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Different Pattern Designs with Printing Method on Classic Worsted Wool Fabrics

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Abstract

It is a well-known fact that the use of artificial fibers is increasing today. However, some reasons such as the high amount of chemicals, energy, water used in the production of artificial fibers and environmental pollution, allergic reactions on the skin it comes into contact with, and not being destroyed in nature for a long time have caused natural fibers have been preferred again. Among these fibers, which have been most preferred from the past to the present, wool fiber comes after cotton. The products produced from wool fiber provide the comfort features expected for the user in the best way, with their elasticity, drape, brightness, adaptability to the human body's thermal responses, and rapid transfer of heat and water vapor. Nowadays, the emergence of the need for functional and comfortable clothing in business life has necessitated different patterns and construction studies in wool fabrics. For this reason, different searches have emerged in conventional patterning (dobby patterning) techniques made on classical wool fabrics. The need to expand the boundaries of patterning studies created with conventional production techniques, different knitting, and yarn colors has led to the emergence of new patterns with printing techniques.

In this study, different printing pattern studies were carried out on woolen dress/uniform fabrics in different constructions and weights. The pattern studies were carried out on woolen fabrics by using colors with different themes. As a result of printing patterns on woolen fabrics, it was aimed to increase the use of wool-based products in daily clothing.

Keywords: Worsted wool fabric, Casual wear, Pattern & Design, Printing technique, Acid dye, Wool printing

Introduction

Fabrics are the locomotive of innovative approaches in the textile industry. Making fabrics different with different colors, patterns, and finishing processes are about meeting fashion expectations [1-3].

The creation of different designs in fashion expectations is one of the most important factors that activate the fabric industry and cause the search for innovative looks. The desire to make a difference in clothing designs, which is considered to be a particular niche, is strongly influenced by color, patterns, and trends [4,5].

Textile printing is an important art of creating decorative textile fabric. Coloring is provided by pigment dyes in the printing paste. Successful printing includes the determination of the right color, the smoothness of the print, the good adhesion of the printing paste to the fabric, and the efficient use of ink [6-10].

Digital printing

In this study, different printing pattern studies were carried out on woolen dress/uniform fabrics in different constructions and weights. The pattern studies were carried out digital printed on woolen fabrics by using colors with different themes. As a result of printing patterns on woolen fabrics, it was aimed to increase the use of wool-based products in daily clothing.

Method and Material

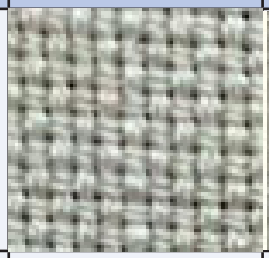
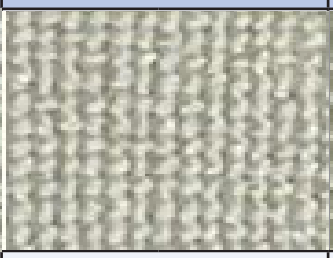
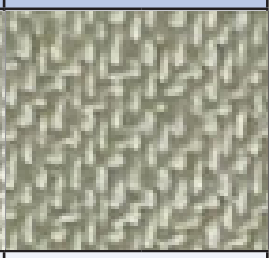
In this study, 98/2 % Wool/Lycra and 88/8/4 % Wool/PA6.6/Lycra blend fabrics were used (Figure 1-3). The properties of the wool fabrics are mentioned in Table 1.

Figure 1: K1

Figure 2: K2

Figure 3: K3

Table 1: The properties of the wool fabrics used in this study

Fabric code	K1		K2		K3	
Weave and sample image						
Weave type	2/2 Hopsack (or basket)		Plain		2/2 Twill	
Fabric blend	%98 Wo %2 Lycra		%88 Wo %8 PA6.6 %4 Lycra		%100 Wool	
Width (excluding edges) (cm)	150 ±2		148 ±2		150 ±2	
weight (g/m^2)	215 ±10g		185 ±10g		275 ±10g	
	Warp	Weft	Warp	Weft	Warp	Weft
Yarn blend (%)	Wool	Wo/Lycra	Wool/ PA6.6/Lycra	Wool /PA6.6/ Lycra	Wool	Wool
Yarn number (Nm)	70/2	72/2	72/2	72/2	80/2	40/1
Ends/10cm	260 ±10	280 ±10	230 ±10	215 ±10	320 ±10	310 ±10

Digital printing process applied to Woolen Fabrics

The flow chart of the preliminary finish process before printing applied on woolen fabrics is given in Figure 4.

Figure 4: The flow chart of the digital textile printing process for woolen fabrics

Preliminary finish processes applied to wool fabrics before printing

The woolen fabrics were pre-treated in the woolen finishing mill, with the detailed process conditions given in Table 2. The washing process was carried out at 70°C in order to remove the blending and twisting oils, which must be used in the wool worsted yarn production process, and the wax and sizing materials used in the warp unwinding process, from the fabric surface before the printing processes. In order to balance the internal tensions of the fabric during weaving, the crabbing process was carried out at 95°C.

In addition, due to the nature of the wool fiber, the fluffs on the fabric surface are considerably more than other synthetic and cotton fibers. These fluffs on the surface were removed by burning with the gause process and washing before the printing process. Especially with the tweezers process, which is a standard process in almost all woolen fabrics, physical yarn defects such as large neps, mechanical knots, and fish on the fabric surface that can reduce the print quality were removed from the fabric surface.

Then, a shearing process was reapplied to minimize the fluffs remaining on the fabric surface and bring them to the standard length all over the fabric. Since both fabrics contain lycra, the fixing process of lycra was carried out in a stenter machine at 190°C. Finally, in order to ensure dimensional stability in the fabrics, the decaturing process, which is specific to the wool fiber, was performed and the fabrics were made ready for the printing process by obtaining the desired touch and brightness.

Table 2: Finishing preparation processes before the digital printing

Processes	Aim	Process conditions (Speed, temperature, chemicals g/L)
Washing	The aim of washing is to remove the contaminants from the wool fabric and to relax the fabric	70°C, 20m/min, soap 1.5g/L
Crabbing	A pre-setting process used to apply the required amount of flat set in wool fabrics	95°C - 100°C, 15m/min
Drying	The removal of adsorbed water from wool fabric.	110°C, 40m/min
Singeing	Singeing removes protruding fibers from the fabric surface by burning them, leaving the fabric smooth and bare	90m/min
Washing	After the singeing, the aim of washing is to remove the burned fibers from the fabric surface	With water (no chemicals, room temperature sıcaklığı)
Washing	The removal of adsorbed water from wool fabric	110°C, 40m/min
Mending	It is the process of correcting the yarn and weaving faults in the fabric with a special needle and tweezers	
Shearing	It is the process of cutting long hairs on the fabric surface	
Lycra setting	Providing lycra stability with stenter machine	190°C 24m/min
Decatising (Decofast)	A pre-setting process is used to stabilize the properties of wool fabrics developed during the finishing	
Decatising (Pressure decatising)	A final-setting process is used to stabilize the properties of wool fabrics developed the during finishing	1.2 bar

The pre-treatment process in the printing

Before starting the printing process in special printing machines, all fabrics were cleared from all impurities in order not to have any issues later on. Besides, the fabrics were hydrophilized, flattened, and dimensionally stabilized. After all these requirements were provided, in order to make the fabrics ready for digital printing, the pre-treatment processes, which are mentioned in Table 3, were carried out. The digital printing machine with brand Robustelli Monna Lisa was used in this study with 80m/h speed, temperature, and %65 Rh condition (Figure 5).

Table 3: The pre-treatment chemicals before the digital printing

Component	(g/L)
Deionized water	794
Urea	80
Ammonium sulfate	40
Thickener	80
Wetting agent	1
Leveling agent	5
TOTAL	1000

Figure 5: Shown from different angles Robustelli Monna Lisa Digital Printing Machine

Digital Printing Process

In this study, Epson GENESTA ® AC series acid dyestuffs were used for the printing process. Acid dyestuffs, the general formulas of which can be written as BM- SO3-Na+ (BM: dyestuff), include one or more (-SO3H) sulfonic acid groups or (-COOH) carboxylic acid groups in their molecules. These dyestuffs are used to dye protein fibers (and nylon) composed of proteins with -NH2 amino groups [11].

The general structure of acid dyestuffs is given in Figure 6. [12]

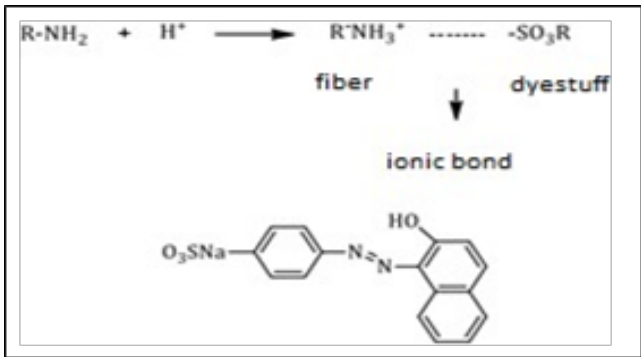


Figure 6: The general structure of acid dyestuffs [11]

After-printing processes applied to fabrics in the printing department

After the digital printing process was applied to the fabrics, the drying, steaming, and washing processes detailed in Table 4 were carried out respectively. The paint sprayed on the fabric surface was dried at 100°C and fixed at 102°C in order to bind the paint to the fiber. Then, cold washing, hot washing with mild alkaline, cold rinsing, and drying processes were applied.

Table 4: The processes after digital printing

Processes	Process conditions
Drying (dye)	100°C
Steaming (dye fixation)	102°C 40 min
1. washing tank	25°C water
2. washing tank	25°C 2g/L soap solution
3. washing tank	25°C 2g/L soap solution
4. washing tank	50°C water
5. washing tank	Rinse in cold water
Drying (fabric)	110°C

Fastness and physical performance tests applied to the fabrics

Washing fastnesses of the printed samples were made in a washing fastness tester (Gyrowash- James H. Heal) following ISO 105-C06 standards. The samples were evaluated with a grayscale after they were treated in a Gyrowash Washer Tester device for 30 minutes at 40°C at a 1/100 liquor ratio from the ECE detergent solution, which was prepared to be 4 g/L.

Acid-alkali and water fastnesses were made according to ISO 105-E04 and ISO 105-E04 standards, respectively. The color change of the samples was evaluated according to ISO105-A02 and the contamination was evaluated with grayscale according to ISO105-A03 and acid-alkali and water fastness values were determined.

ISO 105-D01 standard was used for dry cleaning fastness; color change and staining of the accompanying cloth were evaluated according to ISO 105-A02 and ISO 105-A03.

Rubbing fastnesses were tested in the Crockmeter test device according to ISO 105-X12:2016 and wet and dry staining fastness values were determined via grayscale.

Tearing strength and seam slippage tests were performed on the TITAN 5 Universal Strenght Tester, and abrasion resistance and pilling tests were performed on the MARTINDALE Abrasion and Pilling test device.

The fastness tests and standards, and the physical performance tests and standards applied to the fabrics used in the study are given in Table 5 and Table 6, respectively.

Table 5: Fabcolour fastness tests and standards

Tests	Test standard	Acceptance criteria
Dry Cleaning	ISO 105-D01	4
Water	ISO 105-E01	4
Perspiration- alkali	ISO 105 E04:1996	3/4
Perspiration - acid	ISO 105 E04:1996	3/4
Rubbing fastness-dry	ISO 105 X12:1995	4
Rubbing fastness-wet	ISO 105 X12:1996	3-3/4*
* It changes depending on the color. Dark colors 3, light colors 3/4		

Table 6: Fabric physical tests and standards and minimum acceptance criteria

Tests		Test standard	B	P	D
Tensile strength (kgf)	warp	ISO13934-1	min.18	min.25	min.25
Tensile strength (kgf)	weft	ISO13934-1	min.18	min.15	min.25
Tearing strength (gf)	warp	ISO13937-2	min.1200	min.1200	min.1100
Tearing strength (gf)	weft	ISO13937-2	min.1200	min.1200	min.1100
Seam slippage (kgf)	warp	ISO13936-1	min.12	min.10	min.12
Seam slippage (kgf)	weft	ISO13936-1	min.12	min.10	min.12
Pilling Martindale	-	ISO 12945-2	min.3/4	min.3/4	min.3/4
Abrasion Resistance (cycle)	-	ISO 12947-2	min.10000	10.000	10.000

Results

The changes in physical and fastness values after the digital printing on the woolen fabrics with different weave and blending ratios are given below comparatively. The characteristics of patterning, blending ratios and weaving structure are also mentioned.

The fastness test results of the fabrics after printing

The results of the fastness tests of prints made on K1 in Table 7, K2 in Table 8, and K3 in Table 9 are given in comparison with acceptable test values before printing (Table 5).

Table 7: Comparison of colorfastness tests of the K1 weave fabrics

Tests		Dry Cleaning	Water	Perspiration-alkali	Perspiration-acid	Rubbing fastness-dry	Rubbing fastness-wet
Test Standards		ISO 105-D01	ISO 105-E01	ISO 105 E04:1996	ISO 105 E04:1996	ISO 105 X12:1995	ISO 105 X12:1996
Acceptance criteria		4	4	3/4	3/4	4	3-3/4*
K1- Flower pattern	Color Change	4/5	4/5	4/5	4/5		
	Staining	4/5	4/5	4/5	4/5	4/5	4
K2- Checked pattern	Color change	4/5	4/5	4/5	4/5		
	Staining	2/3	2/3	2/3	2/3	4	3/4
* It changes depending on the color. Dark colors 3, light colors 3/4							

When the results of the color change and dyeing fastness of K1 woven fabrics with 88/8/4% wool/nylon/lycra content are examined in Table 7, it is seen that the fastness values of the fabrics colored with digital printing are at a positive and acceptable level. The dark or light colors of the digital printing did not have a negative effect on the fastness test results.

Table 8: Comparison of colorfastness tests of the K2 weave fabrics

Tests		Dry Cleaning	Water	Perspiration-alkali	Perspiration-acid	Rubbing fastness-dry	Rubbing fastness- wet
Test Standards		ISO 105-D01	ISO 105-E01	ISO 105 E04:1996	ISO 105 E04:1996	ISO 105 X12:1995	ISO 105 X12:1996
Acceptance criteria		4	4	3/4	3/4	4	3-3/4*
K2A Narrow stripe pattern-warp direction	Color change	4/5	4/5	4/5	4/5		
	Staining	4/5	4	4	4	4	3
K2B Vertical wide stripe pattern-warp direction	Color change	4/5	4/5	4/5	4/5		
	Staining	4/5	4/5	4/5	4/5	4/5	4
K2C Horizontal stripe pattern-weft direction	Color change	4/5	4/5	4/5	4/5		
	Staining	4	4/5	4/5	4/5	4	3/4
K2D Leopard pattern	Color change	4/5	4/5	4/5	4/5		
	Staining	4/5	4/5	4	4/5	4/5	4
K2F- Flower pattern	Color change	4/5	4/5	4/5	4/5		
	Staining	4/5	4/5	4/5	4/5	4/5	4/5
K2G- Special pattern	Color change	4/5	4/5	4/5	4/5		
	Staining	4/5	4/5	4/5	4/5	4/5	4/5
* It changes depending on the color. Dark colors 3, light colors ¾							

When the results of the fastness values of the lycra-containing woolen K2 weave pattern fabrics are examined in Table 8, it has been seen that the fastness values of the fabrics colored with digital printing are positive and acceptable. When the digital printing results are evaluated, the color change of striped patterns in dark colors is lower than in other intense patterns. However, improvements in colorfastness were observed in light color patterns. Colorfastness values of dark patterns such as flower (K2D), leopard (K2E), and special pattern (K2F) are better

Table 9: Comparison of colorfastness tests of the T-Twill weave fabrics

Tests			Dry Cleaning	Water alkali	Perspiratio acid	Rubbing fastness-dry	Rubbing fastness-wet
Test Standards		ISO 105-D01	ISO 105-E01	ISO 105 E04:1996	ISO 105 E04:1996	ISO 105 X12:1995	ISO 105 X12:1996
Acceptance criteria		4	4	3/4	3/4	4	3-3/4*
K3- Spotted pattern	Color change	4/5	4/5	4/5	4/5	4/5	4
	Staining	4/5	4	4/5	4/5	4/5	4/5
K3- Checked pattern	Color change	4/5	4/5	4/5	4/5	4/5	4/5
	Staining	4	3	3	3	4	2
* It changes depending on the color. Dark colors 3, light colors 3/4							

When the fastness values of 100% Wool 2/2 twill (K3) fabrics are examined in Table 9, it is seen that the color change and staining fastness values in the K3-spotted pattern are acceptable. However, although the color change fastness values are quite good, the staining fastness values are close to the acceptable values for the K3-checked pattern[12-15].

Physical performance test results on fabrics before and after printing

As a result of the study, the physical test evaluation results of the plain K1 fabric are given in Table 10, the physical test evaluation results of the K2 fabric are shown in Table 11, and the physical test evaluation results of the K3 fabric are given in Table 12.

Table 10: Physical Test Values of the K1 Fabric

Tests		Standards	Acceptance criteria	K1
Tensile strength (kgf)	Warp	ISO13934-1	min.25	44.7
Tensile strength (kgf)	Weft	ISO13934-1	min.15	14.6
Tearing strength (gf)	Warp	ISO13937-2	min.1200	2.465
Tearing strength (gf)	Weft	ISO13937-2	min.1200	1.239
Pilling Martindale	-	ISO 12945-2	min.3/4	4/5
Abrasion Resistance (cycle)	-	ISO 12947-2	10.000	10.000

The results of the physical properties of K1 fabrics after digital printing were evaluated according to Table 10. There is an increase in the breaking strength in the warp direction compared to the raw fabric. In the weft direction, the breaking strength remained within the limits. There was an increase in weft and warp directions for tear strength. Seam slippage and abrasion resistance values remained within the limits and did not show any significant change. Pilling values, on the other hand, increased.

Table 11: Physical Test Values of the K2 Fabric

Tests		Standards	Acceptance criteria	K2A-Striped	K2B-Striped	K2C-Striped	K2D-Leopard
Tensile strength (kgf)	Warp	ISO13934-1	min.18	31.5	30.6	31.0	24.9
Tensile strength (kgf)	Weft	ISO13934-1	min.18	29.5	25.5	29.0	22.1
Tearing strength (gf)	Warp	ISO13937-2	min.1200	1.734	1.683	1.710	1.332
Tearing strength (gf)	Weft	ISO13937-2	min.1200	1.650	1.479	1.230	1.397
Pilling Martindale		ISO 12945-2	min.3/4	5	5	5	5
Abrasion Resistance (cycle)		ISO 12947-2	min.10000	12.000	12.000	12.000	12.000

The results of the physical properties of K2 fabrics after digital patterning were evaluated according to Table 11. Compared to the raw fabric, the increase in breaking strengths in the warp and weft directions is higher, except for leopard patterning. It is seen that the increase in breaking strength in front of the warp for leopard patterning is above the limits compared to the raw fabric. An increase in tear strength was observed in the weft and warp directions. There was an increase in seam opening and abrasion resistance and pilling values. The reason for this is considered to be the contribution of the polyamide fibers in the content of the fabric. It is also considered that the pattern structure of the fabrics has regular and homogeneous transitions.

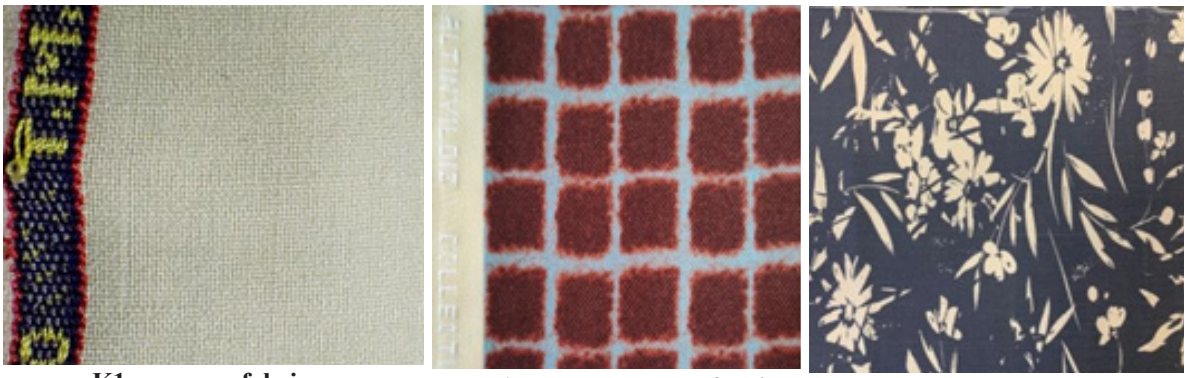
Table 12: Physical Test Values of the K3 Fabric

Tests		Standards	Acceptance criteria	K3
Tensile strength (kgf)	Warp	ISO13934-1	min.25	38.1
Tensile strength (kgf)	Weft	ISO13934-1	min.25	30.2
Tearing strength (gf)	Warp	ISO13937-2	min.1100	1.348
Tearing strength (gf)	Weft	ISO13937-2	min.1100	1.085
Seam slippage (kgf)	Warp	ISO13936-1	min.12	20.5
Seam slippage (kgf)	Weft	ISO13936-1	min.12	20.5
Pilling Martindale	-	ISO 12945-2	min.3/4	4/5
Abrasion Resistance (cycle)	-	ISO 12947-2	10.000	13.000

After the digital printing of K3 fabrics, the results of the physical properties showed an increase in the physical test performances in the warp and weft direction compared to the raw fabric. The digital printing content has a positive effect on the physical performance of 100% wool fabrics and has increased the usability life in fabric structures [16].

Visual results of fabrics patterned with digital printing

In this project, which we realized with the theme of "The rebirth of wool", we reflected different surface designs, that could not be produced with classical dobby looms, with the printing patterning technique on wool and wool/nylon fabrics. The printing patterns we used in this study are shown in Figures 6-8.



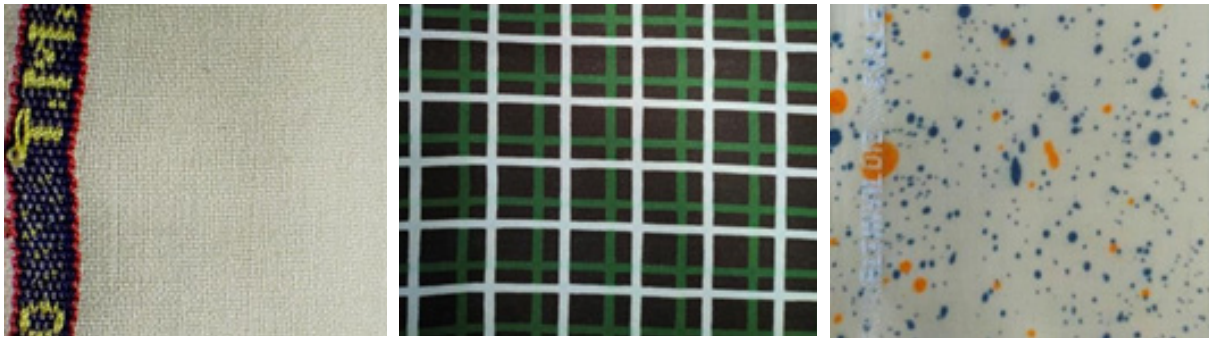
K1 ecru raw fabric | K1 check patterned fabric | K1 special patterning

Figure 6: Images of K1 wool fabric with the printing process

K2 Raw Wool fabric | K2 longitudinal wide line patterning | K2 cross dashed line patterning

K2 leopard patterning | K2 floral pattern | K2 special patterning

Figure 7: Images of K2 wool fabric with the printing process



K3 Raw Wool fabric | K2 floral pattern | K3 spotted patterning

Figure 8: Images of K3 wool fabric with the printing process

In this study, in which digital printing techniques and acid dyestuffs, and print quality of wool and wool/polyamide fabrics were investigated, “line”, “flower”, “plaid”, animal pelt" and "special" patterns were used. In the patterning, the inspirations of nature were handled and reflected in the patterns. Depending on the structural properties of the fabrics, it has been observed that the digital printing methods made with acid dyestuffs reflect bright, vivid, and clear visual contents [16-17].

Conclusions

In this study, in which digital printing technique, acid dyestuffs, and print quality of wool and wool/polyamide fabrics were investigated, "line pattern", "flower pattern", "checked pattern", "animal pelt pattern" with light and dark tones (different dye amounts) and special patterns were designed. Dry cleaning, water, perspiration-alkali, perspiration-acid, and rubbing fastnesses for both plain and hopsack weave and printed sample fabrics were in the range of values accepted by the industry. Although there was a problem in all fastness values only K2 patterns and K3 patterns, it was thought that the high amount of red and green dyes used in these patterns affect this. In addition, the values obtained from the physical performance tests of the printed sample fabric made in all three weaving types remained within the general test acceptance criteria [18].

When both fastness and performance test results were evaluated in general, it was determined that the printing process was effective on wool and wool/nylon fabrics, but the effect was limited. It has been concluded that "printing with digital acid dyestuffs" is applicable for wool and wool/nylon fabrics as well.

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