Journal of the Advances in Agricultural Researches (JAAR) Volume: 29 (4)

Impact of Dying Cotton Fibers before Spinning on The Resulting Yarn Mechanical Properties

Mashhout G. E. Beheary[1]; Ibrahim Abbas E. Ibrahim[1]; Suzan A. Sanad[2]; Eman Z. Btisha[3], Nashwa F.R.H.Taha[3]

1: Department of Plant Protection, Faculty of Agriculture (Saba Basha), Alexandria University, Egypt
2: Department of spinning Research - Agricultural Research Center - Giza - Egypt
3: Spinning and Staple Department - General Authority for Cotton Arbitration and Testing

DOI:10.21608/JALEXU.2024.321614.1228

Article Information

Received: September 20th 2024

Revised: September 25th 2024

Accepted: September 30th 2024

Published: December 31th 2024

ABSTRACT: This investigation was carried out at Faculty of Agriculture (Saba Basha), Alexandria University Egypt, in 2023 season. To evaluate mechanical properties of cotton fibers and the resulting yarns as affected by variety, dying fibers before spinning and their interaction. It was conducted in a completely randomized design (CRD) with three replicates. The main results:

- Super Giza 92 cotton variety recorded the highest averages for the yarn strength and elongation compared to the rest of the studied varieties.
- The blended yarn (50% raw cotton fibers + 50% dyed cotton fibers) recorded the highest mean values for of yarn strength and elongation, while the lowest values were recorded by the yarn made of raw fibers dyed after the spinning stage.
- Cotton variety super Giza 86 recorded the highest mean values for the characteristics of the yarn irregularity (evenness CV %, the number of thin, thick places and neps), but the highest value for the hairiness characteristic was observed from the extra Giza 92 cotton variety, while the lowest thin and thick places and degree of hairiness were recorded from the super Giza 94, while the lowest number of neps was recorded from the extra Giza 92.
- The highest values for the characteristics such as (evenness CV %, the number of thin, thick places, neps and degree of hairiness) were given from the yarn made from raw fibers dyed after the spinning stage. While, the lowest values of yarn evenness CV %, the number of thin, thick places, neps were verified from the raw yarn (without dying).

Keywords: ***cotton; varieties; dying; spinning; yarn; mechanical; physical.***

INTRODUCTION

Egyptian cotton is recognized as the best quality cotton, it is botanically known as *Gossypium barbadense* L. Despite Egypt's growing industrialization investments, the cotton, spinning, and weaving sectors remain critical to the country, accounting for a sizable amount of export figures and national returns.

Dying cotton fibers or yarns used in manufacturing improves the aesthetic appeal, color fastness, and general marketability of final textile items. Cotton, one of the most often used natural fibers in the textile industry, may be dyed to achieve a broad spectrum of brilliant colors and tints. Cotton spinning steps are critical in transforming raw cotton fibers into yarn, which may then be used to make various fabrics and garments.

These procedures include carding, drawing, and spinning, all of which serve to align the fibers, eliminate impurities, and twist them together to make yarns of different thickness and strength. This guarantees that the resulting textile items are both high quality and long-lasting. Different dyes can be used to color cotton products, including reactive, vat, Sulphur, azoic, basic, and natural dyes. Depending on their molecular structure, dye molecules adhere to the fiber by a variety of physical and chemical processes during dying. Over time, dying technologies and related apparatus have evolved to produce optimal dying of the textile products in diverse forms (**Dutta and Bansal 2020**). Dying is the technique of putting coloring matter directly to fiber, yarn, or cloth without using any additives. From antiquity until the eighteenth century, natural dyes were employed exclusively for textile coloring. Natural dyes are made from natural materials, as the name implies. Colorants derived from natural resources of plant, animal, mineral, and microbiological origin were utilized to color diverse textile fabrics. Today's dying technology is the most scientific and modern in the world. Coloration may be accomplished using a variety of methods. Colors are utilized both naturally and artificially. Dying is a process of adding beauty to textiles by applying various colors and tones to them. Dying can take place at any stage of the textile production process, including fiber, yarn, fabric, and finished textile products such as garments and clothing. Color fastness is determined by two factors: the choice of the appropriate dye for the textile material to be dyed and the procedure used to dye the fiber, yarn, or cloth **(Daberao *et al*., 2016).** The dying temperature and duration should be kept to a minimum. The effective spun length of fibers decreased with increasing dying temperature; increasing dying duration also reduced effective spun length marginally. Overall, raising dying time had a greater effect on yarn evenness than rising dying temperature. The hairiness was greater in samples obtained with increasing coloring time. Extending the dying temperature of the dye bath resulted in a higher short fiber index, and extending the dying duration increased it even more. Increasing dying time had no significant effect on the tensile qualities of mélange yarns. Tensile qualities as tenacity and elongation deteriorated significantly as the dying temperature increased (**Memon *et al*., 2015**).

Vadicherla and Saravanan (2014) stated that textile materials are being used at unprecedented rates due to the appearance, acceptability, and obsolescence of fast fashion. Also, **Karim *et al.* (2007)** discovered that rotor spun yarn lost much more mechanical properties than ring spun yarn. On the other hand, **Yan *et al.* (2015)** reviled an exponential link between entropy and bulk of yarns in theoretical deviations, with textured yarns having greater bulk and entropy than classical yarns. Furthermore, **Huang *et al.* (2010)** described dying techniques that are resistant to physical strength loss during dying. It is also environmentally benign since the cotton fibers are colored before spinning, which saves about 50% of water use compared to normal manufacturing. Less processing saves energy, lowers carbon footprint, and benefits the environment. It is also appealing and distinctive in appearance, with a wavy effect, making it the preferred choice of fashion fans and designers. The textiles are silky, lustrous, and have a glossy finish.

Therefore, the objective of this study was to investigate the influence of cotton variety, dying fibers before and after spinning stage on the mechanical and physical yarn properties.

MATERIALS AND METHODS

This study was carried out at Faculty of agriculture (Saba Basha), Alexandria University Egypt during 2023 season. The main purpose of this study is to evaluate mechanical properties of cotton fibers and cotton yarns as affected by variety, dying fibers and their interaction.

Three commercial Egyptian cotton varieties i.e. Extra Giza 96, Supper Giza 94 and Supper Giza 86were used in this study.

Cotton samples were optioned, dyed, and spun in **Filmar Nile Textile Company** in New Borg El- Arab industrial city, 4th Zone, Alexandria, Egypt.

Dying process:

The reactive dye has been used for dying both fibers and yarns. The dying process was done in **Filmer Nile Textile Company** using the shade **Ginestra7074, Which** we obtained by mixing both:

-3025 Gammazol Giallo Brill.4GL 200% 1.23300% 3.576 kg

-3046 Gammazol Golden Yellow RB 0.13600% 0.394 kg

The bulk fiber sample from each variety was divided into three categories as follows:

1- Raw cotton fibers.

2- Dyed cotton fibers.

3- Blending (50% / 50%) of raw and dyed cotton fibers.

A Technique based on the standard method designated by the ASTM standards (D-1441) and the British standards (B.S. Handbook No II), was applied to achieve proper sampling and blending.

Spinning process:

The fibers of the three categories of each cotton variety were carded and drawn and converted to roving by micro machines (Stirolap) and the spinning process was performed at (Mesdan) mini ring spinning frame with 6 spindles at 30 Ne count with spindle speed up to 18000 R.P.M. at the laboratory of **Filmar Nile Textile Company** in New Borg El- Arab industrial city, 4th Zone, Alexandria, Egypt.

Yarns forms:

1- Raw yarn (made out of a 100% raw cotton fibers), **(A).**

2- Dyed yarn (made out of 100% dyed cotton fibers), **(B).**

3- Blended yarn (50% raw and 50% dyed) cotton fibers, **(C).**

1- Dyed after spinning yarn: made of(100%raw cotton), **(D).**

Studied yarn characters:

A- **Yarn mechanical characters i.e.** Tenacity or breaking force in Newton (B-Force (N), the breaking length in Km (RKM), the work of rupture or the breaking work or in Cent/ Newton (B-Work (Cm/ N), time to break in seconds (s) and elongation (El.%) were determined using **UsterTenserapid** apparatus. Following the standard method of the ASTM D 2256– 97.

B- **Yarn physical properties i.e.** evenness C.V.%, thin places, thick places, neps and hairiness were measured using **Usetr Tester 4 (UT4)** apparatus. Following the standard method of the ASTM D 5867 – 12 (Reapproved 2020).

Statistical analysis:

The completely randomized design (CRD) with three replicates was used to outline this study. Collected data were statistically evaluated using the analysis of variance (ANOVA) method for the CRD as described in (**Gomez and Gomez, 1984)**. The differences between the treatment means were tested using the least significant difference (L.S.D.) method at the 5% level of probability. The **CoStat, 2005** program for windows was used to perform all data analysis.

RESULTS AND DISCUSSION:

A- Yarn mechanical properties:

Analysis of variance of the studied yarn mechanical characters i.e. tenacity or breaking Force in Newton (B-Force (N), the breaking length in Km (RKM), the work of rupture or the breaking Work in Cent/ Newton (B-Work (Cm/ N), time to break in seconds (s) and elongation (El.%), as affected by cotton variety, fiber dying and their interaction was shown in Table (1).

Table (1): Analysis of variance and mean of squares of the studied yarn mechanical characters as affected by cotton variety, dying and their interaction

S.O.V.	d.f.	Tenacity M.S.				
		B- Force	RKM	B-Work	Time to break	Elongation %
Variety (V)	2	0.255**	3.560**	1.135**	0.007**	0.364**
Dying (D)	3	2.041**	54.308**	9.349**	0.017**	4.473**
(V x D)	6	0.318**	6.726**	0.768**	0.009**	0.193**
Error	24	0.001	0.007	0.008	0.008	0.002
Total	35					

***** significant at 0.01 level of probability***

Data presented in Table (1), revealed that the cotton variety (V), dying process (D) and their interaction had highly significant effects on all studied yarn mechanical properties i.e., tenacity or B- Force (N), breaking length or (RKM), work of rupture or B- work (CmN), time to break (s) and elongation(%).

The varietal effect:

Mean values of the studied yarn mechanical characters as affected by the variety, dying and their interactions were shown in Tables (2). Data presented in the before mentioned Table, reveal highly significant differences between studied cotton varieties in all the yarn mechanical parameters i.e. B- Force (N), RKM, B- Work (CmN)}, Time to break (s) and El.(%).

Extra Giza 92 cotton variety recorded the greatest mean values of the single yarn tenacity or the B- Force (N), RKM, B-Work (Cm/ N), Time to break (s.) and El. %, while the Super Giza 94 gave the lowest mean values of B- Force (N) , RKM and B-Work (Cm/ N).

As for the Time to breaks (s.) and yarn elongation (%), the lowest mean values were recorded by the Super Giza 86.

Similar results were reported by **Hassan and Ibrahim (2018); Ibrahim (2018); El-Gedwy (2020; 2021) Nassar *et al.* (2021)** who stated that cotton varieties varied on all the studied characters, also they showed the correlation coefficients among three fiber properties and three fibers and yarn quality/technological properties.

Dying effect:

Mean values of the studied yarn mechanical characters as affected by the fiber dying process were presented in Table (2).

As for the fiber dying process effect, the highest mean values for single yarn tenacity or B-Force (3.87N), RKM (20.09), the work of rupture or B-Work (6.06 Cm/N) and Elongation%. (5.82%) were recorded by the blended (50% raw: 50% dyed) yarn. Meanwhile, the lowest mean values for the previously mentioned traits were attained by the dyed after spinning yarn.

Table (2): Mean values of the studied yarn mechanical characters as affected by cotton verity (V), dying (D) and their interaction

Treatments	Single yarn tenacity characters				
	B- Force (N)	**RKM**	**B-Work (Cm/N)**	**Time to break(s)**	**Elongation %**
Cotton variety (V)					
Extra Giza 92	3.57	18.49	5.18	0.339	5.70
Super Giza 94	3.30	17.43	4.60	0.332	5.43
Super Giza 86	3.51	18.17	4.72	0.325	5.37
LSD at 0.05 for Variety	0.03	0.07	0.07	0.002	0.04
Dying (D)					
Raw (100%)	3.85	20.04	5.97	0.367	5.46
Dye (100%)	3.18	16.86	5.45	0.329	4.49
Blended (50 %:50%)	3.87	20.09	6.06	0.360	5.82
Dyed after spinning	2.93	15.13	4.52	0.272	3.56
LSD at 0.05 for Dying	0.03	0.08	0.05	0.003	0.09
Interaction					
(V x D)		**	**	**	**

- ****, *= significant differences at probability levels of 0.01 and 0.05, respectively.**

Reprocessing of dyed fibers causes reduction in mean length, increase in short fibers and neps. Strength of fiber was reduced after dying (**Karim *et al*., 2007**; **Regar *et al*. 2017; Ray *et al.*, 2018a, b, c).**

In this trend, **Hanumanth Naik (2008); Huang *et al*. (2011)**; **Ashraf *et al*. (2014); Memon *et al*. (2015)**; **Baxramovna*et al.* (2021); Khazratova *et al*. (2023)** revealed that treating fiber or yarn of cotton by dying substances during any stages of spinning significantly affected quality fabrics/mechanical/ physical properties of cotton and reduced fiber damage.

The interaction:

It is worth to mention that the first order interaction (V x D) was highly significant for all the yarn mechanical characteristics (Table 2). Mean values of the studied yarn mechanical characters for the interaction between cotton verity and dying (V x D) are shown in Table (3). The highest mean value of the single yarn tenacity, B-Force (4.05N), was recorded by the raw (100%) spun yarn of the Super Giza 86 and the highest mean value (20.35) of RKM was attained by the blended (50% raw : 50% dyed) yarn of the same cotton variety. Meanwhile, the highest mean value of work of rupture, B-work (6.14 Cm/N)was gained from the blended (50% raw:50% dyed) yarn of the Extra Giza 92 cotton variety. The maximum time to break (0.370s) and elongation(6.14%) were possessed by the raw (100%) spun yarn of the same cotton variety Extra Giza 92.

Table (3): The interaction between variety and dying (V x D) on yarn characters.

Variety (V)	Dying (D)	Single yarn tenacity				
		B-Force (N)	**RKM**	**B. Work (Cm/N)**	**Time to break(s)**	**Elongation (%)**
Extra Giza 92	Raw (100%)	3.71	19.32	5.40	0.370	6.14
	Dyed (100%)	3.85	19.83	5.66	0.367	6.07
	Blended (50 %:50%)	3.84	19.83	6.14	0.350	6.06
	Dyed after spinning	2.88	14.99	3.52	0.270	4.53
Super Giza 94	Raw (100%)	3.78	19.62	5.49	0.370	5.95
	Dyed (100%)	2.73	15.20	3.91	0.310	5.15
	Blended (50 %:50%)	3.83	20.10	5.59	0.370	6.06
	Dyed after spinning	2.84	14.79	3.41	0.277	4.57
Super Giza 86	Raw (100%)	4.05	21.18	5.50	0.360	5.81
	Dyed (100%)	2.97	15.54	3.89	0.310	5.14
	Blended (50%:50%)	3.95	20.35	5.73	0.360	6.07
	Dyed after spinning	3.06	15.60	3.75	0.270	4.47
LSD at 0.05 for V x D		0.05	0.14		0.15	0.08

It could be concluded that the best yarn mechanical characters were attained by the blended (50% raw: 50% dyed) yarn of the Extra Giza 92 cotton variety.

B- Yarn physical properties:

The analysis of variance and mean of squares of the studied yarn physical properties as affected by the cotton variety, dying and their interaction are shown in Table (4).

Data presented in Table (4), revealed that the cotton variety (V), dying (D) and their interaction had highly significant effects on all studied yarn physical properties i.e. Evenness C.V.%, thin places, thick places, neps and hairiness.

Mean values of the studied yarn physical parameters as affected by the variety, dying and their interactions are shown in Table (5).

Table (4): Analysis of variance and mean of squares of Yarn physical properties of as affected by variety, dying and their interaction

		M.S.				
S.O.V.	**d.f.**	**Evenness C.V.**	**Thin places**	**Thick places**	**Neps**	**Hairiness**
Variety (V)	2	3.63**	3210.66**	121539.32**	878493.90**	0.939**
Dying (D)	3	77.13**	62954.67**	4421219.30**	4837118.40**	1.444**
V x D	6	8.74**	4078.99**	267728.54**	441520.39**	0.833**
Error	24	0.03	87.79	3058.72	915.26	0.003
Total	35					

***** significant at 0.01 level of probability***

The varietal effect:

Super Giza 86 gave the highest mean value of the yarn evenness. The lowest evenness C.V. 17.84%) was attained by the Extra Giza 92 cotton variety. Meanwhile, the highest mean values of the yarn imperfections i.e., thin places (83.97), thick places (995.17) and (1027.54), Neps were recorded by the Super Giza 86, but the highest mean value (4.55) of Hairiness was obtained by the Extra Giza 92 cotton variety, as shown in Table (5). The minimum values of thin places, thick places and hairiness were recorded by the Super Giza 94 and the lowest mean value of neps was recorded by the Extra Giza 92 cotton variety.

The pervious results were confirmed by **Ibrahim (2018), El-Gedwy (2020; 2021), and Nassar *et al.* (2021)**who indicated that there were significant differences among cotton varieties on all of the studied characters, as well as correlation coefficients between three fiber properties and three fibers and yarn quality/technological properties.

Table (5): Mean values of Yarn physical properties as affected by cotton verity, dying and their interaction.

Treatments	**Evenness C.V.%**	**Thin places**	**Thick places**	**Neps**	**Hairiness**
		Variety (V)			
Extra Giza 92	17.84c	75.49 b	843.04 b	556.75 b	4.55 a
Super Giza 94	18.41b	52.38 c	805.00 b	1023.13 a	4.00 c
Super Giza 86	18.94a	83.97 a	995.19 a	1027.54 a	4.38 b
L.S.D. at 0.05 for Variety	0.13	7.89	46.60	25.49	0.02
		Dying (D)			
Raw (100%)	16.03 d	10.44 c	328.83 d	253.78 d	4.30 b
Dye (100%)	18.98 b	70.16 b	945.34 b	1176.44 b	3.89 d
Blended (50 %:50%)	16.26 c	12.81 c	402.03 c	284.33 c	4.20 c
Dyed after spinning	22.30 a	189.03 a	1848.11 a	1762.00 a	4.85 a
L.S.D. at 0.05 for Dying	0.15	9.12	53.81	29.43	0.02
(V x D)	**	**	**	**	**

- If the mean value (s) in a column has the same letter, it indicates that there was no significant difference between the treatments (s).
- **, *= significant differences at probability levels of 0.01 and 0.05, respectively.

Dying effect:

For the dying effect on the yarn, the greatest mean value for the yarn evenness (lowest evenness C.V. 16.03 %) was recorded by the raw (100%) yarn, while the highest mean values of evenness C.V.(22.30 %),thin places (189.03), thick places (1848.11), neps (1762.00), and hairiness (4.85)it were attained by the dyed after spinning yarn. The lowest mean values for the yarn imperfections i.e. thin places, thick places, and neps it attained by the raw (100%) spun yarn.

Reprocessing colored fibers reduces mean length while increasing short fibers and neps. Dying reduces fibre strength .

Hanumanth Naik (2008); Huang et al. (2011); Ashraf et al. (2014); Memon et al. (2015); Baxramovna et al.(2021); and Khazratova et al. (2023) they all stated that dying cotton fibers or yarns during the spinning process resulted in high-quality fabrics/mechanical/physical properties of cotton and reduced fiber damage.

The interaction:

It is worth to mention that the interaction between variety and dying (V x D) was significant for all studied physical yarn characteristics as shown in Table (5). The interaction between variety and dying (V x D) for all studied physical yarn characteristics is presented in Table (6).

Table (6): The interaction between cotton verity and dying (V x D) on yarn physical properties.

Variety (V)	Dying (D)	Evenness C.V.%	Thin places	Thick places	Neps	Hairiness
Extra Giza 92	**Raw (100%)**	15.84	17.00	326.50	227.17	4.33
	Dyed (100%)	15.67	27.17	448.67	238.33	4.07
	Blended (50 %:50%)	16.24	15.50	436.00	270.50	4.27
	Dyed after spinning	23.60	242.27	2161.00	1491.00	5.52
Super Giza 94	**Raw (100%)**	16.01	5.00	321.67	260.83	4.26
	Dyed (100%)	20.36	70.00	1091.67	1600.00	3.85
	Blended (50 %:50%)	16.17	5.00	281.67	225.00	4.25
	Dyed after spinning	21.10	129.50	1525.00	2006.67	3.64
Super Giza 86	**Raw (100%)**	16.24	9.33	338.33	273.33	4.30
	Dyed (100%)	20.19	113.30	1295.67	1691.00	3.74
	Blended (50 %:50%)	16.39	17.93	488.43	357.50	4.09
	Dyed after spinning	22.20	195.33	1858.33	1788.33	5.39
L.S.D. at 0.05 for (V x D)		0.27	15.79	93.20	50.98	0.03

The dyed (100%) spun yarn of Extra Giza 92attained the lowest mean value(15.67%) of yarn Evenness C.V. and recorded the highest yarn evenness among all treatments. Meanwhile, the raw (100%) spun yarn gained the lowest mean values of yarn imperfections5.00, 321.67and 620.83 of %, for thin places, thick places and neps, respectively.

The highest mean values of yarn Evenness C.V. (23.60%), Thin places(242.27), Thick places(2161.00), and Hairiness(5.52) were recoreded by the dyed after spinning yarn of the Extra Giza 92 cotton variety, meanwhile the highest mean value of neps (2006.67) was recorded for the dyed after spinning yarn of Super Giza 94.

It could be concluded that the raw (100%) spun yarn of Super Giza 94 attained the best yarn physical properties, the lowest mean values of the yarn Evenness C.V. % and imperfections, i.e. thin places, thick places and neps.

CONCLUSION:

The attained results revealed highly significant differences in all studied yarn mechanical and physical properties among the three investigated cotton cultivars. As for the fiber dying process effect, the highest mean values for single yarn tenacity, B-Force, RKM, B-Work and El.% were recorded by the blended (50% raw: 50% dyed) yarn. The best yarn mechanical characters were attained by the blended (50% raw: 50% dyed) yarn.

The raw (100%) spun yarn recorded the best yarn physical properties, the lowest mean values of the yarn Evenness C.V. % and imperfections, i.e. thin places, thick places and neps.

In comparison to the other varieties, the Extra Giza 92 variety responded better to dying techniques.

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الملخص العربي

تأثير صباغة ألياف القطن قبل الغزل على الخواص الميكانيكية للخيط الناتج

مشحوت جناب اسماعيل بحيري[1] ، ابراهيم عباس السيد ابراهيم[1] ، سوزان الحسينى سند[2] ، ايمان زكريا بطيشة[3] ، نشوه فؤاد رمضان حسن طه[3]

1 قسم الإنتاج النباتي – كلية الزراعة سابا باشا – جامعة الإسكندرية

2 قسم بحوث الغزل– مركز البحوث الزراعية – الجيزة – مصر

3 قسم الغزل والتيلة – الهيئة العامة للتحكيم واختبارات القطن

اجرى هذا البحث بكلية الزراعة (سابا باشا) جامعة الاسكندرية،,خلال موسم 2023,الهدفالرئيسى لهذه الدراسة هو تقييم الخواص الميكانيكية لشعيرات القطن والخيط الناتج وتاثير الصنف وصباغة الألياف قبل الغزل والتفاعل بينهما. تم تنفيذ هذا البحث بتصميم تام العشوائية (CRD) مع ثلاث مكررات.

ويمكن تلخيص النتائج فيما يلي:

- سجل صنف القطن سوبر جيزة 92 أعلى متوسطات لمؤشرات متانة واستطالة الخيط بالمقارنة بباقى الاصناف المدروسة.
- وسجل الخيط المخلوط بنسبة (50 % الياف قطن خام + 50 % الياف قطن مصبوغة) اعلى القيم لمعظم مؤشرات متانة وإستطالة الخيط، بينما اقل القيم سجلت من الخيط المصنوع من الياف خام وتم صباغتة بعد مرحلة الغزل النهائى.
- سجل صنف القطن سوبرجيزة 86 أعلى القيم لصفات عدم انتظامية الخيط (معامل اختلاف الانتظامية، عدد المناطق الرفيعة والسميكة وعدد العقد) ، ولكن أعلى قيمة لصفة درجة التشعير فى الخيط سجلت من صنف القطن اكسترا جيزة 92، بينما اقل عدد مناطق رفيعة وسميكة ودرجة تشعير فى الخيط سجلت من صنف القطن سوبرجيزة 94، بيتما اقل عدد عقد سجلت من صنف إكسترا جيزة 92.
- سجلت اعلى القيم لصفات عدم إنتظامية الحيط (معامل اختلاف الانتظامية، ، عدد المناطق الرفيعة والسميكة والعقد، ودرجة التشعير) من الخيط المصنوع من الياف خام وتم صباغتة بعد مرحلة الغزل. اما اقل معامل اختلاف لإنتظامية الخيط، وعدد مناطق الرفيعة والسميكة وعدد العقد سجلت من الخيط الخام (بدون صباغة).