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Flame Resistance and Natural Dyeing Cotton Fabrics Using Plant Waste of Banana Pseudo stem (BPS)

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(REFEREED RESEARCH)

Abstract

The present study has demonstrated the flame retardancy effect of the Banana pseudo stem (BPS) as plant wastes at different concentrations on bleached and mercerized Egyptian cotton fabric made of Giza 90. Alkaline method was used to produce the extract BPS. The cotton fabric after the treatment was found to produce stable natural semi-yellow color. Flame retardant properties of both the untreated and the treated cotton fabrics were analyzed in terms of limiting oxygen index (LOI), and horizontal and vertical flammability. The results revealed that the treated mercerized cotton fabrics were found to have good flame retardant properties of LOI at SAP concentration of 10% compared to the bleached and control fabrics. In the vertical flammability test, the mercerized treated fabric showed flame for a few seconds and then, got extinguished. In the horizontal flammability test, the treated fabric showed no flame but was burning with a propagation rate of 7.5 mm/min, which was almost 10 times lower than that noted with the control fabric, and there was no significant degradation in mechanical strengths. Based on the results, the mechanism of imparting flame retardancy to cotton samples and the formation of natural color on it using the proposed BPS treatment have been postulated.

Keywords: Egyptian cotton, fire retardant, eco-friendly, plant waste, Banana Pseudo stem Sap (BPS)

INTRODUCTION

Egypt is the largest producer in Africa and worldwide of long (LS) and extra-long staple (ELS) cotton varieties [1]. Petrilli, pointed out that Cotton is 100% cellulosic in nature, catches flame readily and it is quite difficult to extinguish the same, resulting in serious health risks and damage to textile products, [2]. The application of flame retardant products on cotton is an important textile issue, especially for the protection of consumers in the military and the airline industry, [3]. Many researches have been made to improve the flame retardant property of cotton textile using various synthetic chemicals. The more effective fire-retardant chemicals available in the market are inorganic salts, borax, and boric acid mixture, di-ammonium phosphate, urea, etc [4]. When such formulations are applied to cotton fabric, its tear and tensile strengths are reduced, and the fabric becomes stiff as it's applied in acidic conditions. Besides, the treatment is toxic, hazardous, expensive, and also time-consuming due to the involvement of high quantity chemicals and high temperature curing processes [5]. Development of ecofriendly natural products fire retardant is still under investigation, and a challenge for the researchers. To maintain cotton fabrics quality to a great extent, there is the need to develop more cost-effective, natural, environmentally friendly, and sustainable fire-retardant products. To prevent the quantity of formaldehyde released from fire retardant fabric, Butane tetracarboxylic acid (BTCA) binding formulation was used [6]. Recently, polycarboxylic acid and ZnO nanoparticles were used to make environmentally-friendly fire-retardant cotton fabric [7]. Fire retardant was produced from natural products such as natural dyes for coloration, and enzymes for bio-polishing [8]. Neem and aloe vera is getting attention in research and development [9]. Due to recent awareness about human health and hygiene, very few researches have been reported regarding the fire retardancy of cellulosic fabric using bio-macromolecules. The main target of present study made to provide the flame retardancy and natural dye to cellulosic cotton textiles by using banana pseudo stem sap (BPS), a plant waste extract as it contains phosphorous, nitrogen, chlorine and other metallic constituents. According to the official report issued by the Ministry of Agriculture and Land Reclamation represented in the Central Administration of Horticulture, the annual cultivated area from banana plant in Egypt was about 1800000 feddans in 2018 and it gave about 20 tons per Fadden. Banana waste materials are rich in nutrients and minerals, [10]. According to our previous work, the alkaline fractions of banana peel (Musa, cv. Cavendish) of fruits have been used as a natural dye for cotton fabrics. In our study, banana peel was evaluated as a multi-functional antibacterial and UV protective agent on the cotton substrate, [11]. Banana peel can also be used in wine [12], ethanol production [13], as substrate for biogas production [14], and as the base material for pectin extraction. Peel ash can be used as fertilizer for banana plants and as the source of alkali for soap production [15]. Ethanol extract of Banana peels can be used as an inhibitor for mild steel corrosion [16]. Banana peel can also be used in wastewater treatment plants [17]. Our previous work also aimed to use the extracted solution from banana leaves as a natural waste source to dye some Egyptian cotton fabrics. Both alkaline and acetone extracted solutions were analyzed by high-performance thin-layer chromatography (HPTLC) analysis technique, [18]. The application of Banana pseudo stem sap (BPS) in cotton textile for coloration and functionalization will give the advantages of value addition using natural products. It is also eco-friendly and produced from renewable sources. Chips, fig, ready-to-serve drink, flour, jam, confections, dehydrated slices, and pickles and various products such as Paper board, tissue paper, etc., can be made and prepared from Banana pseudo stem sap (BPS). Due to its higher specific strength modulus and lower strain at break, Banana pseudo stem sap (BPS) fibers can be used as natural sorbent, bio-remediation agent for bacteria in natural water purifier, for mushroom production, in handicrafts and textiles when mixed with paddy straw. It is also used in production of marine cordages, high quality paper cardboards, tea bags, string thread, high quality fabric material, paper for currency notes, and good rope for tying purposes [19]. Lectins found in Banana pseudo stem sap (BPS) possessing antimicrobial properties [20]. Banana pseudo stem sap (BPS) can be recycled to be used as bio-fertilizer [21], and as color absorbent from wastewater containing textile dyes [22]. Flame retardancy was imparted in cellulosic cotton textile using Banana pseudo stem sap (BPS), an eco-friendly natural product. The extracted Banana pseudo stem sap (BPS) was made alkaline and applied in pre-mordanted bleached and mercerized cotton fabrics [23]. Fang et al, studied that the flame resistance of cotton fabric was greatly enhanced by a novel reactive flame retardant with serrated structure, ammonium salt of 1,3-diaminopropane tetra-(methylenephosphonic acid) (ADDTMPA), and the softness of cotton fabric was retained very well [24]. In the present study, the effect of Banana pseudo stem sap (BPS) on the cotton textile with regard to assessment of flammability, coloration and mechanical properties have been extensively investigated and characterized as it contains phosphorous, nitrogen, chlorine and other metallic constituents.

MATERIALS AND METHODS

Materials

1- The fabric samples used in this investigation were long sable Egyptian cotton scoured plain weaved of Giza 90 purchased from Misr-El-Mehala Company for Spinning and Textile-Egypt. The cotton fabrics had the following specification: yarn count: 38 x 40 tex; weight: 150 g/m^2. Specimens of size of 40 cm x 40 cm were used.

2- Banana pseudo stem sap (BPS) plant waste was obtained from the research farm, Faculty agricultural, Cairo University, and used as an eco-friendly natural dye and fire retardant.

3- All chemicals used were of analytical grade using doubly distilled water.

Methods

1- Bleaching of the cotton fabrics was carried out according to our previous work, [25].

2- The bleached samples were immersed in 20% aqueous sodium hydroxide for two minutes at room temperature. Treatment was carried out in the slack state of fabrics and then washed with tap water, neutralized with an aqueous solution containing 0.1% acetic acid followed by washing with hot water to ensure removal of residual chemicals. Finally, Samples were air-dried

3- The treated cotton fabric samples were pre-mordanting with both 0.2 g/l tannic acid and alum at goods to liquor ratio 1:40 for 10 min at room temperature. The samples were then dried in the oven at 130°C, for 5 min.

4- The dirt and impurities attached to BPS were removed using tap water and detergent, filtered, washed successively with tap water, and left to dry. Then, BPS was cut into small sizes, ground in a Wiley mill, and the powder produced was treated with 1N Na_2CO_3 for one hour at a temperature of 60˚C.

5- The bleached and mercerized fabrics treated with pre-mordanting with both 0.2 g/l tannic acid and alum were dipped in four different concentrations (2.5, 5, 7.5, and 10%) with the BPS extract for 30 minutes, then, dried at 110˚C for 10 min. and finally cured at 150˚C for 3 min.

Evaluation tests

Determination of add-on%

The treated cotton fabric samples were conditioned at 65% RH and 27ºC for 48 h. The increase in the sample weight relative to the original weight was determined after the application of the BPS using the gravimetric method as follows:

$$\text{Add-on (\%)} = \frac{[(M2-M1)]}{M1} \times 100$$

Where M1 and M2 are the oven-dried weights of the control and the BPS treated samples respectively. The reported results are an average of 3 readings.

LOI, and Flammability assessment

LOI and flammability tests for the treated cotton fabric samples were carried out according to the standard methods ISO 4589 (1996), and D 1230-94 (reapproved 2001) respectively.

Fourier transformer infrared spectroscopy (FTIR) analysis

The Fourier Transform Infrared (FTIR) Analysis were carried out for samples Using FTIR Model Cary 630 FTIR spectrometer produced by Agilent technologies Company, for both Qualitative and Quantitative (for liquid samples) analysis, in spectral range (wavenumbers cm-1) from 4000cm^{-1} to 400cm^{-1} without any treatment.

Thermo-gravimetric analysis (TGA)

The thermo-gravimetric measures the gradual weight loss of a sample with respect to time at a constant heating rate. It also indicates the effect of any flame retardant chemical on the pyrolysis of the polymer substrate. The TGA curves of the control and the treated fabrics were drawn on a Simultaneous Thermal Analysis (Model STA PT 1600- 2019) in a nitrogen atmosphere at 2 ml/min flow rate and at 10ºC/min heating rate. The TGA curves of the control and the BPS treated fabrics were also taken in air atmosphere under similar flow and heating conditions to understand the thermo-oxidative decomposition.

Mechanical strengths

The tensile strength and elongation % were measured using Zweigle of model Z010, at a tension speed of 100 mm/min under the standard atmospheric conditions (temperature = 20 ± 2◦C and relative humidity = 65 ± 5%). The testing was carried out according to ASTM D412-98a. The measurements were carried out three times, and the results indicated in this paper are the mean values

Color parameters

The color parameters such as K/S, L, a, and b were measured using a Perkin-Elmer Model 35 Lambda equipped with an integrating sphere. The color depth of the BPS treated fabrics was determined in terms of K/S from the reflectance data using the Kubelka–Munk equation as follows:

$$K/S = (1 - R)^2/2R$$

Where, K is the absorption coefficient, S the scattering coefficient and R is the reflectance of the treated fabric at the wavelength of maximum absorption. The K/S was determined at (λ max) of the respective dye. Other color parameters such as L* (lightness-darkness), a* (red-green) and b* (blue-yellow component), hue (h) and chroma (c) were measured using the Win lab software.

RESULTS AND DISCUSSIONS

Add-on%

The results represented in Table 1 showed increase in the sample weight relative to the original weight after the application of the BPS. It has been noted that the weight increased as BPS concentration increased till the concentration reached 10%.

LOI, and flammability tests

The untreated and treated cotton fabric samples were dried in the horizontal position in an oven for 30 min at 105˚C to discount the effect of moisture content. Material must be considered flammable as long as the LOI value is smaller than 0.26. The cotton fabric samples have been shown to ignite in shorter exposure to an ignition source, and burn with higher the time taken by a flame on a burning textile to travel a specified distance and specified conditions (flame spread rate) when oven-dried than when tested at higher moisture content. The LOI value is dependent on the weight, construction, moisture content, and purity of the sample, the temperature of the testing environment, and the size and construction of the sample holder. The results of flammability tests were represented in Tables 2, and 3. LOI, describe the tendency of a material to sustain a flame and it is defined as the minimum fraction of oxygen in a mixture of oxygen and nitrogen that will just support combustion after ignition. The LOI of the control and treated samples were given in table 2. Van and Nijinhuse mentioned that LOI of cellulose was 0.19 [26]. The results showed that the control sample (bleached, mordanted, and mercerized) was found to 0.22. However, the application of BPS in the control samples was found to increase till it reached the value of 3.6 which is almost 30 times than that obtained with the control. These results might be due to that during mercerization, cellulose I converted to cellulose II, followed by recrystallization during subsequent washing and subsequently increase the chemical activity due to the free hydroxyl groups (amorphous cellulose). The presence of metal salts in Tables 1, 2, and 3.

Table 1: Add-on% of the cotton fabric samples before and after treatments

Cotton Fabric (Giza 90)	Weight before/ gram	Weight after/ gram	Add-on%
Control*	75	-----	-
Mordant sample	75	77.6	3.46 %
Sample with BPS 2.5%	77.6	79.3	2.2 %
Sample with BPS 5%	77.6	81.6	5.15%
Sample with BPS 7.5%	77.6	83.2	7.21%
Sample with BPS 10%	77.6	83.3	7.35%

Control * bleached and mercerized Egyptian cotton Giza 90

TABLE 2. Flammability parameters of control, and BPS treated cotton fabrics.

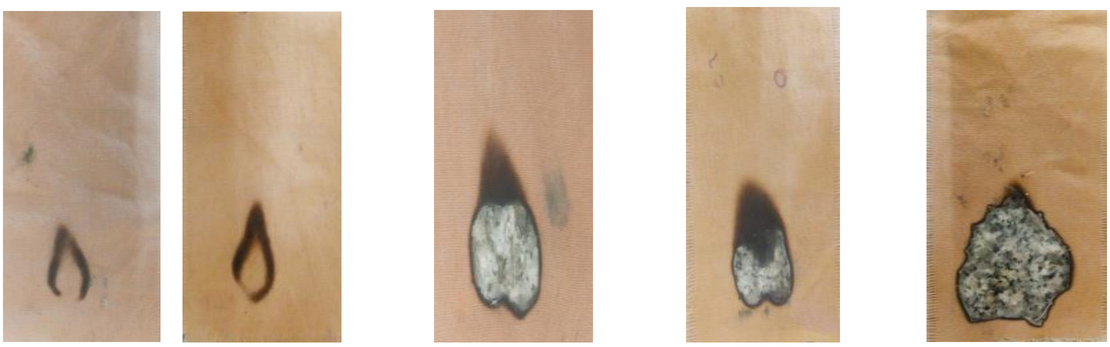
Flammability parameters	Control*	BPS treated cotton fabric concentrations %			
	--	2.5	5	7.5	10
LOI	0.22	0.65	1.1	3.4	3.6
Horizontal Flammability					
Warp way burn rate (mm/min)	44	30	21	14	12.5
Vertical Flammability					
State of the cotton fabric in contact with flame	C. B	B.I	B.I	B.I	B.I

Where C. B: completely burnet with flame, B.I: burnet initially with flame

TABLE 3. Ignition parameters of control, and BPS treated cotton fabrics.

Time	Control*	BPS treated cotton fabric concentrations %			
		2.5	5	7.5	10
3 s	NO.I	NO.I	NO.I	NO.I	NO.I
4 s	I.O	I.O	NO.I	NO.I	NO.I
5 s	I.O	I.O	I.O	NO.I	NO.I
6 s	I.O	I.O	I.O	I.O	NO.I
7 s	I.O	I.O	I.O	I.O	I.O

Where NO.I : Ignition did not occur I.O : Ignition occurred



Control* BPS 10% BPS 10% BPS 10% BPS 10%
Time: 3 sec. 5 sec. 6 sec. 7 sec.

Figure 1: comparison of burning behavior of control and BPS treated cotton fabrics at the different time intervals

BPS and alum might react with the free hydroxyl groups and lead to a decrease in the hydrogen to carbon ratio in the cotton samples, and lower the tendency to burning. Table 2, and Figure 1 represented the vertical burning behavior of the control and the BPS treated sample at different concentrations with different intervals of time. It has been noted that the BPS treated samples showed that ignition could occur after 4 sec for the control followed by BPS 2.5% treated fabric after 5 sec, and with BPS 5% after 6 and finally the ignition happened at 7 sec for the cotton fabric treated with BPS 10%.

FTIR assignment

Figure2 (A and B) showed the FTIR spectra of both untreated cotton samples and treated with BPS at 10% respectively. For the untreated cotton fabric samples, the FTIR absorption bands observed at 1607 cm^{-1} might be assigned to the $(AlH_4)^-$. The observed peak at 2156 cm^{-1} was mainly due to the presence inorganic salts such as Fe, and Mn, [28]. It can clearly be observed that cotton samples with (BPS) showed a wide band from 3600 cm^{-1} to 2600 cm^{-1} confirming the presence of water. The observed peaks between 800 cm^{-1} to 1300 cm^{-1} wavelength was mainly due to the presence of $(PO_4)^{3-}$ in the BPS [26-27]. The new observed peaks at 2040 cm^{-1} wavelength was mainly due to the presence of Fe^- in the BPS [2].

Thermo-gravimetric analysis (TGA)

Figure 3 (A and B) showed the TGA curves of both cotton untreated samples and treated with BPS at 10% respectively in N2 atmosphere at a heating rate of 10oC/min. The TGA curves of the control (A) and the BPS (B) samples evidenced stages of progression. In the initial stage at temperature below 300°C, the little mass loss occurred mainly due to the presence of metal salts in BPS and alum might react with the free hydroxyl groups and lead to the removal of bound and unbound absorbed moisture from the cellulose polymer. These results were in accordance with the results obtained by Shen et al. [30]. However, the main thermal decomposition occurred in the temperature range of 300–360oC, where the mass of the sample sharply decreased at around 340oC. This has happened mainly due to the pyrolysis of cellulose producing the volatile compounds proceeds through two primary simultaneous reactions: (a) the initial scission of glucosidic linkages, and (b) chemical changes in anhydro glucose unit such as dehydration and scission of C-C bonds. The mechanism of formation of the volatile compounds, however, has remained to be resolved. These results indicated that in mercerized samples, heating affected the amorphous regions of cellulose more than the crystalline. These results were in accordance with the results represented in references [31-32]. Above the temperature of 360oC, both dehydration and char formation occurred. In Figure 3 (A), degradation was observed only in the control samples where the non-oxidizable water and CO2 might have been released. The control and the treated sample treated with 10% BPS lost approximately 98% of its mass below 500°C. In Figure 3 (B), unlike the control fabrics, the BPS treated cotton fabrics started losing more mass at the initial stage below 200°C. This might be due to the presence of the BPS that had reduced the thermal decomposition and the dehydration temperature of cellulose. The BPS also influenced the chemical process of incomplete combustion of certain solids when subjected to high heat (char formation). It has increased the char formation and produced non-oxidisable gases such as CO2 and H2O, while reducing the production of flammable volatile gases. As a result, the BPS treated samples showed more LOI value and a lower rate of burning.

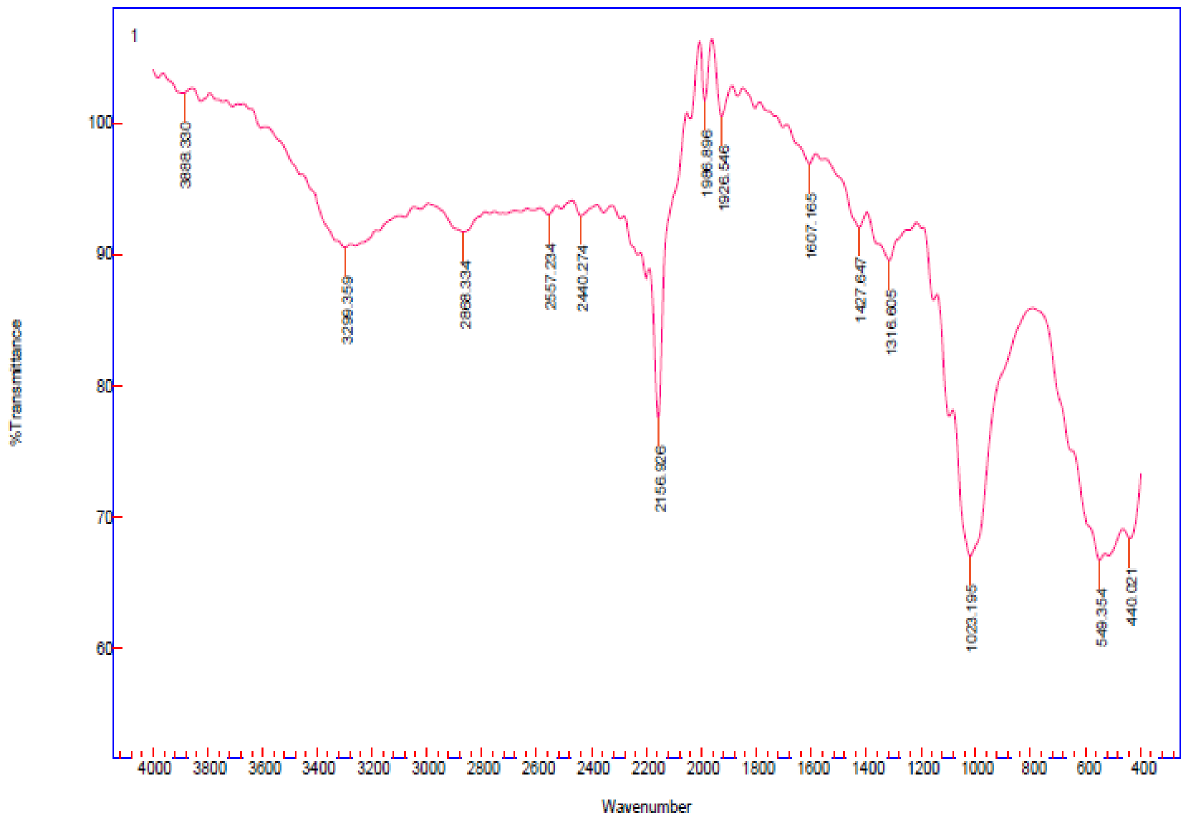


Figure 2 (A) The FTIR spectra of cotton samples

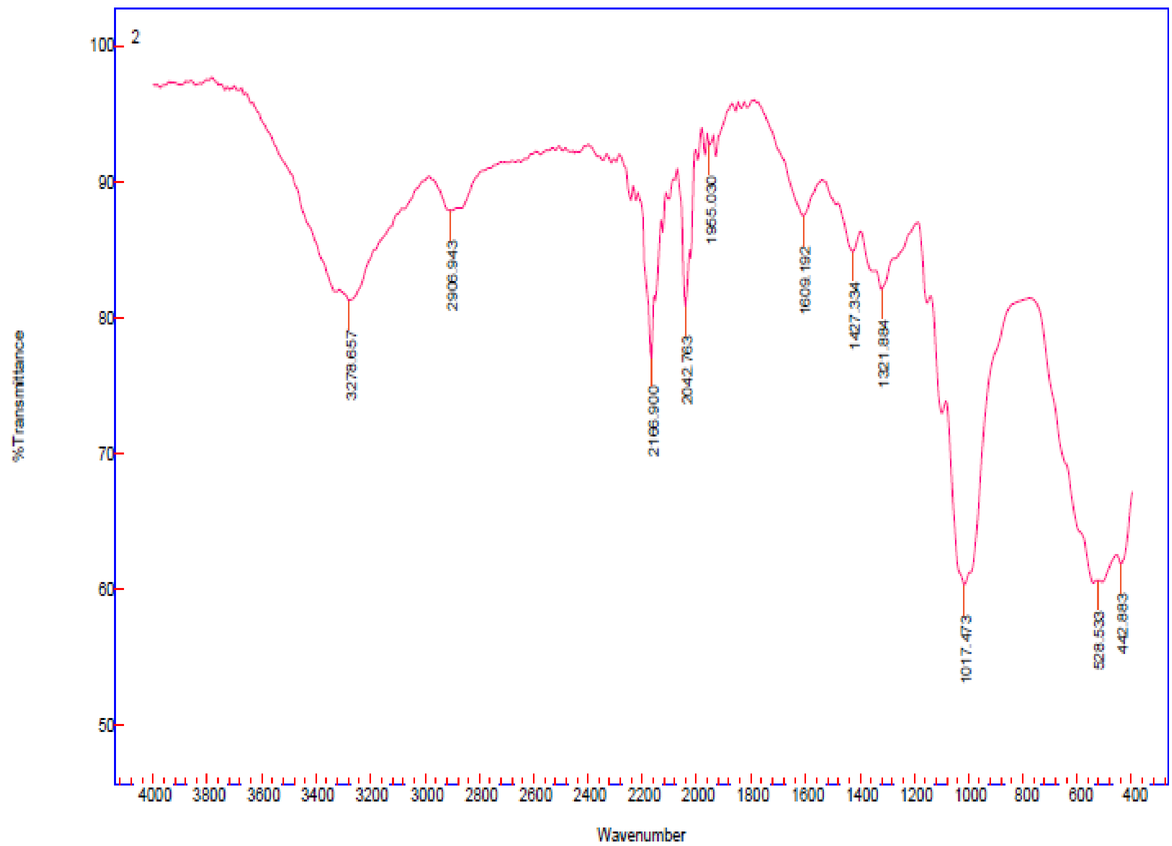


Figure 2 (B) The FTIR spectra of cotton samples treated with BPS at 10% concentration

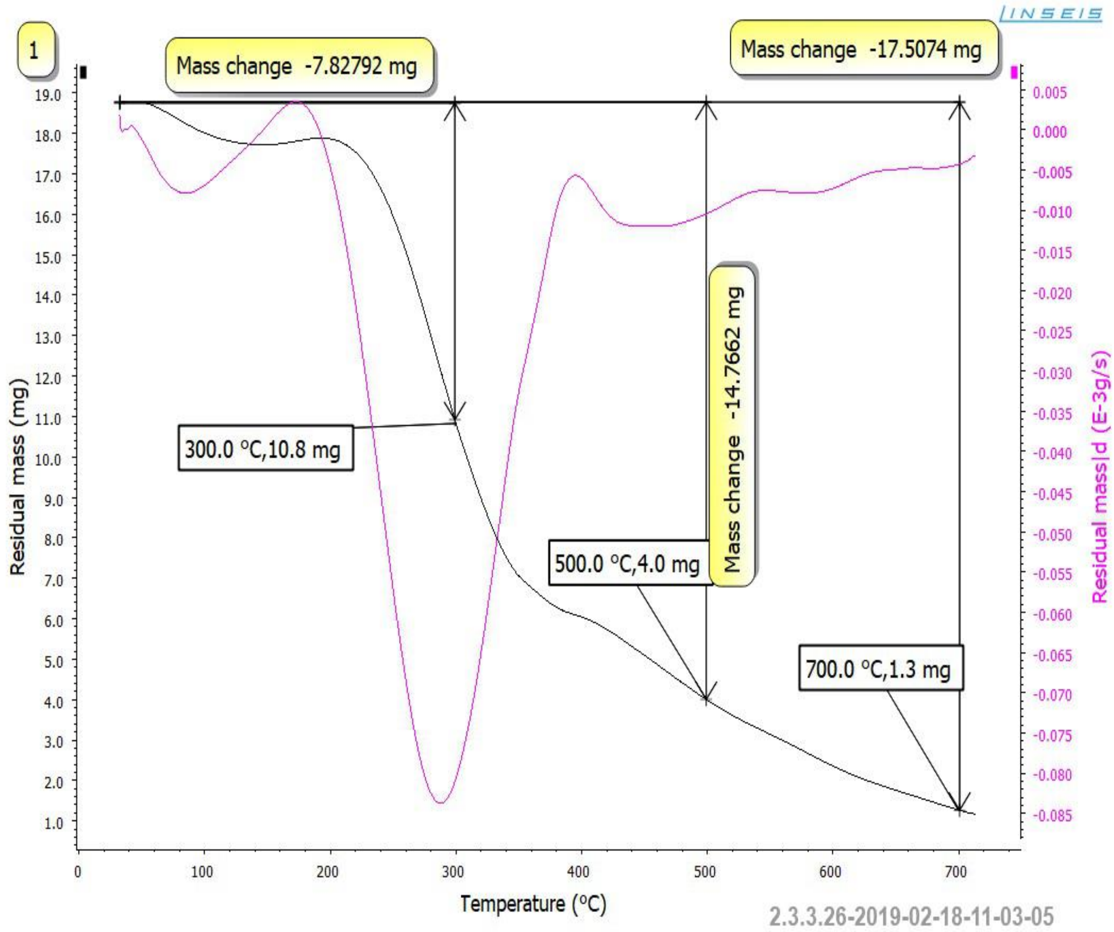


Fig. 3 (A) Thermo-gravimetric analysis of the control cotton samples

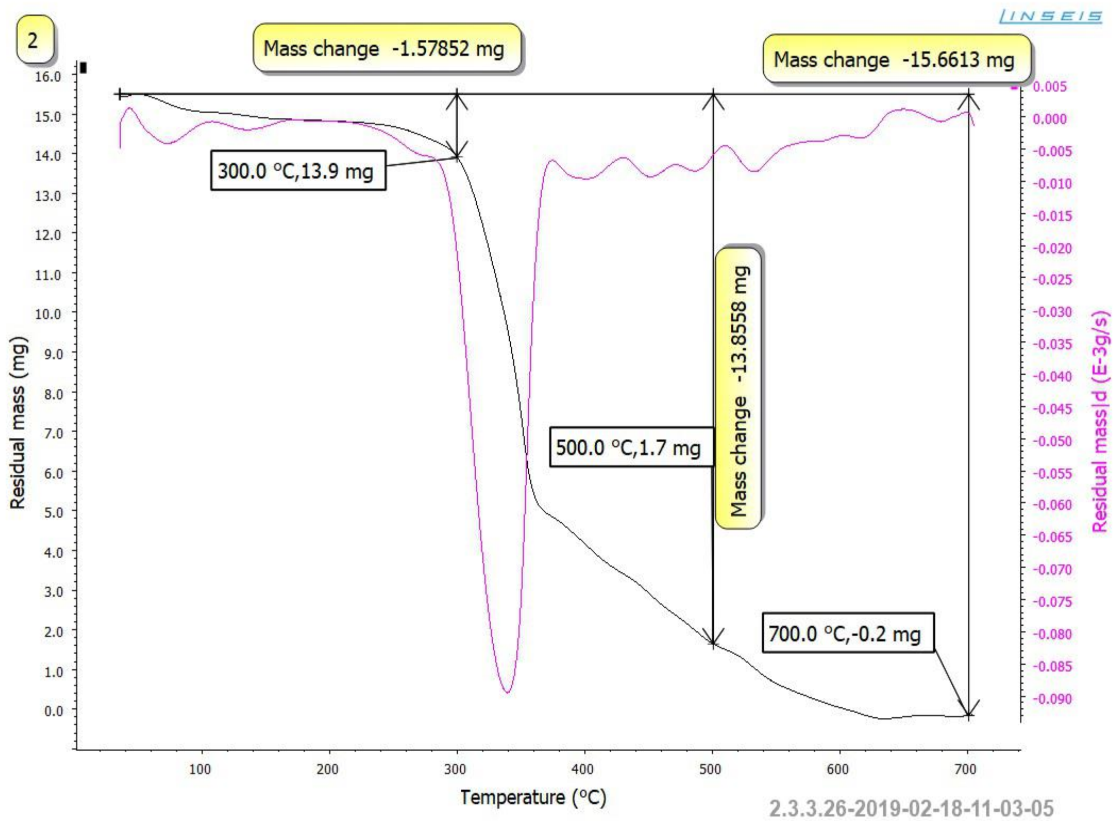


Fig. 3 (B). Thermo-gravimetric analysis of the treated cotton samples with BPS 10% concentration.

Mechanical strengths

The present application of BPS was found to have a significant adverse effect on both the tensile strength and elongation percentage. In most cases of application of conventional and commercial flame retardant finishes, there occurred a significant loss of tensile strength, in the range of 10–30%**,** [33]. Another assumption is that in mercerization treatment, concentrated sodium hydroxide penetrates inside the fibers and reacts with the hydroxyl groups inside the macromolecule in such a way that it either produces sodium cellulosate or its links to the molecules through the pulling forces increase the amorphous region which leads to decrease the tensile strength. As shown in Table 4, there was no significant change in tensile strength. The application of BPS on the control cotton samples caused a very slight increase in tensile strength and that might be due to the linkage between the free hydroxyl groups of the cotton fabric and the metal salts present in BPS. On the other hand, an observable increase in elongation percentage in the control samples due to the elongation percentage after the control fabric was treated with BPS.

Table 4. Tensile strength (Kg/f) and Elongation % of control, and BPS treated cotton fabrics.

Samples	Tensile strength (Kg/f)	Elongation (%)
Control*	44.67	14.10
Sample with BPS 2.5%	43.64	14.39
Sample with BPS 5%	42.54	14.43
Sample with BPS 7.5%	39.93	15.36
Sample with BPS 10%	36.88	17.89

Where Control: cotton samples without BPS*

Color Parameters

The K/S (depth of color) changed from 0.01 for the control to 5.13 for the BPS treated samples at 10% concentration. With further increase in the BPS concentration, K/S was found to increase, and L (lightness-darkness) tends to decrease. These results indicate that mercerization treatment has an influence on K/S values due to that cotton fabrics can be considerably modified during mercerization in terms of crystallinity, the orientation of crystallites, as well as orientation of macromolecular chains resulting in increased amorphous and less crystalline but with an improved orientation of fibers micro and macro units. The mercerization process involves partial destruction of intermolecular bonds. The fibrous transformation from cellulose I to cellulose II occurs during mercerization, which consists of swelling of the initial fibers in alkali, followed by recrystallization during subsequent washing and subsequently increases the chemical activity due to the free hydroxyl groups (amorphous cellulose) which react with the dyes more than the un-mercerized samples [25]. The presence of alum and tannic acid would affect the dye uptake due to the formation of the complex with the hydroxyl ions. According to our previous study, Tannin is not a metal salt; actually, it is a water-soluble phenolic compound. When tannic acid was used as mordant, the tannin reacted forming strong complexes. On soaking the fabric into the solution, a reaction between the hydroxyl groups in the fabric surface and the charged complex was carried out [34]. The (*) values changed as the BPS concentrations changed from 2.5% to 10%.

In the presence of BPS, the fabric samples were more redness in compared with the fabrics with tannic acid mordant. The (+b*) values indicated that the cotton fabrics tend to a pale yellow color, and the (+b*) values have their maximum BPS concentration at 10%. The hue angle (h) was from 60 degrees to 47 with BPS concentration at 10% and the treated fabrics tend to the kaki color more than that of the samples' BPS concentrations at 2.5, 5, and 7.5%. The results also revealed that the saturation of the color values changed with the application of BPS concentrations. It has been noted that the colored cotton has good color fastness to light and perspiration and poor fastness for washing due to partial removal of the active

BPS molecules such as metal salts, phosphate, and silicates.

Table 5. Colorimetric data of Giza 90 cotton fabric samples before and after treatments.

Sample	K/S	L*	a*	b*	C	h
Control	0.02	98.4	0.09	0.21	-----	-----
Sample with BPS 2.5%	2.23	62.8	3.32	17.40	10.10	59.80
Sample with BPS 5%	3.25	59.1	3.50	16.76	11.80	56.20
Sample with BPS 7.5%	3.79	57.3	3.96	16.21	13.30	52.10
Sample with BPS 10%	5.13	53.8	4.30	15.90	14.40	47.20

CONCLUSIONS

The present study has demonstrated the natural dyeing and flame retardancy effects of BPS on Giza 90 Egyptian cotton fabric and postulated the scientific basis of the same. BPS is abundantly available in Egypt and is normally considered as a plant waste material, though it is an eco-friendly natural product and produced from a renewable source. After application of BPS under alkaline condition (mercerization), the LOI increased almost 30 times than that obtained with the control cotton fabric samples when the concentration of BPS reached to 10%. This will provide more safety time to a human being either to extinguish the fire or to escape from zone of fire hazards. According to the FTIR spectra, the flame retardancy in the BPS treated cotton fabric might be attributed to the presence of AlH_4, Fe, Mn, and $(PO_4)^{3-}$ and water molecules. Also, the presence of such inorganic salts in BPS treated cotton fabric might have aided in the production of more char and nonflammable gases. The TGA curves revealed that the dehydration and the char formation phenomena in the BPS treated cotton fabrics have been observed. The BPS application treatment is simple, cost-effective, and no costly chemicals are used. The added advantage is that the BPS treated cotton fabric could also be considered as a naturally dyed cotton fabric. The cotton fabrics acquired the khaki color which is quite attractive due to the application of BPS. The newly process can be used beneficially in coloration and in imparting flame retardant finishing of different textiles like window curtain, railway curtain, hospital curtain, table lamp, and as a covering material of non-permanent structures like those used in book fair, festival, religious purposes and such on, where a large quantity of textile is used thus, posing possible threats of fire hazards.

REFERENCES

1- Salah. M. Saleh., El-Badry, K. 2012. Dyeing of Cotton/Nylon Blended Fabric to a Solid Shade in one Bath, *Global Journal of Science Frontier Research, Agriculture and Veterinary Sciences*, Volume 12 Issue 7 Version 1.0.

2- Petrilli, T. 2008. *Technology and development programme,* 0851-2348P-MTDC: 1-10.

3- Horrocks, A. 2011. Flame retardant challenges for textiles and fibers, *Polym. Degrad. Stabil.* 96 (3), 372-3932

4- Kandola, B.K., Horrocks, A.R., Price, D., Coleman G.V. 2006. Flame retardant treatments of cellulose and their influence on the mechanism of cellulose pyrolysis. *J. Macromol. Sci*., 36(4), 721–794. DOI: 10.1080/15321799608014859.

5- Kei, S. 2010. The effect of atmosphere pressure plasma on flame retardant property of cotton. Institute of cotton and clothing, Bachelor of Arts and Fashion technology thesis, Hong Kong poly Technique University.

6- Katovic, D., Grgae, S.F., Vukusic, S.B. Katovic, A. 2012.Formaldehyde free binding systems for fl ame retardant fi nishing of cotton fabrics. *Fibres Text. East. Eur.* 1(90), 94–98.
7- Hady, A.A.E., Farouk, A. Sharaf, S. 2013. Flame retardancy and UV protection of cotton based fabrics using nano ZnO and polycarboxylic acid. *Carbohydr. Polym.* 92 *(1), 400–406. DOI: 10.1016/j.carbpol.2012.08.085.*
8- Sarvanan, D., Lakshmi, S.N.S., Raja, K.S. Vasahi, N.S. 2013. Biopolishing of cotton fabric with fungal cellulose and its effect on the morphology of cotton fibres, *Indian. J. Fibre Text. Res.* 38 (2), 156–160.
9- Joshi, M., Ali, S.W. Rajendran, S. 2007. Antibacterial finishing of polyester cotton blend fabric using neem: A natural bioactive agent. *J. Appl. Polym. Sci.*106 (2), 793–800., DOI: 10.1002/app.26323
10- Oliveira L, Cordeiro N, Evtuguin D V, Torres, I. C., Silvestre, A. J. D. 2007. Chemical composition of different morphological parts from 'Dwarf Cavendish' banana plant and their potential as a non-wood renewable source of natural products, *Ind Crops Prod*, **26,** 163-172.
11- Saleh, M. Salah. 2013. Antibacterial activity and ultraviolet (UV) protection property of some Egyptian cotton fabrics treated with aqueous extract from banana peel, *Afr. J. Agric. Res.* Vol. 8(29), pp. 3994-4000, 1 August, DOI: 10.5897/AJAR10.845.
12- Faturoti, B. O., Emah, G. N., Isife, B. I., Tenkouano, A., Lemchi, J. 2006. Prospects and determinants of adoption of IITA plantain and banana based technologies in three Niger Delta States of Nigeria, *Afric J Biotechnol,* 5, 1319-1323
13- Castro-Gomez, R. J. H., Tamburini, E. R., Cal-Vidal, J. 1988. Alcohol from tropical crop residues, *Pesquisa Agro Brasil*, 23, 1151-1159.
14- Ilori M, O., Adebusoye, S. A., Lawal, A. K., Awotiwon, O. A., 2007. Production of biogas from banana and plantain peels, *Adv Environ Biol*, 1, 33-38.
15- Udosen, E. O., Enang, M. I. 2000. Chemical composition and soaping characteristics of peels from plantain (Musa paradisiaca) and banana (Musa sapientum), *Global J Pure Appl Sci,* 6, 79-81.
16- Eddy, N. O., Ebenso , E. E. 2008. Adsorption and inhibitive properties of ethanol extracts of Musa sapientum peels as a green corrosion inhibitor for mild steel in H_2SO_4, *Afric J Pure Appl Chem*, 2, 46-54.
17- Memon, J. R., Memon, S. Q., Bhangar, M. I., Memon, G. Z., El- Turki, A., Allen G. C. 2008. Characterization of banana peel by scanning electron microscopy and FT-IR and its use for cadmium removal, *Colloids Surfaces B: Biointerfaces*, 66, 260-265.
18- Salah. M. Saleh., Yasser. A. Abd-El-Hady., El-Badry, Kh. 2013. Eco-friendly Dyeing of Cotton Fabric with Natural Colorants Extracted from Banana Leaves,*International Journal of Textile Science*, 2(2): 21-25 DOI: 10.5923/j.textile.20130202.01
19- Debabandya, M., Sabyasachi, Mi., Namrata, S. 2010. Banana and its by-product utilisation: an overview, *Journal of Scientific &M InOdHusAtrPiaAlT RReAse aert cahl:,* Vol. 69, May, pp. 323-329
20- Uma, S., Kalpana, S., Sathiamoorthy, S., Kumar, V. 2005. Evaluation of commercial cultivars of banana (Musa spp.) for their suitability for the fibre industry, *Pl Genetic Resour Newslett,* 142, 29-35.
21- Phirke, N. V., Patil, R. P., Chincholkar, S. B., Kothari, R. M. 2001. Recycling of banana pseudostem waste for economical production of quality banana, *Resour Conserv Recycl*, 31 () 347-353.
22- Yavuz, Ö., Audin, A. H. 2006. Removal of direct dyes from aqueous solution using various adsorbents, *Polish J Environ Stud*, 15, 155-161.
23- Basak, S., Kartick. K. S., Saxena, S., Chattopadhyay, S.K., Narkar, R., Mahangade, R., Hadge, G.B. 2015.Flame resistant

cellulosic substrate using banana pseudo stem sap, *Polish Journal of Chemical Technology*, 17, 1, 123 —133,

24- Fang, Z., Song, P., Tong, L., Guo, Z. 2008. Thermal degradation and flame retardancy of polypropylene/ C60 nanocomposites. *Thermochimica Acta, 473, 106–10.* https://doi.org/10.1016/j.tca.2008.04.019

25- Eman, A., Shereen, O., Salah, M. 2015. Environmentally Plasma Treatment on Giza 86 Egyptian Cotton Fabric, *Int. J. Adv. Sci. Eng.,* Vol. 1 No. 17-22, ISSN 2349 5359

26- Van Krevelen, D.W., Nijenhuis, K. Te. 2009. Properties of polymers, 4th Edition, Elsevier science publisher.

27- Destainville, A., Champion, E., Bernache-Assollante, D. 2003. Synthesis, characterization and thermal behaviour of apatite tricalcium phosphate, *Materials Chemistry and Physics*, No. 80, pp. 269 – 277

28- Mobasherpour, I., Heshajin, M. 2007. Synthesis of nanocrystalline hydroxyapatite by using precipitation method. *Journal of Alloys and Compounds*, N 430, pp. 330 – 333

29- Zhenga, F., Dequan, Z., Xiaohui, S., Qianwang, C. 2014. Metal-Organic Framework-derived Porous Mn1.8Fe1.2O4 Nano cubes with an interconnected channel structure as High-Performance Anodes for Lithium Ion Batteries, *The Royal Society of Chemistry*, pp.51-58.

30- Shen, Y.M., Kuan, F.C., Kuan, C.H., Chen, H.C., Wang, H.J., Yip, C.M., Chiang, L.C. 2013. Preparation, characterization, thermal, and flame retardant properties of green silicon-containing epoxy functionalized grapheme nanosheets composites. *J. Nanomat,* 1–10. DOI: 10.1155/2013/747963.

31- Xing, T.L., Liu, J., Li, S.W. & Chen, G.Q. (2012). Thermal properties of flame retardance cotton fabric grafted by dimethyl methacruloyloxy ethyl phosphate. Therm. Sci. 16 (5), 1472–1475. DOI: 10.2298/TSCI1205472X.

32- Shimazu, F., and Sterling, C. 1966. Effect of Wet and Dry Heat on Structure of Cellulose, *j. Food Sci*., 31, 548.

33- Banerjee, S.K., Day, A., Ray, P.K. 1985. Fire proofing jute. *Text. Res. J.* 56 (5), 338–339.

34- Salah M. Saleh., Heba, A. Mohamed. 2019. Effect of Natural Mordant on Dyeing Process of Some Egyptian Cotton Fabrics Using Natural Dye, *Int. J. Adv. Sci. Eng.* Vol.6 No.2 1370-1375.

Investigation of The Performance of yarn quality Produced from Different Types of Cellulosic/Cotton blends

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(REFEREED RESEARCH)

Abstract

In this study, the physical and mechanical properties of Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended ring-spun yarns were compared. Yarn properties such as breaking force and elongation, unevenness, imperfections hairiness, and abrasion resistance were evaluated. In general, the effects of different blend ratios on a yarn's structural, physical, and mechanical properties were examined by using 100% cotton, 100% regenerated cellulosic fiber, and 67%–33%, 50%–50%, 33%–67% cotton-regenerated cellulosic fiber blended yarns. In general, an increasing ratio of regenerated cellulosic fiber content in the blend decreases breaking force, unevenness, imperfections, and hairiness values; on the other hand, it increases elongation values. The effect of blend type is also statistically significant for many yarn properties.

Keywords: Regenerated cellulosic fibers, blend ratio, yarn counts and yarn quality properties

Introduction

Today most apparel textiles are manufactured from yarns spun from staple fibers. Population expansion and consumer growth increase demand for textiles. Ring spinning is an important process involved to produce spun yarns of various qualities required for different applications from different natural or synthetic or regenerated cellulosic fibers. Blending enables the technician to combine fibers so that the good qualities are emphasized, and poor qualities are minimized. Usually, different natural and synthetic fibers are blended to achieve better qualities of both natural and synthetic materials.

A blend is an intimate mixture of fibers of different compositions, length, diameter, and color spun together into yarn. The accepted definition of a blend, as stated by ASTM, is a single yarn spun from a blend or mixture of different fiber species. Blending is a complicated and expensive process, but it makes it possible to build in a combination of properties that are permanent.

The fiber blend ratio is an important factor that determines the properties of spun yarn and is specified by the types of fibers and their ratio in the resultant mixture, (Malik *et al*. 2012, Samander *et al*. 2016 and Sekerden 2011). The objectives of blending two or more staple fibers are to improve the functional and aesthetic quality of textiles, processing performance, and economy of production. However, blending has a major limitation -continuous man-made filament cannot be processed with staple fibers. Therefore, blending techniques are mainly restricted to producing apparel textiles rather than technical textiles.

Kılıç and Okur (2011) compared the structural, physical, and mechanical properties of cotton-Tencel and cotton- ProModal blended ring, compact and vortex spun yarns. Effects of different blend ratios on a yarn's structural, physical, and mechanical properties were examined by using 100% cotton, 100% regenerated cellulosic fiber, and 67%–33%, 50%–50%, 33%–67% cotton-regenerated cellulosic fiber blended yarns. They found that an increased ratio of regenerated cellulosic fiber content in the blend decreases unevenness, imperfections, diameter, and Roughness (CV FS %)values; on the other hand, it increases breaking force, elongation, density, and shape values. They also resulted that the effect of blend type was statistically significant for many yarn properties, mainly, while cotton-ProModal yarns have better physical properties, cotton-Tencel yarns have better mechanical properties.

Prakash *et al*. (2011). investigated bamboo/Cotton blended ring-spun yarn properties by spinning these yarns in three yarn counts in different blend ratios. It was revealed that the quality of 50%/50% bamboo/Cotton blended yarn is most closely comparable with that of 100% cotton yarn. They found that the quality of the yarns decreases by increasing the bamboo content in the yarns.

Thanks to micro gaps in its structure, bamboo fiber has high air permeability and water absorption properties. Bamboo-based fabrics are antibacterial and very soft, with a low amount of pilling and creasing, (Karahan *et al*. 2006). Modal fiber, regenerated cellulosic viscose fiber and cellulosic fibers having better characteristics such as strength, moisture absorption, length uniformity, shrinkage, softness, and appearance, is found to be compatible to blend with natural cotton fiber in different blend ratios to produce cellulosic/Cotton blended yarn. Blended yarn qualities are highly dependent on the fiber-material-dependent parameters such as the blend ratio of fibers and the ring frame spinning machine setting parameters.

In this study, unlike the previous researches, most of the regenerated cellulose fibers were produced by 100% and blended with different ratios of cotton in ring spinning system with different yarn counts. The mechanical and physical properties of the yarns were compared with each other to determine how the properties of the yarns changed when the cotton blend was used.

Materials and Methods

In this study, blended yarns made of cotton and regenerated cellulosic fibers were used. Each of Tencel, Bamboo, Viscose, and Modal blended with cotton fibers and mixed in five different ratios were used in this work towards the design and development of high-quality blended yarn. Furthermore, controllable factors in ring spinning such as break draft affecting the output performance of blended yarn were selected in three different yarn counts to produce blended yarn samples. The variations caused in the output performance of blended yarn such as tenacity, unevenness, neps, and hairiness were evaluated.

The basic HVI characteristics of Giza 94 cotton fiber such as UHM, uniformity index, fineness, and bundle strength of cotton fibers selected for this work are 33.2 mm, 86.7, 4.3 μg/inch, and 42.2 g/tex, respectively.

The corresponding characteristics of chosen Tencel, Bamboo, Viscose, and Modal fibers are 38 mm, 100, 1.3 denier, and 35 g/tex, respectively. The Tencel/ cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns were prepared in a conventional ring spinning process. Here natural cotton fibers and cellulosic fibers were processed separately in spinning preparatory machines to produce slivers. Then the cotton slivers and its blends draw frame slivers were blended in various blend ratios in the finisher draw frame (HSR 1000) to produce Tencel/ cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton slivers. The above draw frame blending was done according to the individual number of slivers and its weight per unit length.

A suitable composite roving was produced as per weight/unit length of composite sliver by processing in a roving machine (Rieter F16). This composite roving was fed into a ring frame (Marzoli RST1) fitted with a Texpart drafting system) that produced the ring blended yarns. In this study, Ne 30/1, Ne 40/1, and Ne 50/1 Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton yarns with 100% cotton, 100% regenerated cellulosic fiber and 67%–33%, 50%–50% and 33%–67% cotton-regenerated cellulosic fiber ratios were produced in ring spinning system to investigate the physical and mechanical properties of blended yarns made from different blend ratios. The twist coefficient was α_e=4.2 for ring yarns.

and hairiness (hairiness index), imperfections, and roughness values of yarns were measured by using an Uster Tester 5 S800 at a crosshead speed of 400 m/min.

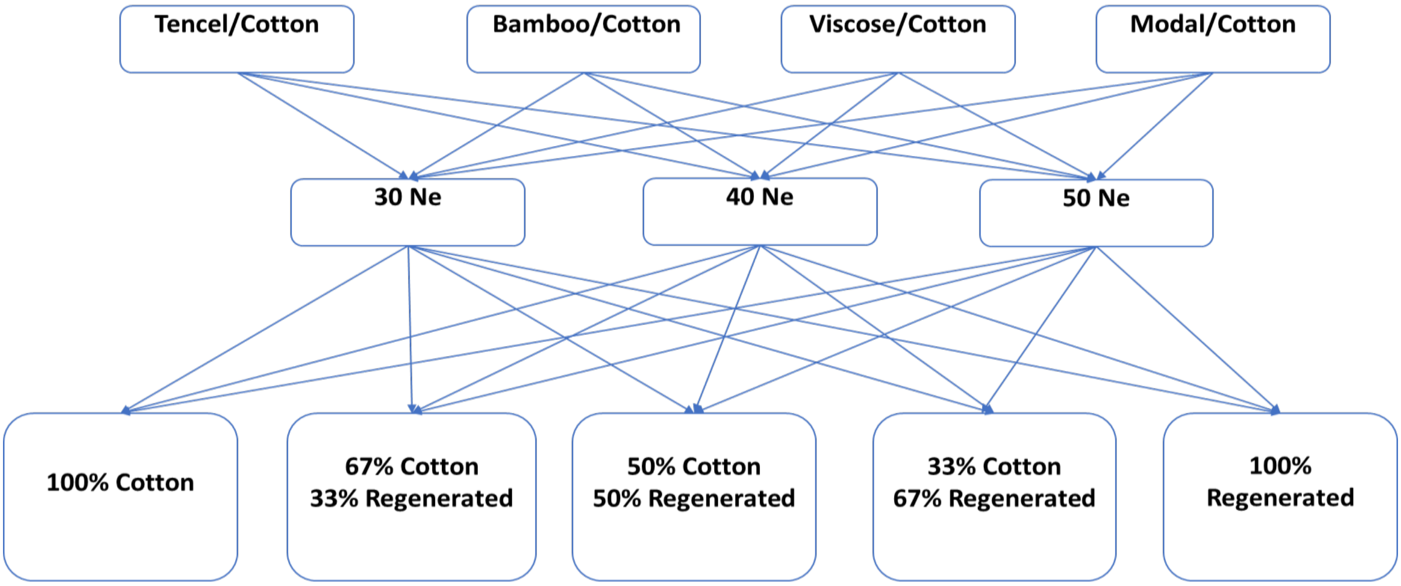

Figure 1. Experimental outline of the work

Table 1. Properties of Tencel, Bamboo, Viscose and Modal

	Tencel	Bamboo	Viscose	Modal
Titre "Dtex"	1.3	1.3	1.3	1.3
Cut Length "mm"	38	38	38	38
Tenacity "cN/Tex"	35	33	30	37
Elongation "%"	13	12	12	13

Table 2. Uster HVI results for Giza 94 Cotton

	Giza 94
UHM (mm)	33.2
U.I. (%)	86.7
Strength "cN/Tex"	42.2
Elongation "%"	6.2
Micronaire	4.3

The tenacity of Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns were measured using the Statimat ME+ at a cross head speed of 50 m/min. The unevenness (U%)

Results and Discussion

In this section, the effects of the yarn count, blend ratios, and blend types on yarn properties were evaluated for strength, elongation, abrasion resistance, unevenness, imperfections, hairiness, and some structural properties. SPSS software was used to compare the main effects. ANOVA analyses were performed for α0.05 significance level.

Yarn tenacity

Breaking force (cN/Tex) and elongation (%) values of ring-spun Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns are shown in Figures 2–5 and Tables 3 and 4. Upon a general evaluation of the yarn count, the effect of the yarn count is found to be statistically significant on yarn breaking force (cN/Tex) and elongation (%) values for all Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns. Breaking force and elongation values are the highest at 40 Ne, while they are the lowest for 50

Ne yarns for cotton-regenerated cellulosic blended yarns. Furthermore, elongation values of 50Ne are less than 30Ne yarns. When the effect of blend ratio on yarn strength is studied, it is seen that the increasing ratio of regenerated cellulosic fiber content in the yarn structure causes a decrease in breaking strength and elongation values for both blend types and three yarn counts. This decrease is also statistically significant.

The increasing regenerated cellulosic fiber ratio means increasing fiber length, fiber length uniformity, and the number of fibers in the yarn cross-section depending on fiber fineness. Although Tencel, Bamboo, Viscose and Modal yarns have smaller tenacities than cotton fiber, the effects of fiber length and fiber fineness cause an increase in the breaking force of the yarn. In addition to the fiber length and fineness, since the elongations of regenerated cellulosic fibers are greater than cotton, an increase in yarn elongation is also inevitable. The effect of blend type on yarn strength is seen to be statistically significant on breaking force for all yarn counts and breaking force values are greater for cotton-Tencel yarns.

Roughness (CV FS %)

Roughness is a measure of the texture of a surface. A surface can never be perfectly smooth and will always have two components of surface texture; namely, roughness and waviness. They may vary from fine to coarse according to the production process used. Roughness is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces, Akgun *et al.* 2015 and http://www.scribd.com. 2011.

Roughness (CV FS %) values of ring-spun Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns are shown in Figures 6–7 and Tables 3 and 4.

A general assessment of yarn counts shows that the effect of the yarn count is statistically significant on the Roughness (CV FS %) for all Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns. For abrasion resistance, 30Ne yarns have the lowest values, while 50Ne yarns have the highest values for both blend types. Lastly, for roundness, 100% regenerated cellulosic yarns have the highest values, whereas 100% cotton yarns have the lowest values (Figures 6–7 and Tables 3 and 4).

An examination of the effect of the blend ratio on Roughness (CV FS%) indicates that the increasing ratio of regenerated cellulosic fiber content in the yarn structure causes an increase in Roughness (CV FS%) values for all Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns. For Roughness (CV FS %) values, the increasing ratio of regenerated cellulosic fiber content causes an increase in Roughness (CV FS %) for all blend types.

Unevenness

Unevenness (U%) values of ring-spun Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns are shown in (Figures 8-9). It is seen that the effect of yarn count and blend ratios are statistically significant on yarn unevenness for all blend types of yarns. Unevenness values are the lowest for 30Ne yarns, however, they are highest for 50Ne.

If examined, the effect of the blend ratio on yarn unevenness is seen to change unevenness values. As a result of the increasing ratio of regenerated cellulosic fiber content in the yarn structure, unevenness values decrease for both blend types and three yarn counts. This decrease is due to the increasing mean fiber length and decreasing mean fiber linear density in the yarn structure. In addition, this decrease is statistically significant. However, evenness values are the lowest for 100% regenerated cellulosic fiber blend ratio for both blend types and three yarn counts (Figures 8–9).

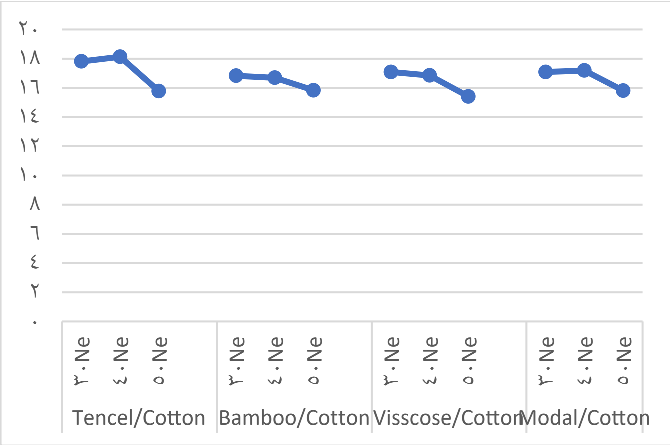

Figure ٢. Effect of blend type and yarn count on yarn strength

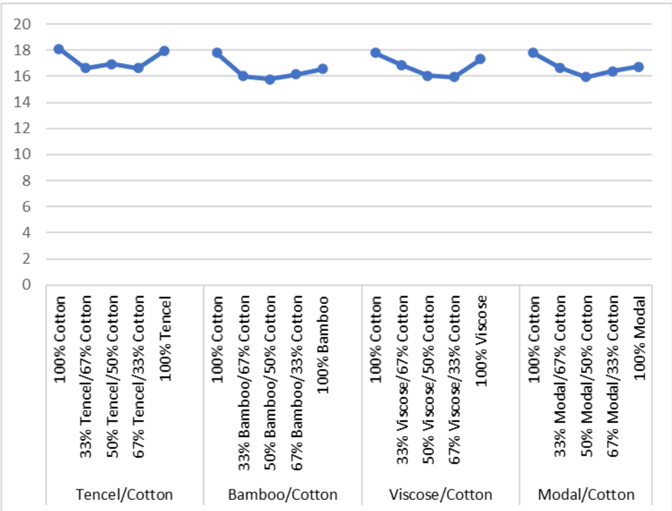

Figure ٣. Effect of blend type and blend ratio on yarn strength

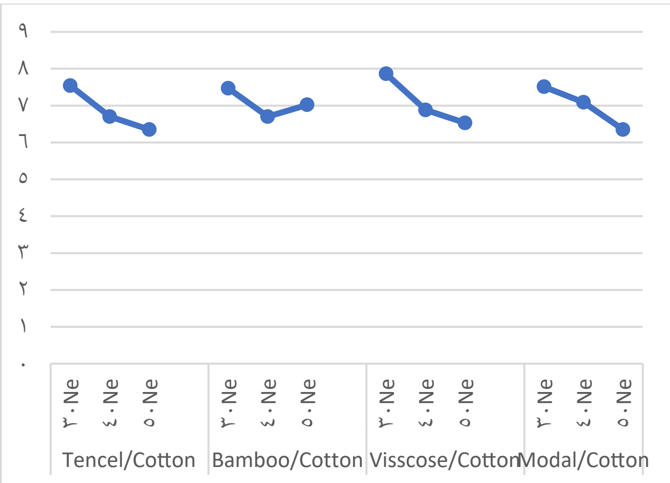

Figure ٤. Effect blend type and yarn count on yarn elongation

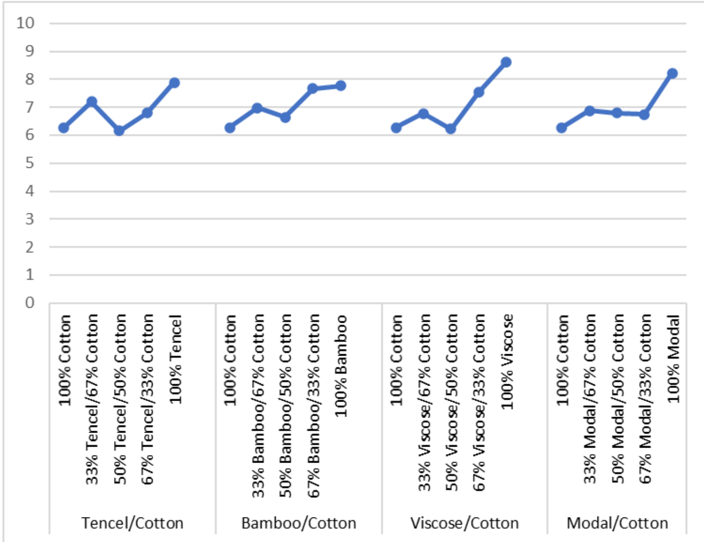

Figure ٥. Effect of blend type and blend ratio on yarn elongation

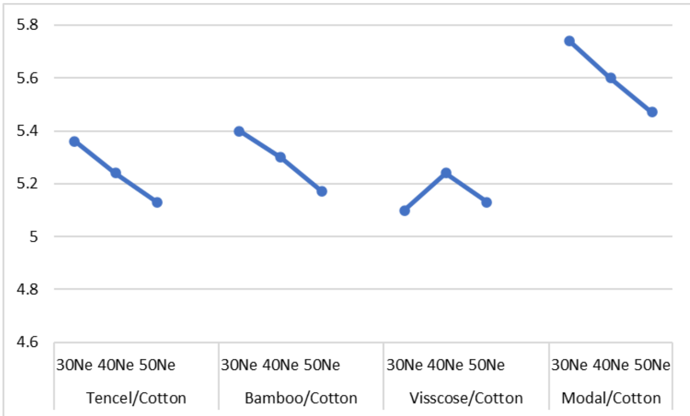

Figure ٦. Effect blend type and yarn count on Roughness

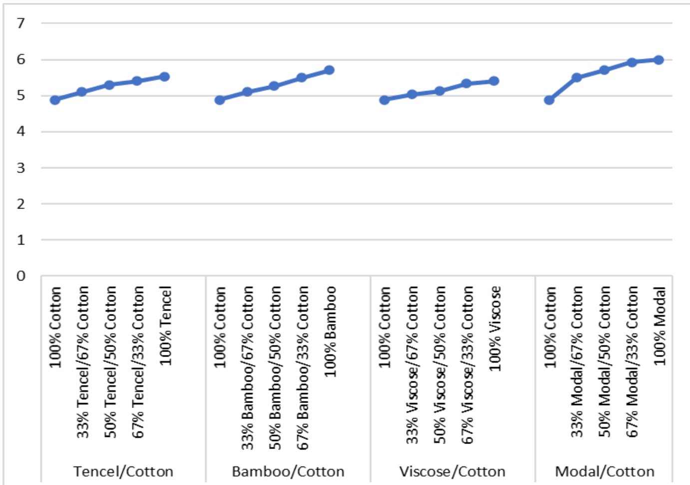

Figure ٧. Effect of blend type and blend ratio on Roughness

Imperfections

Values of thin places (-50%/km), thick places (+50% /km) and neps (+200% /km) of ring-spun Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns are given in Tables 3 and 4. Line graphs of these values are shown in Figures 10–15. Upon a general assessment of the yarn count, its effect is seen to be statistically significant in thin places (-50%/km) and thick places (+50% /km), and neps (+200% /km) for all Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns. Values of thin places and thick places are the lowest for 30Ne yarns but are the highest for 50Ne yarns. When the ANOVA pairwise comparisons of blend ratios are taken into consideration, it is seen that differences between thin places values of ring-spun yarns are statistically significant for blend types of blends. Furthermore, pairwise comparisons of blend ratios for blend types of blends show that differences between values of either thin or thick places of ring-spun yarns are statistically significant (Tables 3 and 4).

If examined, the effect of blend ratio on imperfections is found to be statistically significant in thin and thick places for either yarn counts and for either blend type.

For thick places and neps values, the increasing ratio of regenerated cellulosic fiber content causes decreases in these values for both blend types and the three yarn counts and these decreases are also statistically significant. When the effect of blend type on imperfections is examined, for ring yarns, the effect of blend type is statistically significant on thin places and these values are less for Bamboo/Cotton yarns.

Hairiness

Hairiness (H) values of ring-spun Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns are given in Figures 16–17. When a general evaluation is made in terms of yarn count, it is seen that the effect of yarn counts is statistically significant on yarn hairiness for both Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended yarns. These values are the highest for 50Ne, on the other hand, they are the lowest for 30Ne yarns, (Tables 3 and 4 and Figures 16–17). If the effect of blend ratio on yarn hairiness is examined, it is seen that the effect of blend ratio is statistically significant on hairiness values of Tencel/Cotton, Bamboo/Cotton, Viscose/Cotton, and Modal/Cotton blended ring yarns. The increasing ratio of regenerated cellulosic fiber content causes a decrease in hairiness values and this decrease is statistically significant (Figures 16–17). This decrease in hairiness of yarn counts is more likely to be because of the increasing length uniformity fibers associated with the increasing mean fiber length. When the effect of blend type on yarn hairiness is examined, for yarn counts, the effect of blend type is statistically significant on hairiness values. Besides, these values are greater for Viscose/Cotton yarns than other blend types of yarns.

Conclusions

The effect of a material parameter such as the blend ratio of fibers (Cotton, Tencel, Bamboo, Viscose, and Modal) and ring spinning process parameters such as different yarn counts "30Ne, 40Ne, and 50Ne" on blended yarn quality characteristics was investigated in this study. Material for the work was chosen from regenerated cellulosic fibers which have been widely used recently. Tencel, Bamboo, Viscose, and Modal, were blended with cotton fibers and 100% cotton, 100% regenerated cellulosic fiber, 67%–33%, 50%–50%, and 33%–67% cotton-regenerated cellulosic fiber yarns were spun in three yarn counts. Yarn properties such as breaking force and elongation, Hairiness, abrasion resistance, unevenness, imperfections, and hairiness, were compared to evaluate the effects of yarn counts, blend ratio, and blend type. The increasing ratio of regenerated cellulosic fiber content in the yarn structure, in general, decreases the unevenness, breaking force, and imperfections values whereas it increases the elongation values.

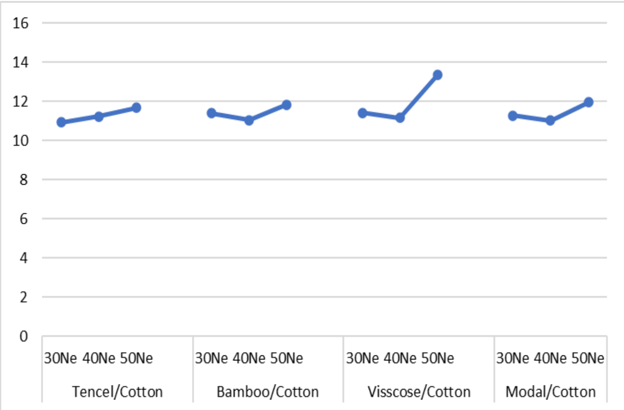

Figure ٨. Effect of blend type and yarn count on yarn evenness

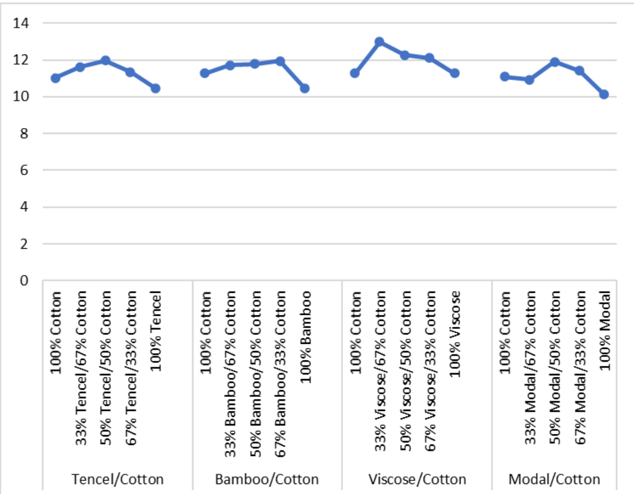

Figure ٩. Effect of blend type and blend ratio on yarn evenness

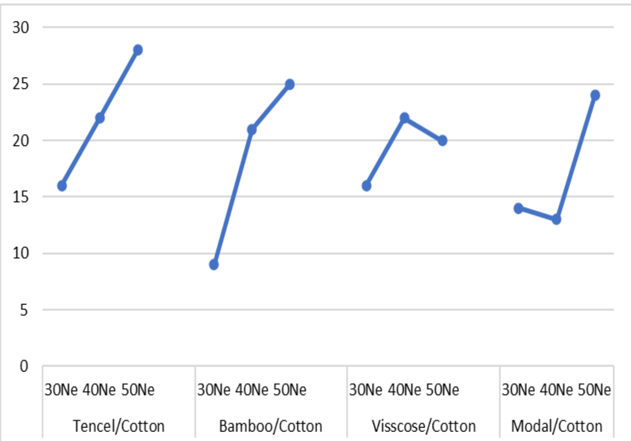

Figure ١٠. Effect blend type and yarn count on thin places

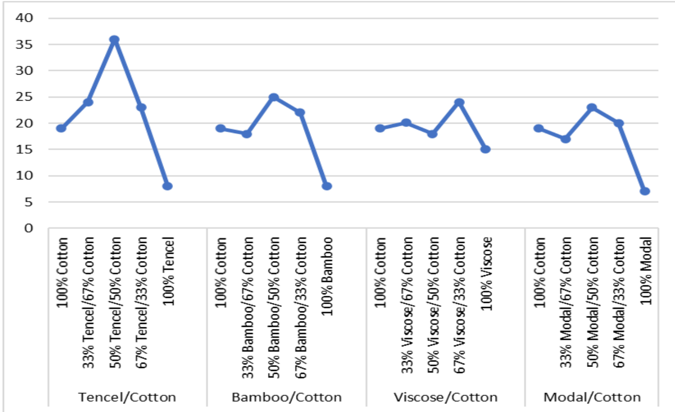

Figure ١١. Effect of blend type and blend ratio on thin places

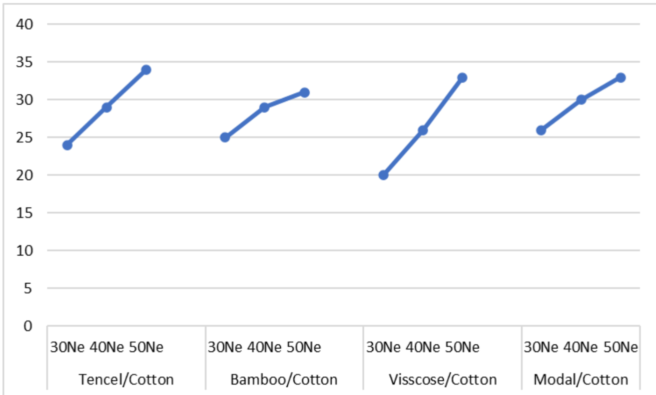

Figure ١٢. Effect blend type and yarn count on thick places

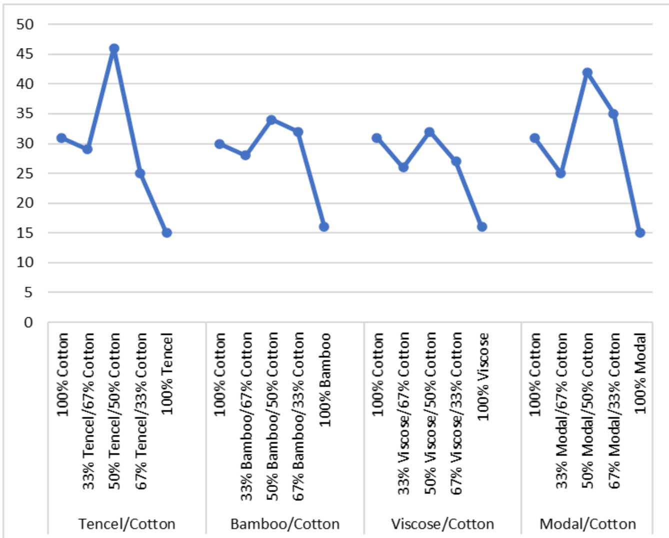

Figure ١٣. Effect of blend type and blend ratio on thick places

Table 3. Effect of Blend type and yarn count on yarn quality properties

S.O.V	Yarn Count	Strength (CN / tex)	Elongation%	Roughness (CV FS %)	U %	Thin Places (1000m)	Thick Places (1000m)	Neps/1000m	Hairiness
Tencel/Cotton	**30Ne**	17.81	7.54	5.36	10.94	16.00	24.00	23.00	3.51
	40Ne	18.13	6.7	5.24	11.23	22.00	29.00	30.00	3.32
	50Ne	15.78	6.35	5.13	11.69	28.00	34.00	37.00	3.48
Bamboo/Cotton	**30Ne**	16.83	7.47	5.40	11.41	9.00	25.00	33.00	3.71
	40Ne	16.69	6.7	5.30	11.06	21.00	29.00	40.00	3.3
	50Ne	15.83	7.02	5.17	11.84	25.00	31.00	46.00	3.71
Visscose/Cotton	**30Ne**	17.09	7.86	5.10	11.42	16.00	20.00	37.00	3.88
	40Ne	15.85	6.88	5.24	11.16	22.00	26.00	34.00	2.95
	50Ne	17.41	6.53	5.13	13.38	20.00	33.00	40.00	4.79
Modal/Cotton	**30Ne**	17.09	7.51	5.74	11.29	14.00	26.00	38.00	3.68
	40Ne	17.19	7.09	5.60	11.02	13.00	30.00	29.00	3.4
	50Ne	15.81	6.35	5.47	10.96	24.00	33.00	46.00	3.77

Table 4. Effect of blend type and blend ratio on yarn quality properties

S.O.V		Strength (CN / tex)	Elongation%	Roughness (CV FS %)	U %	Thin Places (1000m)	Thick Places (1000m)	Neps/1000m	Hairiness
Tencel/Cotton	100% Cotton	18.11	6.27	4.88	11.01	19.00	31.00	36.00	3.41
	33% Tencel/67% Cotton	16.62	7.2	5.1	11.63	24.00	29.00	41.00	3.51
	50% Tencel/50% Cotton	16.92	6.16	5.3	11.97	36.00	46.00	22.00	3.85
	67% Tencel/33% Cotton	16.61	6.8	5.4	11.34	23.00	25.00	37.00	3.95
	100% Tencel	17.95	7.88	5.53	10.47	8.00	15.00	15.00	2.48
Bamboo/Cotton	100% Cotton	17.78	6.27	4.88	11.27	19.00	30.00	36.00	3.41
	33% Bamboo/67% Cotton	16	6.98	5.1	11.72	18.00	28.00	35.00	3.62
	50% Bamboo/50% Cotton	15.78	6.64	5.26	11.78	25.00	34.00	52.00	3.71
	67% Bamboo/33% Cotton	16.15	7.66	5.5	11.95	22.00	32.00	47.00	4.47
	100% Bamboo	16.55	7.76	5.7	10.44	8.00	16.00	26.00	2.67
Viscose/Cotton	100% Cotton	17.78	6.27	4.88	11.27	19.00	31.00	31.00	3.41
	33% Viscose/67% Cotton	16.85	6.78	5.03	12.98	20.11	26.00	40.00	4.27
	50% Viscose/50% Cotton	16.04	6.23	5.13	12.27	18.00	32.00	53.00	4.11
	67% Viscose/33% Cotton	15.94	7.53	5.33	12.11	24.00	27.00	43.00	4.87
	100% Viscose	17.31	8.63	5.4	11.27	15.00	16.00	17.00	2.71
Modal/Cotton	100% Cotton	17.78	6.27	4.88	11.1	19.00	31.00	32.00	3.41
	33% Modal/67% Cotton	16.66	6.88	5.5	10.92	17.00	25.00	39.00	3.61
	50% Modal/50% Cotton	15.94	6.79	5.7	11.9	23.00	42.00	46.00	3.99
	67% Modal/33% Cotton	16.38	6.75	5.93	11.42	20.00	35.00	51.00	3.92
	100% Modal	16.72	8.22	6	10.13	7.00	15.00	19.00	3.15

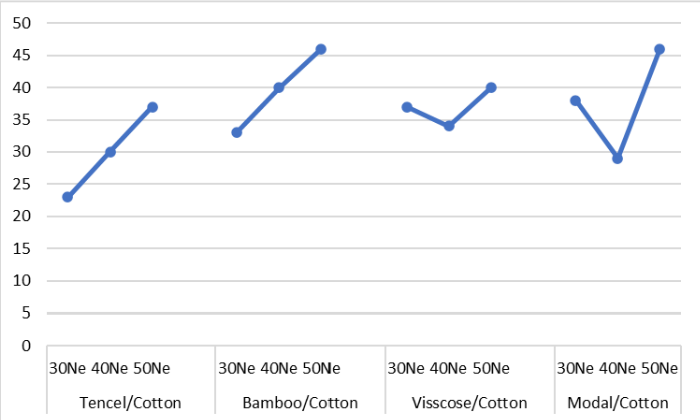

Figure 14. Effect of blend type and yarn count on yarn neps

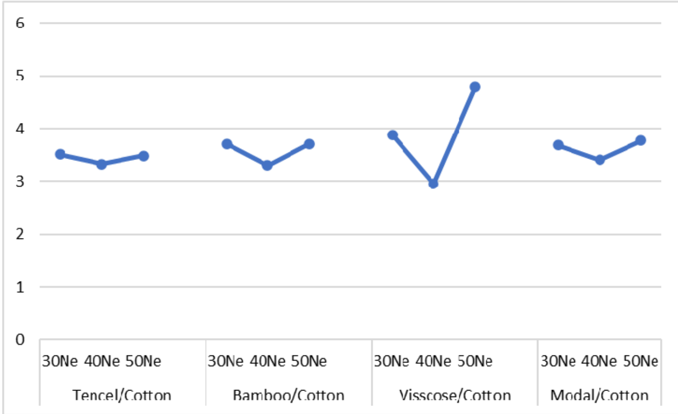

Figure 16. Effect blend type and yarn count on hairiness

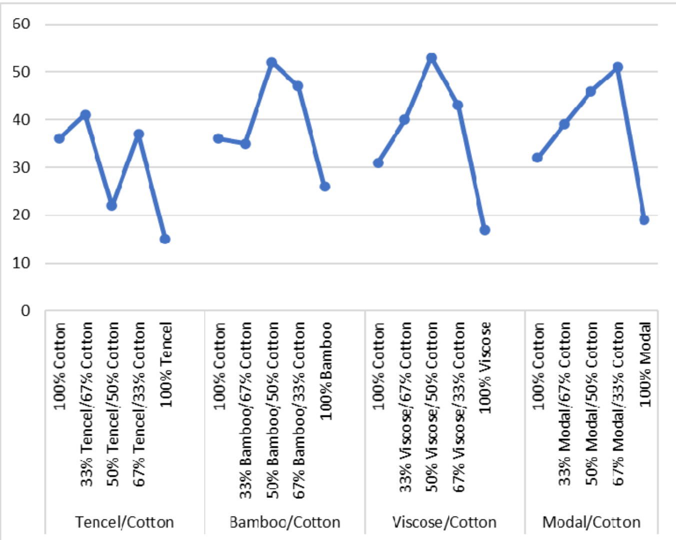

Figure 15. Effect of blend type and blend ratio on yarn neps

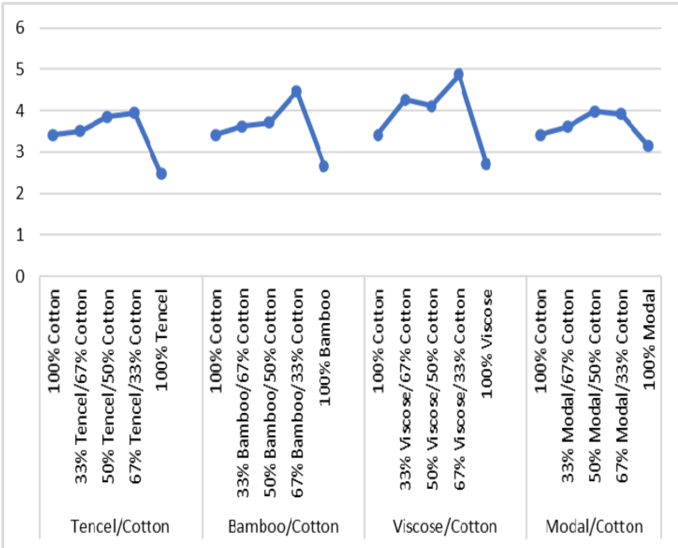

Figure 17. Effect of blend type and blend ratio on hairiness

References

1. Akgun M, Becerir B and Alpay HR. 2015. Assessing the effect of measurement parameters on surface roughness values of polyester woven fabric structures. Tekstil Konfeksiyon 2015; 25: 66–72. 2.
2. Bhattacharya, S., S., Ajmeri, J. R (2013). Investigation of Air Permeability of Cotton & Modal Knitted Fabrics, International Journal of Engineering Research and Development, 6(12), 01-06.
3. Gonca Balic KilicAyse okur (2016). A Comparison of the Physical Properties of Cotton, Modal and Acrylic Yarns spun in Ring and OE-Rotor Spinning Systems, Industria Textila, 67(2), 81-90.
4. http://www.scribd.com/doc/31287387/Surface-Roughness (accessed 11 June 2011).
5. Kılıç M., Okur A., 2011, "The Properties of Cotton-Tencel and Cotton-ProModal Blended Yarns Spun in Different Spinning Systems", Textile Research Journal, 81(2) 156–172.

6. Karahan A. Öktem T., Seventekin N.; "Natural Bamboo Fibres", Journal of Textile and Apparel, Vol: 4, 2006, pp. 236-240.
7. Malik, S. A.; Tanwari, A., Syed, U., Qureshi, R. F.; & Mengal,N. (2012). Blended Yarn Analysis: Part I—Influence of Blend Ratio and Break Draft on Mass Variation, Hairiness,and Physical Properties of 15 Tex PES/CO Blended Ring Spun Yarn. Journal of Natural Fibers, 9(3), 197-206.
8. Prakash C, Ramakrishnan G, Koushik CV, 2011, "Effect of Blend Ratio on the Quality Characteristics of Bamboo/Cotton Blended Ring Spun Yarn", Fibers & Textiles in Eastern Europe, 19, 6: 38-40
9. Samander Ali Malik, Assad Farooq, Thomas Gereke & Chokri Cherif (2016). Prediction of Blended Yarn Evenness and Tensile properties by using Artificial Neural Network and Multiple Linear Regression, *AUTEX* Research Journal, Vol. 19, No 1, March 2019, 16(2), 43-50.
10. Sekerden, F (2011). Investigation on the Unevenness, Tenacity and Elongation Properties of Bamboo/Cotton Blended Yarns, Fibers & Textiles in Eastern Europe,19(3), 26-29.

Fabrication of High-Quality Genome Assembly of Cultivated Alloltetraploid Cottons: A Way Towards Achieving Sustainability in Cotton Production

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ABSTRACT

The cotton plant achieved two remarkable milestones at the start of 2019. It has been first-ever plant grown on the lunar surface. Secondly, the construction of high-quality contagious genome assemblies of tetraploid cultivated cotton—remained instrumental in elucidating the evolution and adaptation and redesigning the genetic circuits of high-quality fiber of these polyploids.

INTRODUCTION

Cotton, the first ever plant grown on the surface of moon, has been providing natural fiber for clothing as well as edible oil to mankind since ages. The genus Gossypium contains ~52 species (Wendel and Albert, 1992; Krapovickas and Seijo 2008); however, *G herbaceum*, *G. arboreum, G. barbadense and G. hirsutum* have been domesticated, together sustain the textile industry of $899 billion (Rahman et al., 2021). Cotton researchers made efforts across the world to enhance the genetic diversity of cultivated cotton varieties by introgressing new traits from other cotton species; however, phyletic barriers and linkage drag of bad genes together hinder the progress of introgressing desirable genes. Even though limited success was claimed to replace these genes by attempting several rounds of backcrossing with the adapted cotton cultivars. In the present genomic age, these detrimental genes can be eliminated within short time using targeted genome, location of the genes, and their role in genetic circuiting in conferring important traits.

First step was taken towards cracking the sequence of the diploid cotton species, *G. raimondii* in 2007 (Chen et al., 2007). Two publications appeared in 2012 on sequencing of the D-genome cotton species (Paterson et al., 2012; Wang et al., 2012). Two years later, sequence information of *G. arboreum* was published (A-genome, Li et al., 2014). A year later, genome sequencing information of *G. hirsutum* (known for high yield) was made public by the two independent research groups (Li et al., 2015; Zhang et al., 2015). The genome of *G. barbadense*—known for producing high quality fiber, was cracked down (Liu et al., 2015; Yuan et al., 2015). Assemblies of these two species were not contiguous that limits their utility for using them as a reference genome. Their intergenic regions information was poorly presented. It is an established fact that contagious assemblies of big sized genome are very difficult to construct. For example, genome size of tetraploid cotton is ~2.6 Gb that was evolved through incurring several whole genome duplications in their progenitor species. Also, the cultivated tetraploid cotton is evolved through allopolyploidy event through uniting ‘A’ and ‘D’ genome species around 1-1.5 million years ago (Wendel, 1989; Senchina, 2003).

In 2019, two publications on improvement of contiguity of assemblies of *G. hirsutum* and *G.*

barbadense (Hu et al., 2019; Wang et al., 2019). Wang and his colleagues produced sequencing data of about 194 Gb for *G. hirsutum* and 210.98 Gb for *G. barbadense* with 80x depth of coverage using single-molecule real-time sequencing technology (PacBio RSII). Their sequences were assembled into contigs with L50 value of 2.15 megabases (Mb) for *G. barbadense* and 1.89 for *G. hirsutum*. These contigs were assembled into 3,032 for *G. barbadense* (L50= 6.89 Mb) and 2,190 scaffolds for *G. hirsutum* (L50= 5.22 Mb). The genome assembly of *G. hirsutum* was 55-fold more contagious than the previously reported assemblies. While the genome assembly of *G. barbadense* was 90-fold more contiguous than the earlier reported assembly. A total of 70,199 and 71,297 genes were found in *G. hirsutum* and *G. barbadense* genomes, respectively. A total of 9,135 presence/absence variations (PAVs) in *G. hirsutum* while 7,710 were found in *G. barbadense* (Wang et al., 2019).

In another paper published by Hu and his colleagues in 2019 produced a high-quality genome assembly for each of *G. hirsutum* and *G. barbadense*. They generated sequence reads of about 800 Gb with coverage of >330x. The huge depth of coverage enabled them to identify errors in actual sequence. These overwhelming majority of sequencing data was exploited to construct assemblies of both the cotton species. A large number of scaffolds with big sizes were generated, and few of these were reaching the length of a chromosome. The three-dimensional proximity information and ultra-dense genetic map (produced by mapping 6.1 million SNPs) were used to know their order and orientation. A total of 2.22 gigabases of *G. barbadense* var Hai7124 (91.4% of the total genome size) was assembled. The increased in contiguity over the published genomes was 47- and 90-fold (Hu et al., 2019). Their studies have shown that overwhelming majority of the sequencing reads (98.2%) were assigned to 26 chromosomes. They constructed a genome of assembly of *G. hirsutum* var TM-1 by assembling 2.36 Gb that was 10-fold more contiguous to one assembly (Zhang et al., 2015) and 20-fold more to another published genome assembly (Li et al., 2015). All the aforementioned genome assemblies can be used as reference to align the newly sequenced genotypes of different cultivated and wild cotton species.

It is well known fact that centromere of each chromosome is comprising of repetitive sequences, and these sequences have the ability to keep on expanding or contracting. This phenomenon may produce new sequences very quickly which makes the process of mapping of a centromere difficult. This challenge was addressed by producing a contiguous genome assembly which helped in mapping the centromeres on each chromosome mapped very accurately. Now the size of centromeric regions was confined to 270 Kb for Hai7124 and 385 kb for TM-1. This feature is further established the authenticity of newly developed high quality genome assemblies (Hu *et al*., 2019).

A total of 75,071 genes were found in *G. barbadense* while 72,761 genes for *G. hirsutum* var TM-1. Also, these genes have shown very clear boundaries for exon-intron. They also reported an overwhelming majority of transposable elements (TE) in both the species, i.e. 1460.46 Mb in TM-1 versus 1374.61 Mb in Hai7124. These elements are almost double in A subgenome than that of the D subgenome (Hu et al., 2019). It was estimated that these elements introgressed during the process of whole genome duplications occurred thrice around 15, 26 and 48 MYA (Zhang et al., 2015). It was also shown that high collinearity and conserved gene order between the two tetraploid species suggest that these species diverged around 0.4-0.6 MYA from a common progenitor. Frequent exchange of chromosome block in subgenomes of allotetraploids as compared to their diploid progenitors, accelerated the process of evolution fosters resulted in rapid evolution in tetraploid subgenomes. Signature of strong selection pressure was reported for A subgenome as compared to the D subgenome owing to the occurrence of high number of lost, disrupted and positively selected genes. They also confirmed the introgression of large genomic regions in all *G. barbadense* through deep sequencing of genotypes of *G. barbadense* and *G. hirsutum*. These introgressions played a gigantic role in adaptation of domesticated cottons in different environments (Hu *et al*., 2019).

As we know that cotton crop is facing several challenges which were depressing the cotton production. Another academic challenge is to define the genetic circuits and mechanisms of several important traits including quality and high yield traits, resistance to biotic and abiotic stresses, etc. By developing deep understanding about these mechanisms, then will be possible to design experiments for improving traits precisely. Recently, it has been shown that that Na^{+}/H^{+} antiporter (*GbNHX1*), sucrose transporter (*GbTST1*), vacuole-localized vacuolar invertase and aluminium-activated malate transporter (*GbALMT*) confer extra-long fiber trait in *G. barbadense* var Hai7124. Also, the preferential expansion of ADP-ribosylation factor (ARF) GTPase played a gigantic role in producing long as well as strong fiber**.** Similarly, high yield potential as well as resilience in *G. hirsutum* var TM-1 are defined by the divergent evolution of several genes after domestication (He *et al.,* 2019).

The high-quality genome assemblies of the cultivated cotton species will have synergistic effect on cotton breeding research—thus will prove a game-changer for achieving sustainable increase in cotton productivity beyond 2050. Using the high-quality genome assemblies, genome wide association studies (GWAS) can help in identifying genes as well as understanding the genetic mechanisms behind the traits. It is suggested that maximum benefit can be achieved from these high-quality sequenced genomes by initiating 1000-genome project for constructing a cotton pan-genome as demonstrated in rice. The generated information would be extremely useful for breeders for redesigning breeding strategies aiming for developing a super cotton plant, even that can survive for more extended time period at the moon.

These studies will also complement the ongoing research on other dicots especially those plants producing lint on their seed—will showcase several alternate options for cotton community to improve cotton. For example, *Calotropis procera* learns to grow in deserts of several countries including China, India, Pakistan, North Africa, South Asia, etc., and it produces hollow trichomes much longer than cotton ought to be sequenced preferentially for getting insight into the biology and evolution of long hallow fibers (Varshney and Bhoi, 1988; Cheem et al., 2010). Using the generated information will require invigorated efforts for improving resilience as well as staple length in cotton (Fig.1).

These findings also have the potential in initiating cotton precision breeding by editing the cotton genome precisely using CRISPR–Cas9 gene-editing assay. Gossypol free cotton seed (for aiding human health) can be produced by silencing the corresponding genes. Similarly, resilience can be induced in cotton either by overexpressing the genes or by silencing them. In conclusions, efforts at the genomic front will make the instrumental box of cotton breeders much more powerful for developing resilient cotton varieties with improved yield, fiber and oil quality—thus cotton production in the changing environments can be sustained beyond 2050 (Rahman et al., 2020).

References

1. Wendel, J. & Albert, V.A. *Syst. Bot.* 17, 115–143 (1992)
2. Krapovickas, A. & Seijo, G. *Bonplandia* 17, 55–63 (2008)
3. Rahman M, Y. Zafar & Tianzhen Zhang (Eds). 2021. Cotton Precision Breeding. Springer Publisher, Cham.

4. Chen, J. et al. Plant Physiology, 145: 1251-1263 (2007).
5. Paterson, A.H. *et al. Nature* 492, 423-427 (2012).
6. Wang, K. et al. Nat. Genet. 44, 1098–1103 (2012).
7. Li, F. *et al. Nat Genet* 46, 567-572 (2014).
8. Li, F. *et al. Nat Biotechnol* 33, 524-530 (2015).
9. Zhang, T. *et al. Nat Biotechnol* 33, 531-537 (2015).
10. Liu, X. *et al. Sci Rep* 5, 14139 (2015).
11. Yuan, D. *et al. Sci Rep* 5, 17662 (2015).
12. Wendel JF. *Proc Natl Acad Sci U S A*. 86(11), 132–6 (1989).
13. Senchina DS. Mol Biol Evol 20(4), 633–43 (2003).
14. Hu *et al*. Nat Gene 51 (4), 739-748 (2019).
15. Wang, M., *et al.*, *Nat Genet* 51, 224–229 (2019).
16. Varshney, A.C. and Bhoi, K.L. *Wastes* 26,(3), 229-232 (1988).
17. Naseer C.H et al. ***Elect J Biotech*,** 1322 11 (2010).
18. Rahman M. *ICAC Recorder* Vol 38, 4: 21-25 (2020).

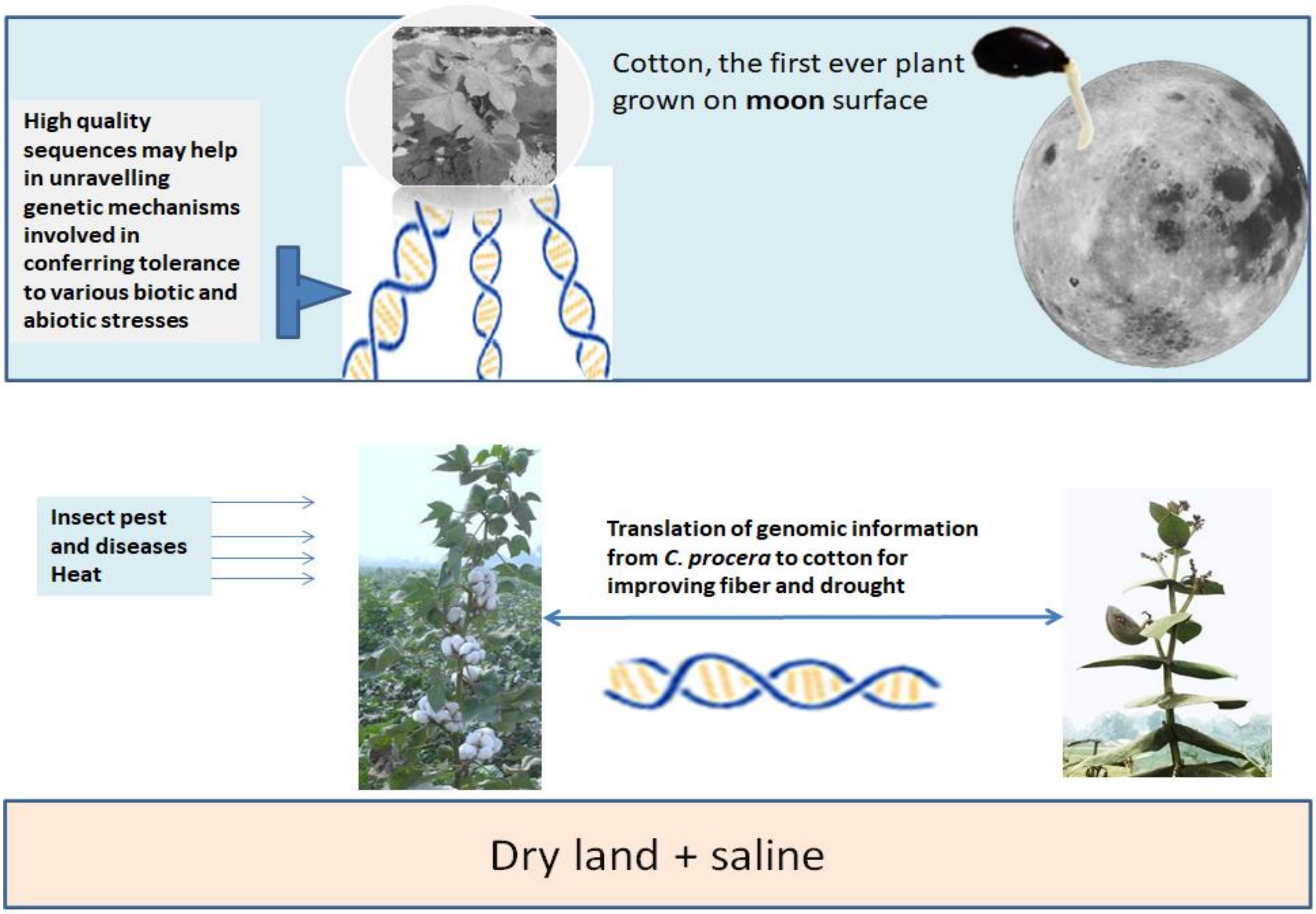

Fig.1. Developing climate smart cotton through bridging conventional and nonconventional genetic resources

Cotton Development Trust: Cotton Breeding in Zambia

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Zambia is a landlocked country located in the southern African region with about 752,617 Km^2 of land. Agriculture takes less than 40 % of this land. Cotton is a major cash crop in Zambia and is grown by over 200,000 small-scale farmers in the southern, Central, and Eastern parts of Zambia. The crop turns out to be a major source of livelihood for millions of people in Zambia.

The Cotton grown in Zambia stems from a resilient Cotton Breeding Program at The Cotton Development Trust (CDT) located in Magoye, Southern Province of Zambia. The Breeding program at CDT has been using different Breeding methods to broaden the variation of its elite germplasm to tackle many agronomic aspects that affect the different Stakeholders in the Cotton Industry. Some of the methods are outlined below.

Pedigree method.

The selection of genetically diverse parents has been a key factor in creating the variation found in the breeding program. Some of the lines come from different species that were collected from collaborations of the institute with other research institutes regionally and internationally. The selection at F2 has given the program an opportunity to identify superior traits at an early stage until the inbred lines attained homogeneity. Selection procedures have gone up to F9 or 9th generation of selection and segregation before subjecting the line to trialing tests. The preliminary trialing stage is usually carried out at research stations and on-farm stations to get attestations from the farmer through their appraisals. The National variety trialing stage involves trialing genotypes for performance in different traits and adaptability. Stability tests are also carried out to establish the sensitivity of the lines with respect to different Agro-ecological conditions. The CDT has used various stability models to help identify stable lines, specific environments, and mega environments. Some current lines up for release have been subjected to Additive main effects and multiplicative interaction (AMMI). Furthermore, Genotype and Genotype by environment interaction (GGE biplot) have also been used in the program to aid the critical cotton breeding decision-making process (Figure 1). More of this is found in this journal (https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3614473). Zambia has four (4) released varieties. Out of these, three commercial varieties namely Chureza, F135, and CDT II were produced through this long conventical pedigree method and hence these varieties have stood the test of time. Chureza has been commercially available for over 30 years while F135 has been on the market for over 20 years. CDT II is over 15 years old from the time of its release. These varieties are high yielding with seed cotton yields of 3000kg per hectare under rainfed conditions. They also have a high ginning out turn of over 45%, a plus for the Ginners. All these varieties are highly tolerant to some major bacterial and fungal cotton diseases. The high pubescence on the stems and leaves gives them a reasonable amount of tolerance to pests such as

Aphids. This conventional method has given an opportunity for breeders to explore their skills and know their variety's behavior through the years.

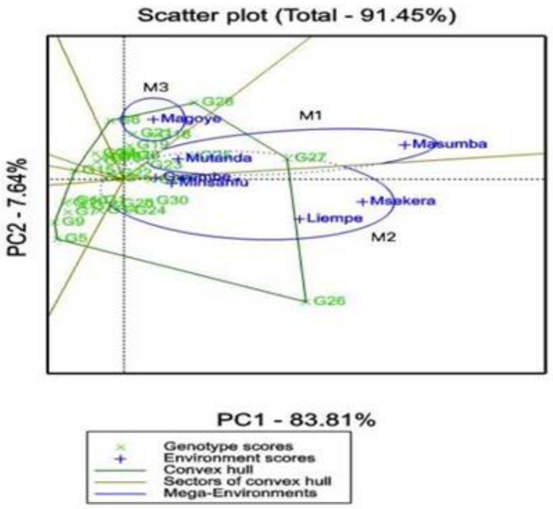

Figure 1: M1-First Mega environment, M2-Second mega environment and M3=Third mega environment, Genotype-Green cross symbol, Environments- Blue plus symbol, Mega environments- Blue circles

Other Breeding Methods

The CDT has used introduction methods to release a variety that was subjected to independent testing across the different environments for release (CDT V). Through collaborations with CIRAD, France, various genotypes were identified for potential release.

Mutation breeding has also been included in the program to create variation in the germplasm through the heritable changes brought about by the mutation induction. The CDT through the National Institute for Scientific and Industrial Research (NISIR) irradiated lines at different gamma radiation levels to produce M2 lines which were subjected to generational selection. Introgression of one or two traits from one cultivar to another has seen the CDT use the backcross method retaining the traits of the recurrent parent with the aim of releasing the variety for value for cultivation and use.

Challenges

The potential of the research center is huge. However, it does not fall short of challenges. The research center lacks a molecular lab to carry out molecular marker-assisted selection which could make the breeding selection process more efficient. This can also provide an opportunity to explore other more robust breeding methods such as the doubled haploids, gene editing, and so on. Furthermore, the research center also lacks a High-Volume instrument (HVI) to evaluate the fiber traits of cotton which are imperative for the textile sector. More collaborations need to be made between CDT and other research centers for the exchange of knowledge and materials where possible. The Zambia Cotton industry has for the past three years has gone down in terms of crop production due to boycott of farmers to grow Cotton and switching to other crops. This has emanated from low prices and poor management of the crop. Cotton Farmers in Zambia have been getting low seed cotton yields of as little as 500kg per hectare compared to the above-stated potential. The Cotton sector in Zambia needs to work together in order to address these challenges and the Cotton Development Trust needs to up its game by developing varieties that will carter to the farmers' needs so that Cotton continues to be an attractive crop to grow.

Way Forward

The CDT research center still continues to explore other Breeding methods such as Mass selection (Initiating selections from populations), Pureline selection, single seed descent, and so on. High selection differentials and breeding gains in key traits are the focus of the program. Several genotypes will be released on the market in less than three years' time.