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Dyeing of Carpet Woolen Yarn using Natural Dye from Cochineal

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Natural dyes from plant sources are preferred for coloration of woolen textiles and they give dark and dull colors. Development of a woolen carpet with elegant and vivid colors from natural dyes is still scanty. Natural dye from *Coccus Cacti* called cochineal was extracted by aqueous extraction method and applied on woolen yarn in presence of five different mordants in single and combination forms. Without mordanting, cochineal dye gave bluish purple color and after mordanting, it gave range of colors from scarlet red to black colors on woolen yarn. If two mordants are applied, the final color will depend on the chelating property of dominant mordant. The dominant mordant forms more amount of coordination complex preferentially with the cochineal dye than other mordants. Woolen yarn dyed with cochineal dye in presence of single and dual mordants, showed moderate (grade 3) to very good (grade 4–5) washing fastness and moderate (grade 5) to excellent (grade 7–8) light fastness properties. It is concluded that natural dye extracted from cochineal has potential to produce selective elegant colors on woolen yarn that can improve the aesthetic value of the woolen carpet.

Keywords: cochineal, natural dye, woolen yarn, mordant, fastness, carpet

用天然染料胭脂虫红染色地毯毛纱从植物来源的天然染料对羊毛织物的着色更为首选，可以得到从深到浅的颜色。用优雅和生动色彩的天然染料的颜色染色羊毛地毯的开发依然稀少。采用水萃取法从天然染料胭脂虫球菌提取，并在五个不同的媒染剂单独和组合形式的染毛线。无媒染，用胭脂染了蓝紫色的颜色和后媒染，得到从鲜红色到黑色的颜色范围的羊毛纱。如果用两媒染剂，最终颜色将取决于主导媒染剂的螯合性质。跟其他媒染剂相比，当占主导地位的媒介形式以更多量的化合物配位，胭脂红染料优先。单和双媒染剂下，胭脂虫红色素染色羊毛纱线，呈中度（3级），和非常好（4–5级），到耐洗色牢度和中度（5级），优秀（7级–8）耐光牢度。结论：从胭脂虫提取天然染料，选择淡雅的色彩，对改善羊毛地毯的美学价值很有潜力。

关键词：胭脂虫，天然染料，羊毛纱线，媒染剂，牢度，地毯

INTRODUCTION

Traditional approach and increasing admiration for nature in recent days have preferred the application of natural dyes on textile materials (Hill 1997). Natural dyes are generally applied in presence

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of a mordant, that forms coordinate complex inside the fiber matrix through nine different types of bonding like coordinate bonding and ionic bonding. Chemical bonding between a mordant and a natural dye molecule leads to formation of various colors inside the textile fiber. The final color of the dye–mordant complex depends on the type and chemical property of the mordant, pH of the bath and chemical constituents of the natural dye (Ammayappan 2009). The mode of bonding between the mordant and the natural dye molecule can be varied, since each mordant has distinct coordination number, empty d-orbitals, electron affinity, and type of chemical bonding with auxophoric groups of the dye molecule (Ammayappan et al. 2004; Jeon et al. 2003; Kenneth 1973; Lee 2007). Metallic salts of chromium, aluminum, iron, tin, copper, and organic compounds, such as tannin, citric acid, tartaric acid, and oxalic acid are also used as organic mordants.

Due to the presence of delocalized electrons and aromatic moiety, most of the natural dyes are very sensitive to change in pH and so form different colors. Being electron donor, the auxophoric groups of natural dye acts as ligand and plays a major role in the final color; for example, Fe^{3+}/Al^{3+} ion prefers to coordinate with lone pair of electron of Cl^{-} ion and Fe^{2+}/Cu^{2+} ion prefers to coordinate with >O (oxygen), $>NH_2$ (Amino), -O^{-} (hydroxyl), -NO_2 (nitro) atoms. However each mordant gives a unique color with natural dye, recently dyers prefer to apply mixtures of metallic mordants (Fe^{3+}, Al^{3+}) with organic mordants (tannic acid, citric acid) in order to produce wide range of colors with improved fastness properties. Literature information inferred that the addition of the organic mordant can improve the bonding between the natural dye molecule and the mordant, since it has additional functional groups such as –OH, -COOH for the formation of the dye–mordant complex (Ammayappan 2009; Ammayappan and Jeyakodi Moses 2007; Bhattacharya and Shah 2000; Hwang et al. 1995; Hwang et al. 2008).

For development of hand knotted woolen carpet, artisans prefer bright colors on the dark color background in order to improve the aesthetic appeal of carpet. For dark and dull colors, dyers prefer metal complex dyes and natural dyes like pomegranate, madder, kamala, lac, myrabolan, catechu, and Himalayan rubrub for dyeing of woolen yarn, while for bright colors they generally prefer synthetic dyes (Ammayappan et al. 2014a; Ammayappan et al. 2014b). However most of the natural dyes gave dark and dull colors, some selective natural dyes like cochineal can be used for development of bright colors. Dyeing of cochineal extract is mainly in practice in South America particularly in Mexico and Peru and they are used for dyeing of animal hair fiber products like yarn, shawl in scarlet, pink, and other red hues.

Cochineal dye is produced by drying and milling of adult female *Dactylopius coccus Costa*, parasitic insects that host on cactus pear pads. It is reported that to extract 1000 g of cochineal dye, nearly 140000 insects are required that may contain nearly 50% natural dye of their total weight. Cochineal dye consists of mainly carminic acid (hydroxyanthraquinone derivative), with small amount of kermesic and flavokermesic acids (Cardon 2007; Gonzalez et al. 2002; Mendez et al. 2004). It is mainly used in coloring food, cosmetics, oil paints, beverages, and pharmaceuticals in wide range of bright colors. It is also used as acid-base indicator, since it exhibits 14 different tautomeric forms with respect to different pH (Schul 2000; Stintzing and Carle 2005; Temani et al. 2011).

Cochineal dye was extracted using pressurized liquid extraction and supercritical fluid extraction techniques and such methods yielded more dye than conventional aqueous and solvent-based extraction (Borges et al. 2012). Ultrasound is an effective technique to extract natural dye from its source. Kamel et al. (2009) inferred that maximum extraction of cochineal dye with less average particle size obtained using ultrasound at 300 W. In addition to ultrasound extraction, more dye uptake is observed on cationized cotton fabric than conventional cotton fabric.

Arroyo-Figueroa et al. (2010) reported that cotton fabrics were dyed with cochineal extract at alkaline medium. Prior to dyeing, cotton fabric was pre-mordanted with 25% alum and 20% tannic acid mordant mixture in order to get good color yield. Since cochineal dye has anthraquinone chromopore, it has been used to impart different colors along with antibacterial property on wool, silk, nylon, cotton, and viscose rayon fabrics (Bae and Huh 2006a; Bae and Huh 2006b; Bae et al.

2006). Woolen yarn dyed with cochineal dye alone showed the limited antibacterial activity, but it is increased by copper and stannous-based mordanting. They also optimized the suitable condition for the good antibacterial activity and it is 2.0% (owm) cochineal dye extract at 90°C/ pH 3.0 / 30 min with 1% pre-mordanting (PMD) for 30 min at 60–70°C. However, the PMD method is preferred for Aluminum and Chromium salts, and the post-mordanting method is preferred for Copper, Tin, and Iron salts in order to improve the color yield as well as anti-bacterial property (Bae and Huh 2006a). Being aninonic in nature, if cochineal dye was applied on a cationized cotton, nylon and polyester fabric, the color value will be increased. Similarly cochineal extract was applied on chitosan applied cotton fabric followed by mordanting with Al, Sn, and Cu as mordants. It is inferred that chitosan pretreatment improved the perspiration fastness without improvement in light fastness (Lee et al. 2005a, 2005b).

Woolen felt mainly used for floor covering and for its ornamentation, so designers prefer to impart multi color design (Ammayappan et al. 2006). An attempt was made to dye woolen felt by cochineal extract in presence of different mordants. It is inferred that stannous-based mordanting gave bright woolen felt with higher lightness (L^*) value than other mordants, while Cu-based mordanting gave bluish and purplish tone on woolen felt (Lee and Kim 2005).

Pashmina, a finest animal hair fiber was dyed with cochineal extract at moderate dyeing condition in order to impart scarlet red color. Being temperature sensitive fiber, PMD was done with mixture of potassium sodium tartarate (7%) and Alum (8%) at 60°C for 1 h followed by dyeing with 10% cochineal extract at 50–60°C for 150 min. This dyeing condition gave better results with 80–95% dye exhaustion, 0.526–0.816 K/S value, very good washing (4–5), and light fastness (6–7) properties than high temperature dyeing condition at 90°C (Temani et al. 2011).

Indian wools have desirable properties of a carpet yarn, i.e. they have 30–35 μm mean fiber fineness and 30–40% medullation and are mainly used for production of hand knotted carpets. The aesthetic value of the carpet could be improved by using intricate design with alternative bright and dark colors (Ammayappan et al. 2012; Ammayappan et al. 2011; Shakyawar et al. 2011). Since majority of the synthetic acid dyes are carcinogenic in nature, now processors prefer eco-friendly dyes particularly like natural dyes for coloration of woolen yarn.

Literature information on development of woolen carpets from Indian wool using distinct bright colors like crimson red, scarlet colors from the natural dye is still scanty. It is well known that cochineal dye can also be used to develop wide range of bright colors along with dark colors on woolen yarn. Mordanting using mixture of mordants is also focused today in order to increase the color value and fastness properties of the natural dye on fiber. Literature information on application of mixed mordants along with cochineal extract on woolen yarn is still scanty.

A study was conducted to develop elegant colors from cochineal extract on carpet woolen yarn using five different mordants in single and combination form through PMD as well as simultaneous-mordanting methods (SMDs).

EXPERIMENTAL

Material

4 Nm woolen yarns prepared from wool processing plant, Central Sheep and Wool Research Institute, Avikanagar, India, was used. It was mild scoured with the solution containing 0.5 g/L non-ionic detergent and 0.25 g/L sodium carbonate at 50°C for 15 min, neutralized with acetic acid solution, washed with water and dried at ambient condition. This mild scoured woolen yarn was used for this study. Dried adult female insects of *Dactylopius Coccus Costa* were supplied by M/s Wild Colours, England, and were used as cochineal dye source. Aluminum sulphate (AS), stannous chloride (SC), ferrous sulphate (FS), citric acid (CA), and potassium hydrogen tartarate (Cream of tartar; CT) were used as mordants; all other chemicals used elsewhere were AR grade.

Extraction of Cochineal Dye

And 10 g of dried cochineal insect was taken, crushed into powdered form, soaked in 100 mL distilled water at 40°C for 30 min and kept for 12 h at ambient condition. After soaking, it was boiled at 95°C for 60 min, cooled gradually and filtered through Whatman filter paper. The filtrate was made into 100 mL with distilled water and used as 10% stock solution for dyeing.

Dyeing Process

Three metallic mordants, such as aluminum sulphate, stannous chloride, ferrous sulphate and two organic mordants citric acid and potassium hydrogen tartarate were used for the development of different colors on woolen yarn using cochineal extract. For two mordants combination, simple factorial design was used, i.e. ${}^5C_2$ $(5\times4/1\times2)$, i.e., ten mordant(s) combinations were selected. For single mordanting, 3% (over weight of the material-owm) mordant was used and for combination mordanting, each mordant in 3% (owm) was taken in order to assess their compatibility. Dyeing of woolen yarn with cochineal extract was carried in pre-mordanting method (PMD) as well as simultaneous mordanting method (SMD) as per standard procedure (Chu and Soh 1998; Trotman 1984).

Pre-Mordanting Method

Woolen yarn was entered in the bath containing required amount of mordant(s), kept at 40°C for 10 min and temperature was raised to 70°C at the rate of 2°C per min. The yarn was mordanted at 70°C for 60 min in 1:30 material:liquor ratio (MLR). After mordanting, the yarn was taken out from the bath, squeezed gently and used for dyeing.

The mordanted sample was entered in the bath containing 5% (owm) dye solution; kept at 40°C for 10 min and the bath temperature was raised to boil at the rate of 2°C per min. Dyeing was carried at 95°C for 60 min and after dyeing, the bath temperature was reduced to room temperature gradually; the dyed sample was taken out; washed and rinsed with water two times and dried at ambient temperature.

Simultaneous-Mordanting Method

The woolen yarn was entered in the dye bath containing 5% (owm) dye solution, kept at 40°C for 10 min and the bath temperature was raised to boil at the rate of 2°C per min. Dyeing was carried at 95°C for 60 min with 1:30 MLR and after dyeing the dye bath temperature was reduced to 40°C gradually. The required amount of mordant(s) was added in the same bath, kept for 10 min at 40°C and then the bath temperature was raised to 70°C at the rate of 2°C per min. Mordanting was carried at 70°C for 60 min. After mordanting, the dyed yarn was taken out; washed and rinsed with water two times and dried at ambient temperature.

Test Methods

Measurement of Colorimetric Value

The colorimetric values (L, a^*, b^*, and K/S) of dyed samples were evaluated using a JAYPAK 4802 Colour Matching System (M/s. Jay Instruments Ltd, Mumbai, India) at D65 illuminate/ 10 Deg Observer. The dyed yarn samples were folded twice to give an opaque sample, measured in two different areas; refolded to expose the other side of the sample, and measured in two different areas. From the average of these four readings, L, a^*, b^*, and K/S values were taken according to AATCC Evaluation Procedure 6 (AATCC 2003).

Evaluation of Fastness Properties

Washing fastness of the dyed woolen yarn samples were evaluated by IS 3361-1984 (ISO-II) method using a SASMIRA launder-O-meter. And 5 gm of dyed woolen yarn samples was taken and treated with 5 g/L soap solution in the launderometer at 50°C for 30 min with 1:50 MLR. After treatment, the samples were washed two times with distilled water and rinsed with distilled water for 10 min. After rinsing, it was gently squeezed and dried at 50°C. Washing fastness was assessed using AATCC grey scale as change in shade in comparison with the control sample (Anon 1985a; Anon 2005).

Color fastness to day light was determined as per IS: 686–1985 method. The dyed samples of woolen yarn were wrapped in a white card (10 × 2.5cm) in which half portion of the pad (5 × 2.5 cm) was covered with black sheet, and the samples were exposed to day light at the rate of 6 h per day (from 9 am to 3 pm) for 24 h. The grade was given from 1 to 8, by comparing the color fading of each experimental sample with control sample using AATCC grey scale. Both light and washing fastness grade was also cross-checked by measuring the loss of depth of color using JAYPAK 4802 Color Matching System attached with relevant software as per IS0 105-A05:1996 standard (Anon 1985a,b; Trotman 1984).

RESULTS AND DISCUSSION

Woolen yarn was dyed with cochineal extract in presence of five different mordants in single and combination form in PMD and SMD. The color obtained, colorimetric values and fastness properties of cochineal extract with respect to mordanting method and mordant combinations are discussed.

Cochineal Extract

Cochineal dye was extracted from the dried bodies of the adult female insect *Dactylopius coccus Costa* by aqueous extraction method. Literature information inferred that cochineal dye chiefly contain 80–86% (owm) carminic acid, i.e. 7-α-D glucosyl pyranosyl-9,10-dihydro-3,5,6,8-tetra hydroxyl-1-methyl-9,10-dioxo anthracene carboxylic acid in which, anthraquinone is the chromophore and -COOH, -OH, >C = O, and –CH_3 are auxophores. The important color producing components of cochineal extract are given in Figure 1 (Francis 1996; Gonzlez et al. 2002; Stintzing et al. 2005). The anthraquinone moiety with α- and β-phenolic groups are mainly responsible for chelating with metallic cation as well as colors.

Color Obtained

Different colors obtained when woolen yarn was dyed with cochineal extract in presence of the single/two mordants in PMD and SMD methods are given in Table 1. Wool fiber polymer

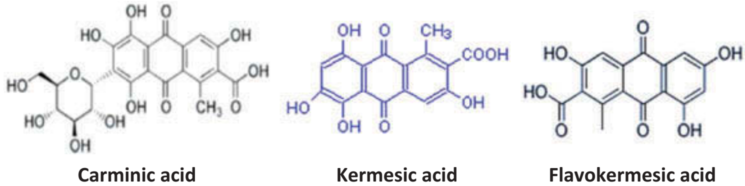


FIGURE 1 The components of cochineal extract.

TABLE 1
Color of woolen yarn dyed with cochineal extract in presence of single and two mordants

Single mordant		*Two mordants*	
Mordant	*Color obtained*	*Mordants*	*Color obtained*
–	Purple	SC + CA	Blood red
AS	Reddish Purple	SC + FS	Grayish purple
CT	Reddish Purple	SC + CT	Pinky red
CA	Purplish red	SC + AS	Reddish purple (light)
SC	Purple	CT + CA	Reddish brown
FS	Yellowish grey	FS + CA	Grey
		FS + CT	Yellowish grey
		FS + AS	Purple grey
		AS + CA	Reddish purple (dark)
		AS + CT	Crimson red

has both cationic and anionic functional groups, such as hydroxyl (–OH), amino (-NH_2), amide (-CONH-), and carboxyl (-COOH) groups. During mordanting with divalent or trivalent metal cation (X^{2+}/Y^{3+}), the hydrogen atom of the functional groups (-OH / -COOH) of wool fiber are exchanged by metal cation through ionic bonding. During dyeing, the carbonyl group ($>C = O$) and alpha hydroxyl groups (-OH) in the anthraquinone moiety of carminic acid/kermesic acid form coordinate bonding with metal cation. The carboxylic acid group of the cochineal dye can easily ionize into carboxylate anion (-COO^-) due to tautomerism and it also formed ionic bonding with—NH_3^+ group of wool fiber. Due to this ionic bonding, the diffused dye molecule led to formation of metal–dye coordination complex. Such bonding can also lead to enhance the coordination bonding between metal ion and dye molecule and their aggregation inside the fiber matrix due to intimate contact of both dye and metals. Each chelating complex differed in their shape, composition, geometry and so it gives wide range of colors (Angelini et al. 1997; Mendez et al. 2004).

Cochineal dye is well known for its coordination complex formation with transition metals. Carminic acid present in the cochineal dye interacted with metal cation and is responsible for red shift, i.e. the bathochromic shift of the main hue Kinkley and Vogler (2011). This effect could be attributed to the H-substitution of the hydroxyl group bonded to C_5 of the dye by each metallic ligand. They also inferred that Al^{3+}-carminic acid complex showed fluorescence while the Ni^{2+}-carmininc acid complex is not luminescent due to the presence of low-energy ligand field states. Similarly Velisek et al. (2007) inferred that during interaction between dye and metal ion, if the bonding will occur between 2-hydroxy group of dye molecule and metal cation, the complex could induce a small red shift; if it will occur in 7-hydroxy group, the complex could induce a small blue shift. If bonding will occur in both 2 and 7-hydroxy groups, the complex could induce smaller red shift than former one. This anthroquinone–metal complex induces the red and blue shift of the visible region, i.e. in the range of 460–570 nm and so the final colors are ranged from scarlet red to purple color (Trotman 1984).

When two mordants are applied (say M_1 and M_2), each mordant can form its respective dye–metal complex and both complexes might be present as **M_1-Dye-Wool, M_2-Dye-Wool, or M_1-Dye-M_2-Wool/M_2-Dye-M_1-Wool**, inside the fiber matrix. The final color will be based on maximum proportion of dominant dye–metal complex formed and present in the fiber. It is confirmed from Table 1, that ferrous mordant combinations gave grayish chrome; stannous mordant combinations gave reddish chrome and aluminium mordant combinations gave purple chrome. The final color of dyed woolen yarn each with and without mordants are given further (Figure 2).

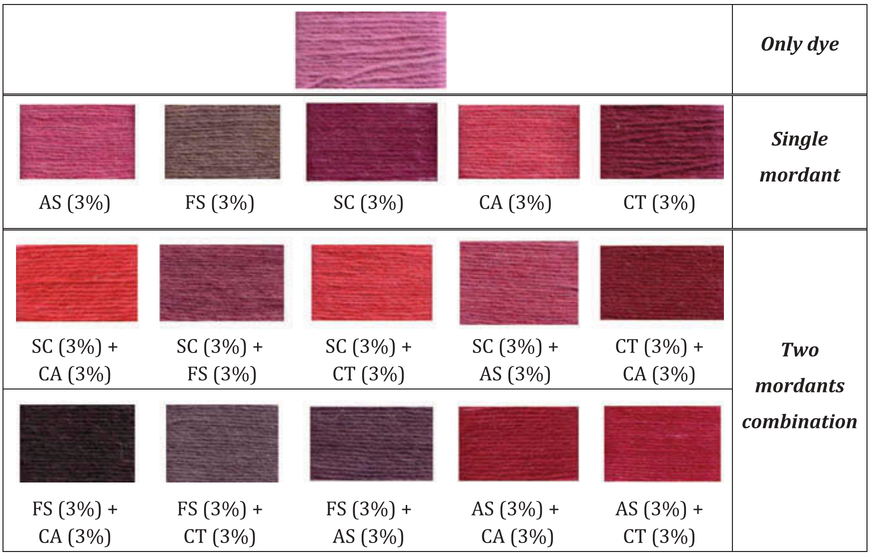


FIGURE 2 Colors obtained from dyeing of woolen yarn with cochineal extract in presence of mordants in single and combination form.

Colorimetric Values

The *L, a**, and *b** value of dyed woolen samples are given in Table 2.

It is observed that, the lightness of dyed samples ranged between 47 and 60, while it is slightly higher in SMD method (47.5–63.4) than PMD method (45.4–58.0). In PMD method, the metal

TABLE 2
*L, a**, and *b** values of woolen yarn dyed with cochineal extract in presence of single and two mordants in PMD and SMD methods

	L		*a**		*b**	
Mordant used	*PMD*	*SMD*	*PMD*	*SMD*	*PMD*	*SMD*
No mordant	61.6		13.9		−5.0	
AS	58.0	60.2	19.7	19.2	−1.9	3.3
CT	47.2	50.5	10.5	9.7	−1.3	−1.1
CA	50.6	55.0	21.9	6.4	0.0	−2.9
SC	49.0	57.1	12.5	9.4	−3.9	−3.7
FS	54.6	54.0	0.6	0.6	3.2	1.4
SC + CA	53.7	56.4	33.8	35.7	9.1	10.6
SC + FS	52.7	60.1	11.3	25.8	−0.7	3.7
SC + CT	53.8	57.9	29.9	34.9	6.6	10.1
SC + AS	53.8	63.4	16.6	18.2	−1.6	0.9
CT + CA	47.9	49.6	11.8	11.7	0.5	2.2
FS + CA	45.4	47.5	−0.5	0.4	−1.1	−0.3
FS + CT	52.8	52.7	−0.1	2.6	−0.5	−2.1
FS + AS	49.7	50.4	2.4	5.4	−2.2	−3.5
AS + CA	48.1	52.3	17.6	23.7	1.3	5.3
AS + CT	49.3	52.3	20.6	21.7	0.3	0.6

cation initially diffused well inside the fiber matrix and so formed ionic bonding with functional groups of wool fiber.

During dyeing, the fixed metal cation formed the coordinate bonding with the cochineal dye molecule that resulted in better aggregation of dye–metal complex than dye molecules. In SMD method, the cochineal dye molecule initially diffused inside the fiber matrix and during mordanting, the metal cation formed the coordinate complex with cochineal dye molecule both in the bath as well as in the fiber matrix. It might lead to lesser aggregation of dye–metal complex inside the wool fiber than PMD method. So, lightness of dyed samples in SMD methods is higher than in PMD methods (Montazer et al. 2004).

The a^* value of dyed samples of both methods are in positive values (>11.8), which confirmed that all colors ranged in purplish chrome except in ferrous salt combination (grayish chrome). The ferrous mordanted samples showed negative and lower values (-0.07 to 5.36) than other samples. After mordanting, the hue of dyed samples changed from bluish to yellowish and so all dyed samples showed increase in the values of b^* in both mordanting methods. The b^* value is positive in CT/CA mordant combinations and negative for all other combinations, which inferred that metallic cations gave bluish hue, while organic mordants gave yellowish hue.

K/S Value

K/S value generally indicates the aggregation of dye molecule inside the textile substrates. K/S values of cochineal dyed woolen yarn in two methods are given in Figure 3a and b. It is noted that the color strength of cochineal dyed woolen samples in PMD method are higher than respective SMD method, due to variation in aggregation of dye–mordant complex inside the matrix. The amount of aggregation of the natural dye may depends on the type of chromophoric/auxophoric groups and their nature of bonding with mordants as well as functional groups of fiber. From the spectral data of the dyed samples, it is inferred that cochineal dye could be preferred to dye in PMD method rather than SMD method (Han 2000; Kim and Lee 1998).

Fastness Properties

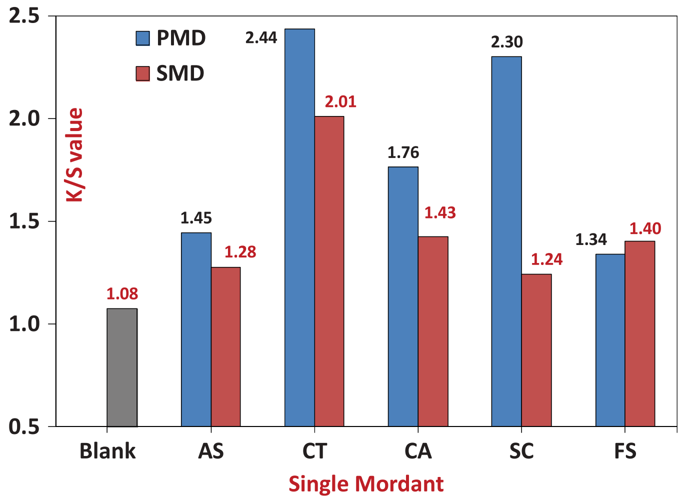
Washing Fastness

Washing and light fastness properties of woolen yarn dyed with cochineal dye in presence of single and two mordants in two different (PMD and SMD) methods are given in Table 3.

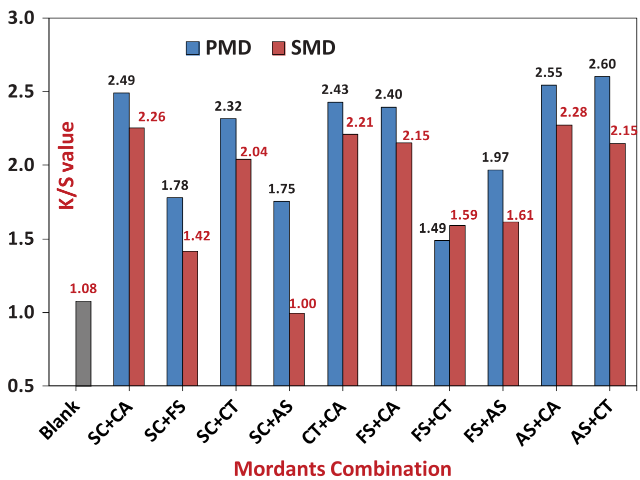
It is inferred that washing fastness of woolen yarn dyed with cochineal dye in presence of single mordant ranged from fair (grade 3) to very good (grade 4–5) and there is no variation in grades between two mordanting methods. In two mordant combinations, there is no difference in washing fastness of dyed woolen yarn between two mordanting methods except in AS mordant combinations viz. fastness is better in SMD method than PMD method. We observed that there is no staining of un-dyed wool and cotton fibers by cochineal dye–mordant complex, which inferred that cochineal–mordant complex did not have affinity towards undyed samples (Lee and Kim 2004).

Light Fastness

Light fastness of woolen yarn dyed with cochineal extract in presence of single mordant are ranged from fair (grade 3) to very good (grade 7–8) and it is lower in AS/CA based mordanting in PMD method than SMD method. In two mordants combinations, the light fastness is ranged from good (grade 5–6) to excellent (grade 7–8) in all samples, however light fastness is lower in SMD method than PMD method. Literature information inferred that light fastness of the



a: Single mordant



b. Two mordants

FIGURE 3 K/S value of woolen yarns dyed with cochineal extract in presence of single and two mordants in PMD and SMD methods.

natural dye increased with respect to increasing in the average size and symmetry of the aggregated dye molecules (Venkiduswamy and Ammayappan 2002). The reduction in light fastness of cochineal dyed woolen samples in SMD method might be due to either non-uniform aggregation of two different dye-mordant complexes inside the fiber matrix, which led to reduction in symmetry of dye-mordant complex or any one of the mordant-dye complex might has lesser photo stability than other complex. The non-uniform aggregation of dye might also lead to decrease in light fastness in SMD method, since aggregated dye molecules resists the photofading (Cristea and Vilarem 2006; Vickerstaff 1954). Light fastness of dyed woolen yarn in AS + CT and AS + CA (grade 7–8) combination is better than other combinations (from grade 3–4 to 7).

TABLE 3
Washing and light fastness properties of woolen yarn dyed with cochineal extract in presence of single and two mordants

	Washing fastness (Change in shade)		*Light Fastness*	
Mordant(s) used	*PMD*	*SMD*	*PMD*	*SMD*
Control	3		4	
AS	3–4	3—4	3	6
CT	4	3—4	6	5—6
CA	2–3	3—4	3	5
SC	4–5	4—5	6	5
FS	4–5	4—5	6	6
SC + CA	4–5	4—5	7	6
SC + FS	3–4	4	5–6	3—4
SC + CT	4–5	4—5	7	5—6
SC + AS	3	3—4	4–5	2—3
CT + CA	4	3	5	3—4
FS + CA	4–5	4—5	5–6	5—6
FS + CT	4	4	5–6	3—4
FS + AS	3–4	3	6	4
AS + CA	4–5	3	7–8	5—6
AS + CT	4–5	4	7–8	5–6

CONCLUSION

Cochineal dye was extracted from dried adult female insects of *Dactylopius coccus Costa* by conventional aqueous extraction method and dyed with woolen yarn both in pre-mordanting as well as SMD with five different mordants in single and two mordants combination. Without mordanting, cochineal dye gave bluish purple color and after mordanting, it gave different colors, ranged from scarlet red to black color on woolen yarn. When two mordants are applied, the final color of woolen yarn will depend on the properties of the dominant mordant. The dominant mordant could preferentially form more coordination complex with the cochineal dye molecule than other mordants. Fe^{2+}, Sn^{2+}, and Al^{3+} mordant-based combinations gave grayish, reddish, and purplish chrome, respectively, on woolen yarn. Color strength and light fastness properties of dyed samples are better in PMD method than SMD method, while there is no variation in washing fastness between two methods. Washing fastness of woolen yarns dyed with cochineal dye in presence of mordant(s) are ranged from moderate (grade 3) to very good (grade 4–5) and light fastness ranged from moderate (grade 5) to excellent (grade 7–8). It is concluded that cochineal can be used as potential natural dye for developing selective gorgeous colors on woolen yarn, which can improve the aesthetic value of woolen carpets.

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