Pak. j. sci. ind. res. Ser. A: phys. sci. 2024 **67A**(2) 157-163

# Comparative Study of Tensile Properties of Organic Cotton Yarn Spun at Siro and Ring Spinning Systems Under Various Machine Variables

**Muhammad Qamar Tusief*, Nasir Mahmood and Rana Atique-ur-Rehman**
Department of Fibre and Textile Technology, University of Agriculture, Faisalabad, Pakistan

(received November 16, 2021; revised May 8, 2023; accepted May 30, 2023)

**Abstract.** The textile industry in Pakistan covers the biggest part of its present industrial sector. The application of organic cotton opens new lines for human health eco friendly textile products free from all kinds of chemical residues. Chemical free textile products are highly demanding on consumer's end at national and international market with high value. The present study endeavours to explore the quality parameters of organic cotton yarns made by conventional ring spinning and siro spinning techniques in respect of their tensile properties. The general objective of the research was to comparative evaluation of impact of siro and ring spinning techniques on the quality of the organic cotton yarn especially on its tensile properties. The core objective was to find the optimal settings and speeds of both spinning systems in order to have yarn of optimum tensile properties. For this study three different spindle speeds (8000, 10000 and 12000 rpm), three twist levels (3.75, 4.00 and 4.25) and three variant ring diameters (35, 38 and 40 mm) were selected. For analyzing the data statistically, three factor factorial design was applied. It was observed that the organic yarns made at siro spinning system, for slow spindle speed (8000 rpm), at high twist level (4.25) and with small ring dia (35 mm) which had better tensile properties as compared to that of yarn made at conventional ring spinning system for these settings.

**Keywords:** organic cotton, ring spinning, siro spinning, tensile properties

## Introduction

Cotton is one of the main consumable fibre existing naturally and is being cultivated worldwide. Cotton is considered superior in respect of its wearing comfort, hygroscopic nature and natural appearance. Cotton has about 25 % share in the world textile fibre market (Gunydina *et al*., 2020). The significance of textile raw material depends upon its kind, handing out and end uses. The list of major cotton producing countries is given in Table 1. Pakistan ranks 5$^{th}$ in cotton production with 5 million bales of 480 lbs in the year 2021-2022 (Cotton Incorporated, 2021).

Cotton crop in Pakistan faces high threats in respect of insect-pests attack, water shortage and climate change. All these have increased immense pressure on cotton growers in the country and they are turning their attention towards growing other cash crops like sugarcane instead of cotton. Under all this scenario organic cotton is one of the more appealing and sustainable option for the farmers. The organic cotton production reduces the use of harmful insecticides and pesticides and allows farmers to grow other crops safely next to their cotton crop. More over rising demand of organic cotton from USA, Europe, UK and other world markets have sent a strong message to Pakistan like developing countries that if they convert towards organic cotton growing then they will be able to secure substantial financial rewards along with contribution towards environment, economy and social development (Erdal *et al*., 2022; Baloch *et al*., 2021).

The cotton fibre is processed to make staple yarn by spinning process. There exist many yarn spinning techniques but the dominating method of staple yarn spinning is ring spinning. In respect of producing good quality of yarn and having flexibility of yarn count range, ring spinning technique rules over all other staple yarn manufacturing mechanisms (Xia and Xu, 2013; Lawrence, 2010). In ring spinning technique there is formed single spinning triangle between the nip of the front rollers and twisted end of the yarn. The width of this spinning triangle mainly depends upon the yarn tension and varies inversely with the variation in this tension. Moreover, this triangle is narrower than the width of the fibres fed and this is the key weak point of ring spinning technique (Artzt, 2002; Kadoglu, 2001; Olbrich, 2000). The fibres in spinning triangle zone are twist less because of which the edge fibres splay out and make less contribution towards the strength of the

*Author for correspondence; E-mail:qamartosief@yahoo.com

resulting yarn (Fig. 1). The constant variation of this triangle considerably impacts the structural situation of the resultant yarn by influencing the interlacing and embedding of fibres effectively into the yarn (Xu *et al*., 2022). All these issues enforced the elimination or minimization of this spinning triangle to have good quality yarn and result was the development of Siro spinning mechanism (Meena *et al*., 2021).

Siro spinning process was introduced in the beginning of 1980's. This is basically a modified ring spinning system in which original one-ring spinning triangle is divided into three comprising two primary and one final triangle. In this spinning technique two rovings are fed simultaneously into the apron zone at a pre-determined separation. In this way two fibre strands result from the draft zone and move in the nip of front roller. At this stage these two fibre strands receives the primary twist producing two smaller primary triangles. Finally the finishing twist is imposed in these two strands for combining them into a Sirospun yarn. Here final spinning triangle is produced (Fig. 2). The final yarn so produced has same twist direction as that of the substrands (Buharali and Omeroglu, 2019). This technology is used to make special structured yarn in order to provide a pronounced impact on yarn quality.

The characteristics of yarn made from these systems differ from each other because of variant spinning triangle formation and tension values. In addition to spinning mechanism some other variables like twist per inch in yarn, spindle speed and ring diameter, also have considerable impact on the quality of yarn. Twist is considered to have crucial role to optimize the final properties of the yarn. It has been found that with the increase in twist level, the extension at break of the yarn increases along with the increase in its breaking strength (Ding *et al*., 2021). Similarly the spindle speed in ring spinning technique is of vital importance that put significant impact on its quality. Hence the precise setting of the spindle speed results in the reduction of yarn tension and optimizes the quality of yarn with high production rate. One can make good quality yarn with less breakage rate by selecting proper spindle speed (Islam *et al*., 2021).

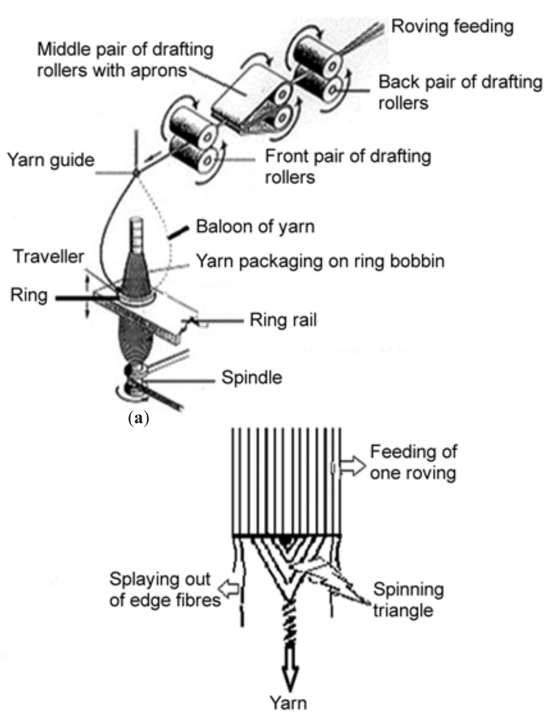


**Fig. 1.** Schematic diagram of yarn path (**a**) and formation of spinning triangle (**b**) in conventional ring spinning system.

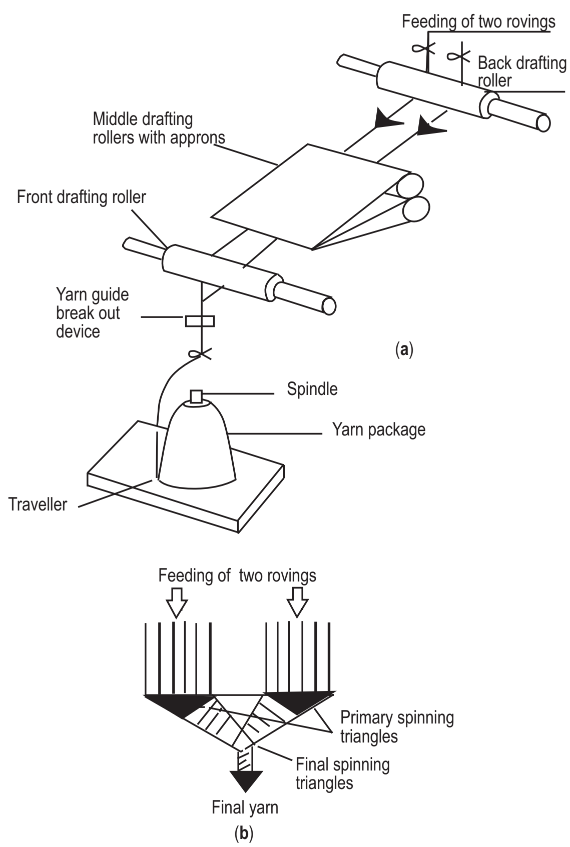


**Fig. 2.** Schematic diagram of yarn path (**a**) and spinning triangle (**b**) in Siro spinning system.

The ring diameter is also an important factor that influences the yarn quality. Increasing the ring diameter to produce larger cops has its limitations and disadvantages in the form of increasing the frictional drag of ring on the traveler during spinning. This will cause heat generation at the ring traveler interface resulting in melting of the traveler and traveler can no longer be effectively used for spinning causing in an increase of yarn breakage rate (Lawrence, 2010).

Hence all the above mentioned spinning machine parameters were found to have significant impact on yarn quality in many studies, however a comprehensive work regarding the comparison of conventional ring spinning and siro spinning system in respect of these parameters for organic cotton yarn specifically needed to be carried out. In this backdrop this research work was attempted. The main objective was to optimize the settings of these machine variables for both siro and ring spinning systems in order to achieve yarn of optimum quality and pave a guide path for organic cotton yarn manufacturers on these spinning systems.

## Materials and Methods

The current study was initially started in the Department of Fibre and Textile Technology, University of Agriculture, Faisalabad and practically conducted in a reputed textile mill "Gulistan Textile Mills Ltd'', Multan road, Lahore, Pakistan. The complete description of the material used and the methods applied for the assessment of effects of ring and siro pinning system and machine variables like twist multiplier, spindle speed, and ring diameter upon quality of yarn are described below.

**Used material.** The raw material (organic cotton) samples were collected from the running stock of the ''Gulistan Textile Mills Ltd''; and tested in order to verify their physical properties on (HVI 900 SA).

**Applied methods.** The raw cotton samples were conditioned in the standard atmosphere conditions *i.e.* 65 ± 2 % relative humidity and 20 ± 2 °C temperature, before testing the physical characteristics. The HVI machine was calibrated first according to the instructions provide in its manual supplied by M/S Zellweger Ltd. (1995) applying ASTM Standards (2008b). The values of the physical properties are given in Table 1.

**Processing at ring frame.** The samples of raw material were processed in the blow room, carding, drawing and roving section at standard machinery setting and processing variables. For Siro spinning purpose a double rove guide was used. It was installed on the same ring spinning frame.

**Table 1.** Physical characteristics of organic cotton

| S. no. | Length (mm) | Strength g/tex | Fineness (mic) | Short fibre content % | Trash content % |
|---|---|---|---|---|---|
| 1 | 27.48 | 27.9 | 4.4 | 11.21 | 5.2 |
| 2 | 27.44 | 27.7 | 4.3 | 11.56 | 5.5 |
| 3 | 27.49 | 27.8 | 3.9 | 11.72 | 5.7 |
| 4 | 27.73 | 28.7 | 4.2 | 12.20 | 5.3 |
| 5 | 27.38 | 27.7 | 4.2 | 11.98 | 5.5 |
| 6 | 27.40 | 27.5 | 4.3 | 12.30 | 5.7 |
| 7 | 27.48 | 27.8 | 4.5 | 11.56 | 5.5 |
| 8 | 27.53 | 28.3 | 4.1 | 12.57 | 5.3 |
| 9 | 27.46 | 28.1 | 4.3 | 11.20 | 5.5 |
| 10 | 27.23 | 27.9 | 4.1 | 12.66 | 5.2 |
| Mean | 27.46 | 27.94 | 4.23 | 11.9 | 5.44 |
| C.V % | 0.01 | 0.11 | 0.03 | 0.25 | 0.03 |
| S. D. | 0.13 | 0.35 | 0.17 | 0.53 | 0.18 |

S.D. = Standard deviation; CV = Co-efficient of variation.

The yarn of 20s was made with roving of 0.8 hank, processed at ring frame with Siro spinning system (Y1) and conventional spinning system (Y2) and their comparative study for the following mechanical variables, twist multiplier, (T1,T2 ,T3). Spindle speed (S1, S2, S3) and ring diameter (D1, D2, D3) was observed, as given in the Table 2.

**Measurement of yarn tensile properties.** The prepared yarn samples were tested for their tensile properties *i.e.* Single end strength (SES), Rupture per kilometer (RKM) and elongation, according to the standard methods ASTM (2008a). By Uster Tensorapid- 3. This instrument uses CRE (constant rate of extension) principle of testing tensile properties with the help of detaching clamps in which specimen is caught. The calculation of breaking tenacity was made from the maximum force applied anywhere between the beginning of the test and the final rupture of the specimen while the breaking

**Table 2.** Settings of different mechanical variables on spinning frame.

| Spinning system (Y) | Spindle speed (rpm) (S) | Twist multiplier (T) | Steel ring diameter (mm) D) |
|---|---|---|---|
| $Y_1$=Siro spinning | $S_1$= 8000 | $T_1$= 3.75 | $D_1$= 35 |
| $Y_2$=Ring spinning | $S_2$= 10000 | $T_2$= 4.00 | $D_2$= 38 |
| | $S_3$= 12000 | $T_3$= 4.25 | $D_3$= 40 |

elongation is calculated from the displacement of the clamps at the point of peak force.

**Data analysis.** For testing the difference among various quality characteristics, the collected data was analyzed using factorial (Montgomery, 2009) using SPSS (statistical package for social sciences) micro-computer statistical program.

## Results and Discussion

The prepared yarn samples according to the selected variables as given in Table 1 were tested for their tensile properties. The results so observed and the analyses of data is as under.

**Single end strength (SES) (g).** The comparison of mean values of yarn single end strength for selected variables is presented in Table 3 that indicates highly significant difference among the values. The SES of yarn made from siro (Y1) and ring (Y2) spinning systems were noted as 455.41 and 444.63 g respectively. It is clear from the data that the SES of yarn made from Siro spinning system was more as compared to that of yarn made from ring spinning system. These findings are in line with the results that the yarn strength improved remarkably for siro spinning system (Lu *et al*., 2019). The SES values for different spindle speeds S1, S2 and S3 were found 459.72, 449.67 and 440.67 g respectively. These results showed that S1 had more single end strength value as compared to that of S2 and S3. Similar observations were noted by Miah *et al*. (2019), that yarn reflected good strength at moderate spindle speed. The SES of yarn noted for various levels of twist, T1, T2 and T3 were 441.33, 449.78 and 458.94 g respectively, while the value of SES for different ring diameter, D1, D2 and D3 were 467.83, 449.33 and 432.89 g respectively. This data reflected that the SES of yarn was more for high twist level and less ring dia (Fig. 3). These findings get support from the previous observations that SES of yarn increased with the increase in twist level (Walle *et al*., 2022) SES of yarn increased with the increase in twist level, while decreased with the increase of ring dia because the increase in ring dia increase ring traveler frictional force that put negative impact on the resultant yarn strength (Yin *et al*., 2021).

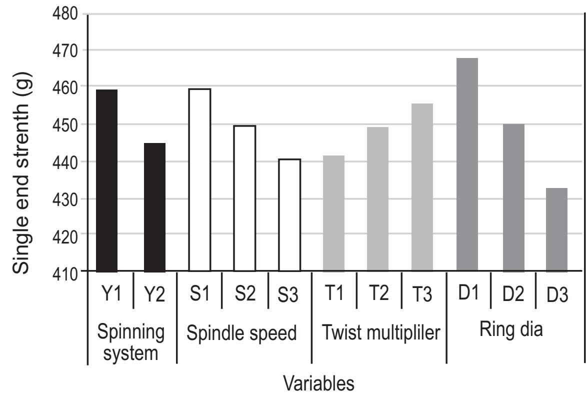


**Fig. 3.** Comparison of yarn single end strength (g) for selected variables.

**Rupture per kilometer [RKM] (g/tex).** The data regarding the comparison of individual mean values of RKM is given in Table 4. All the values have highly significant difference among each other. The RKM values for different spinning systems Y1 and Y2 are 15.436 and 15.009 g/tex respectively. The data depicts that siro spun yarn has more RKM value than that of ring spun yarn. These findings correlate with the results that the yarn breaking strength is positively correlated with the yarn fibre migration and yarn fibre migration is more in compact spinning techniques like siro as compared to that of ring spinning technique that is why compact yarns have more breaking strength than that of ring spun yarns (Basal and Oxenham, 2006). Similarly RKM value noted for various spindle speeds S1, S2 and S3 were 15.46, 15.221 and 14.97 g/tex respectively. These results clear that with the increasing spindle speed yarn strength decreases. Similarly the data regarding the RKM of yarn at various twist levels *i.e*. T1, T2 and T3 were 14.896, 15.297 and 15.474 g/tex respectively.

**Table 3.** Comparison of individual treatment means for Yarn SES (g)

| Spinning system | Means | Spindle speed | Means | T.M | Means | Ring dia | Means |
|---|---|---|---|---|---|---|---|
| Y1 | 455.41 a | S1 | 459.72 a | T1 | 441.33 c | D1 | 467.83 a |
| Y2 | 444.63 b | S2 | 449.67 b | T2 | 449.78 b | D2 | 449.33 b |
| | | S3 | 440.67 c | T3 | 458.94 a | D3 | 432.89 c |

Different letters on mean values indicates their significant difference among each other at 5% significance level

**Table 4.** Comparison of individual treatment means for RKM(g/tex)

| Spinning system | Means | Spindle speed | Means | T.M | Means | Ring dia | Means |
|---|---|---|---|---|---|---|---|
| $Y_1$ | 15.436 a | $S_1$ | 15.468 a | $T_1$ | 14.896 c | $D_1$ | 15.464 a |
| $Y_2$ | 15.009 b | $S_2$ | 15.221 b | $T_2$ | 15.297 b | $D_2$ | 15.277 b |
| | | $S_3$ | 14.978 c | $T_3$ | 15.474 a | $D_3$ | 14.926 c |

Mean values having different letters differ significantly at 5% level of significance.

While the values of RKM for variant ring dia D1, D2 and D3 were recorded as 15.464, 15.277 and 14.926 g respectively. These findings indicate the increase in yarn RKM value with increasing twist level and decrease with the increasing ring diameter (Fig. 4). The decrease in yarn strength due to increasing spindle speed is because, the selvedge fibre tension in spinning triangle increases with increasing spindle speed that results in fibre slippage in the spinning triangle. This reduces the overlap length among the fibres in the yarn that reduces the overall strength of the yarn. Similarly as the twist level increases the fibre compactness in yarn increases that enhances the yarn packing density which is responsible for increase of yarn strength (Ishtiaque *et al*., 2018).

**Yarn elongation (%).** The comparison of individual means of values of yarn elongation for selected variables is presented in Table 5. All the values have highly significant difference among each other. The elongation value for various spinning systems Y1 and Y2 are 6.07 and 5.90 % respectively. These results show that Siro spun yarn had more elongation value as compared to that of ring spun yarn. These results correlate with the findings that yarn made from siro spinning system has more elongation percentage as compared to that of made from ring spinning system (Sun and Cheng, 2000). The elongation value for different spindle speeds S1, S2 and S3 were recorded as 6.08, 5.99 and 5.89 % respectively (Table 5) which depicts that elongation of yarn was more at lower spindle speed than that of yarn made at high spindle speeds. These results are in line with the observations that increasing spindle speed put adverse impact on yarn elongation (Patil *et al*., 2018).

The results regarding the yarn elongation for variant twist level depicted the increase in yarn elongation percentage with the increasing twist (Fig. 5). This is because, the increasing twist level in the yarn, increases the helix angle of core fibres which enhances the force holding the fibres together. Resultantly, the fibres in the yarn held tightly that reduces the slippage of fibres under tensile loading. All this increased the number of fibres contributing the overall strength of the yarn and ultimately the yarn gets immunity to withstand against high load that increases its elongation property (Ahmed *et al*., 2016). Similarly the effect of different ring diameter on yarn elongation percentage is elaborated in Fig. 5. It is clear from the graph that the increasing

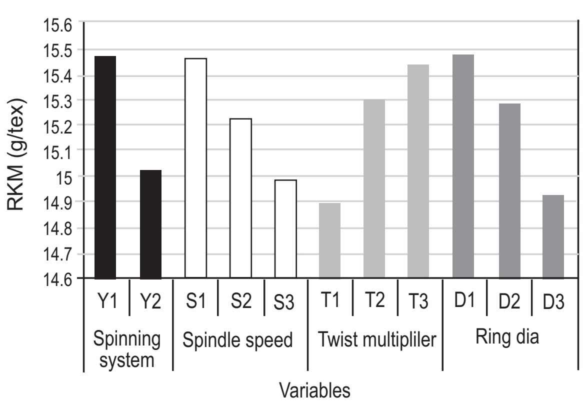


**Fig. 4.** Graphical comparison of yarn RKM (g/tex) for different selected variables.

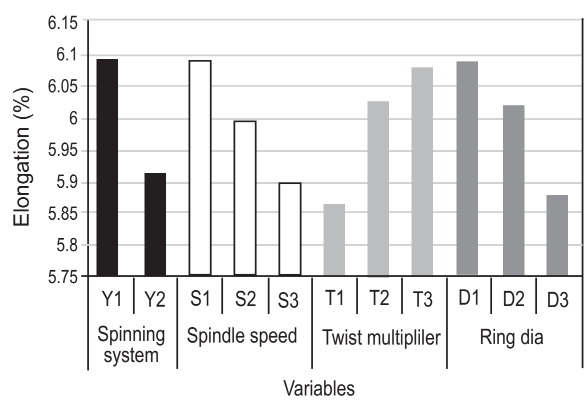


**Fig. 5.** Graphical representation of individual means comparison for yarn elongation (%).

**Table 5.** Comparison of individual treatment means for yarn elongation %

| Spinning system | Means | Spindle speed | Means | T.M | Means | Ring dia | Means |
|---|---|---|---|---|---|---|---|
| Y1 | 6.0770 a | S1 | 6.0899 a | T1 | 5.8646 c | D1 | 6.0881 a |
| Y2 | 5.9090 b | S2 | 5.9923 b | T2 | 6.0223 b | D2 | 6.0147 b |
| | | S3 | 5.8968 c | T3 | 6.0921 a | D3 | 5.8762 c |

The values with different letters have significant difference among each other with 5 % significance level

ring diameter put negative impact on yarn elongation value.

## Conclusions

The overall findings of the study showed significant impact of siro and ring yarn spinning techniques on yarn quality. Different machine variables of these systems like spindle speed, twist multiplier and ring diameter also established profound impact on tensile properties of resultant organic cotton yarn. Moreover, it is depicted from this study that siro spinning proved itself better than ring spinning system in respect of producing yarn of good tensile properties, while individually both spinning techniques revealed better performance in respect of producing yarn of good tensile properties at low spindle speed and small ring diameter with high twist level.

**Conflict of Interest.** The authors declare they have no conflict of interest.

## References


Ahmed, F., Shaikh, G.Y., Pathan, A.A, 2016. Effect of lowering twist levels on quality parameters of rotor spun cotton yarn. *Mehran University Research Journal of Engineering & Technology*, **35:** 425-430 [p-ISSN: 0254-7821, e-ISSN: 2413-7219].

Artzt, P. 2002. Possibilities of improving the efficiency of compact spinning. *Melliand English*, **3:** 19-21.

ASTM committee, 2008a. *Standard Test Method for Measurement of Yarn*. ASTM Designation D: 1907-07, D: 1578-93, D: 2256-02, D: 6197-99. Amer. Soc. for Test. & Mater. Philadelphia, U.S.A.

ASTM Committee, 2008b. S*tandard Test Methods for Measurement of Physical Properties of Cotton Fibers*. ASTM Designation D: 5867-05. Amer. Soc. for Test. & Mater. Philadelphia, U.S.A.

Baloch, B.L., Penrhys-Evans, T., Safdar, U. 2021. *Organic Cotton in Pakistan: Policy Analysis and Recommendations*. https://blog.cabi.org/2021/07/06/organic-cotton-in-pakistan-policy-analysis-and-recommendations/.

Basal, G., Oxenham, W. 2006. Comparison of properties and structures of compact and conventional spun yarns. *Textile Research Journal*, **76:** 567-575.

Buharali, G., Omeroglu, S. 2019. Comparative study on carded cotton yarn properties produced by the conventional ring and new modified ring spinning system. *FIBRES & TEXTILES in Eastern Europe*; **27:** 45-51.

Cotton Incorporated, 2021. Monthly Economic Letter: Cotton market fundamentals & price outlook, September 2021. https://www.cottoninc.com/wp-content/uploads/2021/09/2021-09-Monthly-Economic-Letter.pdf

Ding. Z., Zhao, H., Hu, W., Wang, R. 2021. The role of twist on tensile and frictional characteristics of aramid filament yarns (AFYs). *Material Research Express*, **8:** 025301.

Erdal, U., Zerrin, C., Aynur, G. 2022. Evaluating organic cotton production in Tukiye. *4th International Conference on Organic Agriculture in Mediterranean Climates: Threats and Solutions. May 27-29, 2022*, *11th Ecology Izmir Fair*.

Gunaydina, G.K., Palamutcu, S., Soydan, A.S., Yavas, A., Avinc, O., Demirtas, M. 2020. Evaluation of fibre, yarn and woven fabric properties of naturally colored and white Turkish organic cotton. *The Journal of the Textile Institute*, **10:** 1436-1453.

Islam, M.R., Chakrabortty, A., Ghosh, J., Iqbal, T., Hossen, M.T. 2021. Importance of spindle speed in ring frame. *International Journal of Engineering & Technology*, **10:** 85-88.

Ishtiaque, S.M., Ghosh, D., Yadav, V.K. 2018. Influence of ring frame process parameters on yarn structure and fabric assistance. *Indian Journal of Fibre & Textile Research*, **43:** 164-172.

Kadoglu, H. 2001. Quality aspects of compact spinning. *Melliand International*, **7:** 23-25.

Lawrence, C.A. 2010. *Advances in Yarn Spinning Technology*. Woodhead Publishing, pp. 463. Cambridge, UK.

Lu, Y., Wang, Y., Gao, W. 2019. Strength distribution superiority of compact Sirospun yarn. *Journal of Engineered Fibres and Fabrics*, **14:** 1-8.

Meena, H.C., Shakyawar, D. B., Varshney, R. K., Kumar, A., Chattopadhyaya, R. 2021. Productivity, quality and comfort of Sirospun wool-cotton khadi fabrics. *The Journal of the Textile Institute*, https://doi.org/10.1080/00405000.2021.1910400.

Miah, L., Sharmin, N., Yasmin, J. 2019. Impact of Spindle speed and treveler weight on the tensile properties of yarn explicity the yarn tenacity and elongation at break. *International Journal of Innovative Science, Engineering & Technology*, **6:** 2348-7968.

M/S Zellweger, 1995. Instruction Manual High Volume Fibre testing system. Uster Ltd, Switzerland.

Montgomery, D.C. 2009. *Design and Analysis of Experiments* 7th edition, Arizona State University, ISBN: 978-0-470-12866-4.

Olbrich, A. 2000. The Air-Com-Tex 700 condenser ring spinning machine. *Melliand International*, **6:** 26-29.

*Pakistan Economic Survey, 2020-21*. Agriculture. Government of Pakistan, Finance Division, Pakistan.

Patil, J.D., Kolte, P.P., Gulhane, S.S., Bathla, S. 2018. Effect of spindle speed of ring frame on yarn quality. Spin clinic, Gttes Special Issue, *Spinning Textiles*, Nov-Dec.

Sun, M.N., Cheng, K.P.S. 2000. Structure and properties of cotton sirospun® yarn. *Textile Research Journal,* **70:** 261-268.

Walle, G.A., Desalegn, A., Ermiyas, T., Addisu, W., Addisu, D. 2022. Prediction of mechanical, evenness and imperfection properties of 100% cotton ring spun yarns with different twist levels. *Mehran University Research Journal of Engineering & Technology,* **41:** 14-22.

Xia, Z., Xu, W. 2013. A review of ring staple yarn spinning method development and its trend prediction. *Journal of Natural Fibres*, **10:** 62-81.

Xu, D., Hang, F., Wangwang, Y., Keshuai, L., Weilin, X. 2022. Novel structural composite yarns spun with harmonic migrations of filaments. *Fibres and Polymers*, **23:** 1725-1733.

Yin, R., Ling, Y.L., Fisher, R., Chen, Y., Li, M.J., Mu, W.L., Huang, X.X. 2021. Viable approaches to increase the throughput of ring spinning: a critical review. *Journal of Cleaner Production*, **323:** 129-116.