Studies of Some Natural Dyes

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Summary: The silk fabric was dyed with Hermal leaves (*Peganum harmala* L) and Logwood (Haematoxylum campechianum)by three different processes using various metal sulphates as mordant. The dyeing behaviour had been assessed by different fastness properties and measuring K/S values. The effect of different metal ions at two concentrations had been studied with respect to their influence on colour and fastness properties. CIE Lab coordinates of the dyed silk had also been presented of the controlled and mordanted samples.

Introduction

Dyes are intensely colored chemical compounds which when applied to a substrate impart colour to this substrate. Retention of colour as well as stability are required for functional properties and are accomplished by chemical and physical forces such as chemical bonding, hydrogen bonding, vander waals forces, absorption of solution, electrostatic interac-tion, molecular size enlargement and insolubility in the substrate.

Today the protection of the environment has become a challenge for the chemical industry world wide, and the water pollution caused by synthetic dyes in particular the control of effluent, continues to be a problem. All over the world environmental regulations are becoming more strict and are forcing the shift of technology towards less pollution or practically non-polluting areas of technological development. Although most attention has been paid to modifying synthetic dyeing processes, the need to realise the importance and explore the technology of natural dyes is arguably more urgent. Any effort to reasses and promote the use of natural dyes deserves encouragement [1,2].

Nevertheless natural dyes do have tremendous commercial potential. Natural dyes exhibit better biodegradability and are generally more compatible with the environment and are more acceptable to the environmentally conscious people. Considerable research work is being undertaken around the world on the application of natural dyes [3,4]. The last decade has witnessed a resurgence of interest in the use of natural dyes. During this period several studies on dyeing with these dyes have been carried out but most of them have been empirical in nature. Systematic investigations into the theoretical basis of dyeing with natural dyes are rather limited [5-7].

The present study focuses on the dyeing of silk with the Hermal leaves (*Peganum harmala* L) and Logwood (Haematoxylum campechianum) extract which is sparingly soluble in water but is freely soluble in alcohol. For dyeing three different techniques used are named as pre-mordanting, meta-mordan-ting and post-mordanting. The purpose of this study is also to investigate the dyeing behavior and fastness properties of silk samples dyed with natural dyes and comparison were made between dyeing with and without mordants. The changes in fastness properties and colour coordinates are reported and the depth of shades of all the samples were evaluated in terms of reflectance, K/S and CIE La*b* values of the dyed substrate.

Results and Discussion

In the actual dyeing process a mordant combines chemically with a soluble dye to form a very complex, aggregated, insoluble lake of high molecular weight within the textile fibre. The 'lake' makes the fibre resistant to the external influences in washing and finishing processes. The fastness depends on the formation of lake inside the textile fibres [8]. The silk fabric was dyed with Hermal leaves and Logwood at 2% and 4% dyeing concentrations with different mordants (alum, copper sulphate and ferrous sulphate) at 5g/l and 10g/l concentrations. The results of fastness properties of the two natural dyes are given in Table-1 and Table-2.

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Table-1:The Results of Fastness Properties of Silk Samples Dyed with Hermal Leaves (*Peganum harmala* L.)

Samples	Mordant Concen-tration g/l	Rubbing Fastness Dry	Wet	Washing Fastness Cellulose Acetate	Cotton	Nylon	Polyester	Acrylic	Wool	Light Fastness
Control										
Natural		4	3-4	4-5	4-5	5	5	5	4-5	4-5
Pre-Mordanting										
Alum	5	4	4	3-4	3-4	2-3	4	4-5	3	4
Alum	10	4	4	3-4	3-4	2-3	4	4-5	2-3	2-3
Copper	5	4	4	3-4	3-4	2-3	4	4-5	3	4-5
Copper	10	4	4	3-4	3-4	2-3	4	4-5	3	4
Ferrous	5	3-4	4	3	3-4	2-3	4	4-5	3	4
Ferrous	10	3-4	4	4	4	3	4-5	4-5	2-3	4-5
Meta-Mordanting										
Alum	5	2-3	3	3-4	3-4	2-3	4	4-5	3	4-5
Allum	10	3-4	4	3-4	3-4	2-3	4	4-5	3	4-5
Copper	5	3-4	4	4	3-4	2-3	4-5	4-5	3	4-5
Copper	10	4	4	4	4	3	4-5	4-5	3-4	4-5
Ferrous	5	3-4	3-4	3-4	3-4	2-3	4	4-5	3	4-5
Ferrous	10	3-4	3-4	4	4	3	4-5	4-5	3	4-5
Post-Mordanting										
Alum	5	4-5	4	3-4	3-4	2-3	4	4-5	3	4-5
Alum	10	4	4	4	4	3	4-5	4-5	3-4	4-5
Copper	5	4	4	4	4	3	4	4-5	4	4-5
Copper	10	4-5	4-5	4	4	3	4-5	4-5	4	4-5
Ferrous	5	4	3-4	4	4	3	4	4-5	3	4-5
Ferrous	10	4	4	3-4	3-4	2-3	4	4-5	3	4

Results of Fastness Properties of Hermal Leaves

The silk samples were subjected to dye with hermal leaves and the fastness properties of the dyed samples were assessed by grey scale measurements against the original samples. The results of the fastness properties of hermal leaves are recorded in Table-1.

Wash Fastness

The samples dyed were washed with soap water and the staining on cellulose acetate, cotton, nylon, polyester, acrylic and wool were determined by following ISO CO_2 method. The staining on these samples was compared against the original samples by grey scale measurement and the results are recorded for each mordant in Table-1.

The wash fastness of control samples is found to be poor (3) in case of staining on cotton and nylon (2) whereas for cellulose acetate, polyester, acrylic and wool grey scale reading being 3-4. The staining on silk fabric after dyeing with the mordants in the technique known as pre-mordanting showed satisfactory results (3-4) for cellulose acetate and cotton, but nylon and wool show low fastness properties (2-3) except for polyester and acrylic the fastness property being good (4-5). Ferrous sulphate showed good results at 10g/l concentration for all the substrates except for nylon and wool. The samples dyed with technique known as meta- mordanting showed the approximate same wash fastness as with the pre-mordanting, the rating for polyester and acrylic being good (4-5). Ferrous sulphate at 10g/l showed good results as compared to alum and copper sulphate.

The dyed samples by using the technique named as post- mordanting were assessed for washing fastness and showed good fastness property as compared to the previous technique. In this case high staining on nylon and wool show poor fastness property 2-3.

Rubbing Fastness

The rubbing fastness of dyed samples for both wet and dry is found to be 4 and 3-4 for both dry and wet rubbing of the control samples. In case of pre-mordanting the rubbing fastness (dry and wet) found to be 4 for alum, copper and ferrous sulphates except for dry rubbing fastness for ferrous sulphate which is 3-4 at both the concentrations.The technique known as meta-mordanting showed less rubbing fastness as compare to the pre- mordanting and found to be in the range of 3-4 except for alum which is 2-3 for both dry and wet rubbing fastness.The silk samples dyed with post- mordanting technique showed high rubbing fastness (4-5) except for the ferrous sulphate the grey scale reading being 3-4 of the wet rubbing fastness.

Table-2: The Results of Fastness Properties of Silk Samples Dyed with LogWood (Haematoxylum Campechianum).

Samples	Mordant Concen-tration G/L	Rubbing Fastness Dry	Wet	Washing Fastness Cellulose Acetate	Cotton	Nylon	Polyester	Acrylic	Wool	Light Fastness
Control										
Natural		3-4	3-4	3	1-2	2	3-4	3-4	3-4	4
		4-5	4-5	4-5	2	2-3	4-5	4	4-5	4-5
Pre-Mordanting										
Alum	5	4	3-4	4-5	5	4-5	4-5	5	4-5	4
Alum	10	4	3-4	4-5	5	4-5	4-5	5	4-5	4
Copper	5	4	3-4	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Copper	10	4	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Ferrous	5	4	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Ferrous	10	3-4	4	4-5	5	4-5	4-5	5	4-5	4
Meta-Mordanting										
Alum	5	4	3-4	4-5	5	4-5	4-5	4-5	4-5	4-5
Allum	10	4	4-5	4-5	5	4-5	4-5	4-5	4-5	4
Copper	5	4	3-5	4-5	5	4-5	4-5	4-5	4-5	4
Copper	10	3-4	3-4	4-5	5	4-5	4-5	5	4-5	4-5
Ferrous	5	4	3-4	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Ferrous	10	4	4	4-5	4-5	4-5	4-5	4-5	4-5	4
Post-Mordanting										
Alum	5	4	4	4-5	5	4-5	4-5	5	4-5	3-4
Alum	10	4-5	4	4-5	4-5	4-5	4-5	5	4-5	4
Copper	5	4-5	4-5	4-5	5	4-5	4-5	4-5	4-5	4-5
Copper	10	4-5	4	4-5	5	4-5	4-5	4-5	4-5	4-5
Ferrous	5	3-4	4	4-5	4-5	4-5	4-5	5	4-5	4
Ferrous	10	4	4	4-5	4-5	4-5	4-5	4-5	4-5	4

Light Fastness

The light fastness of the silk samples dyed with hermal leaves extract was determined in day-light and is found to be 4-5 for the controlled sample.

In case of meta-mordanting and post-mordanting the grey scale reading being 4-5 for alum, copper sulphate and ferrous sulphate whereas in the case of pre-mordanting the fastness property is 4. The results showed that the dyeing with pre-mordanting technique resulted in good fastness to light but the grey scale values are lower as compared to meta-mordanting and post-mordanting techniques with all the three mordants at 5g/l and 10g/l concentrations.

Results of Logwood

The fastness properties of silk fabric dyed with logwood were assessed in the same way as subjected to Hermal leaves and the results are presented in Table-2.

Wash Fastness

The wash fastness property of samples dyed with logwood in terms of staining was found to be poor for the control sample and are 1-2 for nylon and cotton and 3-4 for polyester, acrylic and wool fabrics. The staining on fabrics after dyeing with mordants by using the technique called pre-mordanting also showed good wash fastness property (4-5) for nylon, polyester and wool but showed excellent fastness (5)when dyed with alum at both concentrations and with ferrous sulphates at 5g/l concentration respectively.The samples dyed with technique meta-mordanting also showed good wash fastness (4-5) with cellulose acetate, nylon, polyester, acrylic and wool except for cotton which showed excellent fastness property (5) with alum and copper sulphates at both concentrations.The silk fabric dyed with the mordants by using the technique named as post mordanting showed good fastness property (4-5) for cellulose acetate, nylon, polyester and wool whereas for cotton and acrylic the grey scale being 5 for alum and ferrous sulfate.

Rubbing Fastness

The rubbing fastness of control sample dyed with natural dye found to be fair (3-4) for both dry and wet rubbing. The silk samples dyed under pre-mordanting technique showed the dry and wet fastness property is found best with ferrous (4) at both concentrations. The dry and wet rubbing fastness property in meta mordanting is found to be

(4, 3-4) for alum and copper at 5g/l concentration. In the case of post-mordanting the samples showed dry and wet rubbing fastness property in the range of 3-4 of grey scale.

Light Fastness

The light fastness property of silk dyed with logwood is found to be 4 for controlled sample.

In case of pre-mordanting the grey scale reading being 4 for alum and ferrous sulphate whereas for copper sulphate the rating was 4-5.In the case of meta-mordanting the samples showed good light fastness (4 to 5) for the three mordants. In case of post-mordanting the silk samples showed good light fastness (4-5) whereas the rating being low for alum (3-4) at 5g/l mordant concentration.

Colour Measurement of Hermal Leaves

The reflectance and K/S values were determined for both controlled and mordanted samples at 2% dyeing. The samples dyed with three techniques of mordanting with mordant concentrations 5g/l and 10g/l were compared with the values found for the control samples of natural dyes and the results are given in Table-3. The reflectance is actually the ratio of the light leaving an object versus the total light that was hitting the object and K/S is the determination of colorant strength from reflectance measurement. The K/S value is calculated by the formula given below:

$$K/S = \frac{(1-R)^2}{2R} - \frac{(1-R_0)^2}{2R_0}$$

R = reflectance of the colored fabric

R_0 = reflectance of the uncolored fabric

K = absorption co-efficient

S = scattering co-efficient

The Higher the Value Obtained, the Greater the Colour Strength

As shown in Table-3 the reflectance of the silk fabric dyed with hermal leaves (controlled sample) had been determined for 2% dyeing and was found to be 3.77 whereas the K/S calculated from reflectance value was 12.29. The dyeing of silk with hermal leaves by pre-mordanting with alum, copper and ferrous sulfates (5 g/l) had shown increase in the reflectance values (2.93, 2.95 and 3.16 respectively) as compared to the dyeings performed at 10g/l concentration of the three mordants which were (1.37, 2.94 and 3.13 respectively). The results revealed that an increase in the mordant concentration decreased the reflectance which was confirmed by an increase in the K/S value at 5 g/l concentration of alum , copper sulphate and ferrous sulphate .The results also showed high values with copper sulfate as compared to ferrous and alum sulphate.In the case of meta- mordanting the results showed high K/S value for dyeing with alum at 5g/l and 10g/l mordant concentration. For post -mordanting technique the values showed reduction in reflectance at 5 g/l as compare to 10 g/l for alum, copper and ferrous. This confirmed the high strength of colour or high K/S values. For alum, copper and ferrous the K/S values being 16.32, 18.09 and 15.08 at 5 g/l as compared to the K/S value of the control sample (12.29). The values of K/S of the dyed fabric with hermal leaves extract are compared in the figures 1 and 2 at 5g/l and 10g/l concentrations of mordants.

Table-3: The Reflactance and K/S Values of Samples Dyed with Natural Dye of Hermal Leaves (*Peganum harmala* L) .

Samples	Mordant Concentration g/l	K/S Value	Reflactance
Control			
Natural		1.19	24.17
Pre-Mordanting			
Alum	5	3.02	10.23
Alum	10	4.43	9.29
Copper	5	3.94	12.65
Copper	10	7.23	6.10
Ferrous	5	3.38	11.56
Ferrous	10	5.87	7.32
Meta-Mordanting			
Alum	5	2.13	24.09
Alum	10	2.83	18.28
Copper	5	3.68	24.01
Copper	10	4.85	23.02
Ferrous	5	2.83	10.81
Ferrous	10	1.82	8.60
Post-Mordanting			
Alum	5	3.04	12.09
Alum	10	3.79	10.55
Copper	5	5.19	16.28
Copper	10	5.57	10.56
Ferrous	5	2.15	8.13
Ferrous	10	3.79	3.21

Colour Measurement of Logwood

The silk sample dyed with logwood (controlled sample) was measured for 2 % dyeing

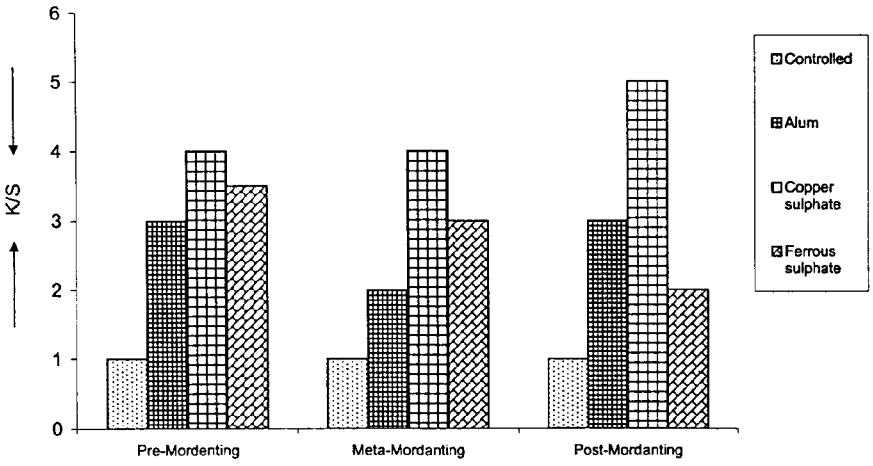

Fig. 1: Effect of mordents (5g/l) on the K/S value of silk dyed with hermal leaves (*Peganum harmala* L.)

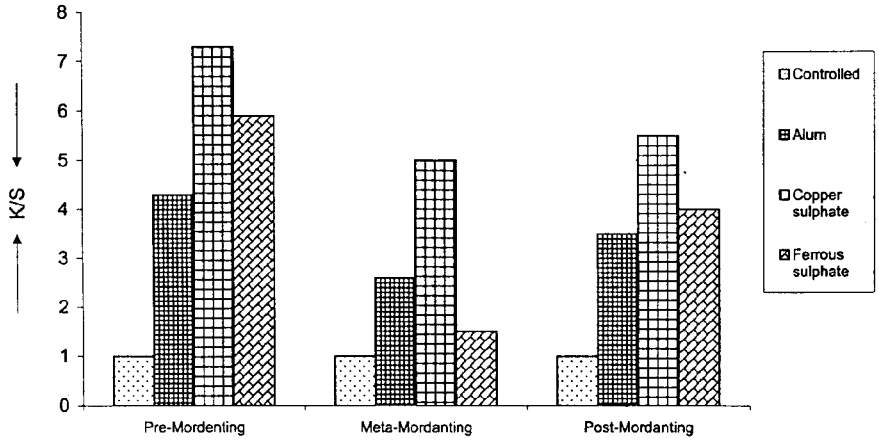

Fig. 2: Effect of mordents (10g/l) on the K/S value of silk dyed with hermal leaves (*Peganum harmala* L.)

regarding reflectance (9.97) and k/s (4.06) as shown in Table-4. The dyeing of silk with pre-mordanting technique showed reduction in the reflectance with the increase in mordant concentration in comparison with k/s values which increased when dyeings were performed with mordants. The values of K/S at 5g/l concentration of mordants were 7.96,11.94 and 7.87 when dyeings were performed with alum, copper and ferrous sulphate respectively.

The meta-mordanting technique of dyeing silk samples followed same trends as for reflectance reduction as for pre-mordanting and the K/S values recorded were 4.83, 6.36 and 9.51 respectively for alum, copper and ferrous sulphate at 5g/l concentration. At 10g/l concentration ferrous sulphate showed best results. In the case of post-mordanting the reflectance values were again less than the control samples indicating that mordant has decreased the reflectance and increased the strength of colour. The results shown in the table indicate that values for ferrous sulphate (10.38 and 9.58) are favorable for dyeing silk with logwood at 5g/l and 10g/l mordant concentrations as compared to alum and copper sulphate.

Colour Co-ordinates of Samples Dyed with Hermal Leaves

The colour coordinates of dyed samples have been determined by spectrophotometer with Data Master V 2.3 software (Data colour, international, USA) against the control sample of natural dye and

Table-4: The Reflactance and K/S Values of Samples Dyed with Natural Dye of Logwood (Haematoxylum)

Samples	Mordant Concen tration g/l	K/S Value	Reflactance
Control			
Natural		1.19	24.17
Pre-Mordanting			
Alum	5	3.02	10.23
Alum	10	4.43	9.29
Copper	5	3.94	12.65
Copper	10	7.23	6.10
Ferrous	5	3.38	11.56
Ferrous	10	5.87	7.32
Meta-Mordanting			
Alum	5	2.13	24.09
Alum	10	2.83	18.28
Copper	5	3.68	24.01
Copper	10	4.85	23.02
Ferrous	5	2.83	10.81
Ferrous	10	1.82	8.60
Post-Mordanting			
Alum	5	3.04	12.09
Alum	10	3.79	10.55
Copper	5	5.19	16.28
Copper	10	5.57	10.56
Ferrous	5	2.15	8.13
Ferrous	10	3.79	3.21

inter comparison of different techniques used for dyeing and the difference in coordinates L* a* and b* are calculated. The L* values represents the difference of lightness of the colour, the a* value corresponds to the difference of color's position on the red-green axis and the b* value is the difference of its position in the yellow-blue axis. The results are given in Table-5.

The color co-ordinates of samples dyed with hermal leaves are tabulated in the Table-5. The L* values in the technique of pre-mordanting showed that values are high at 5g/l mordant concentration as compared to the 10g/l mordant concentration. The similar trend is observed in meta- and post- mordanting technique where 5 g/l mordant concentra-tion showed maximum colour depth and decrease after increasing the concentration of mordants.

The variation of a* values of samples dyed with all the techniques of mordanting are positive indicating red colour along the red-green axis. The change in the b* values is positive in case of pre-mordanting showing yellow color along the yellow-blue axis whereas for meta -mordanting alum and ferrous showed positive b* values and copper showed negative values indicating colour towards

Table-5: The Colour Coordinates of Samples Dyed with Natural Dye of Hermal Leaves (*Peganum harmala* L) .

Samples	Mordant Concen-tration g/l	Colour Coordinates CIE Lab difference DL*	Da*	Db*
Pre-Mordanting				
Alum	5	15.91	-(4.09)	-(3.71)
Alum	10	9.08	-(6.05)	-(6.32)
Copper	5	9.54	-(9.21)	-(8.75)
Copper	10	8.01	-(6.50)	-(9.94)
Ferrous	5	8.78	-(4.45)	+11.00
Ferrous	10	8.46	-(2.70)	+13.55
Meta- Mordanting				
Alum	5	13.73	+14.62	+8.53
Alum	10	13.82	+12.41	+14.60
Copper	5	9.81	+6.77	-(5.17)
Copper	10	11.53	+6.31	-(4.07)
Ferrous	5	2.26	+2.99	+6.01
Ferrous	10	1.75	+1.03	+8.88
Post- Mordanting				
Alum	5	13.76	-(5.04)	+2.20
Alum	10	19.00	-(4.24)	+3.74
Copper	5	22.52	-(4.50)	-(4.15)
Copper	10	25.52	-(3.93)	-(3.10)
Ferrous	5	16.49	-(3.64)	+5.29
Ferrous	10	20.06	-(3.22)	+5.20

blue. The b* values in the post- mordanting technique were found to be positive with alum whereas negative values were found with copper and ferrous sulphate.

Colour Co-ordinates of Samples Dyed with Logwood

The results of color coordinates of samples dyed with logwood were indicated in the Table-6. The coordinate L* is high for the mordant concentration at 5 g/l as compared to 10 g/l showing that color depth is maximum up to 5 g/l and decreases after increasing the conc. of mordants. The variation in the a* value of samples dyed with pre-mordanting and post-mordanting technique showed negative values indicating colour on green side along the red- green axis as compared to the a* values of samples dyed with meta- mordanting in which values are positive showed red colour along the red-green axis except alum which showed negative values. The change in the b * values of the samples dyed with pre- mordanting technique and post -mordanting technique showed positive values indicating colour position towards yellow along the yellow-blue axis where as for meta mordanted samples the copper sulfate at 5 g/l and 10 g/l showed negative values indicating color position towards blue on yellow-blue axis. The values of b* have been found positive for alum and ferrous sulphate at 5 g/l and 10 g/l mordant concentrations.

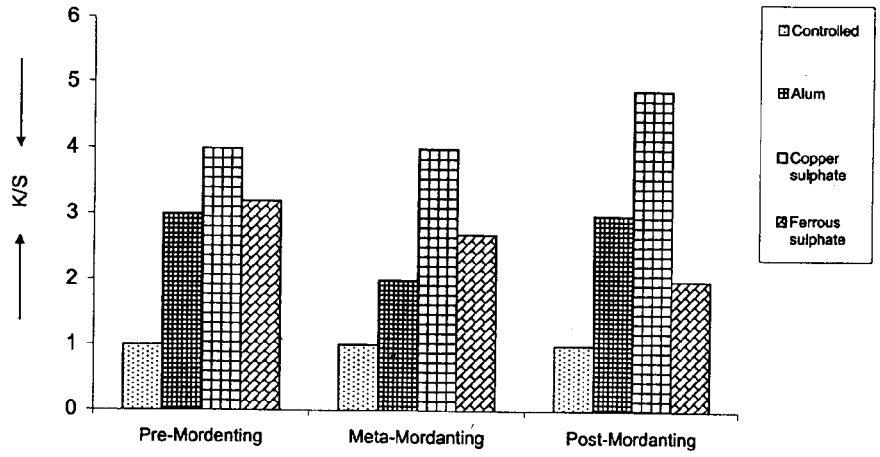

Fig. 3: Effect of mordents (5g/l) on the K/S value of silk dyed with Longwood (Haematoxylum campechianum)

Table-6: The Colour Coordinates of Samples Dyed with Natural Dye of Logwood (Haematoxylum campechianum).

Samples	Mordant Concen-tration g/l	Colour Coordinates CIE Lab difference DL*	Da*	Db*
Pre-Mordanting				
Alum	5	(18.26)	-(1.07)	+7.46
Alum	10	(22.05)	-(0.90)	+4.73
Copper	5	(8.81)	-(0.56)	+13.26
Copper	10	(10.45)	-(2.22)	+9.12
Ferrous	5	10.18	-(2.02)	+8.83
Ferrous	10	(15.87)	-(0.89)	+6.22
Meta Mordanting				
Alum	5	8.01	-(3.66)	+7.84
Alum	10	7.11	-(2.75)	+9.82
Copper	5	10.44	+15.58	-(15.98)
Copper	10	8.68	+20.60	-(15.74)
Ferrous	5	4.95	+3.40	+21.66
Ferrous	10	4.72	+7.33	+23.76
Post Mordanting				
Alum	5	(5.98)	-3.71	+2.63
Alum	10	(7.62)	-3.59	+5.72
Copper	5	(18.64)	-(1.57)	+(3.43)
Copper	10	(24.09)	-(2.08)	+(1.34)
Ferrous	5	(18.77)	-3.65	+17.73
Ferrous	10	(21.65)	-3.08	+20.61

Experimental

Materials

A commercial sample of Hermal leaves and Logwood was purchased from Akbari Mandi Lahore. The aqueous solubility of the dye was estimated using Odvark's method [8]. The silk fabric used in this study was scoured and suitably prepared before dyeing [9] Silk cut into rectangular pieces of 10 cm x 12 cm, weighing 2.0 and 2.5 g respectively were used in dyeing. Aqueous solutions containing 5 and 10g /l of ferrous sulphate hepta hydrate, aluminium potassium sulphate dodecahydrate (alum) and copper sulphate pentahydrate were used as mordants.

Extraction of Dye from Plant Source

Dried samples of Hermal leaves (*Peganum harmala* L) and Logwood (Haematoxylum campechianum) were crushed (10g/l) and soaked for 16hr followed by boiling for 2hrs. The extract was filtered and used for dyeing silk using the same liquor ratio as for mordanting.

Dyeing of Silk with Hermal Leaves without Mordant

To achieve a 1% owf shade on unmordanted silk, fabric was entered into the dyebath at 60°C; this temperature was held for 10 min and then raised to 85°C over 35 min at liquor ratio 30:1. After dyeing the cloth was removed and rinsed, soaped at the boil for 15 min, washed thoroughly and dried. Similar procedures were used for dyeing 2% and 4% of shades.

Dyeing with Mordants

The three different methods of dyeing employed were pre-mordanting, meta-mordanting and post mordanting. Mordant concentration of 5 and 10g/l were used.

In the pre-mordanting method, the fabrics were first immersed in an aqeous solution of alum,

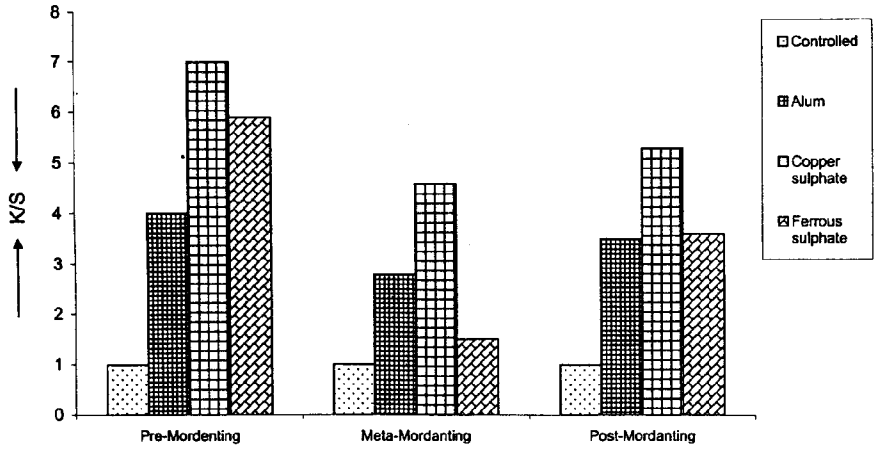

Fig. 4: Effect of mordents (10g/l) on the K/S value of silk dyed with Longwood (Haematoxylum campechianum)

copper sulphate or ferrous sulphate at 45 minutes at 30°C. All of the mordanted fabrics were then dyed by the above method.

For the meta-mordanting method (i.e. dyeing in the presence of mordants) the fabrics were immersed in a bath containing a mordant and the dye extract and the dyebath was maintained at pH 4. The temperature was raised to 90°C over 30 minutes and held for 1h. The fabrics were rinsed washed with at 60°C, washed with water, squeezed and dried.

In post-mordanting method, dyeing was carried out in the absence of a mordant, followed by mordanting in separate bath containing a mordant at 30°C for 45 minutes. Further processing was the same as described in the meta-mordanting method.

Fastness Determination

Fastness to light of different dyed samples was determined by exposing the dyed samples in sunlight according to ISO BO_2, wash fastness of all dyed samples was measured by the appropriate ISO CO_2 method, Rubbing fastness assessment was carried out according to ISO X 12 test method.

Light Fastness

Samples dyed with Hermal leaves and Logwood and then aftertreated were air dried. The sample wound on card were half covered with a hinged black card were exposed to daylight in a glass box along with the SDC blue wool light fastness standards 1 to 8 for 24hr. The samples were withdrawn at regular intervals and the extent of fading examined visually. The exposed and unexposed portions were assessed visually and the extent of colour change in both samples and the blue wool standards was assessed against the grey scale standards (BS 1006). The results of light fastness are given in Tables –1 and 2 respectively.

Washing Fastness

In this test soap solution was prepared containing 5g/l and 2g/l sodium carbonate in distilled water. Each of the specimen (4cm x 5cm) was cut and placed between two adjacent white cotton fabric of the same dimensions and then stitched together. The composite was then placed in the container and necessary amount of soap solution previously heated to 60°C was added to give a liquor ratio of 50:1. Washing was carried out in which supports, radially, stainless steel container (75 ± 5mm x 125 ± 10mm high) of capacity 500 ± 50ml, the bottom of the container being 45 ± 10mm from the centre of the shaft. The schaft/container assembly is rotated at a frequency of 40 ± 2 min^{-1}. The temperature of the water bath is thermostatically controlled to maintain the test solution at the prescribed temperature ± 2°C. The washing was continued at this temperature for 30 minutes. The composite were then removed, rinsed, opened, dried and finally assessed with the aid of grey scales. The change in colour of the specimen and the staining of the adjacent fabrics was assessed

with the grey scale. The results obtained are summarized in Tables-1 and 2.

Rubbing Fastness

This method is intended for determining the resistance of the colour of textiles of all kinds to rubbing off and staining other materials. For testing two pieces of fabric not less than 5cm x 14cm are required for wet rubbing. The test specimens are fastened by means of clamps to the base board of the testing device. With a rubbing cloth that has been wetted with water, rubbed it to and fro in a straight line along a track 10 cm long on the dry specimen, 10 times to and fro in 10 seconds, with a downward force on the finger. After rubbing, dried the cloth at room temperature and assessed the change in shade of the dyed specimen and the staining of the rubbing cloth with grey scale. The results of fastness to rubbing are presented in Table-1 and 2.

Colour Measurement

Dyed samples were prepared for colour measurement, which was carried out by following a standard procedure. Colour values were evaluated by means of K/S and CIELAB colour –difference values by spectrophotometer with Data Master V 2.3 software (Data colour, international, USA). Four measurements were made on each of the four samples and the variation in percentage reflectance values over a range of 400-700 nm was recorded. The reproducibility of the results was also checked and was found to be satisfactory in all the cases. The dyeing performance in the various processes was measured in terms of K/S value at their λ_{max}.

Colour coordinates

The reflectance and K/S values were recorded for all the dyed samples by using a colorimeter and the comparison of the results is presented in Figures-1 to 4 for dyeings with Hermal leaves and Logwood respectively. Changes in colour brought about by sunlight exposure were also measured on the basis of CIELAB colour space in terms of L* a* b* (Cartesian coordinates) and Munsell renotation, where

L* =lightness of sample

a* = redness/greenness of sample

b* = yellowness /blueness of sample

The difference in values obtained for original and faded samples were measured as ΔE and the results are given in Table-5 and 6.

Dyeing of Silk with Logwood

The controlled and mordanted samples of silk dyed with logwood extract were prepared and their fastness properties and colour measurements were determined.The results of these studies are indicated in Table-2, 4 and 6.

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