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Dyeing of cotton and silk with eco-friendly dyes extracted from bark of mangrove species *Rhizophora mucronata* and *Ceriops tagal*

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Abstract : India has a rich biodiversity of plants and it harbours several economically useful plant resources. Hence, the plant kingdom is considered to be treasure-house of diverse natural products. Natural dyes are one such product which can be potentially utilized for the benefit of mankind. Due to the toxic and allergic nature of synthetic dyes, in the present study efforts were made to use natural dyes from the bark of two mangrove tree species viz. *Rhizophora mucronata* and *Ceriops tagal*, for dyeing of cotton and silk fabrics. Aqueous extracts of bark along with various chemical and natural mordants were used to produce different shades of colour ranging from brown, light brown, yellow, black to grey on both cotton and silk fabrics. The present study also revealed colour fastness of the dyed samples and it has been evaluated by washing, rubbing and exposing the fabric to sun light.
Key words : Natural dyes, mangrove species, mordants, dyeing, colour fastness.

Introduction

Colours have influenced the human race since ancient times. Since the invention of synthetic dyes in 1856, the use of synthetic dyes were increasing due to its easy availability, reproducible colours and low fading property[1]. But in terms of health and safety, these dyes are very dangerous as it contains heavy metals like chromium, tin, copper and zinc[2]. On the other hand natural dyes are soothing to eyes, earthly, warm and highly appealing. And hence these natural dyes slowly started gaining its lost importance. These natural colourants though eco-friendly have many limitations of fastness and vividness of shades. However, when used along with some mordants they are known to improve the shades. The mordant is a chemical which enhances the staining property of a dye. Therefore, one can use a technique of dyeing along with mordants to achieve brighter shades of colour in fabrics[3].

Mangroves are coastal plants having multifunction, ecologically theyprotect coastal areas form abrasion[4]. The mangrove forests have been utilized by humans for firewood, charcoal, construction work i.e. furniture, boats and fishing equipments[5]. They are also used for printing of silk fabrics in textile industry[6]. These barks produce 15 to 36% tannins and thus produce reddish brown dyeswhich are used for leather tanning and dyeing[7,8]. *Rhizophora mucronata*, commonly known as the red mangrove, is a mangrove belonging to family Rhizophoraceae and found on the coasts and river banks in EastAfrica and Indo pacific region and reported to have ample uses. The timber is used for making firewood, in construction of building and making fish traps etc. *Ceriops tagal*, commonly called Indian mangrove which belongs to family Rhizophoraceae. It grows naturally in Eastern and Southern Africa, India and China. The wood is used for construction purpose and in the manufacture of charcoal as it is favoured as firewood. The dye is extracted from the bark of the plant.

This paper presents the finding of extraction of natural dyes from the barks of two mangrove tree species viz. *Rhizophora mucronata* and *Ceriops tagal* and dyeing using cotton and silk fabrics along with various chemical and natural mordants. The quality assurances of dyed fabrics were evaluated by wash fastness, light fastness and rub fastness to provide information to the textile and natural dyers.

Materials and Methods

Collection site

The bark of mangroves species *Rhizophora mucronata* Lam. and *Ceriops tagal* (Pers.) C.B. Rob.were collected from the Chorao Island, Goa.

Extraction of dye

The collected mangrove barks of *Rhizophora mucronata* and *Ceriops tagal* were dried in sunlight and later grounded into the powder form with the help of grinder. The dye extraction was performed by mixing the bark powder with distilled water in ratio M:L(material to liquor) 2:20 and boiled for about 2-3 hours in water bath. Then the resulting solution was filtered using muslin cloth and used for dyeing purpose.

Calculation of crude yield

The dye extraction was carried out using 20 grams of dye yielding plant part in powder form with 400 ml of distilled water in hot oven at the temperature of 60˚C. Then the dye extract was filtered by using the muslin cloth. The filtered dye was placed in beaker and heated in an oven to get a solid dye by evaporation of water. This is weighed using electronic balance and termed as crude solid dye. The percentage yield of crude solid dye was calculated using the following formula[9].

$$Wdy = \frac{Wbe - Wae}{Wbe} \times 100$$

WhereW_{dy} = percentage yield of crude dye
W_{be} = dye material weight before extraction (g)
W_{ae} = crude solid dye material weight after evaporation of extracts (g)

Pre-treatment of the fabrics

Cotton and silk fabrics were washed in a solution containing 2g/L of detergent (tide) for 20 minutes to remove the debris. After this the fabrics was thoroughly washed with tap water and dried. Pieces of both fabrics were cut in to the size of 10×10cm and used for the experimental purpose (Fig. 1)

Fig 1 Undyed silk and cotton fabrics

Mordants used

Three chemical mordants such as potassium dichromate, copper sulphate and ferrous sulphate and three natural mordants viz. lemon juice, cow-dung and baking soda were used for obtaining various shades (Table 1).Mordanting was carried out in three steps: Pre-mordanting, Post-mordanting and Simultaneous mordanting.

Table 1 Preparation and application of mordants on fabrics

Sr. No.	Mordant used	Amount of mordant	Water added	Mordanting time	Mordanting temperature
1	Copper sulphate	0.1 g	10 ml	30 min	30℃
2	Ferrous sulphate	0.1 g	10 ml	30 min	30°C
3	Potassium dichromate	0.1 g	10 ml	30 min	30°C
4	Cowdung	0.1 g	10 ml	30 min	30°C
5	Baking soda	0.1 g	10 ml	30 min	30°C
6	Lemon juice	1 ml	10 ml	30 min	30°C

Pre-mordanting

The known quantity of mordants is measured and poured into beakers separately and required quantity of water is added. Mordants are stirred until they are dissolved. The un-dyed cotton and silk specimens is immersed into the mordant solution for 30 minutes and then the material is dipped in the extracted dye.

Post-mordanting

The un-dyed cotton and silk specimens is immersed into the dye solution for 30 minutes and then the specimen is dipped in mordant solution for 30 minutes.

Simultaneous mordanting

During this method, the samples are dyed with dye extract as well as different chemical and natural mordants simultaneously.

Evaluation of colour fastness

The wash fastness, light fastness and rub fastness were performed with the dyed fabrics[3].

Wash fastness

Both the silk and cotton fabrics is washed three times in the distilled water and the retention of the colour in the fabric was noted down.

Rub fastness

The cotton and the silk fabrics are rubbed manually with hands for about 5 min and 15 min to check the fading property of the dye.

Light fastness

The cotton and silk fabrics is exposed to direct sunlight for about 6 and 12 hours to check the fadedness of the colour from the fabric.

Effect temperature and time duration for extraction of dye

The dye from bark of *Ceriop stagal* was extracted in water by using M:L (1:10) ratio. The extraction was carried out using different temperatures such as 30°C, 50°C, 70°C, 90°C and time duration like15min, 30 min, 45 min and 60 min.

Results and Discussion

Extraction of dye and calculation of crude dye yield

The barks of *Rhizophora mucronata* and *Ceriops tagal* were found to release colour in hot water very easily. Boiling the chips of the bark in water for about 2-3 hours is accompanied with the increase in colour strength and depth in colour. It was noted that the colour of the aqueous bark extract of both the plants was dark reddish brown. The crude yield of the dye from the plant specimens is summarised in Table 2. Dye yield is the quantity of crude dye powder obtained after evaporation of water from the extracted dye solution. It was found that the dye yield of *Rhizophora mucronata* bark is 78.7% and *Ceriops tagal* is 88.35% (Fig 2). The lowest dye yield was reported in *Eriobotrya japonica* bark (14.14%) and highest in *Ficus sycomores* bark (26.33%)[9].

Table 2Estimated dye yield obtained from bark.

Sr. No.	Plant species	Part used	Crude dye yield (%)
1	*Rhizophora mucronata*	bark	78.7
2	*Ceriops tagal*	bark	88.35

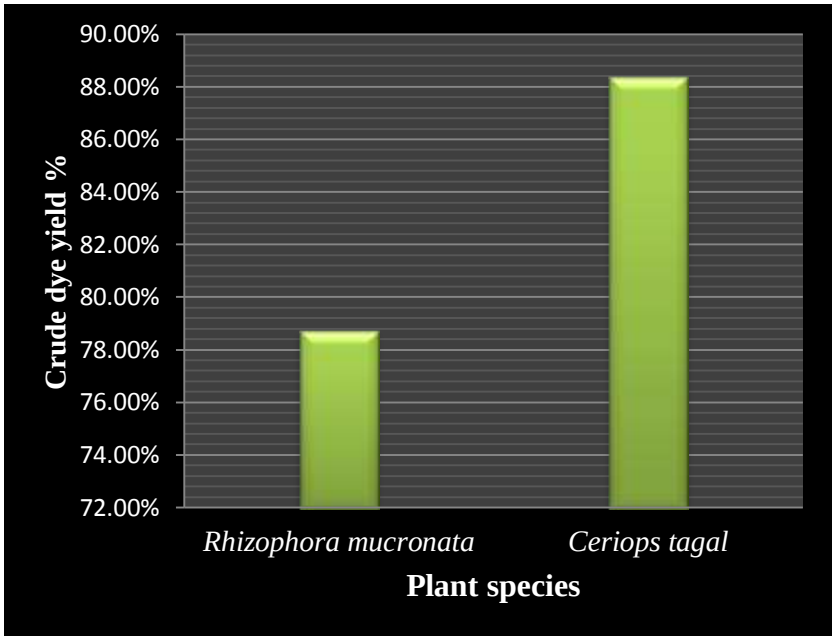

Fig 2Crude dye yield of plant species

Dyeing behaviour of dye extract

Natural dyes are non-substantive in nature and require a mordant to bind with dye to enhance colour in textiles. Both, cotton and silk fabrics were dyed with chemical and natural mordants. The silk fabrics showed higher uptake of colour compared to that of the cotton fabrics (Fig 3).

Dyed Material	Silk	Cotton
Rhizophora mucronata		
Ceriops tagal		

Fig 3 Dyed silk and cotton fabrics with natural dyes

Among the chemical and natural mordants used, chemical mordants showed higher dye uptake then the natural mordants. Mordants are responsible for imparting varying shades of colour to the fabric, with the same natural dyestuff. The mordant ferrous sulphate gives dark black colour shades in all the mordanting methods in both the fabrics, because the strong co-ordination tendency of Fe enhances the interaction between the fibre and the dye, resulting in higher dye uptake[10]. Potassium dichromate is known as brightening mordant and thus produces deeper shades of colour to the fabrics[11]. All the three mordanting methods gave excellent results in both the dye extracts. *Rhizophora mucronata* bark extract produced wide shades of colours like brown, light brown, black, creamish, reddish on silk fabrics and brown, black and grey shades on cotton fabrics (Fig 4).

Name of the mordant	Types of mordanting					
	Pre		Simultaneous		Post	
	Cotton	Silk	Cotton	Silk	Cotton	Silk
Potassium dichromate						
Copper sulphate						
Ferrous sulphate						
Cowdung						
Lemon juice						
Baking soda						

Fig 4 Dyeing with *Rhizophora mucronata* bark extract

Whereas bark extract of *Ceriops tagal* gave yellow, red, brown, black shades on silk fabrics and black, brown, grey on cotton fabrics (Fig 5). The bark of both these plants contains high amounts of tannins and thus produces brown, red, black colour shades[7,12].

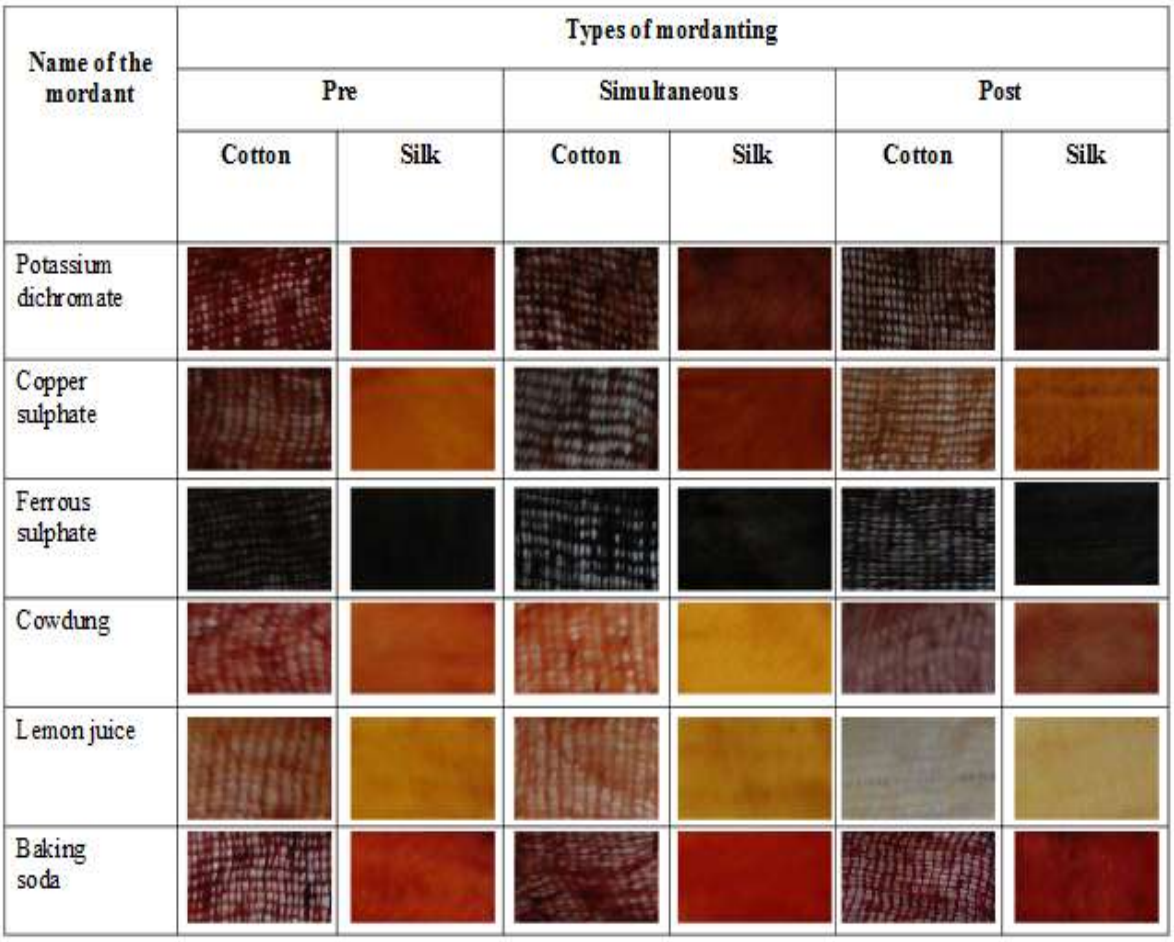

Fig 5 Dyeing with *Ceriopstagal* bark extract

Fastness tests for the dyed fabrics

Fastness property of the fabric (silk) dyed with aqueous extract of *Rhizophora mucronata* bark were reported during this study.

(i)Wash fastness

Dye extracted from the bark of *Rhizophora mucronata* exhibits good to excellent wash fastness. Wash fastness is influenced by the rate of diffusion of the dye from the fabric. Dyeing of the fabrics with the combination of the mordants has an ability of insolubilizing the dye, making the fabric colour fast[10]. Wide ranges of soft and light colours have been obtained on silk using the dyes extracted from *Rhizophora mucronata* bark. The samples dyed with the *Rhizophora mucronata* extract and using Potassium dichromate as a mordant showed excellent wash fastness in all the three dyeing methods followed by ferrous sulphate and copper sulphate. Chemical mordants however showed good fastness compared to the natural mordants (Fig 6).

ii) Light fastness and Rub fastness

Good light and rub fastness was observed in the fabrics dyed with the bark extract of *Rhizophora mucronata*. This is due to the formation of metal dye complex which protects the chromatophore from photolytic degradation. Similar kind of studies on colour fastness of*Capsicum annum* was carried out[13].

Mordants used	Types of mordanting	Dyed material	Wash fastness			Light fastness		Rub fastness	
			First wash	Second wash	Third wash	6 hours exposure	12 hours exposure	5 min	15 min
$K_2Cr_2O_7$	Pre								
	Simultaneous								
	post								
$FeSO_4$	Pre								
	Simultaneous								
	post								

Mordants used	Types of mordanting	Dyed material	Wash fastness			Light fastness		Rub fastness	
			First wash	Second wash	Third wash	6 hours exposure	12 hours exposure	5 min	15 min
$CuSO_4$	Pre								
	Simultaneous								
	Post								
Baking soda	Pre								
	Simultaneous								
	Post								

Mordants used	Types of mordanting	Dyed material	Wash fastness			Light fastness		Rub fastness	
			First wash	Second wash	Third wash	6 hours exposure	12 hours exposure	5 min	15 min
Cowdung	Pre								
	Simultaneous								
	post								
Lemon juice	Pre								
	Simultaneous								
	post								

Fig 6 Fastness property of *Rhizophora mucronata* bark extract on silk fabrics

Effect of time and temperature on extraction of dye

Ceriops tagal aqueous bark extract on dyeing on dyeing properties in relation to various time duration and different temperatureis shown in Fig 7. It was noted that the colour easily gets extracted from the bark with increasein time and temperature. There was increase in colour intensity from 15 to 60 min and also with the increase in temperature. The intensity of the colour became darker at higher temperature (90°C).

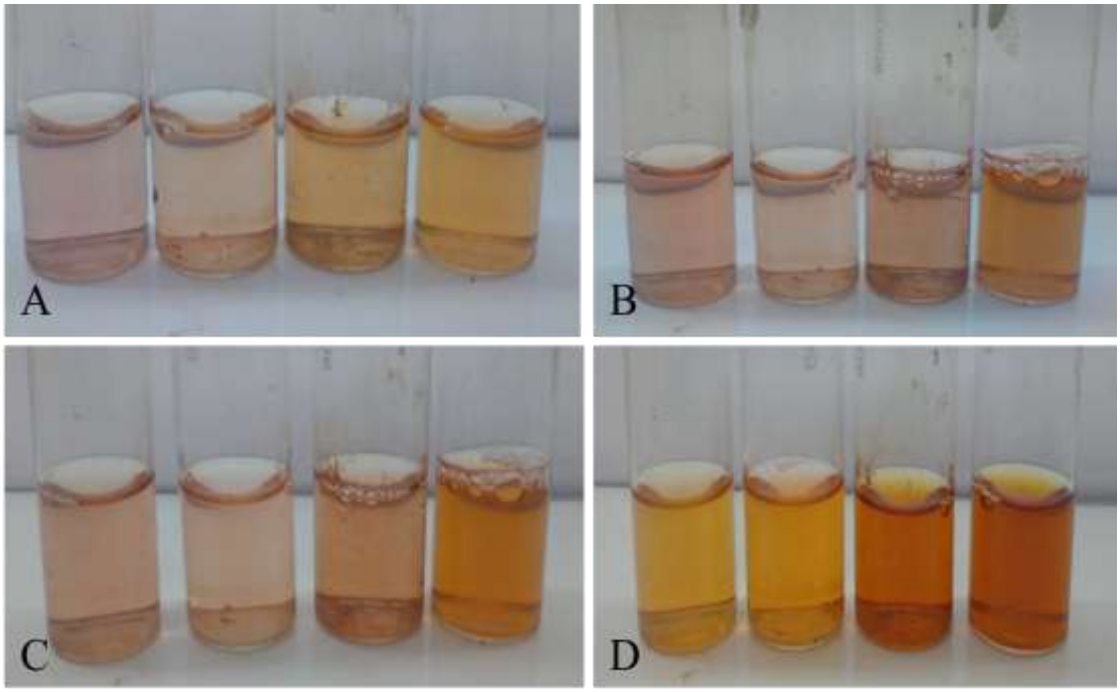

Fig 7 Colour changesobserved with increase in dye extraction time and temperature of *C. tagal* bark extract A. 30˚C; B. 50˚C; C. 70˚C and D. 90˚C

Conclusion

Dyeing of silk and cotton fabrics having appreciable depth of colour and good fastness property is achieved by using the bark extract of both mangroves *Rhizophora mucronata* and *Ceriops tagal*. Dyeing with mordants gave light to heavier shades of colour thus bearing good to excellent fastness property. Also the process of extraction of dyes used during this study is simple and environmental friendly.

Thus, the present study towards the utilization of natural dyes for dyeing purposecan replace the synthetic dyes. Therefore to commercialize the natural dyes, this kind of research work are needed and our future study will also focus on the specific chemical compounds responsible for dyeing properties of these two plant species. More research should also be carried out to explore plant based dyes and developa suitable method for extraction of natural dyes. Conclusively, these aqueous extracts of *Rhizophora mucronata* and *Ceriops tagal* bark could be a promising natural resources to be used as textile dyes for both cotton and silk fabrics.

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