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Extraction of natural dye from *Mammea suriga* and its application on silk and cotton fabrics

N Verenkar & S Krishnan[a]

Department of Botany, Goa University, Goa 403 206, India

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In this study, raw silk and cotton fabrics have been dyed using the aqueous extract from *Mammea suriga* bark in the presence of chemical mordants. The variations in the colour are seen in the silk and cotton fabrics by using different mordants. The preliminary phytochemical tests reveal the presence of tannins in the bark extract of the plant, which is responsible for imparting brown colour shades to the silk and cotton fabrics. The results are found promising with good fastness property in all the three mordanting methods, i.e. pre-mordanting, simultaneous mordanting and post-mordanting. The SEM study shows no physical damage to the fibre dyed with *M. suriga* dye extract. Thus, this bark can be used as a cheaper source of raw material for the extraction of natural dye by dyers in dyeing industries.

Keywords: Cotton fabric, Dyeing, *Mammea suriga*, Mordants, Silk fabrics

1 Introduction

The textile industry is known to be the largest consumers of synthetic dyes[1]. These synthetic dyes are injurious to health as they are produced from cheap petroleum and coal-tar sources[2]. Therefore, the researchers have shifted their attention on the use of natural dyes over these unsafe synthetic dyes. These natural dyes have acquired commercial potential over synthetic dyes due to their eco-friendly nature and thus they are known to be the better alternative to synthetic dyes. Recently, there have been growing interests in the use of natural dyes in textiles applications[3-6]. This increasing popularity of natural dyes over synthetic dyes is probably due to the environmental concerns and due to the non-toxic, non-allergic and non-carcinogenic properties of natural dyes. In addition, natural dyes exhibit better biodegradability and are generally more compatible with the environment, so they serve as a green alternative towards synthetic dyes[7].

The present work focuses on the dyeing potential of *Mammea suriga* bark extract on silk and cotton fabrics, application of chemical mordants along with the dye and checking its fastness property with respect to sunlight exposure, washing and rubbing. Phytochemical study was carried out to identify the chemical constituents in the extract and the SEM analysis was done to know the effect of dye on physical property of the silk fibre.

Mammea suriga (Buch.-Ham.ex Roxb.) Kosterm also known as surangi is one of the medicinal, aromatic and economically important trees in family clusiaceae. It is an endemic and grows abundantly in Western Ghats of India[8]. The flowers are highly fragrant and used for worshipping, perfumery industry and for personal adornment. The red dye obtained from the dried flowers is used in textile industries. It is a well-known Indian traditional medicinal plant. The reports indicated that the flower buds are used in the treatment of cough, vomiting, dyspepsia, skin eruption and itching. Whereas stem bark extract have been used for haemorrhoids, headache, piles, fever and dyspepsia[9]. Essential oil was obtained from the flowers of *Mammea suriga* which finds its application in treatment of leprosy and malaria[10,11]. The phytochemical analysis of bark shows the presence of some secondary metabolites like flavonoids, alkaloids, saponins and tannins[12]. Tannins and flavonoids are considered to be the very useful substances during the dyeing process due to their ability to fix dyes within the fabrics[13].

2 Materials and Methods

2.1 Raw Materials

The medicinal bark of *Mammea suriga* with antioxidant and antimicrobial properties was collected by scrapping of tree trunk from Goa University

[a]Corresponding author.
E - mail: skrish@unigoa.ac.in

campus, Goa and shade dried at room temperature (25°C) for about 4-5 days. After drying, the bark was macerated to fine powder using a laboratory mixer. The powder was stored in zip-lock polyethene bags for further use.

2.2 Extraction of Natural Dye

The dye was extracted from powdered bark using distilled water (7.5g/50mL) at 60°C for 24 h in hot water bath and the extract was filtered through Whatman filter paper Grade-A. This filtered extract was used for dyeing as well as for phytochemical analysis.

2.3 Calculation of Crude Dye Yield

The dried powder (7.5 g) was weighed and extracted in 50 mL of different solvents, viz water, ethanol, methanol and petroleum ether for 24 h in water bath at 60°C. Later the extract obtained was filtered and evaporated to dryness. This dried extract was scraped and weighed. The extraction yield was calculated using the following formula[12].

$$\text{Extraction yield (\%)} = \frac{\text{Weight of the dry extract (g)}}{\text{Weight of the sample used for the extraction (g)}} \times 100$$

2.4 Fabric

Plain woven, raw silk fabric with 28% sericin content was purchased from Reshme Nagar, T.G. Pusa, Bangalore. Prior to dyeing, the silk fibres were scoured using (2g/L) of sodium carbonate in water at 60ºC for 30 min in water bath. The scoured material was thoroughly washed with running water and dried at 25°C. These fabrics were later used for dyeing.

The plain weaved cotton fabrics were used for dyeing purpose. The white cotton was treated with dilute solution of sodium carbonate (2g/L) for about 30 min at 60°C in hot water bath to remove the debris and then thoroughly washed with tap water and dried at 25°C. The dried cotton was later used for experimental purpose.

2.5 Dyeing of Silk and Cotton Fabrics

Dyeing was carried out by placing the raw silk and cotton fabrics in extracted natural dyes for the duration of 30 min following the procedure[14] .

2.5.1 Methods of Mordanting

Pre, simultaneous and post-mordanting methods were carried out using 5% solution of chemical mordants, viz. $K_2Cr_2O_7$ (potassium dichromate), $FeSO_4$ (ferrous sulphate) and $CuSO_4$ (copper sulphate) along with the extracted dye.

2.5.2 Fastness Tests for Dyed Fabrics

The fastness tests for the silk and cotton fabrics were carried out as mentioned earlier[15] and the fastness ratings were given in gray scale (ISO 105-A02).

The gray scale measure the colour fastness of textile fibres. The scale consists of pairs of white and gray colour chips, each representing the difference between the two similar colours corresponding to a numerical grade for staining. Gray scale for colour change indicates the amount of fading or colour alteration with environmental exposure or washing. These scales are used for visual assessment to enable one to specify a rating from 1 to 5 [5-excellent (no change) and 1-poor (severe change)]. The scale has 9 possible values (5, 4/5, 4, 3/4, 3, 2/3, 2, 1/2, 1). Fastness studies were carried out as per the details given below:

- **Wash Fastness** — The wash fastness of the dyed sample was carried out by washing the fabrics for three times in dilute solution of Na_2CO_3 (2g/L) at 25°C in water bath to check the stability of the colour on the fabric.
- **Rub Fastness** — The rub fastness of the dyed fabrics was carried out by rubbing the fabrics manually and checking for fading of colour after 5 min and 15 min.
- **Light Fastness** — The fabric was exposed to direct sun light for 6 h and 12 h. The fading of the colour was evaluated by comparing the colour change of the exposed fabric to the unexposed original fabric.

2.5.3 Photography

All the photographs of the dyed fabrics and also after carrying out the fastness tests were taken using the digital camera fitted with macro lens (Nikon D-90).

2.5.4 ISCC-NBS Colour System

The various shades obtained from the *Mammea suriga* dye along with the mordants on silk and cotton fabrics are described according to the ISCC-NBS (Inter Society Colour Council-National Bureau of Standards) colour system chart. The chart provides around 267 colour categories with non-technical names[16].

2.6 Measurements of Dye Absorbance

The different concentrations of dye solutions were prepared from dye stock solution (5%) by taking 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0 mL of *Mammea suriga* extract and final volume made to

1 mL using distilled water. The absorbance of the dye solution was recorded before and after dyeing on a UV-SHIMADZU visible spectrophotometer at 568 nm. The amount of dye absorbed was calculated by using the following formula[14]:

$$\% \text{ Dye absorbance} = \frac{\text{O.D before dyeing} - \text{O.D after dyeing}}{\text{O.D before dyeing}} \times 100$$

where O.D is the optical density.

2.7 Phytochemical Analysis

Preliminary phytochemical analysis was carried out for the water and ethanol extract of *Mammea suriga* as per the standard methods already described[17]. Following tests were done:

(i) Test for Alkaloids

Following four tests were performed for alkaloid:

- **Hager's Test** — To 1 mL of extract, 1-2 drops of Hager's reagent (saturated picric acid solution) was added. Formation of yellow precipitate indicates the presence of alkaloids[18].
- **Wagner's Test** — To 1 mL of extract, few drops of Wagner's reagent (solution of iodine in potassium iodide solution) was added. Formation of reddish brown precipitate indicates the presence of alkaloids[19].
- **Mayer's test** — To 1 mL of extract, 1-2 drops of Mayer's reagent (potassium mercuric iodide solution) was added. Formation of creamish or white precipitate indicates the presence of alkaloids[20].
- **Dragendorff's Test** — To 1 mL of extract, 1-2 drops of Dragendorff's reagent (potassium bismuth iodide solution) was added. Formation of reddish brown precipitate indicates the presence of alkaloids[21].

(ii) Test for Tannins

To 2 mL of extract, 2 mL of $FeCl_3$ (1% of ferric chloride) was added. Occurrence of blue, black and green precipitate indicates tannins[22].

(iii) Test for Saponins

Five milliliter (5 mL) extract was shaken vigorously with 5 mL of distilled water in a test tube. Formation of stable foam indicates the presence of saponins[23].

(iv) Test for Flavonoids

Following four tests were performed for flavonoids:

- **Ferric Chloride Test**— To 2 mL of extract, few drops of 10% ferric chloride solution was added. Formation of blue or violet colouration indicates flavonoids[22].
- **Magnesium and HCl Reduction Test (Shinoda Test)** — One gram of powdered bark was dissolved in ethanol and warmed for few min, small pieces of magnesium chips were added to the filtrate followed by few drops of concentrated HCl. Formation of pink, orange, red to purple colouration indicates presence of flavonoids[24].
- **Alkaline Reagent Test** — One milliliter of extract was treated with 10% ammonium hydroxide solution. Yellow fluorescence indicates presence of flavonoids[25].
- **Lead Acetate Test** — To 5 mL of extract, 3 mL of lead acetate solution was added. Appearance of buff colour or white precipitate indicates flavonoids[25].

(v) Test for Steroids

Following two tests were performed for steroids:

- **Salkowski's Test**— To 2 mL of extract, 2 mL of chloroform was added, followed by the addition of 2 mL of conc H_2SO_4 along the sides of the test tube. Finally the test tube was shaken well. The chloroform layer appeared red and the acid layer showed greenish yellow fluorescence, indicating the presence of steroids[26].
- **Liebermann-Burchard's Test**— One gram (1 g) of powdered bark was dissolved in 2 mL acetic anhydride. To this, 1-2 drops of conc H_2SO_4 was added slowly along the sides of the test tube. An array of colour changes (first red, blue to green) shows the presence of phytosterols[27].

(vi) Test for Terpenoids

One gram (1 g) of powdered bark was dissolved in ethanol and to this 1 mL of acetic acid was added followed by the addition of conc H_2SO_4. The change in colour from pink to violet indicates terpenoids[28].

(vii) Test for Anthraquinones

To 2 mL of filtrate, 2 mL benzene and 1 mL ammonia solution were added and the solution was then shaken well. Formation of pink/red/ violet colour indicates anthraquinones[29].

2.8 Scanning Electron Microscopy

SEM technique was used to investigate the surface morphology of the silk and cotton fibres before and after dyeing the fibre with natural dye. The samples were coated with gold and palladium and finally observed under × 1.00 magnification under EVO 18 ZEISS Special edition SEM.

3 Results and Discussion

3.1 Extraction Yield

The extraction yield, colour and consistency of different solvent extracts of *Mammea suriga* is provided (Table 1). Dye yield is the quantity of crude dye powder obtained after evaporation of solvent from the extracted dye solution. It is observed that the methanol extract produces maximum yield (21.2%), whereas petroleum ether extract yields only 2.45%. Similarly, 9.51% of yield is noted in water extract of *Withania somnifera* root using soxhlet apparatus[30].

3.2 Effect of Dyeing on Silk and Cotton

Dyeing of silk and cotton with *Mammea suriga* bark extract shows wide variety of yellow, brown and black colour shades. The strong brown colour is obtained on the silk fabric, dyed with *Mammea suriga* bark extract. The strong brown colour is retained even after first and second wash, but the third wash leads to slight fading of colour to brownish orange. After 6 h and 12 h of sunlight exposure the colour is turned to moderate orange. Rubbing the fabric manually turned the fabric to brownish orange after 5 min which later turned the fabric to light brown colour after 15 min. Moderate orange colour is obtained on the cotton fabric, which does not change even after wash, rub and light fastness tests (Fig. 1).

Table 1 — Extraction yield, colour and consistency of bark extracts of *Mammea suriga* in different solvents

Solvents used	Extraction yield, %	Colour and consistency
Water	9.6±0.05	Solid, reddish
Ethanol	12.93±0.00	Gummy, reddish
Methanol	21.2±0.05	Solid, reddish
Petroleum ether	2.45±0.00	Solid, light yellow

Values are mean of 3 readings and ± indicates standard deviation.

In pre-mordanting method, the strong brown colour is obtained using $K_2Cr_2O_7$ mordant along with the dye on the silk fabric. The colour does not change even after first, second and third wash. The exposure of fabric to 6 h of sunlight gives deep brown colour which is unchanged even after 12 h of sunlight exposure. Rubbing the fabric manually for 5 min and 15 min retains the strong brown colour. The use of $CuSO_4$ mordant along with the dye gives brownish orange colour, which later changes to strong brown after first, second and third wash. The exposure to 6 h sunlight imparts deep brown colour to the fabric which remains unchanged even after increasing the exposure period to 12 h. Rubbing the fabrics for 5 min gives strong brown colour to the fabrics, which remains unchanged after 15 min of rubbing. The use of $FeSO_4$ mordant along with the dye gives brownish black colour to the fabrics, which becomes more intense after first, second and third wash. The exposure to light and rubbing the fabrics however does not make any significant impact on the colour (brownish black). The application of $K_2Cr_2O_7$ mordant gives dark brown colour to the cotton fabric, which completely changes its colour to strong brown after first, second and third wash and even after rub and light fastness tests. The copper sulphate mordant dyes the fabric deep orange, and changes its colour to strong brown on washing. The colour (deep brown) does not change after rub and light fastness. The use of ferrous sulphate mordant gives dark greyish shade to the fabrics, which is turned to olive black on washing the fabrics. The exposure to light changes the colour to dark olive and rub fastness changes the colour to greenish black (Fig. 2).

In simultaneous mordanting, the use of $K_2Cr_2O_7$ mordant along with the dye imparts moderate orange yellow colour to the silk fabric which does not change even after f st, second and third wash. However, the colour of the fabric changes to light orange yellow after 6 h and 12 h exposure to sunlight. The moderate

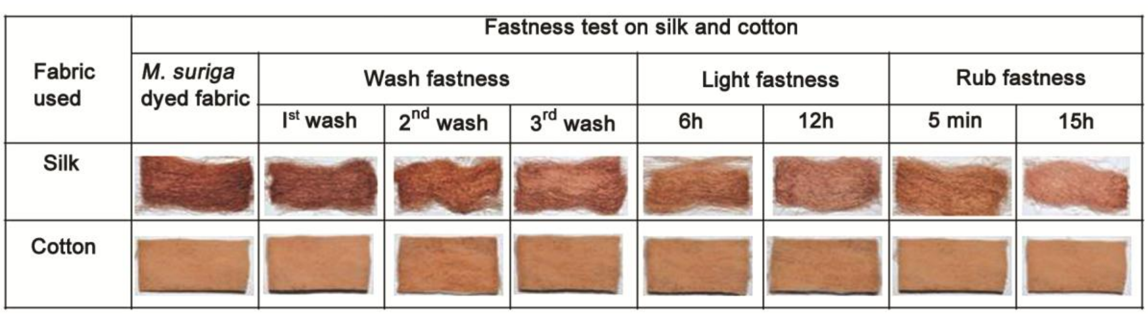

Fig. 1 — Silk and cotton fabrics dyed with *M. suriga* dye

orange yellow colour is observed on the fabric after 5 min and 15 min of manual rubbing. The use of $CuSO_4$ mordant along with the dye gives brownish orange colour to the fabric which is changed to deep brown colour after first, second and third wash. The 6 h and 12 h of light exposure period imparts strong brown colour to the fabric. But the rub fastness does not change the colour of the fabric (brownish orange). The $FeSO_4$ mordant along with the dye imparts brownish black colour to the fabric which does not change after subsequent washing. The colour is consistent even after light and rub fastness. The cotton fabric is dyed light yellowish brown using potassium dichromate mordants, which is changed to pale orange yellow on washing, light and rub fastness. The copper sulphate mordant dyed the fabric deep orange which changed to strong brown on washing. The exposure of light changed to brownish orange colour after 6 h and strong brown colour after 12 h. The rub fastness changes the colour to strong brown. The ferrous sulphate gives olive gray colour to the fabric which is changed to dark greyish brown after first wash and brownish gray after second wash and third wash. No change in colour is seen after light and rub fastness (Fig. 3).

In post-mordanting, the deep brown colour is noticed on the silk fabric dyed with $K_2Cr_2O_7$ mordant. The colour is turned to strong brown after first,

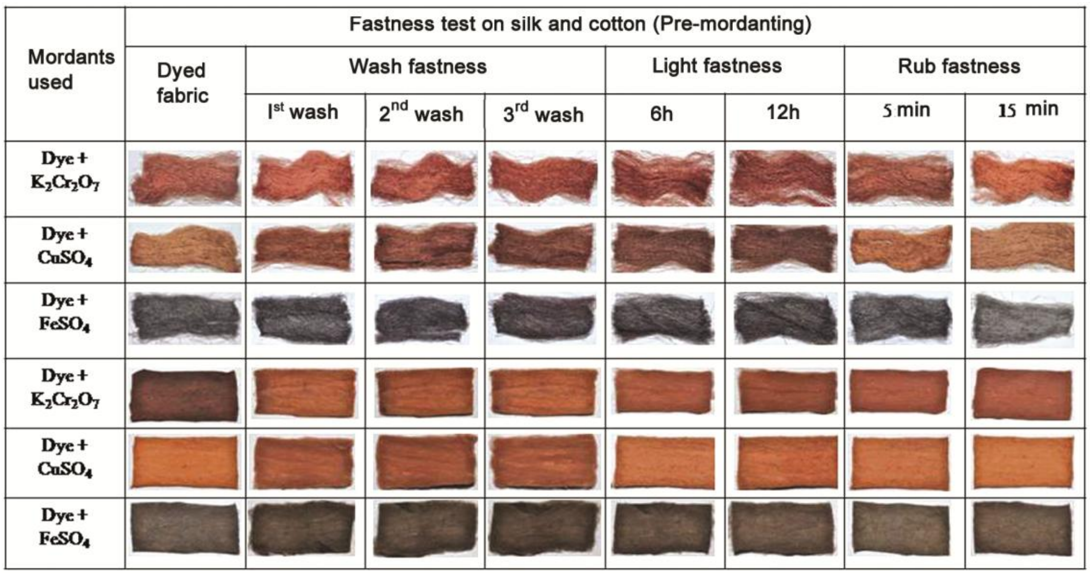

Fig. 2 — Silk and cotton fabrics dyed with *M. suriga* dye along with chemical mordants and fastness tests (pre-mordanting)

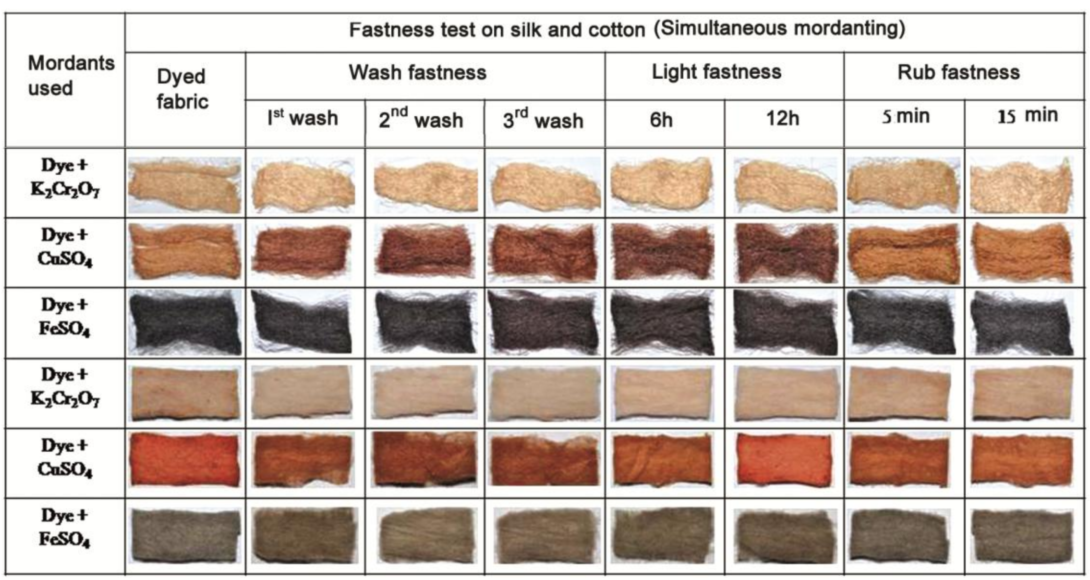

Fig. 3 — Silk and cotton fabrics dyed with *M. suriga* dye along with chemical mordants and fastness tests (simultaneous mordanting)

second and third washes, whereas the colour is found unchanged after light and rub fastness test. The use of $CuSO_4$ mordant with the dye gives brownish orange colour to the fabric which later changes to deep brown after subsequent washing. The exposure to sunlight after 6 h and 12 h gives deep brown colour to the fabric, which is changed later to strong brown after 5 min and 15 min of rubbing. The use of $FeSO_4$ mordant with the dye gives brownish black colour to the fabric, which does not fade even after wash, rub and light fastness test. The cotton fabric is dyed deep brown in colour on application of $K_2Cr_2O_7$ mordant which is changed to strong brown after washing. The exposure of 12 h to sunlight changes the colour to strong brown. However, rub fastness does not change the colour. The $CuSO_4$ mordant gives deep orange colour which is later changed to strong brown after washing. However, the colour does not change on light and rub fastness. The $FeSO_4$ mordant gives olive black colour to the fabric which retains on fabric even after fastness tests (Fig. 4).

The variation in colours is due to the use of different mordants and mordanting methods. The mordant ferrous sulphate gives brownish black colour in all the mordanting methods. This is due to the strong co-oxidation tendency of Fe, which imparts brown to black colour shades thereby enhancing the interaction between the fibre and the dye molecules, resulting in higher dye uptake[31]. Similarly, in $CuSO_4$ mordant, copper metal is well known for its ability to form strong co-ordination complexes which also results in higher dye uptake[32]. Potassium dichromate is known as brightening mordant and thus produces deeper shades of brown-orange colour to the fabrics[33]. The pre-mordanting and post-mordanting methods give brighter shades on both the fabrics as compared to simultaneous mordanting. The silk fabrics show better result as compared to the cotton fabrics.

3.2.1 Fastness Tests

The silk fabrics dyed with *Mammea suriga* dye show (5-2) ratings for colour change. In pre-mordanting method, the use of $K_2Cr_2O_7$ mordant shows excellent ratings (5) with no colour change in all the fastness tests. The $CuSO_4$ mordant with dye shows (4-3) ratings, $FeSO_4$ mordant with dye shows (5-2) ratings. In simultaneous mordanting, the use of $K_2Cr_2O_7$ mordant and $FeSO_4$ mordant shows excellent (5) ratings with no colour change. The use of $CuSO_4$ mordant shows (4-2) ratings. In post-mordanting, the use of $K_2Cr_2O_7$ mordant reveals slight colour change with (4/5-4) ratings. The use of $CuSO_4$ mordant shows the colour change range from (5-3/4) and the use of $FeSO_4$ mordant shows excellent ratings (5) with no loss of colour from the fabric (Table 2).

The cotton fabrics dyed with *Mammea suriga* extract show no colour change in all the fastness tests. In pre-mordanting, the use of mordant along with the dye shows (5-1/2) ratings in all the three fastness tests of wash, rub and light. The use of $K_2Cr_2O_7$ mordant along with the dye shows (1/2) rating, i.e. very poor fastness. The use of $CuSO_4$ mordant shows (3) ratings

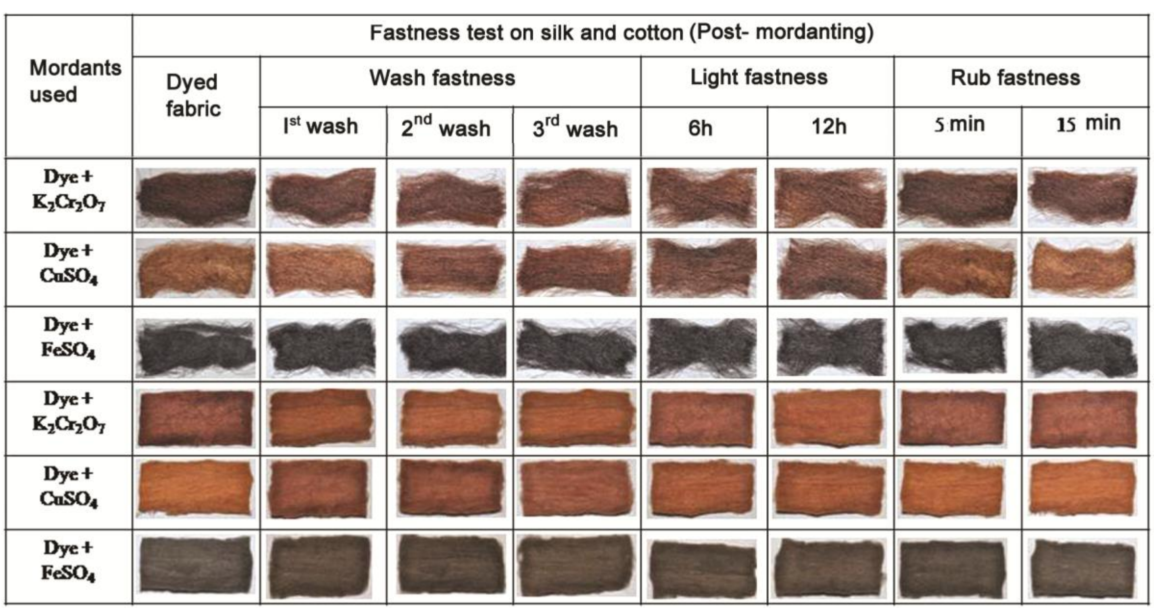

Fig. 4 — Silk and cotton fabrics dyed with *M. suriga* dye along with chemical mordants and fastness tests (post-mordanting)

Table 2 — Ratings of colour fastness of silk fabrics dyed with *Mammea suriga* dye

Dye + mordants	Mordanting method	Wash fastness			Light fastness		Rub fastness	
		1st wash	2nd wash	3rd wash	6 h	12 h	5 min	15 min
Dye		5	5	3/4	3	3	3/4	2
Dye + $K_2Cr_2O_7$	Pre mordanting	5	5	5	5	5	5	5
Dye + $CuSO_4$		4	4	4	3	3	4	4
Dye + $FeSO_4$		5	5	2	5	5	5	5
Dye + $K_2Cr_2O_7$	Simultaneous mordanting	5	5	5	5	5	5	5
Dye + $CuSO_4$		3/4	3/4	3/4	2	2	4	4
Dye + $FeSO_4$		5	5	5	5	5	5	5
Dye + $K_2Cr_2O_7$	Post mordanting	4	4	4	4	4	4/5	4/5
Dye + $CuSO_4$		5	3/4	3/4	3/4	3/4	5	5
Dye + $FeSO_4$		5	5	5	5	5	5	5

Table 3 — Ratings of colour fastness of cotton fabrics dyed with *Mammea suriga* dye

Dye +mordants	Mordanting method	Wash fastness			Light fastness		Rub fastness	
		1st wash	2nd wash	3rd wash	6 h	12 h	5 min	15 min
Dye		5	5	5	5	5	5	5
Dye + $K_2Cr_2O_7$	Pre mordanting	1/2	1/2	1/2	1/2	1/2	1/2	1/2
Dye + $CuSO_4$		3	3	3	3	3	3	3
Dye + $FeSO_4$		4	4	4	3/4	3/4	3	3
Dye + $K_2Cr_2O_7$	Simultaneous mordanting	5	5	5	5	5	5	5
Dye + $CuSO_4$		4/5	4/5	4/5	4/5	4/5	3	3
Dye + $FeSO_4$		4	3/4	3/4	4/5	4/5	4/5	4/5
Dye + $K_2Cr_2O_7$	Post mordanting	4	4	4	4	4	4	4
Dye + $CuSO_4$		4	4	3	3	3	4	4
Dye + $FeSO_4$		5	5	5	5	5	5	5

and the use of $FeSO_4$ shows (4-3) ratings. In simultaneous mordanting, the use of $K_2Cr_2O_7$ mordant gives excellent rating (5) to the cotton fabric. The use of $CuSO_4$ mordant shows the ratings between (4/5-3) and the use of $FeSO_4$ mordant shows the ratings between (4/5 and 3/4). In post-mordanting, the use of $K_2Cr_2O_7$ mordant shows fastness values of (4). The $CuSO_4$ mordant shows the fastness rating from (4-3) and dyeing with $FeSO_4$ mordant shows excellent ratings (Table 3).

The dye exhibits excellent to good results for wash, rub and light fastness in all the three mordanting methods. Wash fastness is influenced by the rate of diffusion of the dye from the fabric. The chemical mordants especially $FeSO_4$ shows excellent fastness with slight diffusion of colour from both the fabric. Also good fastness of dyed fabric to rub and light is observed in silk fabrics, this is due to the formation of metal dye complex which protects the chromophore from photolytic degradation. Similar kind of studies on colour fastness of *Capsicum annum* is carried out[34]. Several other studies have been carried out in this field on use of plant dyes for textile studies[35-43].

3.3 Effect of Dye Concentration on Silk and Cotton Fibres

The absorption of dye on silk (Table 4) and cotton fibres (Table 5) increases with the increase in concentration of dye in the dye bath and reaches maximum at 1 mL concentration. This is due to the strong interaction force between the natural dye and the fibre[14].

3.4 Phytochemical Analysis

The chemical constituents of phytochemical analysis of water and ethanol extract of *Mammea suriga* bark is provided in Table 6. The bark shows the presence of alkaloids, steroids, flavonoids and

Table 4 — Dye uptake percentage of *Mammea suriga* dye on silk fabrics

Dye concentration Stock 5%	Dilution with water mL	Optical density, 568 nm		Dye uptake %
		Before dyeing	After dyeing	
0.1	0.9	0.081	0.080	1.23
0.2	0.8	0.172	0.169	1.74
0.3	0.7	0.185	0.181	2.16
0.4	0.6	0.224	0.219	2.23
0.5	0.5	0.291	0.283	2.74
0.6	0.4	0.296	0.286	3.37
0.7	0.3	0.304	0.289	4.93
0.8	0.2	0.315	0.294	6.66
0.9	0.1	0.327	0.298	8.86
1.0	-	0.331	0.300	9.36

Table 5 — Dye uptake percentage of *Mammea suriga* dye on cotton fabrics

Dye concentration Stock 5%	Dilution with water mL	Optical density, 568 nm		Dye uptake %
		Before dyeing	After dyeing	
0.1	0.9	0.052	0.051	1.92
0.2	0.8	0.070	0.068	2.85
0.3	0.7	0.103	0.099	3.88
0.4	0.6	0.130	0.124	4.61
0.5	0.5	0.280	0.267	4.64
0.6	0.4	0.440	0.419	4.77
0.7	0.3	0.445	0.423	4.94
0.8	0.2	0.491	0.466	5.09
0.9	0.1	0.593	0.562	5.22
1.0	-	0.602	0.569	5.48

Table 6 — Phytochemical analysis of water and ethanol extract of *Mammea suriga* bark extract

Chemical constituents	Tests performed	Water extract	Ethanol extract
Saponins	-	Nil	Nil
Alkaloids	Wagner's	+	+
	Hager's	+	+
	Mayer's	+	+
	Dragendorff's	Nil	Nil
Tannins	-	+	Nil
Flavonoids	Ferric chloride test	+	+
	Shinoda test	+	+
	Alkaline reagent test	+	+
	Lead acetate test	Nil	Nil
Terpenoids	-	Nil	Nil
Anthraquinones	-	Nil	Nil
Steroids	Salkowski's test	+	+
	Liebermann-Burchard's test	+	+

+ Indicates present.

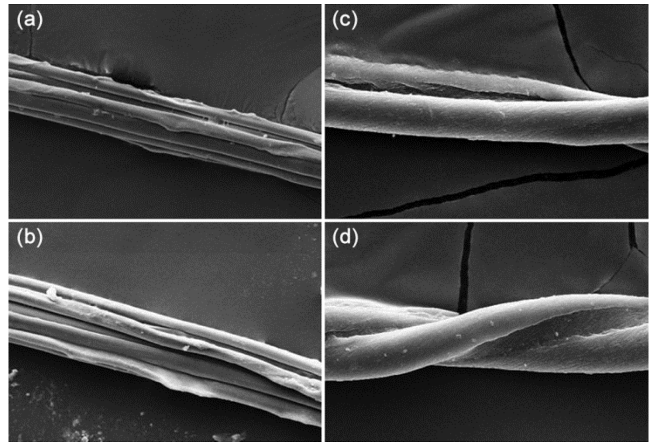

Fig. 5 — SEM images showing the surface morphology (a) raw silk fibre (b) silk fibre dyed with *M. suriga* dye extract (c) undyed cotton fibre and (d) cotton fibre dyed with *M. suriga* dye extract [x1000]

tannins in both the extracts. Tannins are present in most of the bark extracts and are responsible for imparting brown colour shades[44]. Thus, the black shades on the fabric are likely to be attributed due to the presence of tannins and other chemical constituents in the bark extract.

3.5 Scanning Electron Microscopy Analysis

The silk fibre consists of two main proteins, *viz*. sericin and fibroin. Fibroin is a structural center of silk structure. They exist as a continuous filament and are smooth[45]. The cotton fibres are flat with smooth surface and a twisted ribbon-like structure caused by spiraling of cellulose fibrils. The natural folds are present that runs parallel along the cotton fibre axis[46]. Undyed silk fibre have smooth surface [Fig. 5(a)], while the silk fibre dyed with natural dye *Mammea suriga* [Fig. 5(b)] also shows smooth surface. The undyed cotton fibre is shown in Fig. 5(c), and Fig. 5(d) represents the cotton fibre dyed with natural dye *Mammea suriga*. Both the fibres are seen without any physical damage, such as cracks on the surface even after dyeing the fibre with the natural dye extract of *M. suriga* bark.

4 Conclusion

Dyeing of silk and cotton with *Mammea suriga* bark extract gives appealing results with good fastness property. Dyeing with different mordants and following different mordanting methods give light to heavier shades of colour. Pre-mordanting and post-mordanting methods could be adopted for getting deeper shades. The silk fabrics are dyed better then the cotton fabrics. Also, the process of extraction involved is found simple and environmental friendly. The phytochemical analysis reveals the presence of alkaloids, steroids, flavonoids and tannins in the water and ethanol extract. The tannins in the extract are responsible for brown colour shades to the fabric. Thus, the present study would help in conservation and sustainable utilization of plant based dyes for replacing the harmful synthetic dyes. However, the specific chemical compound responsible for the dyeing property will open a way of research feature. Research should go more and more in this field to explore plant based dyes and to develop a suitable method for extraction of the dye. Conclusively, the aqueous extract of the *Mammea suriga* is a potential natural dye could be used for dyeing of silk and cotton fabrics.

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