navy Blue	93	186	4/5	4/5	4	4/5	4	4/5	4
	Organic Dyed-Black	94	188	4/5	4/5	4	4/5	4/5	4/5	4/5

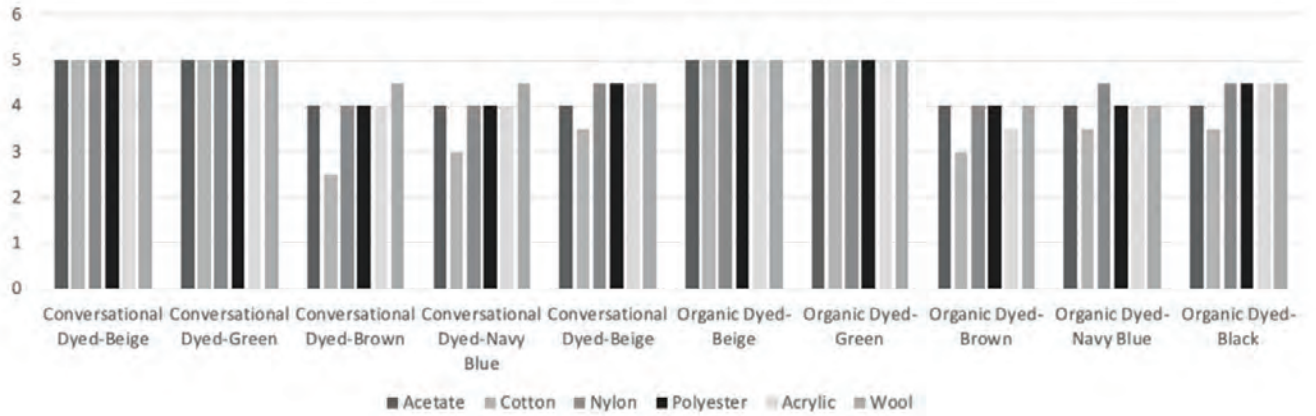


Figure 5: Comparison of color fastness to perspiration (Alkaline) test

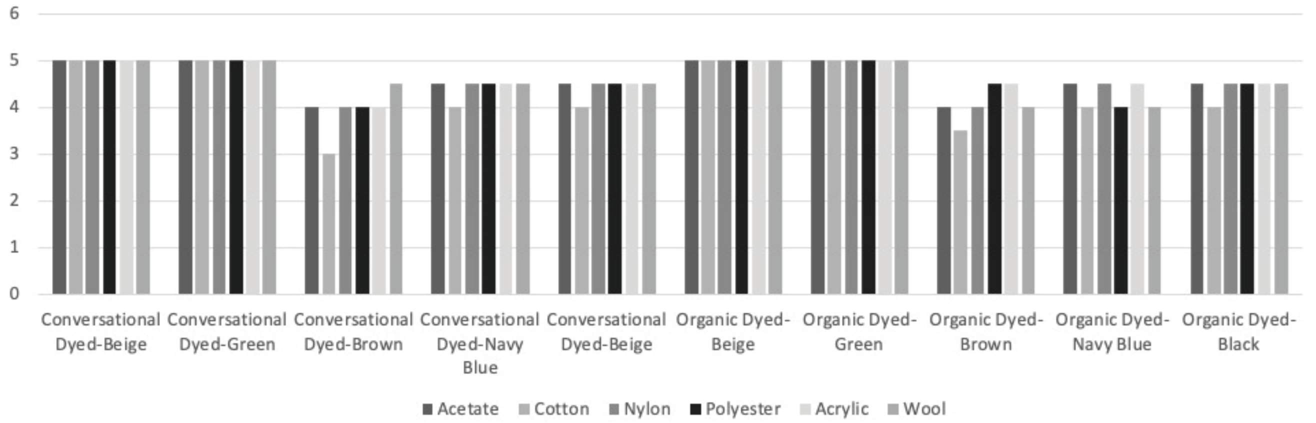


Figure 6: Comparison of color fastness to perspiration (Acid) test

mediums. Overall, color fastness to perspiration is not much different between conventional fabric and organic fabric.

3.8 Color Evaluation

The measurements were performed with the ColorTools QC 2.4.3 software on a Datacolor device. The L, a*, and b* values of the colored fabrics were measured 3 times under the lighting conditions of D65daylight, F11 10, and A 10 by placing the sample in a dual position with the spectrophotometer 'Color Tools QC 2.4.3'. The main aim of performing this test is to provide measurable data which cannot be observed by the bare eye. If the color cannot fit the between manufacturer and supplier order, then reprocessing of the fabric causes extra environmental issues as the water conservation will be repeated. It is already emphasized that the main process causes a very harmful issue and repeating the dyeing process for the color setting has strict rules and renouncement of an agreement. This color evaluation can give a basic idea to compare the organic and conventional cotton fabrics. As it can be seen from Figure L, the type of cotton (organic or convection) has no significant effect on the color values. As it can be seen in the figures, the human eye can distinguish differences of 0.4 and more [14]. For all samples compared, the values are below the difference that the eye can perceive. On other hand, the test can justify the differences in a depth spectrum. It is crucial to mention that the test performed on the dyed fabric before any other wet processing operations such as washing also can change the test result values of color evaluation [51,43].

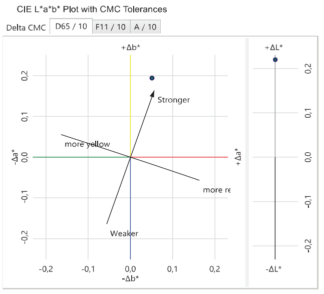
Coordinate deviations of color by planar analysis are given in Figure 7. Although these deviations vary according to color tones, no remarkable change was observed between the fabrics. As expected, the coordinate planes are congruent for color intensity. Detailed values in the corresponding figure are given in full for further studies.

CMC Pass-Fail Coordinates

CMC P/F Tolerances: CMC l = 2,00 CMC c = 1,00 CMC Commercial Factor = 1,00

Illuminant	DL*	Da*	Db*	DC*	Dh*	CMC dE	Decision
D65 10 Deg	0,22	0,05	0,19	0,20	0,01	**0,15**	**Pass**
F11 10 Deg	0,23	0,07	0,21	0,22	-0,00	**0,16**	**Pass**
A 10 Deg	0,24	0,07	0,21	0,22	0,03	**0,16**	**Pass**

Description	DL*	Da*	Db*	Metamerism Index
D65 10 Deg	lighter	more red	more yellow	
F11 10 Deg	lighter	more red	more yellow	0,02
A 10 Deg	lighter	more red	more yellow	0,01



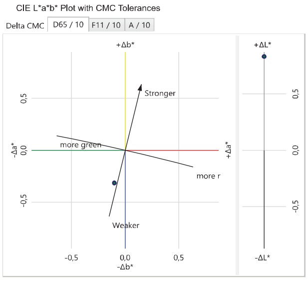
A

CMC Pass-Fail Coordinates

CMC P/F Tolerances: CMC l = 2,00 CMC c = 1,00 CMC Commercial Factor = 1,00

Illuminant	DL*	Da*	Db*	DC*	Dh*	CMC dE	Decision
D65 10 Deg	0,83	-0,10	-0,31	-0,33	0,02	**0,43**	**Pass**
F11 10 Deg	0,82	-0,07	-0,34	-0,34	0,01	**0,42**	**Pass**
A 10 Deg	0,80	-0,13	-0,34	-0,36	-0,01	**0,42**	**Pass**

Description	DL*	Da*	Db*	Metamerism Index
D65 10 Deg	lighter	more green	more blue	
F11 10 Deg	lighter	more green	more blue	0,07
A 10 Deg	lighter	more green	more blue	0,10



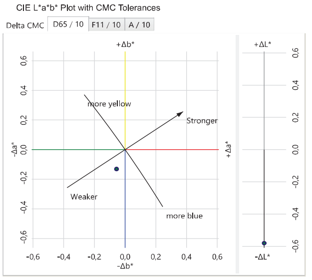
B

CMC Pass-Fail Coordinates

CMC P/F Tolerances: CMC l = 2,00 CMC c = 1,00 CMC Commercial Factor = 1,00

Illuminant	DL*	Da*	Db*	DC*	Dh*	CMC dE	Decision
D65 10 Deg	-0,58	-0,06	-0,13	-0,12	-0,08	**0,46**	**Pass**
F11 10 Deg	-0,58	-0,10	-0,13	-0,16	-0,03	**0,45**	**Pass**
A 10 Deg	-0,59	-0,06	-0,15	-0,14	-0,08	**0,46**	**Pass**

Description	DL*	Da*	Db*	Metamerism Index
D65 10 Deg	darker	more green	more blue	
F11 10 Deg	darker	more green	more blue	0,06
A 10 Deg	darker	more green	more blue	0,02



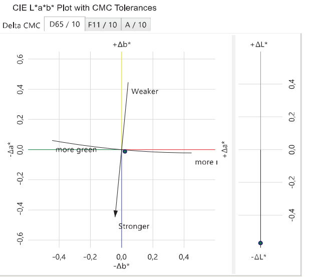
C

CMC Pass-Fail Coordinates

CMC P/F Tolerances: CMC l = 2,00 CMC c = 1,00 CMC Commercial Factor = 1,00

Illuminant	DL*	Da*	Db*	DC*	Dh*	CMC dE	Decision
D65 10 Deg	-0,57	0,02	-0,01	0,01	0,02	**0,50**	**Pass**
F11 10 Deg	-0,59	0,01	-0,04	0,04	0,02	**0,53**	**Pass**
A 10 Deg	-0,57	0,02	-0,01	0,01	0,02	**0,50**	**Pass**

Description	DL*	Da*	Db*	Metamerism Index
D65 10 Deg	darker	more red	more blue	
F11 10 Deg	darker	more red	more blue	0,05
A 10 Deg	darker	more red	more blue	0,01



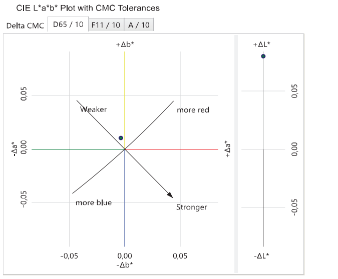
D

CMC Pass-Fail Coordinates

CMC P/F Tolerances: CMC l = 2,00 CMC c = 1,00 CMC Commercial Factor = 1,00

Illuminant	DL*	Da*	Db*	DC*	Dh*	CMC dE	Decision
D65 10 Deg	0,09	-0,01	0,02	-0,02	0,00	**0,09**	**Pass**
F11 10 Deg	0,09	-0,04	0,01	-0,01	-0,04	**0,11**	**Pass**
A 10 Deg	0,09	-0,01	0,01	-0,02	0,01	**0,09**	**Pass**

Description	DL*	Da*	Db*	Metamerism Index
D65 10 Deg	lighter	more green	more yellow	
F11 10 Deg	lighter	more green	more yellow	0,03
A 10 Deg	lighter	more green	more yellow	0,01



E

Figure 7: Organic and Conventional comparison A) Beige, B) Green, C) Brown, D) Navy Blue, E) Black

4. CONCLUSIONS

It was observed that organic cotton gave better results in all of the tests performed in this study. The results obtained show that organically grown cotton performed better than conventional cotton in the strength tests conducted after dyeing. In addition, there were significant differences in mechanical strength and tensile strength, as organically grown cotton fabrics tend to have better tensile strength and elongation after dyeing. However, all colorfastness tests, such as color resistance to artificial light, domestic and commercial laundry, friction, water, and perspiration, showed that both organic cotton fabrics and conventional organic cotton fabrics have similar test results, as these parameters depend on the quality of dyes used to dye the fabrics. The result of the color evaluation of both fabrics was also identical. The results of our study suggest that organic cotton has better properties than conventional cotton and that the cultivation of organic cotton has less impact on the environment as fewer pesticides and water are used to ensure a sustainable environment and the production of sustainable textile products.

5. CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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