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RESEARCH ARTICLE

The Effect of Different Mordants on Strength and Stability of Colour Produced from Selected Dye-Yielding Plants in Uganda

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ABSTRACT

Five dye-yielding plants namely; Morinda lucida, Vitellaria paradoxa, Syzgium cordatum, Albizia coriaria and Justicia betonica were investigated in this study for the effect of mordant on strength and stability of colour. The plants were selected on the basis of their widespread use in dyeing local palm leaves and other cellulosic plant materials used for making mats and other craft items in Uganda. The different types of mordant used played an important role in the development of the perceived colours from the different plants. Colour analysis in terms of the reflectance values (R), hue angle(H),chroma(C), lightness (L) and the cartesian coordinates a and b showed that the overall principal colours on cotton fabric support were yellow, brown, yellow – orange, reddish-pink, bluish-violet and yellowish-green and were mostly unsaturated and affected by the type of mordant used. Some of the mordants exhibited high colour absorption (K/S) values due to their ability to form strong coordination complexes with the dye molecules. The findings from the study reveal that the crude extracts from the five Ugandan selected plants can be used for cotton textile colouration using different mordants.

KEYWORDS: *Mordant, colour strength and stability, colour, dye-yielding plants, Uganda*

INTRODUCTION

Due to the current excessive production and use of synthetic dyes in the textile industry estimated at 10,000,000 tonnes per annum, vast amounts of toxic wastes and unfixed dyes are released into the environment daily, thereby causing serious pollution and health hazards to humans [5]. Secondly, synthetic dyes and corresponding chemical additives including mordants continue to be extremely expensive textile materials for many developing countries to afford especially for the small scale dyers and printers. Consequently, there has been a growing worldwide interest and change of heart towards natural dyes in the last 10 – 20 years as viable alternatives to synthetic dyes [2, 3, 12, 15].

The influence of mordant on colour and fastness properties of natural dyes using different mordants has been widely reported [1, 8, 9, 14]. There is a strong influence on colour strength of many different natural dyes by the nature, type and concentration of different mordants [16]. And because most natural dyes have both poor light stability and low colour yields, different mordants play an important role in enhacement of colour strength of natural dyes and stability of naturally coloured textiles [7].

The use of alum and tin mordants causes significantly more fading and instability of coloured textiles than when chrome, iron, or copper mordants are used [10]. Dye and mordant are the essential two dependant factors responsible for the development of natural colours applied to textiles. And whether pre-mordanted or simultaneous mordanted or post-mordanted, colour absorption and stability depends not only on the natural colourant but also on the mordant and mordating assistants used [10]. It is reported that different types and selective mordants or their combination can be applied on the textile fabrics to obtain varying colour shades, to increase the absorption and to improve the colour fastness and stability of any natural dye [10]. In this study, the effect of different mordants on strength and stability of colour from five selected Ugandan dye-yielding plants was investigated.

MATERIALS AND METHODS

Sample preparation and dyeing

The fabric selected for this research was 100% bleached cotton fabric, plain weave, 23 x 24/cm^2, 8 cm x 10 cm, 27g/m^2, 0.01mm thickness purchased from a local trader in Kampala.

The simultaneous dyeing method described by [6] was used in the mordanting process. 10% of mordant, on weight of fabric (o.w.f) was used in the mordanting baths 10g of dried and pulverized plant material was soaked in 150 mls of distilled water in a beaker overnight. It was then boiled for about 45 minutes and strained in a 250ml pyrex beaker to a natural dye solution which was made up to 200mls and used for dyeing. Cotton fabric samples each weighing about 1.406g were placed in the dye solution at about 60.To this solution was added a mordant(10% o.w.f) and 20% sodium sulphate (o.w.f) and the mixture was left to boil at this temperature for one hour after which the dyed fabric was removed from the solution and then dried in open air.

Colour Measurement and Analysis

Colour shades developed on cotton fabrics using different mordants were evaluated in terms of colour coordinates L, a, b, C and H (L = lightness, a = red-green coordinate, b = yellow-blue coordinate, C = chroma, H = Hue angle) measured using the method described by Shah [11]. The reflectance values (R) of the coloured fabric samples were measured at every 10nm interval between 400 to 700nm by the Datacolour SF 600 double beam spectral reflectance spectrophotometer under illuminant D_{65}, 10^o standard observer with an o/d illumination/viewing geometry. The largest aperture of 30mm was used for all the colour measurements, with the UV component included and the specular reflection component included. Dyed cotton fabric samples were folded so as to present a total thickness of 4 layers of fabric and an average of two readings of each fabric sample were taken. A plot of a and b values with the hue angle H was done for each mordanted cotton fabric in a colour space diagram described by Sule [13].

The relative colour yields for each dyed fabric sample with different mordants were assessed as K/S values using the Kubelka-Munk equation, K/S = $\frac{(1-R)^2}{2R}$ where R = spectral reflectance of the coloured textile material, K = dye absorption and S = light scattering characteristics of the natural dyes which depend on the nature of the substrate used.

RESULTS AND DISCUSSION

Evaluation of colour with different mordants

The colours of the dyed fabrics with different mordants are clearly specified in the colour space diagram(fig 1) using the a, b and H values indicated in tables 1- 6. The elemental composition and nature of the mordants had a significant effect upon colour change leading to noticeable change in values of the hue angle, H, resulting into varied colour locations in the a – b colour space diagram. The greatest influence on colour change occurred with all the mordants in respect of *Morinda lucida* root plant extract where all the values of L were 70 and above, showing lighter shades(table 4). The effect of mordant on colour change, however, depended to a certain extent upon the composition of the dye extract and individual plant species. The values of L appeared to be generally higher for yellow dyes in the case of *Morinda lucida* plant species as compared to the other plants especially when potassium aluminium sulphate, stannous chloride and potassium dichromate were used as mordants. Significant mordant effects were observed with the changes in the hue values, H, for dye extracts from *Justicia betonica* and *Morinda lucida* (root) plant species (tables 1 and 4) indicating that the effect of different mordants on shade appearance was dye dependent. The effect of stannous chloride and potassium dichromate mordants on colour change resulted in the colour shades of *Justicia betonica* appearing more bluish than redder as compared to the effects by alum and ferrous sulphate mordants due to the larger negative values of b (table 1).

The range of colours produced by the same dye-yielding plant species using different mordants was remarkable and this is one of the advantages of natural dyeing. However, each mordant had an individually limited range of colour change; only alum and stannous chloride yielded bright clear yellowish – green shades with the highest values of L and H (above 90^o) occuring in the second quadrant of the colour space diagram in the case of *Morinda lucida* root dye extract while ferrous sulphate mordant in all cases resulted in the dulling of colour shades with lower values of chroma, C as compared to the other mordants.

Colour reflectance measurements with different mordants

The spectral colour reflectance values with different mordants recorded in figs 2 – 7 show the predominance of the yellow to red hues of the dyed cotton fabrics between 560nm – 700nm. The different spectral reflectance curves showed characteristic peaks determining the hues of each coloured fabric and the effect of mordant on the shapes of the curves appeared to be dye dependent. The reflectance values for *Justicia betonica* plant species however indicate a very high percentage of incident light reflection of about 85% of the blue-violet components of the visible band of light and about 10% of the red light was reflected (fig.2). And these reflectances result overall in the particular bluish-violet colour shade of this fabric surface. The effect of change of mordant on reflectances from the fabric surfaces and the nature of the spectral reflectance curves was noticeably significant in respect of all the dyed fabric samples.

The interaction of mordant with dye, however, is not predictable and the effect of mordant on spectral reflectance characteristics depended to a great extent on the type of dye used and the mordant.

Evaluation of colour absorption and strength with different mordants

Metal complex formation has been a prominent feature in textile dyeing from very early times, since it was recognized that the technical performance including dye absorption of many natural dyes could be enhanced by treatment with certain metal ions [4]. No study, however, has been carried out in Africa on the effect of different mordants on dye absorption characteristics of plants with dye-yielding properties. It can be shown that the different mordants used in this study affected the substantivity of the dyes depending on the chemical nature of the dye and the mordant used. Whereas the use of potassium aluminium sulphate in dyeing with the crude extracts from *Albizia coriaria, Morinda lucida* (bark and root extracts) exhibited the highest dye absorption values (K/S)(figs. 9,10,11) in the case of the crude bark extract of *Syzygium cordatum,* it was ferrous sulphate mordant which gave overall higher colour absorption values on the substrate. The change in the K/S values between the different mordants in the case of the crude dye extract from *Morinda lucida* (bark) was less significant as compared to the other dye-yielding plants. The choice of mordant is therefore very critical in natural dyeing for optimum colour absorption and stability. The different mordants did not however, alter significantly the colour locations of the different dyed fabric samples in the colour space diagram represented by the various sample codes given in tables 1 – 6.

The effect of colour change on the same textile substrate therefore depended on the nature of the natural dye and mordant used. This calls for colour matching database for natural dyeing of any particular textile material and match prediction being possible with the use of a computerized software programme in order to address the shade reproducibility and stability problem associated with natural dyeing. The effect of Ferrous sulphate mordant was more pronounced with Vitellaria paradoxa when compared with the rest of the mordants. The results of this study indicate that the type of shades produced and the level of absorption of dye were affected by using the different mordants whose chemical reaction with the natural dyes depended on the unique structures of the colour components and on the strength of the metal dye coordination complex formed during the dyeing process.

Table 1: Effect of different mordants on L, a, b, C and H coordinates of cotton fabric samples dyed with *Justicia betonica* crude leaf extract.

	Colour Coordinates					
Mordant used	L	a	b	C	H	Sample Codes
Potassium aluminium sulphate	67.80	8.10	-6.94	10.66	319.40	A_1
Ferrous sulphate	64.09	6.04	-7.16	9.37	310.13	A_2
Stannous chloride	56.93	1.54	-13.61	13.70	276.46	A_3
Potassium dichromate	56.43	1.64	-9.89	10.03	279.42	A_4

Table 2: Effect of different mordants on L, a, b, C and H coordinates of cotton fabric samples dyed with *Albizia coriaria* crude bark extract.

	Colour Coordinates					
Mordant used	L	a	b	C	H	Sample codes
Potassium aluminium sulphate	58.57	13.26	21.28	25.70	58.08	B_1
Ferrous sulphate	21.47	5.92	6.46	8.76	47.13	B_2
Stannous chloride	63.98	12.05	14.69	19.00	50.63	B_3
Potassium dichromate	68.59	8.22	11.88	14.45	55.31	B_4

Table 3: Effect of different mordants on L, a, b, C and H coordinates of cotton fabric samples dyed with *Morinda lucida* crude bark extract.

	Colour Coordinates					
Mordant used	**L**	**a**	**b**	**C**	**H**	**Sample Codes**
Potassium aluminium sulphate	69.05	3.35	37.92	38.07	84.96	C_1
Ferrous sulphate	57.55	2.08	17.65	17.77	83.27	C_2
Stannous chloride	68.42	4.35	31.33	31.63	82.89	C_3
Potassium dichromate	67.73	2.84	30.19	30.33	84.62	C_4

Table 4: Effect of different mordants on L, a, b, C and H coordiantes of cotton fabric samples dyed with *Morinda lucida* crude root extract.

	Colour Coordinates					
Mordant used	L	a	b	C	H	Sample Codes
Potassium aluminium sulphate	76.24	-0.77	37.52	37.52	91.17	D_1
Ferrous sulphate	70.39	3.58	8.59	9.31	67.38	D_2
Stannous chloride	80.94	-1.59	14.63	14.72	96.21	D_3
Potassium dichromate	75.81	2.68	11.83	12.13	77.24	D_4

Table 5: Effect of different mordants on L, a, b, C and H coordinates of cotton fabric samples dyed with *Syzygium cordatum* crude bark extract.

	Colour Coordinates					
Mordant used	L	a	b	C	H	Sample Codes
Potassium aluminium sulphate	60.13	8.29	14.72	16.89	60.62	E_1
Ferrous sulphate	50.39	5.93	11.34	12.80	62.42	E_2
Stannous chloride	61.52	9.40	11.81	15.10	51.50	E_3
Potassium dichromate	58.09	8.31	14.13	16.39	59.53	E_4

Table 6: Effect of different mordants on L, a, b, C and H coordinates of cotton fabric samples dyed with *Vitellaria paradoxa* crude bark extract.

	Colour Coordinates					
Mordant used	L	a	b	C	H	Sample Codes
Potassium aluminium sulphate	59.43	13.27	19.16	23.31	55.31	F_1
Ferrous sulphate	63.75	3.86	7.96	8.85	64.11	F_2
Stannous chloride	58.96	9.36	12.21	15.38	52.54	F_3
Potassium dichromate	66.05	4.67	14.43	15.16	72.06	F_4

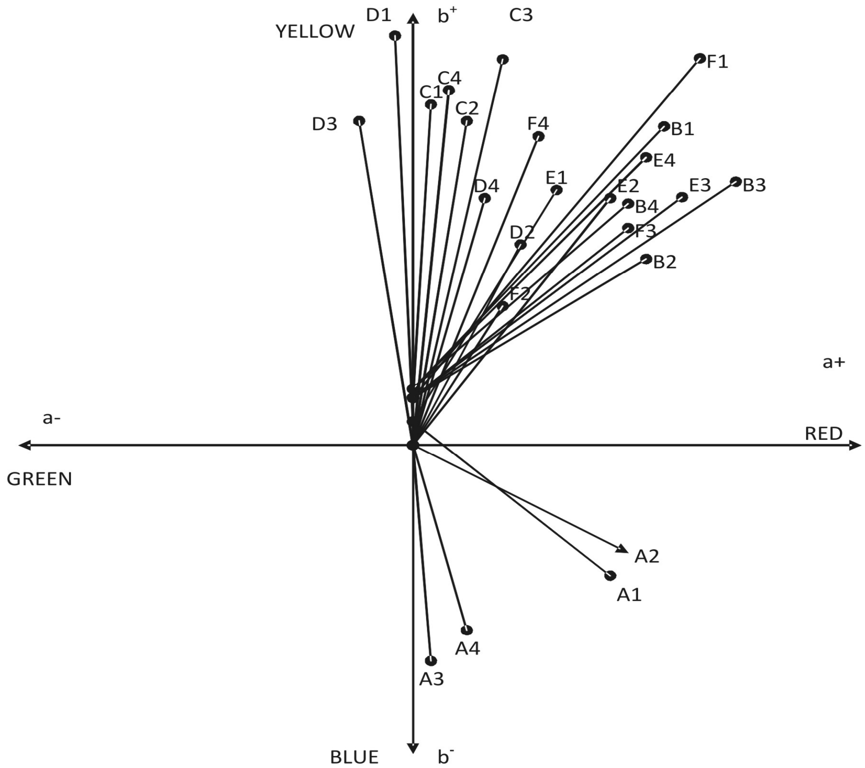

Fig. 1: Specific Location of coloured fabric samples in the colour space diagram with different mordants.

- (A_1—A_4 sample codes are for *Justicia betonica* plant using alum, iron, tin and chrome as mordants respectively, B_1—B_4 are sample codes for *Albizia coriaria* plant using alum, iron, tin and chrome as mordants respectively, C_1—C_4 are sample codes for *Morinda lucida* (bark) using alum, iron, tin and chrome as mordants respectively, D_1—D_4 are sample codes for *Morinda lucida* (root) plant using alum, iron, tin and chrome as mordants respectively, E_1 – E_4 are sample codes *for Syzygium cordatum* plant using alum, iron, tin and chrome as mordants respectively and F_1 – F_4 for *Vitellaria paradoxa* plant species using alum, iron, tin and chrome as mordants respectively.

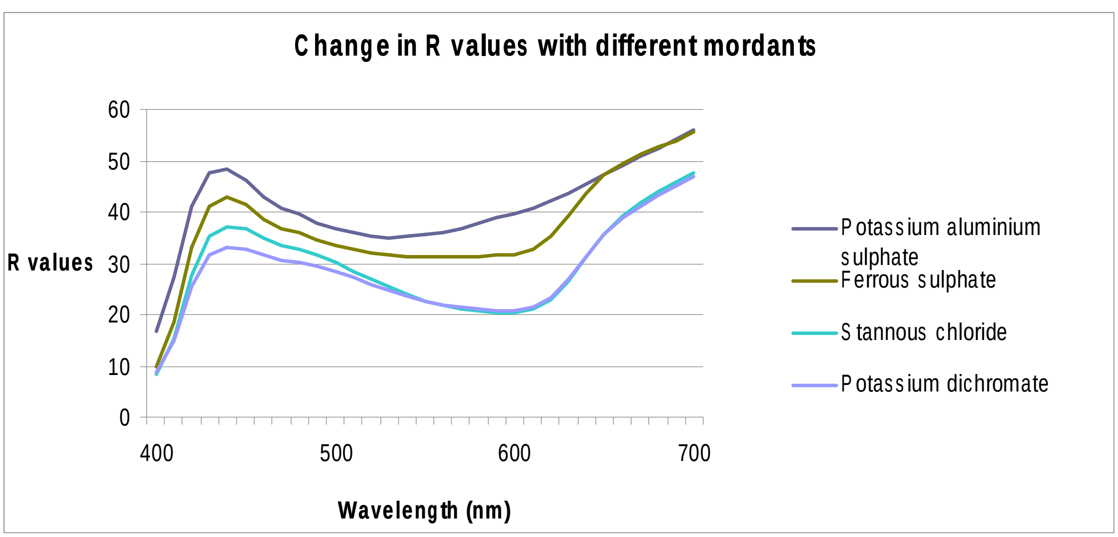

Fig. 2: Change in reflectance values with different mordants for cotton fabrics dyed with *Justicia betonica* crude leaf extract.

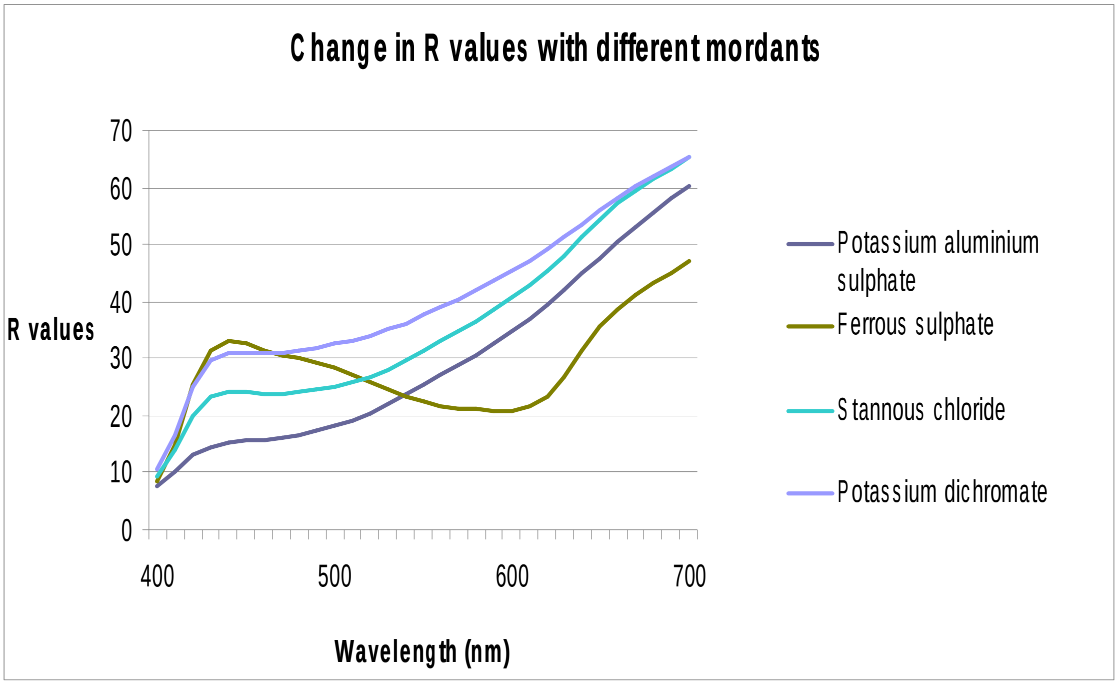

Fig. 3: Change in reflectance values with different mordants for cotton fabrics dyed with *Albizia coriaria* crude bark extract.

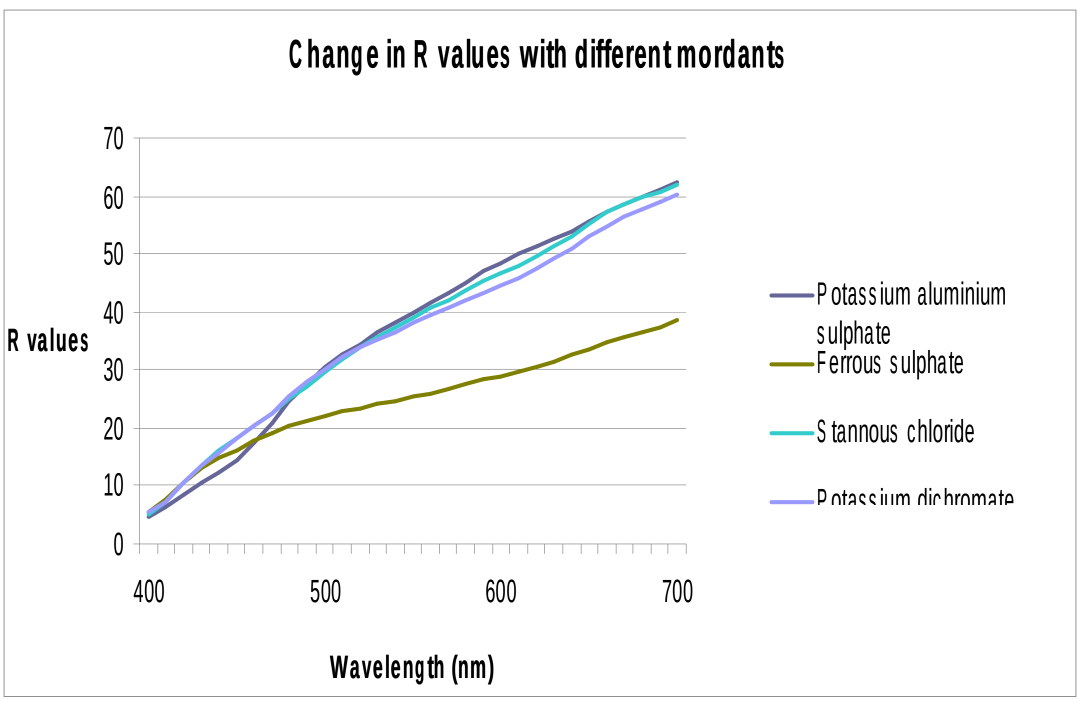

Fig.4: Change in reflectance values with different mordants for cotton fabrics dyed with *Morinda lucida* crude bark extract.

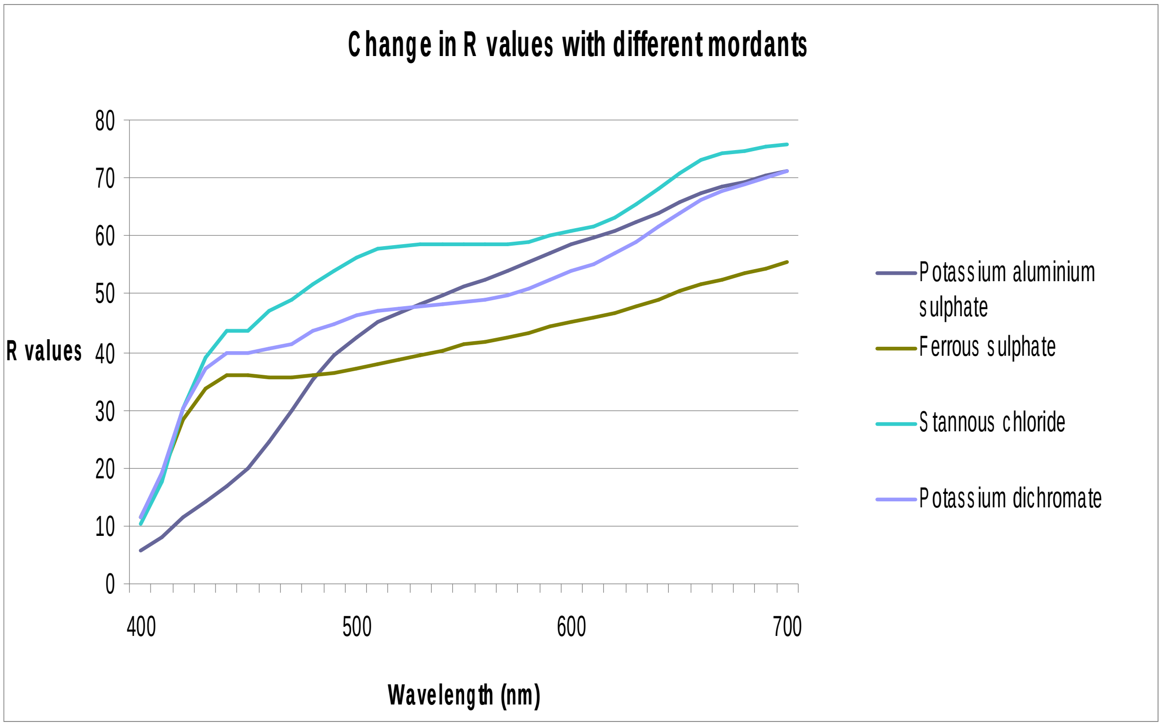

Fig. 5: Change in reflectance values with different mordants for cotton fabrics dyed with *Morinda lucida* crude root extract.

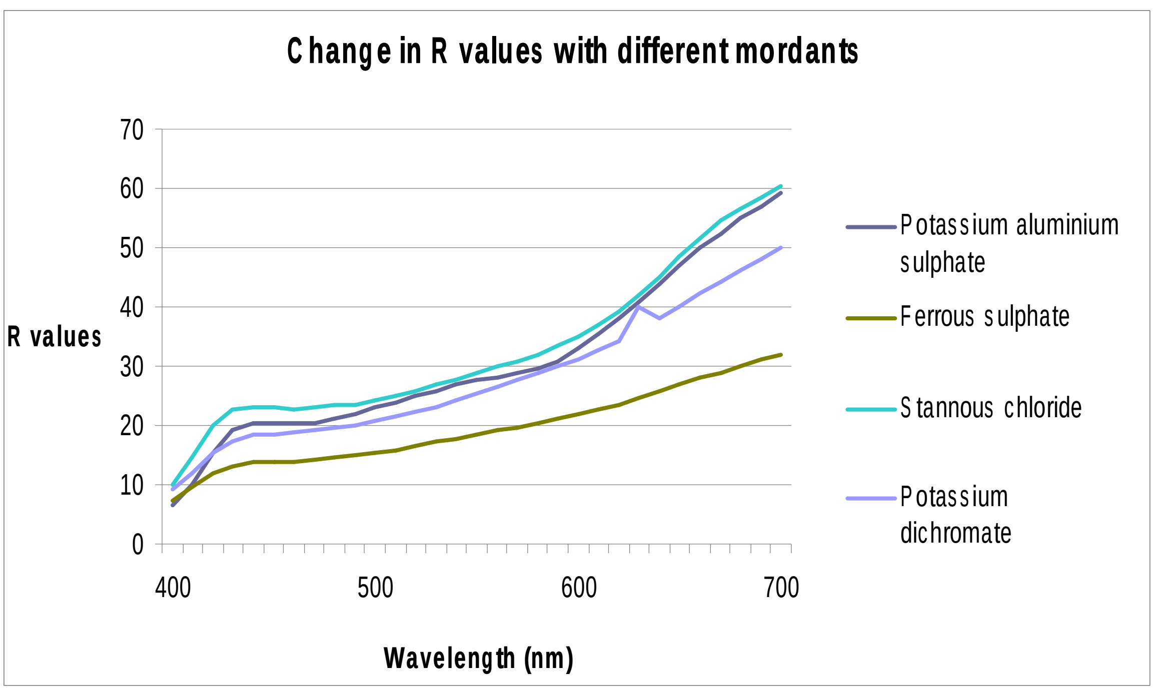

Fig. 6: Change in reflectance values with different mordants for cotton fabrics dyed with *Syzygium cordatum* crude bark extract.

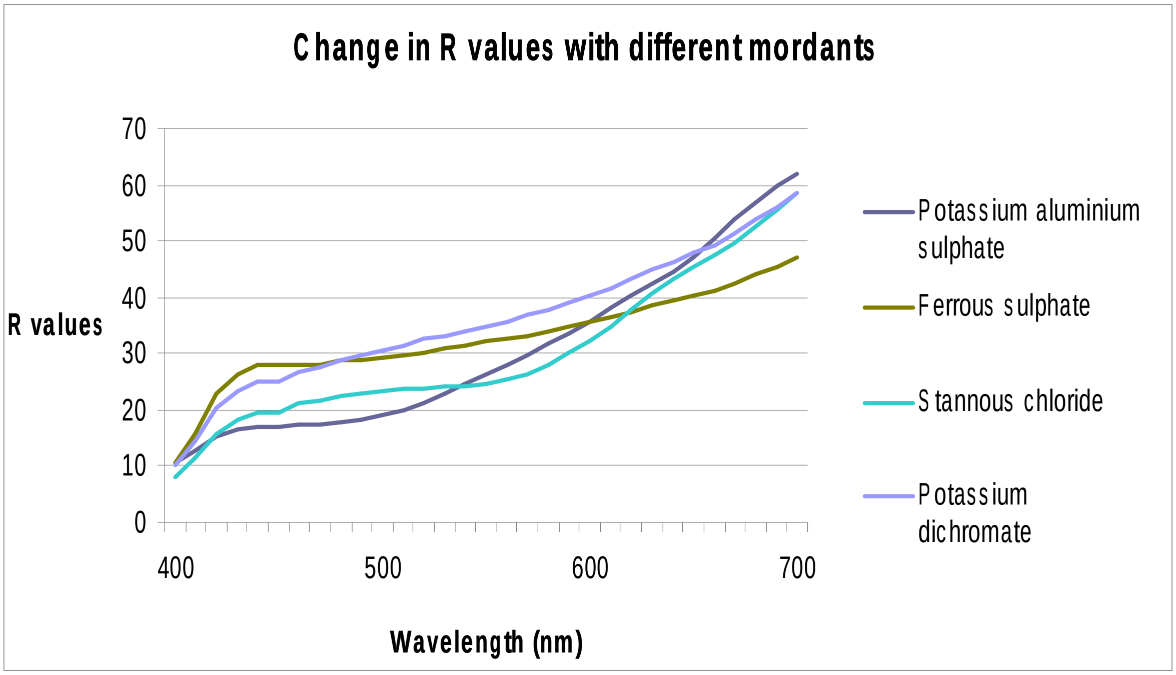

Fig. 7: Change in reflectance values with different mordants for cotton fabrics dyed with *Vitellaria paradoxa* crude bark extract.

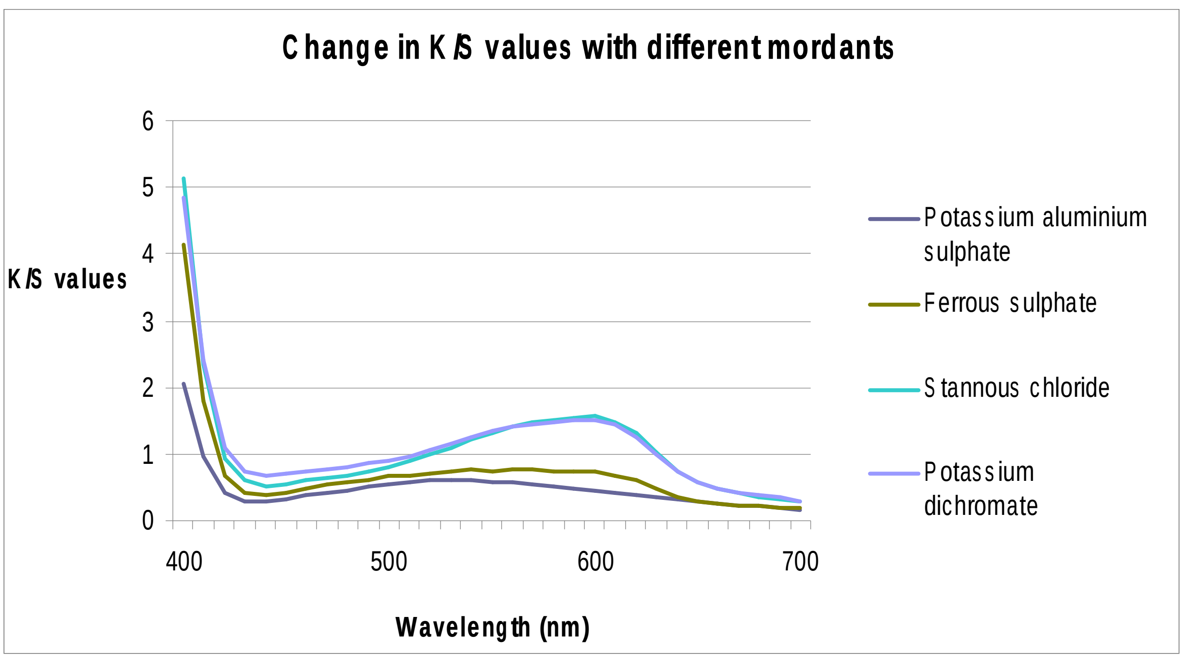

Fig. 8: Change in K/S values with different mordants for cotton fabrics dyed with *Justicia betonica* crude leaf extract.

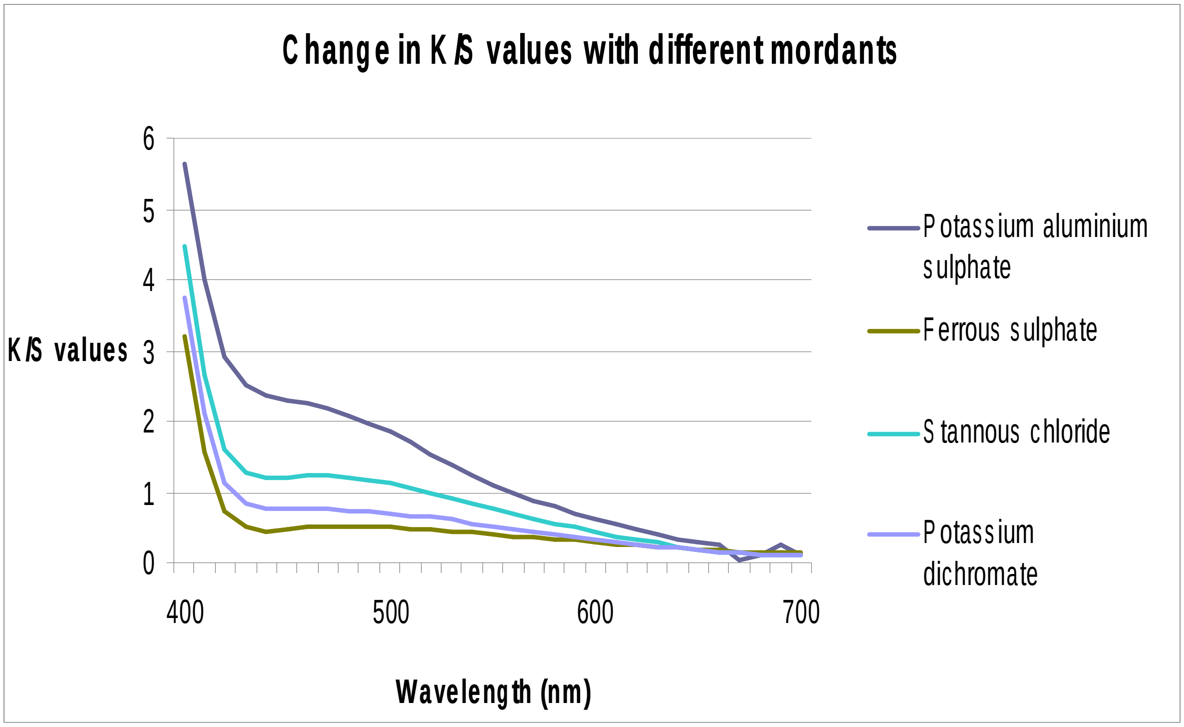

Fig. 9: Change in K/S values with different mordants for cotton fabrics dyed with Albizia coriaria crude bark extract.

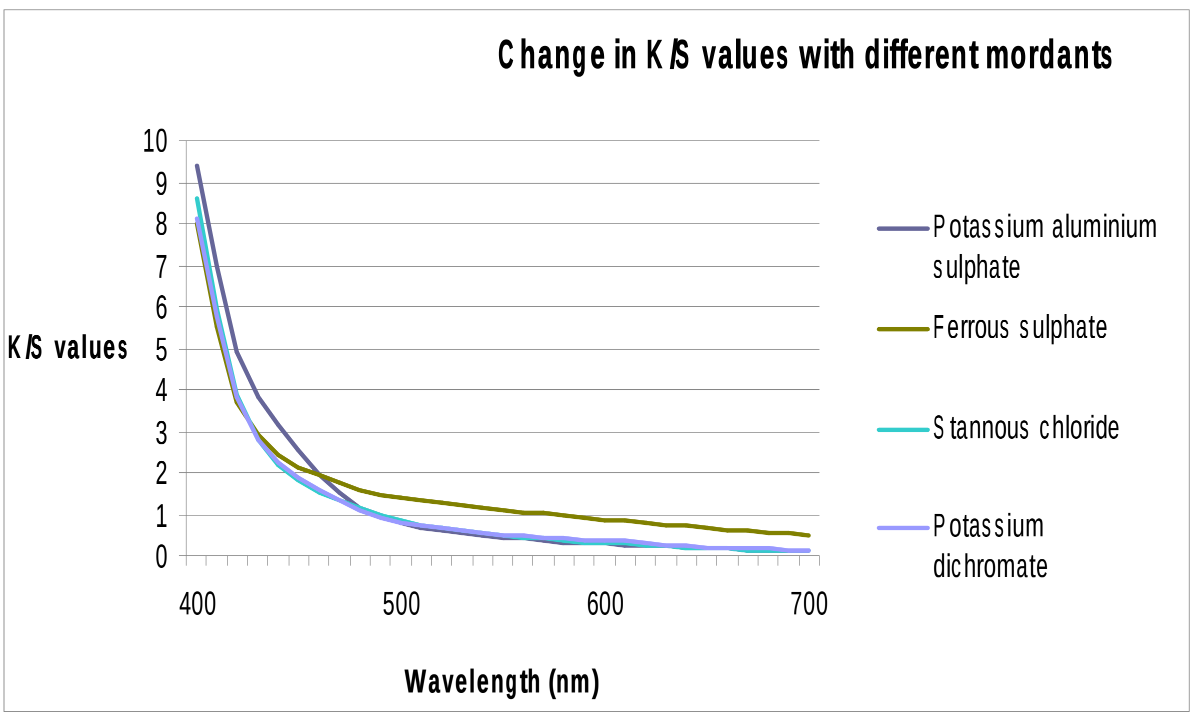

Fig. 10: Change in K/S values with different mordants for cotton fabrics dyed with *Morinda lucida* crude bark extract.

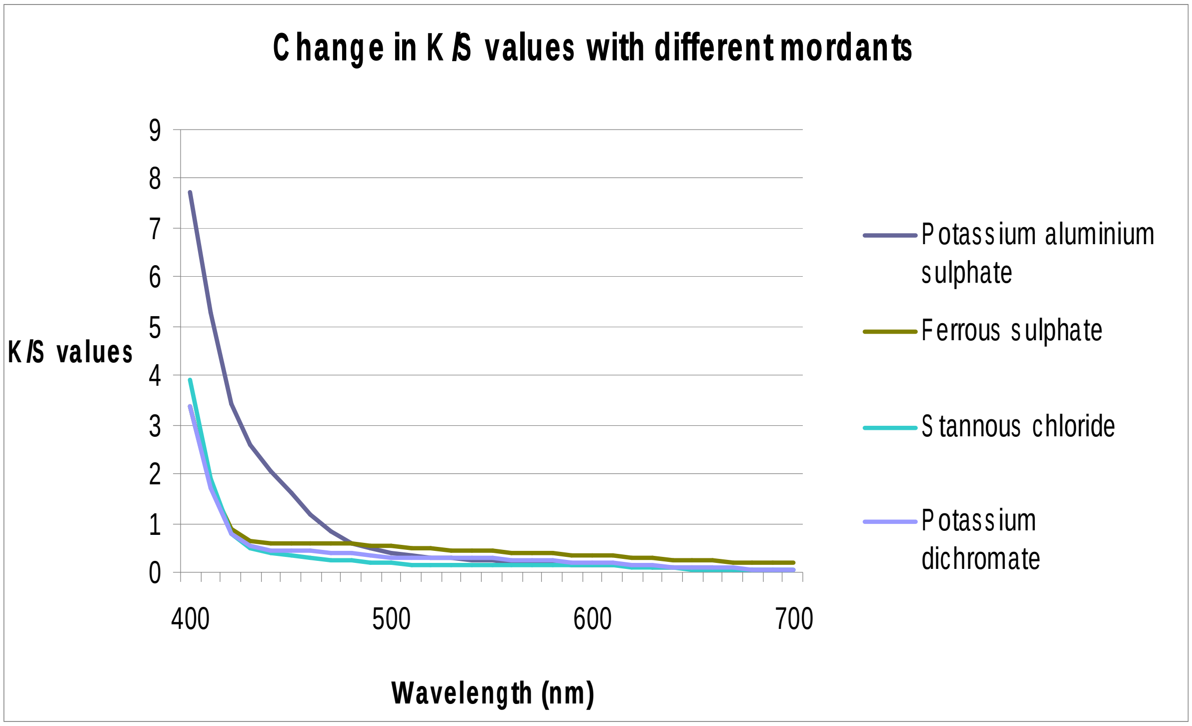

Fig. 11: Change in K/S values with different mordants for cotton fabrics dyed with *Morinda lucida* crude root extract.

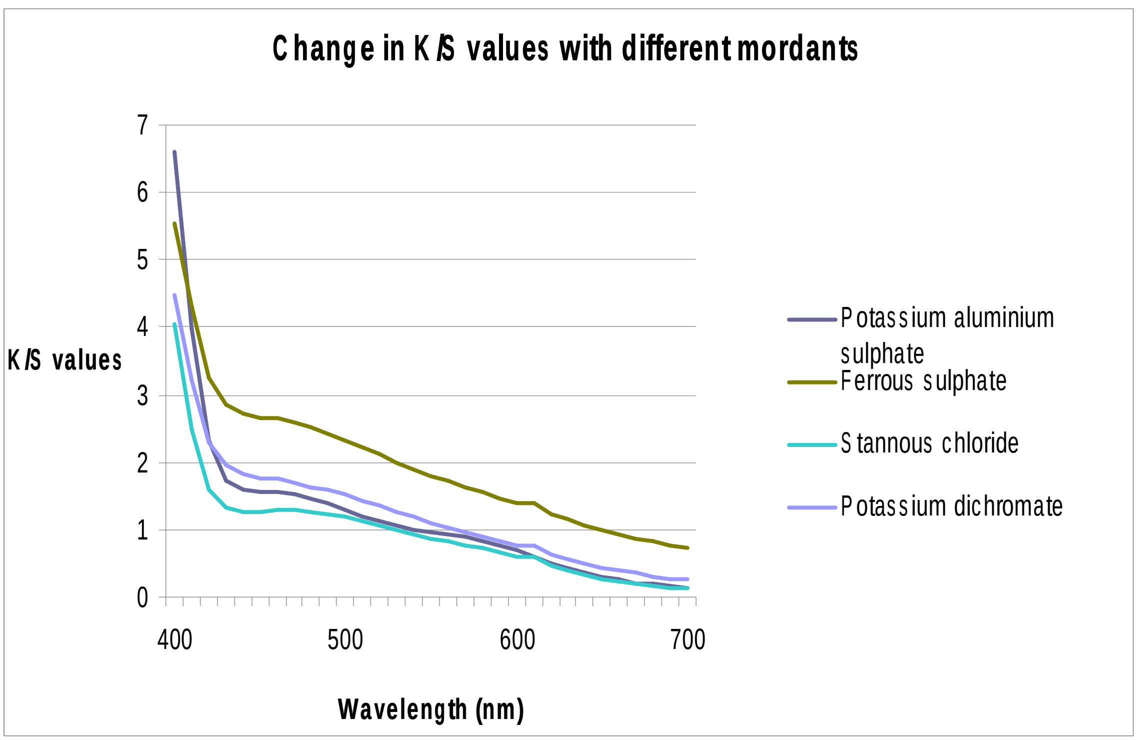

Fig. 12: Change in K/S values with different mordants for cotton fabrics dyed with *Syzigium cordatum* crude bark extract.

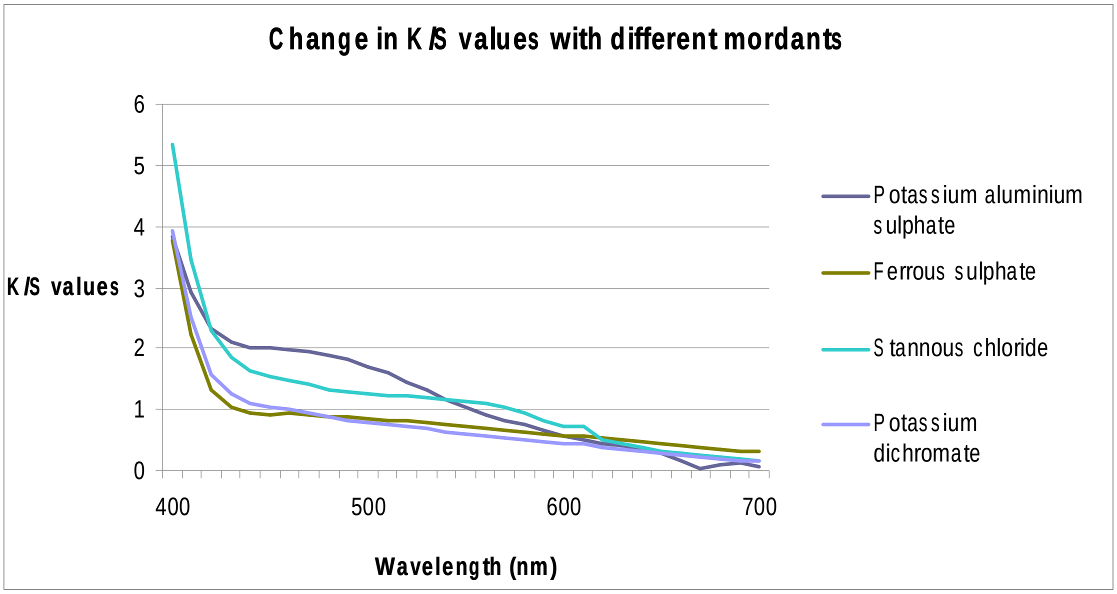

Fig. 13: Change in K/S values with different mordants for cotton fabrics dyed with *Vitellaria paradoxa* crude bark extract.

CONCLUSION

Metal mordants are essential in dyeing cotton fabrics with natural dyes and influence the colour shades produced depending on the nature of mordant – dye complex formed during the dyeing process. The relative colour strength expressed as K/S values was mordant and natural dye dependent. Different mordants caused differences in hue colour (H) and significant changes in K/S values but also in L values. Ferrous sulphate mordant provided dark shades in four of the six cases investigated. The appearances of the colours, their strength and stability on the cotton fabrics depended to a large extent on the choice of mordant used and the nature of the textile material.

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