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Utilizing Babul Bark as an Eco-Friendly Dye Source for Cotton and Silk Fabric

Sneha Gargi[1], Dr. Rupal Babel[2], Sunidhi Shakya[3]

[1]Research Scholar, [2]Associate Professor and Head
Department of Apparel and Textile Science, CCAS, MPUAT, Udaipur
[3]M.Sc. Scholar, Department of AIHC, Vasanta College for Women, BHU, Varanasi

Abstract

There has been an upsurge in environmentally friendly production and utilization to reduce the negative impact on the environment. Textile dyeing is a process where a substantial amount of carcinogenic chemicals was exposed to both humans and the environment. With a shift to an eco-friendly, biodegradable and skin-friendly dyeing process, a new potential source was experimented to provide textile industries with a valuable new dye source i.e. *Vachellia nilotica*. In the present study, an exploration was carried out regarding the colouring potential of the babul bark using simultaneous mordanting processes. Results obtained revealed that babul is an excellent source of natural dye for the textile sector. Alum (5%) was the best simultaneous mordant. The dyeing results indicated that it can be used for cotton and silk. The best shade results were found in silk. Dyeing the fabric with babul leaf extract at 70 ± 10^0 C for 30 minutes produced the finest colour strength.

Keywords: Natural dye, Babul bark, Eco friendly, Silk dyeing

1. Introduction

Textile materials like cotton, silk and wool used to be coloured for price addition, appearance and customer demand. Prior to the invention of synthetic dyes, textile materials were coloured with colours extracted from natural sources. Most dyeing industries shifted towards the use of synthetic dyes after the commercialization of economic synthetic dyes and their ready availability. With the widespread convenience of cheaper artificial dyes and their moderate to wonderful colour fastness properties, there was a speedy decline in natural dyes (Ghatole, 2025). Nowadays with the heightened cognizance, consumers and producers are moving towards the environmentally friendly dyeing processes by imparting natural dyes. These dyes are potential options to induce green textiles. Natural dyes, meanwhile, have begun to gain prominence again in the textile dyeing and printing industries due to their non-toxic and environmentally friendly nature (Gargi and Srivastava, 2023). Both large and small textile manufacturers are now investigating natural sources for dyeing and printing textiles in a sustainable manner.

The scientific name of the acacia (babul) tree is *Vachellia nilotica* and it is a member of the Fabaceae family. It is also known as Arabic gum tree. The *Vachellia nilotica* tree is found in various subtropical and

tropical countries. The acacia tree can be used for a variety of purposes. The pods of the acacia (babul) tree are used by African regions for leather tanning and are also a source of dye. The acacia tree also has medicinal properties. It is a laxative, astringent and beneficial for many diseases, like neuralgia. (Rather *et al.,* 2019) The leaves of the tree are used to treat wound ulcers, eye and sore throat diseases. *Vachellia nilotica* has anti-malarial, anti-fungal and anti-bacterial properties. Condensed tannins, flavonoids and hydrolysable tannins contain anti-bacterial compounds. Acacia species contain compounds such as cyanogenic glycosides, alkaloids and amines, seed oils, fatty acids and cyclitol, amino acids, fluoroacetates, nonproteins, gums, terpenes, condensed tannins, flavonoids and hydrolysable tannins, diester, pentacosan dioic acid, dihexaic acid, esters, ellagic acid and leucocyanidins. (Rasel *et al.,* 2022)

Textile chemists and dyers or dyeing artisans are facing day to day challenges for assuring reproducibility and shade matching with natural dyes due to insufficient scientific information and lack of optimised processes of dyeing for specific fibre-mordant-dye system for any natural dye to achieve uniform and optimum color yield. However, recently there are some reports available on study of dyeing process variables and standardization of dyeing process with few other natural dyes on cotton and silk but this work has still not been done with babul bark as natural dye source that too for its application for dyeing of cotton and silk. (Sinnur *et al.,* 2018; Kumar *et al.,* 2015) So, an essential need was felt to standardize dyeing process conditions for obtaining uniform and reproducible brown shades by varying type and concentration of mordants, concentrations of dye and other dyeing process variables using babul bark extract as natural dye for standardizing its dyeing process with suitable mordants as well as to obtain correct and desirable shades. So, in the present work, effects of simultaneous mordanting on dyeability and color fastness properties for dyeing cotton and silk fabric with standardized aqueous extract of babul bark i.e. *Acacia Nilotica* (L.) as natural dye has been studied. Obtained colour value assessment is carried out to analyse the fastness properties and colour values of the fabric dyed.

METHODOLOGY

Sample Preparation: Pure silk and cotton fabric were procured locally from Udaipur, Rajasthan. Babul bark was collected locally. The obtained bark was dried and grinded into fine powder. The fabric was scoured to remove the impurities.

Dye Extraction: An aqueous method of extraction was used to extract the dye from the powdered bark of babul. Two different concentrations were formed using a ratio of 5% and 10% of finely ground powder added to added in 100 ml of water and kept in water bath at 60^0 C for one hour. The resulting liquid was filtered to obtain the pure dye. The extracted colour was reddish translucent liquid. With the increase in the powdered bark extract, there was an increase in the colour strength in the dye liquor obtained. The 10 % dye extract was used for dyeing the samples as the color of dye was darker as compared to other concentrations.

Preparation of Mordants: The four different powdered mordants employed in the study were Alum, $FeSO_4$, $SnCl_2$ and Citric Acid. A concentration of 5% with respect to the fabric weight was added to a separate water bath to obtain a wholly dissolved solution. The dissolved solution is added to the dye bath to produce a simultaneous mordanting sample. The temperature of the dye bath was increased to up to

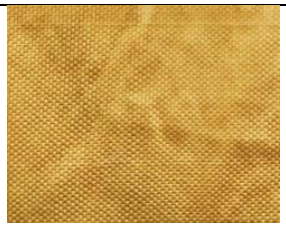
70^0C for a period of 30 minutes. Occasional stirring was done for even distribution of the dye, later the samples were removed from the dye bath and rinsed in distilled water.

Fabric Dyeing: The cotton and silk fabric was divided into samples and were dyed using the extracted dye liquor. The material liquor ratio (M: L) was kept at 1:30. Dyeing temperature was maintained at 70^0C and the procedure was carried out for 30 minutes.

RESULTS AND DISCUSSION

The obtained dye liquor from the babul dye 10% was used to dye the cotton and silk fabric. It was observed that the colour obtained was yellowish shade. After obtaining the pure colour, simultaneous mordanting procedure was followed to dyeing the samples. Dye uptake was found to be optimum with vibrant shades.

Table 1: Babul bark extract dyeing with different mordants

Dye source	Mordant	Type of Mordanting	Shades Obtained	
			Cotton	Silk
Bark of babul	Alum	Simultaneous mordanting		
	$FeSO_4$			
	$SnCl_2$			
	Citric Acid			

Color Fastness tests: Color fastness properties like light exposure, wash and rubbing fastness were assessed. Color depth for all the dyed samples was evaluated. Measurements for color strength were noted using

Table 2: CIE Lab Values of Babul bark extract dyed samples

Fabric	Mordant	L*	a*	b*
Cotton	Control	78.53	7.02	21.60
	Citric acid	79.59	4.23	16.22
	Alum	81.14	2.72	23.53
	$FeSO_4$	77.04	5.42	18.15
	$SnCl_2$	80.85	2.98	23.89
Silk	Control	68.87	6.29	28.28
	Citric acid	68.42	4.72	34.26
	Alum	72.39	3.39	29.77
	$FeSO_4$	72.17	5.94	28.85
	$SnCl_2$	70.76	8.47	27.50

The Table 02 presents the effect of 5% mordant concentration on the colour characteristics of cotton and silk fabrics in terms of L*, a*, b* values. The colour values of dyed cotton and silk fabrics were significantly influenced by the mordants applied at 5% concentration. In cotton fabric, the L* values ranged from 77.04 to 81.14, where alum-treated cotton showed the highest L* value (81.14), indicating the lightest shade, while $FeSO_4$ treated cotton showed the lowest value (77.04), indicating a darker shade. The a* values ranged from 2.72 to 7.02, with alum showing the lowest redness value and control sample showing the highest. The b* values varied from 16.22 to 23.89, with $SnCl_2$ treated cotton exhibiting the highest yellowness value.

In silk fabric, the L* values ranged from 68.42 to 72.39. Alum treated silk showed the highest L* value (72.39), while citric acid treated silk showed the lowest value (68.42). The a* values ranged from 3.39 to 8.47, where $SnCl_2$ treated silk showed maximum redness and alum-treated silk showed minimum redness. The b* values ranged from 27.50 to 34.26, with citric acid-treated silk recording the highest yellowness value.

Overall, the results demonstrate that mordant type significantly affected the colour coordinates of both cotton and silk fabrics. Alum treatment generally produced lighter shades with lower redness values, whereas $FeSO_4$ tended to develop darker tones. Citric acid and $SnCl_2$ enhanced yellowness in selected

samples. Thus, mordant selection plays a crucial role in determining final shade characteristics and colour quality of dyed natural fibre fabrics.

Table 03: Colour fastness of Babul leaf extract dyed samples

Fabric	Mordant	Wash	Rub		Light
			Dry	Wet	
Cotton	Control	2	4	3	4
	Citric acid	3	4/5	3/4	7
	Alum	5	5	4	8
	$FeSO_4$	4	5	3/4	6
	$SnCl_2$	5	4	4/5	6
Silk	Control	3	3	4	4
	Citric acid	4	4	4/5	6
	Alum	5	4/5	4	8
	$FeSO_4$	4/5	4	3/4	5
	$SnCl_2$	4	4/5	4	6

The table 03 presents the effect of different mordants (05%) on the colour fastness properties of cotton and silk fabrics, evaluated through wash, rubbing (dry and wet) and light fastness tests using a standard rating scale.

The colour fastness properties of dyed cotton and silk fabrics were significantly influenced by the type of mordant applied at 5% concentration. In cotton fabric, the control sample exhibited comparatively lower fastness ratings, with wash fastness of 2, dry rubbing fastness of 4, wet rubbing fastness of 3 and light fastness of 4. Application of mordants markedly improved the fastness behaviour. Among the mordanted cotton samples, alum and stannous chloride ($SnCl_2$) showed the highest wash fastness rating of 5, while alum and ferrous sulphate ($FeSO_4$) demonstrated excellent dry rubbing fastness of 5. Wet rubbing fastness was highest in alum-treated cotton (4), whereas citric acid, $FeSO_4$ and $SnCl_2$ produced moderate to good ratings ranging from 3/4 to 4/5. Light fastness was substantially enhanced by mordanting, with the highest rating observed for alum-treated cotton (8), followed by citric acid (7), while $FeSO_4$ and $SnCl_2$ recorded values of 6.

Similarly, in case of silk fabric, the control sample showed poor fastness values, with wash and dry rubbing fastness of 3, wet rubbing fastness of 4 and light fastness of 4. Mordant treatment improved all colour

fastness parameters. Alum treated silk fabric exhibited the best overall performance, with wash fastness of 5, dry rubbing fastness of 4/5, wet rubbing fastness of 4 and light fastness of 8. Citric acid and $SnCl_2$ mordants also showed moderate results, particularly in case of wet rubbing fastness (4/5 and 4, respectively) and very good light fastness (6). $FeSO_4$ treated silk exhibited moderate wash fastness (4/5) and good light fastness (5).

Overall, the results clearly indicate that mordanting significantly enhanced the colour fastness characteristics of both cotton and silk fabrics compared to the untreated control samples. Among the mordants, alum found to be the most effective mordant, yielding superior wash, rubbing and light fastness ratings in both substrates. Therefore, alum may be considered the most suitable mordant for improving dye fixation and durability of colour on natural fibre fabrics under the present experimental conditions.

CONCLUSION

The present investigation is focused more on the utilization of the diverse natural resources for dye pigment development in textiles as counteract to the synthetic compounds. This trend is aimed at safeguarding human health as well as protecting and prolonging life on earth. Natural dyes have to be thoroughly studied and explored in various ways so that they can be commercialized in replacement of synthetic dyes. One of the underutilized dyes is babul which can bring true sustainability with minimum use of water and chemicals for its development and processing. The dye intensity and the colourfastness properties which were obtained from the present investigation have shown promising results so far. The overall results demonstrated that mordanting at 5% concentration significantly influenced both the colour fastness and colour characteristics of dyed cotton and silk fabrics. Application of mordants improved wash, rubbing and light fastness properties compared to the control samples, confirming the beneficial role of mordants in enhancing dye fixation on natural fibres. Among all mordants studied, alum showed the best overall performance, providing superior fastness ratings and producing comparatively lighter and brighter shades in both cotton and silk fabrics. $FeSO_4$ developed relatively darker tones, while citric acid and $SnCl_2$ contributed to higher yellowness and shade variation depending on the fabric type. Cotton generally exhibited better rubbing fastness, whereas silk showed deeper colour tones. Therefore, the study concludes that mordant selection plays a crucial role in determining final shade quality and durability of dyed fabrics, with alum emerging as the most effective mordant under the present experimental conditions.

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