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Eco-dyeing of cotton with madder (*Rubia cordifolia*) root dye using bael (*Aegle marmelos*) rind as mordant

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ABSTRACT

Wet-processing in the textile industry has acquired great attention now-a-days because of rising concept of sustainability and eco-friendliness. Release of vast amount of water waste and unfixed colorants effluent during dyeing and printing process using synthetic dyes and chemical additives poses a threat to the eco-balance of the nature. Such environmental concerns have compelled man to think about their substitutes which are environment friendly or have a green approach. Hence there is an increase in awareness and sensitivity about the usage of natural dyes and natural mordants, though these were known and used in ancient times too. Keeping this in mind, the present study was undertaken to dye cotton fabric with readily available and low cost natural dye *i.e.* Madder (*Rubia cordifolia*) root using rinds of Bael (*Aegle marmelos*) as mordant. Aqueous extraction method was used to extract the dye as well as the mordant. Dyeing was carried out by three mordanting techniques *i.e.* pre, post and simultaneous. Colour measurements of the dyed samples were evaluated. Dyed samples were subjected to various tests of colour fastnesses to washing, rubbing, artificial perspiration and light fastness. This experimental work suggests another opportunity for using rinds of Bael (*Aegle marmelos*) fruit as a green mordant

Key Words : Madder, Natural mordant, Bael fruit rind, Colour measurement, Colour fastness.

INTRODUCTION

Recently sustainable and eco-friendly development has taken a perceptible shift more than ever before to repeal natural resources devastation and maintain a healthy environment. The three basic needs *i.e.* food, clothing and shelter of human being is now expanded to uncontaminated air and water in a clean and habitable environment. Consumers are showing greater interest in natural and eco-friendly products which have encouraged many companies and firms to initiate GPI's (Green Product Innovations) in their product development (Rather and Rajendran, 2014). This concept has also given due consideration in the field of textiles with main aim of ensuring human and environment safety aspects without compromise on fashion and function. Now-a-days various textile industries are working with eco-friendly wet processing methods and sustainable practices such as Eco-friendly bleaching; Eco-friendly dyeing and printing; use of Low impact dyes; Natural dyes; Azo free dyes; Phthalates free printing (Sharma, 2013). The textile processing industry is one

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of the major users of synthetics dyes. Certain synthetic dyes have been banned due to their toxic nature as well as water pollution caused by the effluent waste from such industries. Thus, a renewed international attention for natural coloured substances is intensifying, as these are non toxic, biodegradable and eco-friendly in nature (Carvalho and Santos, 2015).

Natural dyes are well known for their use in coloring of food substrate, leather as well as natural fibers like wool, silk and cotton and textiles as a major area of application since pre-historic times. These colouring agents producing extensive range of shades can be obtained from various parts of plants including roots, bark, leaves, flowers and fruit (Samanta and Agarwal, 2009). But most of the natural dyes do not fix permanently to the textile fibers and require a substance, mordant, to create an affinity between the fiber and the pigment (Singh *et al*., 2003). A mordant is a dye fixative substance of organic or inorganic origin which helps in binding dyes or the colouring matter on a textile base by forming a coordination complex with the dye which then attaches to the fabric (Barhanpurkar and Kumar, 2015). Mordants can be broadly classified into three categories: Metal salts or metallic mordants such as aluminum, tin, iron etc.; Tannins or tannic acid such as myrobalan , sumach leaves or, gall nuts etc. and thirdly Oil and oil mordants such as Turkey red oil, sulphonated oil etc. (Patel, 2011). It has been found that metallic mordant helps in obtaining bright and a wide range of shades but they are typically based on heavy metals which are very toxic in nature and causes threat to environment as well to human well-being also. Many researchers confirm the harmful effects of many metallic mordants *viz.*, Alum, though is non-toxic but is an irritant if inhaled; Chrome is poisonous and can provoke an allergic reaction to anyone with sensitive skin; Copper is noxious and has little effect on vegetable fibres; Tin is poisonous and an irritant (Sneddon, n.d; Rajeswari and Sailaja, 2014; Sheshir, 2014).

Considering the drawbacks of metal salts there is need to explore more natural mordants as many studies show that various natural sources with good tannin content can be used as mordants like iron water, ash water, cow dung, lemon juice, tamarind seed coat, pomegranate rind, myrobalan, babul bark etc. And these showed good results in terms of colour strength and colorfastness properties (Janani and Winifred, 2013; Prabhu and Teli, 2014; Sangeetha *et al.*, 2015). Bael fruit rinds have 18-22% tannin content (Tyagi *et al.*, 2016), hence present study was undertaken to explore the possibilities of using bael rinds extract as mordant with one of the most widely used and readily available natural dye *viz.*, Indian madder roots. Dyed samples were also assessed for colour measurements test as well as for various colorfastness properties to washing, crocking, perspiration and light fastness.

METHODOLOGY

Plant source:

The following two plants were chosen for the study:

Name of plant	Used part	Sourcing place	Purpose
Indian madder (*Rubia cordifolia*)	Roots		Dyeing agent
Bael (*Aegle Marmelos*)	Fruit rinds	Local market	Mordant

Substrate:

Desized, scoured and bleached 100 % cotton fabric was used for dyeing.

Experimental method:

Extraction of dye:

The aqueous extraction method was used to extract dye from the roots. Firstly, roots were washed, dried and then converted into powder form. The powder was taken according to the 100% concentration of dye multiply by the on weight of fabric (owf) and then soaked in a known volume of water for overnight. The extraction process was carried out for 2 hours by maintaining the level of solution at 60^0C in the container followed by filtration using muslin cloth to obtain a clean dye solution.

Extraction of mordant:

Rinds of bael fruit were separated from seed and pulp, dried for few days, crushed with hammer into small pieces and then grounded into fine power to be used as natural mordant. The powder was taken according to the 20% concentration of mordant multiply by the on weight of fabric (owf). The extraction process was carried out for 3 hours by maintaining the level of solution at 100^0C in the container and followed by filtration through muslin cloth to get a clean solution.

Mordanting process:

Mordanting was carried out by treating the cotton fabric with solution of rinds of bael fruit (20% owf) at 100°C for 30 minutes with known volume of water. The process was carried out at three stages *i.e.* pre-mordanting (mordanting followed by dyeing), simultaneous mordanting (dyeing and mordanting is carried out together) and post-mordanting (dyeing followed by mordanting).

Dyeing:

Dyeing of cotton fabric was done by solution of madder roots (100% owf) maintaining the known volume of water at 100°C for 30 minutes. After dyeing, samples were washed with water and then dried.

Table 1 : Nomenclature of sample

Dye conc. (100%owf)	Mordant (30%owf)	Mordanting technique	Nomenclature of samples
Indian madder roots	Rinds of Bael fruit	Pre-mordanting(B_1)	(MB_1)
(*Rubia cordifolia*)	(*Aegle marmelos*)	Simultaneous mordanting(B_2)	(M B_2)
(M)	(B)	Post-mordanting(B_3)	(M B_3)

Measurement of colour strength :

The colour characteristics of the dyed samples were determined based on the CIELAB system via the Data colour 650 spectrophotometer with illuminant D65 and 10^0 observers.

Colour fastness :

Colour fastness properties i.e. washing, crocking (dry and wet), artificial perspiration and light fastness of dyed samples were tested according to IS standards.

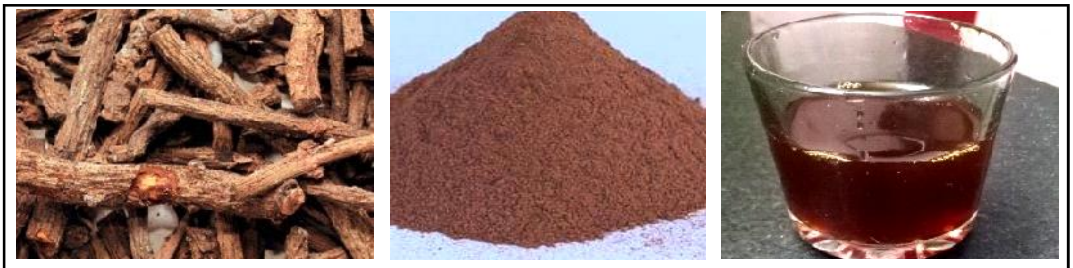
Table 2 : Colourfastness properties, IS standards and equipment used for testing

Colour fastness properties	IS Standard	Equipment used
Washing	ISO 105 CO2	Laundr-o-meter
Crocking	ISO 105 -X12	Crockmeter
Artificial perspiration	ISO 105 E04	Perspirometer
Light fastness	ISO 105 BO2	Xenotest Light fastness apparatus

RESULTS AND DISCUSSION

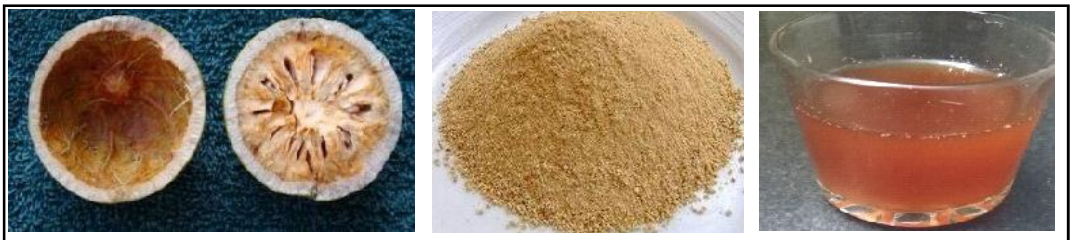
Extraction of Madder (*Rubia cordifolia*) root and rinds of Bael (*Aegle marmelos*):

It was observed that colour of dye extracted from Madder (*Rubia cordifolia*) root powder was dark red colour (Fig. 1) whereas rinds of Bael (*Aegle marmelos*) extract was dark yellow in colour (Fig. 2).



(a) (b) (c)

Fig. 1 : a) Madder roots, b) Grounded powder of roots, c) Aqueous extract of roots



(a) (b) (c)

Fig. 2 : a) Rinds of Bael, b) Grounded powder of rinds, c) Aqueous extract of rinds

Shade obtained on cotton fabric:

Different shades were obtained on the unmordanted and mordanted samples as shown below:

Table 3: Shades obtained on cotton fabric

Dye source	Mordant	Mordanting technique	Shades obtained
Indian madder roots (*Rubia cordifolia*) (100%owf)	Rinds of Bael fruit (*Aegle marmelos*) (30%owf)	Unmordanted	(M)
		Pre-mordanting	(MB_1)
		Simultaneous mordanting	(M B_2)
		Post-mordanting	(M B_3)

M- Madder root dyed sample, MB_1 –Pre mordant sample, MB_2- Simultaneously mordant sample, MB_3- Post mordant sample

Colour measurements of dyed cotton fabric :

Cotton fabrics dyed with madder root and mordanted with Bael rind gained darker shade in simultaneous mordanting techniques whereas lighter shades in pre and post mordanting techniques (Table 4). It was also observed that there is increase in colour strength with post mordanting in comparison to pre and simultaneous mordanting technique.

Table 4: Colour characteristics of dyed fabric

Dyed samples	ΔL	ΔC	ΔH	ΔE	Description
M		Standard			--
MB_1	0.40	1.00	2.98	3.17	Lighter more red more yellow
MB_2	-0.09	1.69	3.63	4	Darker more red more yellow
MB_3	2.19	-0.93	-7.93	8.28	Lighter more red more blue

M- Madder root dyed sample, MB_1 –Pre mordant sample, MB_2- Simultaneously mordant sample, MB_3- Post mordant sample

Colour fastness properties of dyed samples:

Dyed samples were tested for various colour fastness properties according to IS methods as shown in Table 3. With regards to colour fastness for washing, it was found that sample with post mordanting showed excellent fastness whereas samples with pre and simultaneous mordanting showed good fastness. It was also observed that, there was no colour staining on multifibre fabric *viz.*, Acetate, Cotton, Nylon, Polyester, Acrylic and Wool. Post mordant sample showed very good to excellent fastness in wet and dry crocking too. All dyed samples showed same colour fastness to light i.e. average. Artificial perspiration fastness were also tested under acidic and alkaline condition and it was observed that mordanted sample showed same results in both conditions *i.e.* average to good.

Table 5: Color fastness properties of dyed cotton fabric

Dyed samples	Washing ISO 105 CO2		Crocking ISO 105 -X12		Light ISO 105 E04	Perspiration ISO 105 BO2			
			Dry	Wet		Acid		Alkaline	
	CC	CS	CS	CS	CC	CC	CS	CC	CS
M	2/3	5	3/4	2/3	3	3	3/4	2/3	3
MB_1	3/4	5	4	3	3	3/4	4	3	3/4
MB_2	3	5	4	3	3	3	3/4	3	3/4
MB_3	4/5	5	5	4	3	3/4	4	3	3/4

CC- Colour Change, CS- Colour Staining

M- Madder root dyed sample, MB_1 –Pre mordant sample, MB_2- Simultaneously mordant sample, MB_3- Post mordant sample

It was concluded that post mordanted sample showed good to excellent fastness properties to washing, crocking and artificial perspiration.

Conclusion :

From the present research, it can be concluded that rinds of bael (Aegle marmelos) can be successfully employed as natural mordant for dyeing cotton with natural dye *i.e.* Indian madder roots. Dyed Cotton showed darker colour characteristics in simultaneously mordanted sample whereas lighter colour characteristics in both pre and post mordanted samples. Furthermore when dyed samples were tested for colour strength, post mordanted sample showed highest colour

strength value and also found to be good to excellent in colorfastness properties to washing and crocking.

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