Indian Journal of Fibre & Textile Research
Vol. 50, September 2025, pp. 323-327
DOI: 10.56042/ijftr.v50i3.7704

Short Communication

Ecofriendly dyeing of recycled cotton yarn using babool bark extract and biomordants for enhanced performance

Ramakrishnan Govindan[1,a], Poongodi Bhupathy[2], Priyadarshini Rajasekaran[3] & Sri Ganapriya Rajan[4]

[1]Department of Fashion Technology, Kumaraguru College of Technology, Coimbatore 641 006, India

[2]Associate Professor, Kumaraguru College of Technology - Business School 641 094, India

[3]Department of Fashion Technology, Kumaraguru College of Technology 641 006, India

[4]Department of Fashion Technology, Kumaraguru College of Technology 641 006, India

Received 31 December 2023; revised received and accepted 25 April 2024

This study investigates an eco-friendly process for producing naturally dyed recycled cotton yarn, integrating traditional desizing and scouring techniques with natural mordanting and dyeing. An aqueous extract of babool bark is employed for natural dyeing. Mordanting with myrobalan and pomegranate rind is reported to enhance dye fixation and colour vibrancy. FTIR analysis confirms characteristic functional groups associated with improved dye–fibre interactions, with spectral variations between mordants.

Keywords: Babool bark, Dyeing, Natural mordant, Recycled cotton yarn

The importance of handloom textiles dyed with natural colours lies in their ability to encapsulate the essence of a bygone era while aligning with modern aspirations for sustainable living. The application of natural dye on handloom fabric gained significant interest in recent years, driven by the growing demand for eco-friendly textile production[1]. Natural dyes ensure that the materials' sources are sustainable and do not contribute to habitat destruction or overharvesting[2,3]. Natural dyes are considered to be eco-friendly[4,5], in contrast with synthetic dyes, which are often made from petroleum products and can be harmful to the environment[6-9], due to several reasons, including biodegradability, being synthesised from renewable resources, low energy consumption, water conservation, etc. With advancements in research and technology, artisans, designers, and the textile industry are rediscovering and embracing the rich history and potential of natural dyes. The dyeing and finishing process uses hazardous chemicals[10-12], making it a major source of cancer-causing and other reasons leading to toxicity in humans. However, natural dyeing is not technologically or economically feasible for the power loom industry [13,14].

Handloom textiles, woven with tradition and imbued with cultural significance, face the dual challenge of maintaining quality while embracing sustainable practices. The use of natural dyes in handloom textiles has a positive impact on local economies and artisan communities. Among various natural dye sources, Babool (*Acacia nilotica*) stands out for its abundance in India, ease of cultivation, and rich tannin content, which yields a range of warm brown shades[15]. Traditionally used for medicinal and textile purposes, Babool bark contains compounds such as gallic acid, catechins, quercetin, kaempferol, and ellagic acid, which contribute to its dyeing potential. Studies have shown that Babool bark extracts—both aqueous and ethanolic—can achieve good colour fastness on wool and silk[16,17], especially when used with suitable mordants[18-20]. The use of Babool bark not only reduces dependence on synthetic dyes but also supports local artisan communities by preserving traditional dyeing practices.

Biodegradable mordants also play a crucial role in textile dyeing processes, providing a sustainable alternative to conventional mordants while minimising environmental impact. Biodegradable mordants like Myrobalan (*Terminalia chebula*) and pomegranate rind have emerged as sustainable alternatives. Myrobalan is rich in hydrolysable tannins, chebulagic acid, and gallic acid, enabling strong dye–fibre bonding. Similarly, pomegranate rind contains phenolic compounds, punicalagin, and ellagic acid, which improve dye stability and impart antioxidant benefits[21,22]. Pomegranate (*Punica granatum*) peel is rich in phenolic compounds, particularly hydrolysable tannins[23] and flavonoids, with punicalagin occurring in the highest concentration[24]. These bioactive compounds enhance the binding of natural dyes to fibres, improve colour stability, and provide antioxidant benefits, making pomegranate peel an effective, eco-friendly mordant

[a]Corresponding author.
E-mail: ramakrishnan.g.ft@kct.ac.in

for textiles and also reported to improve UV protection and antimicrobial properties[25]. These mordants not only facilitate dye fixation but also offer additional benefits such as improved colour yield and compatibility with organic and eco-friendly dyeing techniques. By incorporating biodegradable mordants into textile dyeing processes, manufacturers can reduce their environmental footprint and contribute to sustainable practices in the textile industry, meeting the growing demand for eco-friendly and socially responsible products.

This study explores the dyeing of recycled cotton with Babool bark extract using biodegradable mordants (myrobalan and pomegranate rind), assessing their mordanting efficiency, bonding affinity, and impact on colourfastness properties. Performance evaluation includes FTIR analysis to understand dye-fibre interactions and standard tests for colourfastness in washing and rubbing.

Experimental

Recycled cotton (Ne 10s) yarn was selected to align with sustainable practices, minimising waste and promoting eco-friendly production. Myrobalan and pomegranate rind were used as natural mordants to enhance dye fixation and durability. Only recycled cotton yarn (Ne 10s) was dyed and tested in this study. Staining behaviour was evaluated using the ISO multifibre adjacent fabric containing wool, acrylic, polyester, nylon, cotton and acetate.

Desizing was conducted using a saponin-rich extract from soap nut (*Sapindus mukorossi*). 50 g of soap nuts were soaked in 1 L of water for 12 h at room temperature. From this, a 30 g/L solution was transferred to a 10 L vessel filled with water, heated to 60 ºC, and maintained for 30 min with gentle stirring. The yarn was subsequently rinsed under tap water.

Scouring was performed using a natural alkali solution made from wood ash mixed with water at a ratio of 150 mL/ 10 L. The solution was heated gradually to 60 ºC and held for 30 min, allowing a thorough scouring effect on the desized recycled yarn. After scouring, the yarn was rinsed thoroughly and cold-washed to remove residual alkali. The post-treatment yarn—now termed "ready-for-dyeing" (RFD)—exhibited a pH of approximately 5.3.

Mordant baths of myrobalan and pomegranate rind were prepared at 50 g/L concentrations. Each was boiled until its volume reduced from 1.0 L to approximately 700 mL. 200 mL of each extract was then filtered and diluted with 600 mL of water to yield 800 mL of mordant solution. The RFD yarn was pre-wetted and introduced into the mordant bath at 40 °C (material-to-liquor ratio 1:30), raised to 60 °C over 15 min, and held for 30 min. After mordanting, the yarn was rinsed and air-dried.

Approximately 1.2 kg of babool bark was boiled with 6 L of water at 80 °C for 2 h and then filtered to remove insoluble residues. Dyeing was conducted immediately thereafter; the mordanted yarns were introduced at 40 °C (MLR 1:30), gradually heated to 80 °C over 20 min, and held at that temperature for 60 min with intermittent stirring. Following dyeing, the yarn was rinsed to neutral pH and air-dried.

Capillary rise was measured on conditioned yarn samples. A yarn sample was suspended with its lower end in contact with water, and the height of moisture rise due to wicking was recorded at 5-min intervals for 30 min.

FTIR analysis helps identify the chemical functionalities of the dye molecules, providing insights into the dyeing mechanisms and potential interactions with the fibre. The experiment was carried out using IRAffinity-1S (Shimadzu Japan), and the spectra were recorded.

The colour fastness to washing of the dyed recycled cotton yarn was tested by washing it together with ISO multifibre adjacent fabric (wool, acrylic, polyester, nylon, cotton, acetate). The colour fastness to rubbing was conducted according to the ISO 105-X 12:2016 standard. Tests were performed under ISO 139 conditioning (20 ± 2 °C, 65 ± 4 % RH). A 16.0 ± 0.1 mm rubbing finger was used with a downward force of 9.0 ± 0.2 N, for both dry and wet rubbing (95–100 % wet pick-up). Staining was assessed using the ISO standard grey scale.

Results and Discussion

Determination of Weight Loss in Bio-Scouring

The bio-scouring process effectively removes impurities from the recycled cotton yarn, as evidenced by a measurable reduction in material weight. Before weighing, both unscoured and scoured samples are conditioned to the same moisture level to ensure accuracy. The weight loss observed after scouring with ash water is 4.68 %, calculated from the initial yarn weight of 82.16 g and the final weight of 78.31 g.

This loss reflects the removal of non-cellulosic substances such as oils, waxes, dirt, and residual sizing agents from the yarn. Ash water, derived from the combustion of plant materials, contains alkaline

compounds that function as natural surfactants, breaking down and dissolving these impurities. The significant weight reduction confirms the efficacy of ash water as a sustainable and eco-friendly scouring agent, providing an effective preparation step before dyeing.

Wicking Test

The wicking performance of the bio-scoured yarn demonstrates a rapid initial water uptake, followed by a marked decline (Fig. 1). At 5 min, the wicking height reaches 8.9 cm, showing a strong initial wicking capacity. By 10 min, this height drops significantly to 2.6 cm, indicating a rapid loss of wicking potential. From 15 min onward, the wicking height stabilises around 1.8 cm, with only minor decreases to 0.7 cm by the 30-min mark. This behaviour suggests that while the yarn absorbs water efficiently at first, the capacity diminishes significantly within the first 10–15 min. The slower rate of uptake thereafter may be due to the saturation of capillary spaces and increased resistance to further liquid migration.

Colour Fastness

Washing fastness

In this study, only recycled cotton yarn was dyed and tested. The staining ratings for wool, acrylic, polyester, nylon, cotton, and acetate were evaluated using standard ISO multifibre fabric, as recommended in ISO 105-C10:20069RA 2021[26]. The washing fastness testing was carried out in-house using well-equipped facilities, ensuring reliable and accurate assessment of colour stability. The controlled procedure simulated actual laundering conditions, allowing precise evaluation of shade retention. The results shown in Table 1 indicate that both mordanted samples exhibit stable colour performance with a slight change in colour (4/5) and negligible staining on multifibre fabric (rating 4/5), confirming good colour fastness property.

Rubbing fastness

Table 1 shows the colour fastness to rubbing as per the ISO standard. It can be seen that both dyed samples exhibit stable colour performance with moderate to good colour fastness properties. Myrobalan mordanted sample shows good (dry rubbing) and moderate (wet rubbing) colour fastness property. Samples mordanted with pomegranate rind showed moderate to good (dry rubbing) colour fastness property and moderate (wet rubbing) colour fastness property. Similar observations have been reported for pomegranate rind as bio mordant[27].

FTIR Results

The FTIR spectra (Fig. 2) reveal characteristic peaks of cellulose and functional groups introduced by the mordanting process. The strong peak near 3300 cm^{-1} corresponds to O–H stretching vibrations of hydroxyl groups in cellulose[28]. The hydroxyl groups in myrobalan tannins can form hydrogen bonds with the OH groups in cellulose, slightly altering the peak position and intensity. By promoting dye attachment, myrobalan can indirectly affect the O-H stretching

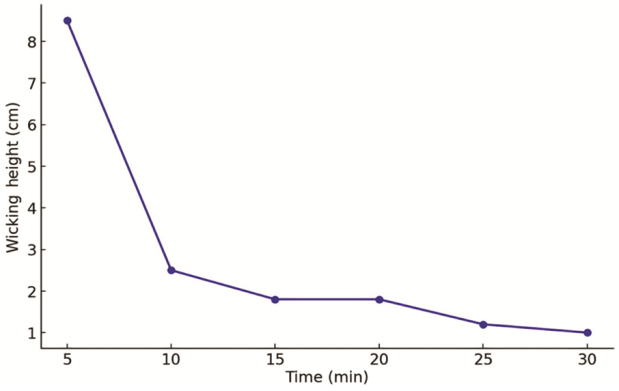

Fig. 1 — Wicking height of bioscoured sample over time

Table 1 — Colour fastness to rubbing & washing in recycled cotton yarn dyed with babool bark and two biomordants

Property	Colour fastness to washing Sample A (myrobalan mordant)	Sample B (pomegranate rind mordant)
Change in colour	4/5	4/5
Staining	4/5	4/5
Colour fastness to rubbing		
Dry rubbing (staining)	4	3/4
Wet rubbing (staining)	3	3

Grey Scale Rating for change in colour: 5-No change, 4-Slightly changed, 3-Noticeably changed, 2-Considerably changed, 1-Much changed.
Grey Scale Rating for staining: 5-No staining, 4-Slightly stained, 3-Noticeably stained, 2- Considerably stained, 1-Much stained.

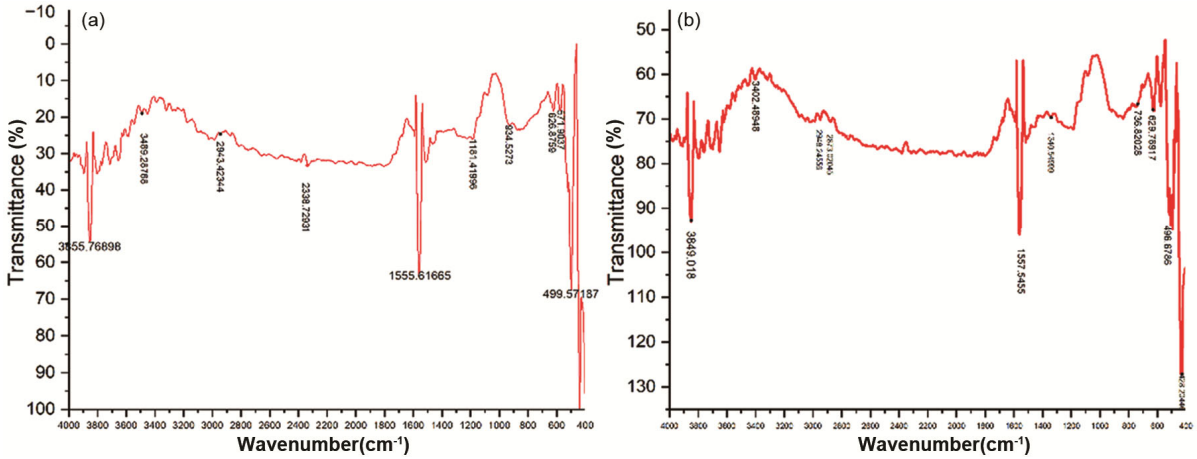

Fig. 2 — FTIR analysis of the recycled yarn dyed with babool bark and myrobalan (a) and pomegranate rind (b) as mordant

peak. Dye molecules containing hydroxyl groups may further increase the intensity of the peak around 3409 cm^{-1} indicating enhanced dye–fibre interactions, consistent with findings reported and demonstrated similar functional group modifications during tannin cellulose interactions.

For Sample A (myrobalan mordant), peaks at 1316.44 cm^{-1} and 3409.24 cm^{-1} correspond to the stretching vibrations of alcoholic O - H groups, while the broad peak between 2921.24 cm^{-1} and 2359.06 cm^{-1} suggests N-H stretching vibrations, possibly from amine compounds originating from an amine salt used in the dyeing process. The peak at 1652.06 cm^{-1} might be attributed to the C=C stretching vibrations of a disubstituted alkene (cis configuration).

For Sample B (pomegranate rind mordant), peaks at 1373.44 cm^{-1} and 3380.31 cm^{-1} similarly indicate alcoholic O-H groups, confirming the presence of hydroxyl groups, likely introduced by the pomegranate rind pre-mordant. Weak peaks at 2857.59 cm^{-1} and 2968.64 cm^{-1} correspond to C-H stretching vibrations, while weaker than in the myrobalan case, they still hint at the presence of hydrocarbon chains in the yarn. A medium-intensity peak at 1649.17 cm^{-1} might be linked to the C=C stretching vibrations of a conjugated alkene system.

Conclusion

The study demonstrates that recycled cotton yarn, prepared using natural scouring with ash water, effectively removes non-cellulosic impurities, as confirmed by the 4.68% weight loss. The yarn shows strong initial wicking performance, although the rate declines sharply after the first 10 min due to capillary saturation. Natural dyeing with babool bark, in combination with myrobalan or pomegranate rind mordants, results in good wash fastness and moderate rubbing fastness, with minimal staining to adjacent fabrics. FTIR analysis confirms the presence of functional groups that enhance dye–fibre bonding, with distinct spectral features for each mordant. The process aligns with sustainable textile production practices, offering an eco-friendly approach to producing naturally dyed recycled cotton yarn, aligned with recent trends in sustainability.

Acknowledgement

The authors thank the support of the AICTE – IKS Division for providing the research grant under the Research Project Scheme (F.no:2-23/AICTE/IKS-BGS1/Research Project/2022-23/19).

References

1 Md-Salauddin S K, Rony M, Anamul H & Shamim A M, *Text Leather Rev*, 4 (2021) 218.
2 Gokhale S B, Tatiya A U, Bakliwal S R & Fursule R A, *Nat Prod Radiance*, 3 (4) (2004) 228.
3 Shrivastava S, *J Text Eng Fash Technol*, 6 (6) (2020) 241.
4 Sathianarayanan M P & Narendra B, *Res J Text Appar*, 16 (2) (2012) 25.
5 Alam S M M, Islam S & Akter S, *Adv Res Text Eng*, 5 (2) (2020) 1050.
6 Mukherjee A, Roy M, Sankar, Choudhury P K & Ashis Mitra, *Application of natural dyes in handloom sectors*, 48 (2005) 37.
7 Samanta A & Agarwal P, *Indian J Fibre Text Res*, 34 (2009) 384.
8 Lakshmana Naik R, SaiShreesha V, Mayuri A, Prakash P & Swetha S, *J Emerg Technol Innov Res*, 6 (5) (2019).
9 Shahid M, Shahid-ul-Islam & Mohammad F, *J Cleaner Prod*, 53 (2013) 310.
10 Ciccòla A, Serafini I, Ripanti F, Vincenti F, Coletti F, Bianco A, Fasolato C, Montesano C, Galli M, Curini R & Postorino P, *Molecules*, 25 (6) (2020) 1417.

11 Ali N & El-Mohamedy R S R, *J Saudi Chem Soc*, 15 (3) (2011) 257.

12 Sandin G, Roos S, Spak B, Zamani B & Peters G, Environ Assess Swedish Clothing Consumpt, (RISE & Chalmers Univ Technol) (2020), ISBN: 978-91-89049-05-5.

13 Belemkar S & Manickam R, *Int J Text Eng Process*, 1 (2015), 33.

14 Bhat N V, Netravali A N, Gore A, Sathianarayanan M P, Arolkar G & Deshmukh R, *Text Res J*, 81 (10) (2011) 1014

15 Kumar A, Pareek P, Raja A S M & Shakyawar D, *Indian J Small Ruminants*, 21 (2015), 92.

16 Ali A, Ali S, Saleem H & Hussain T, *Asian J Chem*, 22 (2010) 7065.

17 Samanta P*, Chem Technol Nat Synth Dyes Pigments*, IntechOpen, London (2020) 34.

18 Rasel M Z U, Khatun M, Ahmed F, Kadri H, Maitra B, Saha B & Rabbi M, *Res Square*, (2022) 22.

19 Sawant R, Godghate A, Sankpal S, Walaki S & Kankanwadi S, *Asian J Plant Sci Res* (2014) 22.

20 Samanta, P, Konar A & Mukhopadhyay A, *Adv Colorimetry*, IntechOpen, London (2024) 238.

21 Shabbir M, Islam S U, Bukhari M N, Rather L J, Khan M A & Mohammad F, *Text Cloth Sustain*, 2 (2017) 1

22 Juang L J, Sheu S J & Lin T C, *J Separ Sci*, 27 (9) (2004) 718.

23 National Center for Biotechnology Information, (2025). *Pub Chem Compound Summary for CID 44584733, Punicalagin, Technical grade*.

24 Man G, Xu L, Wang Y, Liao X & Xu Z, *Front Nutr*, 8 (2022) 807447.

25 Jung J, in *MATEC Web Conference*, 49 (2016) 03001.

26 Standard ISO 105-C10:20069RA (2021).

27 Babu K M, Selvadass M & Somashekar R, *J Text Inst*, 104 (10) (2013) 1101.

28 Rani N, Jajpura L & Butola B S, *Indian J Fibre Text Res*, 50 (2025)189.