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ORIGINAL ARTICLE

Dyeing studies with henna and madder: A research on effect of tin (II) chloride mordant

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Abstract The present paper deals with the application of natural dyes extracted from powdered henna (*Lawsonia inermis*) leaves and madder (*Rubia cordifolia*) roots on woolen yarn and assessment of effect of stannous chloride mordant on dyeability, color characteristics, fastness properties and antifungal activity of dyed woolen yarn. Sixteen shades have been developed for the characterization of their color characteristics and fastness properties. The color strength (K/S value) has been found to be very good in all dyed woolen yarn samples. The color fastness with respect to light exposure, washing and rubbing was quite satisfactory for both henna as well as madder dyed samples. Henna leaves extract was found very effective against *Candida glabrata* both in solution as well as after application on wool substrate but no antifungal activity is reported in case of madder both in solution as well as on wool substrate.

1. Introduction

Natural dyes are comprised of those colorants (dyes and pigments) that are obtained from animal (insect) or vegetable source without chemical processing. They are mainly mordant dyes, although some vat, solvent, pigment, direct and acid types are also known. People have used natural dyes since ancient times for dyeing carpets, rugs and clothings by using roots, stems, barks, leaves, berries and flowers of various dye plants (Gulrajani, 1992). Uses of synthetic dyes are involved with the release of some hazardous chemicals into the environment during their processing and production (Dutta, 1996). In the present context of eco-preservation, the use of natural dyes has been revived in the coloration of textiles and food materials (MacDougall, 2002). Considerable research work has been undertaken on the application of natural dyes in the coloration of textiles around the globe in the recent past

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(Ali and El-Mohamedy, 2010; Kamel et al., 2005; Khan et al., 2010b, Moiz et al., 2010; Vankar et al., 2007).

Textiles composed of proteinous materials such as wool and silk as well as cellulosic materials such as cotton, jute, flax and other fibers come in contact with the body, which provide an ideal environment for the growth and multiplication of pathogenic microbes leading to objectionable odor, dermal infection, product deterioration, allergies, and other related diseases (Khan et al., 2011). These factors necessitate the development of methods to impart microbial resistance to textiles with all usual desirable characteristics of textiles, as these textile materials find extensive use in different sectors related to a hygienic and healthy life style apart from the conventional apparel usage (Sathianarayanan et al., 2010; Velmurugan et al., 2009). Dyeing of textile materials with natural colorants is a promising area which needs to be explored systematically and scientifically for producing diversified value-added products.

Natural vegetable fibers such as cotton fiber are probably used for the first time for spinning and weaving into cloth; animal fibers in the form of furs, and skins were undoubtedly the earliest forms of clothings used by primitive people. Wool has specific physical and chemical properties such as high water absorption, high elasticity and flexibility, bulkiness, comfort, easy dry-cleaning and good dyeability. It is undoubtedly the first natural protein fiber of dyers' choice for dyeing. These properties enabled the use of wool fibers in various textile products (Cook, 1984; Knecht et al., 1941).

Lawsonia inermis, commonly known as Mehdi/Mehandi is a shrub or small tree frequently cultivated in India, Pakistan, Egypt, Yemen, Iran and Afghanistan. Henna is an ancient dye, evidence being the Egyptian mummies found in the tombs that had their nails dyed with henna. It is also used in many countries for dyeing hair, eyebrows and fingernails during religious festivals and marriages etc. the powdered leaves of this plant (aqueous paste) are used as a cosmetic for staining hands, palms, hairs and other body parts. The dyeing property of henna is attributed to the presence of a colorant, lawsone; 2-hydroxy-1, 4-naphthoquinone component shown in Fig. 1 with Color Index Number 75480; Natural Orange 6 (Color Index, 1971a; John and Cannon, 1994a; Mayer and Cook, 1943a). Antibacterial properties of henna dyed wool fabrics against *E. coli* and *S. aureus* are also reported (Dev et al., 2009).

Rubia cordifolia belongs to the family *Rubiaceae,* also known as majith or manjista, is a perennial herbaceous climbing plant with very long roots; cylindrical, flexuous, with a thin red bark. Stems often have a long, rough, grooved, woody base. Plants belonging to this family are known to contain substantial amounts of anthraquinones, especially in the roots.

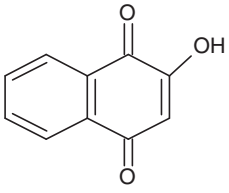

Figure 1 Coloring component of henna (*L. inermis*) leaves – Lawsone.

The coloring pigments present in the root of *R. cordifolia* are pupurin (I), munjistin (II) in major amount, and xanthopurpurin (III), pseudopurpurin (IV) in little amounts shown in Fig. 2 (Anonymous, 1972; Color Index, 1971b; John and Cannon, 1994b; Mayer and Cook, 1943b; Perkin and Everest, 1918).

The present study is focused on the effect of tin mordant on color, fastness and antifungal properties of woolen yarn dyed with henna leaves and madder roots extracts. This will help to make natural dye as an alternative co-partner of synthetic dyes in an era of environmental awareness and eco-preservation.

2. Experimental

An experimental study was planned keeping in view the objective of the study.

2.1. Materials

2.1.1. Woolen yarn, mordant and natural dyes

Woolen yarn was purchased from MAMB Woollens Ltd., Bhadohi, S R Nagar Bhadohi (UP), India. A commercial sample of powdered henna leaves was obtained from New Kirana Store, Khari Baoli, Delhi-110006, India. Powdered madder roots were obtained from SAM Vegetables, Moradabad-244001 (UP), India. All other chemicals including the mordant (stannous chloride) used were of Laboratory grade.

2.2. Methods

2.2.1. Extraction of dye from powdered henna leaves

In the view of reported (Ali et al., 2009) better color yield in case of alkaline extraction of colorant from henna leaves than aqueous extraction, colorants from henna leaves were extracted in alkaline medium. Required quantities (1%, 5%, 10% and 20% on weight of fiber) of powdered henna leaves were taken in an aqueous solution of Na_2CO_3 main-

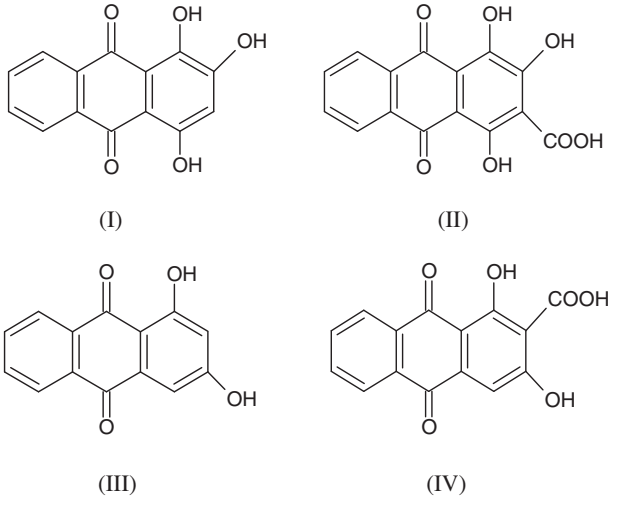

Figure 2 Coloring components of madder (*R. cordifolia*) root-Purpurin (II) Munjistin (III) Xanthopurpurin (IV) Pseudopurpurin.

taining pH at 8.5–9 using M:L (material to liquor) ratio 1:20 and heated at 80–85 °C for one hour with occasional stirring, then cooled and filtered through a clean cotton cloth. The solution is reddish orange in color. The remaining residue was percolated with Na_2CO_3 until all of the color has been extracted and then filtered again. The filtrate was made neutral (pH 7) using HCl and used for dyeing woolen yarn samples.

2.3.1. Extraction of dye from powdered madder roots

Required quantities (10%, 20%, 50% and 100% o.w.f.) of powdered madder roots were taken in an acidic aqueous solution of 2–3 pH using M:L ratio 1:20 and kept for 12 h, boiled for one hour with occasional stirring, then cooled and filtered through a clean cotton cloth. The extracted madder dye is reddish yellow in color. The remaining residue was percolated with acid (HCl) until all of the color had been extracted and then filtered again. The filtrate obtained is extracted liquid dye. The pH of the filtrate was adjusted to 4 and used for dyeing woolen yarn samples.

2.3.2. Mordanting of wool

Woolen yarn samples were soaked in water. 1% tin chloride as mordant was dissolved in water keeping M:L ratio 1:40. In order to make the mordant solution clear, few drops of HCl were added. Water soaked woolen yarn samples were immersed in the warm mordant solution. Temperature of the mordanting bath was raised till simmering point (91–93 °C) and this process was continued for 1 h with constant stirring. After that, mordanted woolen yarn samples were removed, cooled and washed with tap water in order to remove superfluous mordant particles.

2.3.3. Dyeing of wool

Dyeing was carried out by conventional method in the absence and presence of mordant.

2.3.3.1. Control dyeing (in the absence of mordant). Before dyeing, the woolen yarn samples were soaked in water for 30 min. Water soaked woolen yarn samples without any mordant were drenched in extracted dye solution keeping M:L ratio 1:40 maintained at pH 7 for dyeing with henna, and at pH 4 for madder in separate baths. Temperatures of the dye baths were raised till simmering point (91–93 °C) and left at that temperature for 1 h with regular stirring. The dyed woolen yarn samples were washed with 5 g/L non-ionic detergent (Safewash, Wipro) and thereafter, rinsed with tap water. The dyed woolen yarn samples with henna and madder were dried in shade at room temperature.

2.3.3.2. Dyeing of mordanted wool. Mordanted woolen yarn samples were drenched in the dye bath containing extracted dye maintained at pH 7 for dyeing with henna and at pH 4 for madder respectively. The M:L ratio was kept at 1:40 and the temperatures of the dye baths were raised till simmering point (91–93 °C) and left at that temperature for 1 h. In order to get uniform dyeing the samples were stirred regularly. The dyed woolen yarn samples were washed with 5 g/L non-ionic detergent (Safewash, Wipro) and thereafter, washed with tap water. The samples were dried in shade at room temperature.

2.3.4. Color measurement

Color characteristics were obtained as L^*, a^*, b^*, c^*, h^o and K/S values of the dyed samples on the 45/0 LAV Mini Scan XE Plus reflectance spectrophotometer integrated with an IBM computer. For this purpose measurement of reflectance was performed at the wavelength of maximum absorption (λ_{max} 450 nm) under D65 illuminant (10^o observer). K/S values for the corresponding wavelength of maximum absorption were obtained by using Kubelka Munk equation.

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

where K is the absorption coefficient and S is the scattering coefficient. Chroma (c^*) and hue angles (h^o) were calculated using the following equations:

$$\text{Chroma}(C*) = \sqrt{a^2 + b^2} \quad (2)$$

$$\text{Hue angle } (h^0) = tan^{-1}\tfrac{b}{a} \quad (3)$$

2.3.5. Color fastness tests

The dyed woolen yarn samples were assessed for color fastness with respect to light exposure, washing and rubbing (dry and wet).

2.3.5.1. Light fastness. The light fastness of the dyed woolen yarn samples were conducted on digi light Nx^{TM} having water cooled Mercury Blended Tungsten lamp, according to the test method AATCC 16e-2004 similar to ISO 105-B02:1994 (Amd.2:2000).

2.3.5.2. Wash fastness. The wash fastness of the dyed woolen yarn samples were measured in Launder-o-meter as per the ISO 105-C06:1994 (2010) specifications. A layer of parallel lengths of dyed yarn were sewed between the two pieces of adjacent fabrics (wool and cotton). The specimen was treated with 5 g/L non-ionic detergent at 50 °C for 45 min in Launder-o-meter. The samples were assessed for color change on washing and staining on adjacent fabrics.

2.3.5.3. Rub fastness. Dry and wet rub fastness of the dyed woolen yarn samples were tested using a Crock-meter as per Indian standard IS 766:1988 (Reaffirmed 2004) based on ISO 105-X12:2001 by mounting the fabric on panel and giving ten strokes for both dry and wet rub fastness tests. The samples were assessed for staining on white adjacent fabrics (wool and cotton).

2.3.6. Assessment of antifungal activity

The antifungal activity was evaluated as described in our earlier work (Khan et al., 2010a; Khan et al., 2011) with slight modifications. Stock culture of *Candida glabrata* was maintained on agar slants (stored at 4 °C) and was grown and sub-cultured in YPD (Yeast Extract Peptone Dextrose) medium at 37 °C in orbital shaker at 200 × rpm (REMI CIS 24 BL).

2.3.6.1. Growth studies of C. glabrata. The test microorganism was sub-cultured at least twice and grown for 24 h at 35 °C on SDA plates. For growth studies, 10^6 cells (optical density A_{600} = 0.1) of test strains were grown aerobically in 50 ml

Table 1 Color values and color strength of un-mordanted henna dyed woolen yarn.

% Dye (henna)	L^*	a^*	b^*	c^*	h^o	K/S
1	79.45	1.57	15.3	15.38	84.14	0.41
5	74.75	4.06	18.87	19.3	77.85	0.88
10	73.35	5.5	19.58	20.33	74.31	1.84
20	66.65	7.75	22.55	23.84	71.03	2.74

Table 2 Color values and color strength of 1% tin mordanted henna dyed woolen yarn.

% Dye (henna)	L^*	a^*	b^*	c^*	h^o	K/S
1	79.95	1.93	16.95	17.05	83.5	0.43
5	73.76	7.24	26.69	27.65	74.82	1.01
10	71.66	5.56	30.65	31.15	79.71	1.85
20	67.53	8.52	30.54	31.7	74.41	2.81

media on automated shaker set at 35 °C with agitation of 200 × rpm. Aqueous solutions of henna leaves extract and madder roots extract with final concentrations of 20% w/v along with negative control (distilled water) and positive control (1% w/v of fluconazole) were also added to the cultures. At pre-determined time points (after every 2 h) for 24 h, aliquots were removed and growth was followed turbido-metrically at 595 nm using LABOMED Spectrophotometer (USA). Optical density was recorded for each concentration against time.

2.3.6.2. Determination of antifungal activity of dyed woolen yarn. To determine antifungal activity of dyed woolen yarn specimens, 1 inch^2 yarn was introduced in the 10 ml nutrient broth inoculated with *C. glabrata* and incubated overnight at 37 °C. The reduction of fungal growth by the dyed woolen yarn was expressed as follows:

$$R = B - A/A \times 100 \quad (4)$$

where R = % reduction in fungal population; B = absorbance (595 nm) of the media inoculated with microbe and un-dyed yarn; A = absorbance (595 nm) of the media inoculated with microbe and dyed woolen yarn.

Enhancement in microbial growth is directly proportional to turbidity and optical density which are directly related to the number of fungal cells in media.

3. Result and discussion

3.1. Color measurement

Color characteristics of all the dyed woolen yarn samples were assessed in terms of CIE L^*, a^*, b^*, c^*, h^0 and color strength (K/S values).

3.1.1. Shades obtained with henna leaves extract

Color values and color strength of henna dyed woolen yarns are given in Table 1 (un-mordanted) and Table 2 (1% tin mordanted). Observation of color values and color strength showed that mordanting with tin has little effect on shades of woolen yarn obtained with henna leaves extract.

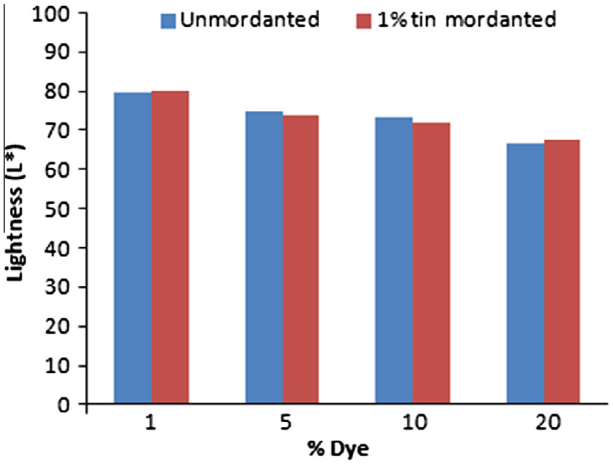

Figure 3 Effect of tin mordant on lightness (L^*) of henna dyed woolen yarn.

3.1.1.1. Lightness (L^*). Lightness values graph of henna dyed woolen yarns shown in Fig. 3 reveals that darker shades were obtained with high dye concentration and lightness of shades decreases with increase in dye concentration. Mordanting has almost negligible effect on the lightness of shades.

3.1.1.2. a^*–b^* values. It has been observed from comparative evaluation of data presented in Table 1 and Table 2 that mordanting with tin has increased both a^* and b^* values in all henna dyed woolen yarn samples. Increase in b^* value (yellowness) of samples is more prominent than increase in a^* value (redness). a^*–b^* plot of henna dyed woolen yarn samples shown in Fig. 4 indicate that all the samples dyed with henna leaves extract were found to be in the red yellow zone.

3.1.1.3. Color strength (K/S). Higher color strengths were observed in the case of shades obtained with higher dye concentration. It has been observed from the K/S value graph shown in Fig. 5 that there is marginal increase in color strength in the case of tin mordanted woolen yarn samples.

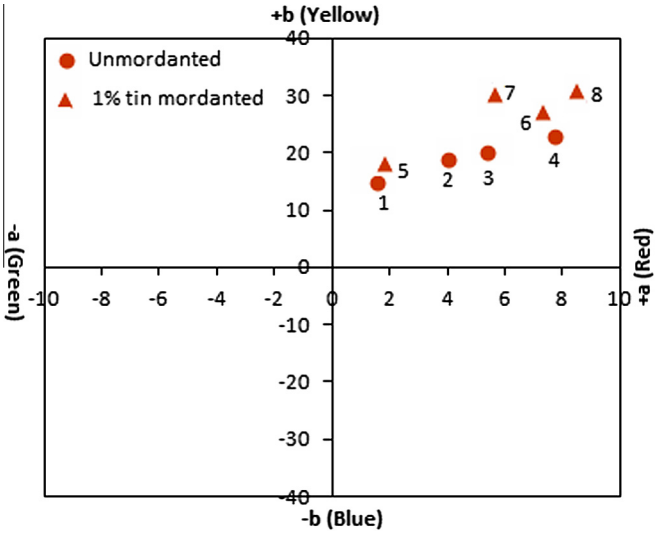

Figure 4 a^*-b^* plot of henna dyed woolen yarn samples: (1) 1% Henna, (2) 5% henna, (3) 10% henna, (4) 20% henna, (5) 1% tin +1% Henna, (6) 1% tin +5% henna, (7) 1% tin +10% henna, (8) 1% tin +20% henna.

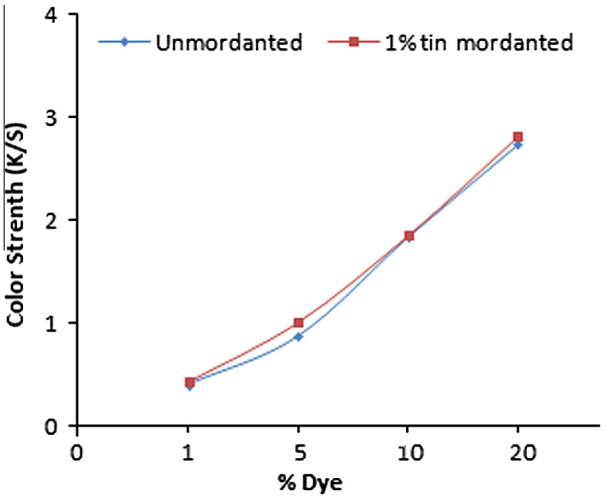

Figure 5 Effect of tin mordant on color strength (K/S) of henna dyed woolen yarn.

3.1.2. Shades obtained with madder roots extract

The coloring component is present only in thin red barks of madder roots, and is not more than 10% of the whole root. Hence higher quantities of madder roots powder is required for dyeing to obtain darker shades. Color values and color strengths of madder dyed woolen yarns are given in Table 3 (un-mordanted) and Table 4 (1% tin mordanted).

As madder dye is obtained from outer layers of roots, hence higher quantity of madder roots powder is required for satisfactory results.

3.1.2.1. Lightness (L^*). Lightness values graph of madder roots dyed woolen yarns shown in Fig. 6 reveals that darker shades were obtained with high dye concentration and lightness of shades decreases with increase in dye concentration. Mordanting has significant effect on the lightness of shades.

3.1.2.2. a^*-b^* values. The a^*-b^* plot of madder dyed woolen yarn samples presented in Fig. 7 indicates that all the samples dyed with madder roots extract were found in the red–yellow zone. Furthermore on the comparison of a^*-b^* values of

Table 3 Color values and color strength of un-mordanted madder dyed woolen yarn.

% Dye (madder)	L^*	a^*	b^*	c^*	h°	K/S
10	55.67	32.56	33.97	47.05	46.21	5.03
20	47.68	34.64	30.94	46.44	41.77	7.38
50	40.84	35.05	36.21	50.39	45.93	21.9
100	30.11	39.34	33.2	51 .47	40.16	37.16

Table 4 Color values and color strength of 1% tin mordanted madder dyed woolen yarn.

% Dye (madder)	L^*	a^*	b^*	c^*	h°	K/S
10	50.05	48.82	42.54	64.75	41.3	9.66
20	48.21	49.08	44.15	66.01	41.97	13.34
50	40.5	42.33	43.41	60.63	45.72	35.24
100	35.98	41.43	39.84	57.47	43.87	45.74

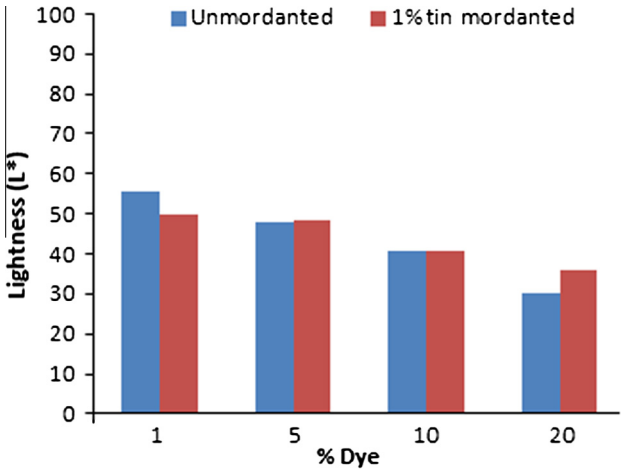

Figure 6 Effect of tin mordant on lightness (L^*) of madder dyed woolen yarn.

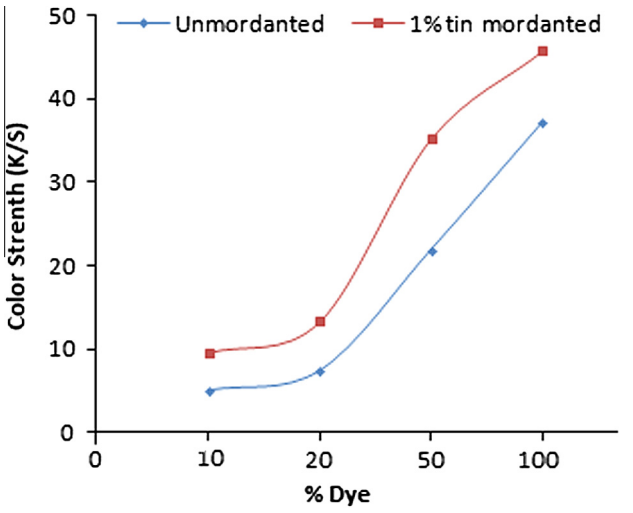

Figure 8 Effect of tin mordant on color strength (K/S) of madder dyed woolen yarn.

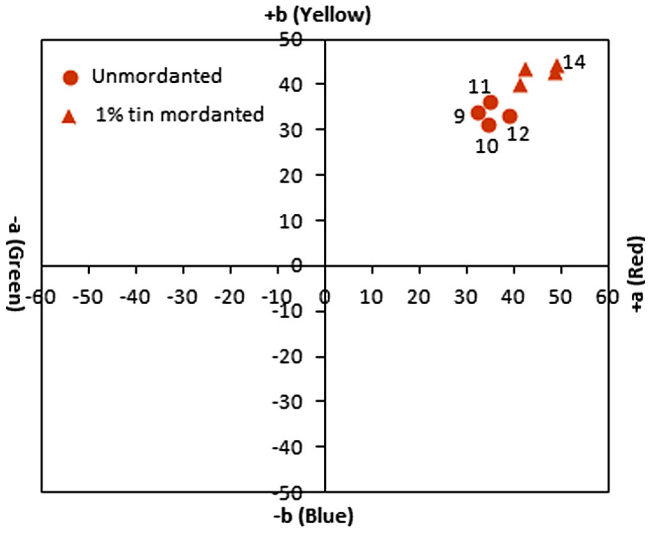

Figure 7 a^*-b^* plot of madder dyed woolen yarn samples: (9) 10% madder, (10) 20% madder, (11) 50% madder, (12) 100% madder, (13) 1% tin + 10% madder, (14) 1% tin + 20% madder, (15) 1% tin + 50% madder, (16) 1% tin + 100% madder.

un-mordanted and mordanted samples it is observed from the data that mordanting with tin chloride was found to be helpful in increasing both redness (higher a^* values) as well as yellowness (higher b^* values) of the samples.

3.1.2.3. Color strength (K/S). It is clear from the K/S values graph (Fig. 8) of madder dyed woollen yarn samples that color strengths of the mordanted woollen yarn samples are significantly higher than their corresponding un-mordanted samples in all concentrations of madder roots dye. The increase in the K/S values of dyed woolen yarn samples in the presence of mordant may be due to the increase in fixation of the color by the mordant. Dyeing with madder yielded dark shades, and generally darker shades show little difference in numerical values of lightness, however considerable increase in color strength (K/S) values after mordanting with tin (II) chloride indicates higher dye uptake in the case of mordanted samples.

3.2. Color fastness properties

The overall fastness properties, i.e. color fastness to light, washing and rubbing of all the samples were obtained and are presented in Tables 5–8. Fastness data of henna dyed samples are given in Table 5 (un-mordanted) and in Table 6 (1% tin mordanted) whereas madder dyed samples are presented in Table 7 (un-mordanted) and in Table 8 (1% tin mordanted).

3.2.1. Light fastness

From Tables 5–8 it is observed that all woolen yarn samples dyed with both henna and madder have shown good light fastness ratings of 5 on gray scale. Mordanting has no effect on light fastness properties.

3.2.2. Wash fastness

It is observed from wash fastness data in Table 5 and in Table 6 that, all the henna dyed samples (un-mordanted as well as mordanted) showed good to very good wash fastness rating of 4–5 and no staining on adjacent white fabrics (wool and cotton) was observed. Observation of fastness data of madder dyed samples shown in Table 7 (un-mordanted) and Table 8 (1% tin mordanted) show that wash fastness of un-mordanted and mordanted samples are nearly same.

3.2.3. Rub fastness

Woolen yarn samples dyed with both henna as well as madder using 1% tin as mordant have shown better rub fastness in comparison to corresponding un-mordanted samples. Dry rub fastness of un-mordanted henna dyed samples were found to have fairly good to good rating of 3–4 on the gray scale whereas mordanted henna dyed samples showed good to very good dry rub fastness rating of 4–5. Wet rub fastness values of all henna dyed samples were found to have fairly good to good rating of 3–4. Dry rub fastness of un-mordanted madder dyed samples ranges from fairly good to very good (ratings 3–5) whereas mordanted samples were found to have good to very

Table 5 Fastness properties of un-mordanted woolen yarn dyed with henna.

% Dye (henna)	Light fastness	Wash fastness			Rub fastness	
		c.c.	c.s.	c.w.	Dry	Wet
1	5	5	5	5	3–4	3
5	5	4–5	5	5	3–4	2–3
10	5	5	5	5	3	2–3
20	5	4	5	5	3	2–3

Table 6 Fastness properties of 1% tin mordanted woolen yarn dyed with henna.

% Dye (henna)	Light fastness	Wash fastness			Rub fastness	
		c.c.	c.s.	c.w.	Dry	Wet
1	5	4–5	5	5	4–5	4
5	5	4–5	5	5	4–5	3–4
10	5	4–5	5	5	4–5	3–4
20	5	4–5	5	5	4–5	3–4

Table 7 Fastness properties of un-mordanted woolen yarn dyed with madder.

% Dye (madder)	Light fastness	Wash fastness			Rub fastness	
		c.c.	c.s.	c.w.	Dry	Wet
10	5	3–4	4–5	4	4–5	4
20	5	3	4–5	3	4–5	3–4
50	5	3–4	4–5	3	3–4	3
100	5	4	4–5	4	3–4	3

Table 8 Fastness properties of 1% tin mordanted woolen yarn dyed with madder.

% Dye (madder)	Light fastness	Wash fastness			Rub fastness	
		c.c.	c.s.	c.w.	Dry	Wet
10	5	3–4	5	3–4	4–5	4
20	5	3–4	4–5	3–4	4–5	3–4
50	5	3–4	4–5	4–5	4–5	3–4
100	5	4–5	4–5	4	4–5	4

good rating of 4–5. Wet rub fastness of madder dyed samples had fairly good to good (ratings 3–4). Overall rub fastness of madder dyed samples was found to be better in comparison with henna dyed samples.

It is observed from the data that, the fastness properties of both henna as well as madder dyed samples are quite satisfactory for practical textile dyeing purposes. The results indicate that mordanting has provided more dye sites and bears high color depth of shades as compared to those without mordanting. These can be explained on the basis that natural dyes contain ionizable groups (auxochromes) such as –OH, –COOH. In aqueous solution at appropriate pH value, ionizable groups became soluble due to their conversion in anionic forms. Metal ions with vacant orbitals of the suitable energy have the ability to create complexes between fiber, mordant and dye molecule known as chelate that shifts the natural dye colors and, are most effective with natural protein fibers i.e. wool and silk (Mihalick and Donelly, 2006).

3.3. Antifungal activity

3.3.1. Growth studies

By the use of growth curve studies, the effect of henna leaves and madder roots extracts on the growth of *C. glabrata* was assessed. The absorbance obtained for the growth control (only organism) showed that the test culture reached the stationary growth phase after 16–18 h showing a normal growth pattern. The curve depicts a lag phase in the initial phase of growth, active lag phase and stationary phase. Aqueous henna extract was found to be quite effective in inhibiting the growth of *C. glabrata*. However, madder root extract has shown very little effect on fungal growth which can be observed from Fig. 9.

3.3.2. Antifungal activity of *L. inermis* dyed woolen yarn

Antifungal activity test based on growth studies have been performed both on henna as well as madder extracts, since only henna leaves extract has shown very good antifungal activity

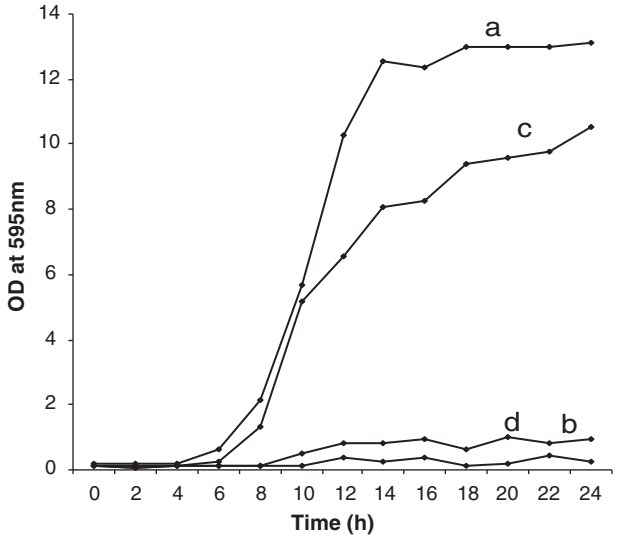

Figure 9 Effect of natural dyes on the growth of *C. glabrata:* The cells were grown with (a) 0% dye (Control −ve), (b) 20% henna, (c) 20% madder and (d) 1% w/v of fluconazole (Control +ive).

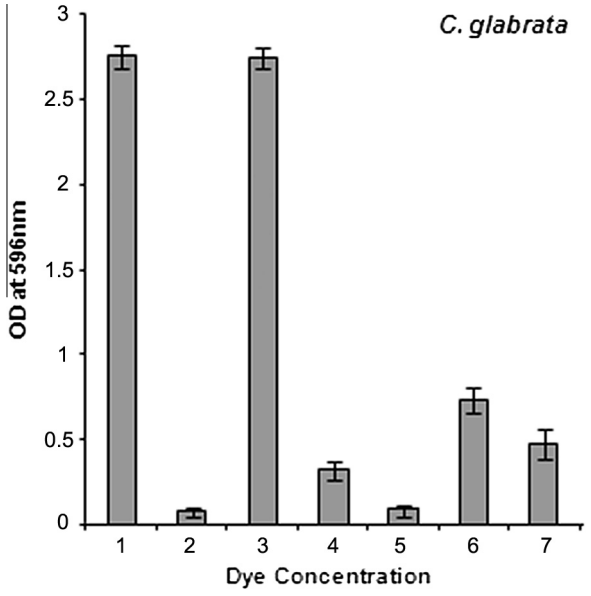

Figure 10 Antifungal activity of the woolen yarn treated with henna dye. Bar 1 represents the control cells without any treatment; 2 represents the treatment of cells with fluconazole; 3 is untreated wool; 4 and 5 represent 10% Henna and 20% henna respectively; 6 and 7 represent 1% tin + 10% henna and 1% tin +20% henna, respectively.

in solution against *C. glabrata*, antifungal activity of henna dyed woolen yarn samples along with untreated wool and commercial antifungal agent (fluconazole) against *C. glabrata* was assessed quantitatively and shown in Fig. 10. The results demonstrate that untreated woolen yarn samples showed zero percentage fungal reduction whereas dyed substrate showed significant activity against *C. glabrata*. Fig. 10 illustrates the relation between dye concentration on wool and antifungal activity as well as the effect of mordants on bioactivity of henna dyed wool. Henna extract was found to be more effective in fungal growth inhibition when applied alone (85–96% fungal reduction). Effective inhibition of *C. glabrata* required high concentration of henna leaves extract. An inhibition rate of more than 95% was obtained when 20% henna extract was applied on un-mordanted wool. The reduction in antifungal activity of henna against *C. glabrata* was evident in the case of mordanting with tin (75–84% fungal reduction). Decline of antifungal activity in the case of tin chloride mordanted samples could be the consequence of complex formation between active functional groups of the dye with the tin chloride mordant.

4. Conclusion

Two natural dyes namely henna and madder were extracted, and applied onto woolen yarn and investigated for dyeing characteristics and antifungal activity. Henna leaves extract yielded beautiful orange–brown to light yellowish-green shades, whereas madder roots extract resulted in orange–red to scarlet shades. As anticipated, mordanting with tin chloride led to improvement in color strength as well as color fastness properties to a significant extent along with apparent change in hue and tone in color. The effect of mordant on color strength was higher in the case of henna than madder. Henna leaves extract was proved as significantly effective in inhibiting the growth of *C. glabrata*, both in solution as well as when applied on the woolen yarn. It is hoped that with systematic research natural colorants can be tailored to approach stringent functional parameters of synthetic dyes and can be a viable commercial alternative for the textile and apparel industries up to some extent.

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