

Extraction of Natural Dye from *Melastoma polyanthum* (Bovitiya) and a Natural Mordant from *Symplocos cochinchinensis* (Bombu)

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Abstract – Dyes for textile applications are broadly categorized into natural and synthetic dyes. The growing environmental awareness and preference for sustainable practices have driven a global revival in the use of natural dyes, valued for their eco-friendliness and perceived safety. Consequently, an effort was made to address those concerns thoughtfully. In this study, cotton fabric was dyed using a natural dye extracted from Bovitiya fruit powder through aqueous extraction. The fabric samples underwent standard pre-treatment processes, including desizing, scouring, and bleaching, to optimize dye uptake. Dyeing was performed using 2 natural mordants (Bombu and Aloe vera) and 3 metallic salt mordants (copper sulphate, ferrous sulphate and potassium alum). The optimal dyeing conditions were established at a temperature of 40°C, a pH range of 4, and a heating duration of 15 minutes. The colour range of the extracted dye was identified as violet. Mordanting was conducted in three stages: pre-mordanting, simultaneous mordanting and post-mordanting. The dyed fabric samples were evaluated for colour fastness properties, including light fastness (ISO 105 BO2), wash fastness (ISO 105 CO3) and fastness to crocking (ISO 105 X12). Results showed that the Bovitiya dye exhibited very good dry and wet rubbing fastness (4–5), particularly when using the Bombu mordant. However, it showed relatively poor light and wash fastness. Colour changes were assessed using a lightbox and greyscale for assessing change in colour and assessing staining. The findings suggest that while Bombu mordant enhances the rubbing fastness of the dye significantly, further optimization is needed to improve wash and light fastness for broader applications.

Keywords: Natural dyes, Natural mordants, Cotton fabric dyeing, mordanting techniques

1 INTRODUCTION

The textile manufacturing process is intricate and involves converting natural or synthetic fibres into yarns and fabrics. However, the growing amount of hazardous dye wastewater produced by various industries remains a significant public health and environmental issue (Tohamy et al, 2022). This creates a substantial challenge for traditional water treatment systems, which struggle to effectively address the contamination caused by these industrial effluents (Azanaw et al., 2022).

As a result, there is a growing focus among researchers to replace synthetic chemicals with environmentally friendly alternatives while maintaining the quality and efficiency of production. Before 1856, textiles were primarily dyed with natural substances, which have a long-established history (Kadolph, 2008). With the increasing global awareness of environmental issues and the energy crisis, interest in natural dyes has emerged, despite

the widespread adoption of synthetic dyes (Saxena, S. and Raja, A.S.M., 2014). Natural dyes offer numerous benefits over their synthetic counterparts, such as being non-toxic, non-carcinogenic, and biodegradable (Mirjalili et al, 2011). They can be sourced from renewable resources, including plants, flowers, seeds, insects, bark, roots, and microorganisms (Verma and Gupta, 2017).

Bhandari et al (2021) mentioned that natural dyes are increasingly used for colouring a range of natural fibres, including cotton, linen, wool, and silk, as well as some synthetic fibres like nylon and polyester. However, there are several challenges associated with their use. These include issues with the reproducibility of shades, the lack of standardized application methods and the poor durability of natural dyes, particularly when exposed to washing and light. One of the key difficulties researchers and dyers face is improving the colour fastness of these dyes, especially in terms of their resistance to washing and light exposure.

A mordant is used to create a bond between the fibre and the dye to improve the adherence of natural dyes to fibres. Metallic mordants, typically in the form of metal salts, are commonly employed to enhance the uptake of dye and ensure better retention of colour on the fabric. These mordants play a crucial role in improving the colourfastness of natural dyes, ensuring they are more durable and resistant to fading.

Bovitya (*Melastoma polyanthum*) has been selected as a plant source to extract natural dyes for textiles in the present research. It is a bushy shrub with a rough, grey, scaly stem that can reach up to 2 meters in height (Fig. 1). It is widespread across Southeast Asia and the Pacific. This plant typically grows near freshwater, often alongside *Melaleuca* species and thrives in areas with abundant water and protection from direct sunlight. Its striking purple flowers, ranging from 4 to 8 cm in diameter and prominent yellow stamens, contrast vividly against the bright green leaves. The fruit, which turns grey-black when ripe, contains a purple pulp and small black seeds. It is edible and has a pleasant taste, although it leaves a dark stain in the mouth. The roots and fruit of the plant were historically used as food. *Melastoma polyanthum* can be propagated from fresh seeds or cuttings (Native plant society, 2006).

Bombu (*Symplocos cochinchinensis*) has been selected as the plant source of mordant used in the dyeing process. It is a tall evergreen tree that can reach up to 35 metres in height, with a straight, cylindrical trunk that may grow up to 50 cm in diameter. This tree is often harvested from the wild for various uses, including as a food source, for dye production, and for its wood, tannins and beads. This species prefers the slopes of hills and ridges, often near streams, and is common in areas with brown soils at elevations ranging from 1,300 to 1,800 m (Fern, 2024).



Fig. 1 Bovitya plant

2 METHODOLOGY

2.1 Materials and Sample Preparation

2.1.1 Preparation of Dye Powder

The dye solution was prepared using fruits of Bovitiya (*Melastoma polyanthum*). The fruits were broken to separate the pulp, which was sun-dried for 2 to 9 days until they reached chips. These dried chips were then crushed and ground into a fine powder for subsequent dye extraction.

2.1.2 Preparation of Mordant Powder

The mordant solution was prepared using the bark of Bombu (*Symplocos cochinchinensis*), which acts as a natural fixing agent (McIntosh, L. S., & Peni, Y., 2020). The bark was cut into small chips and sun-dried for 3 to 4 days. Once dried, the chips were crushed and ground into a powder suitable for mordanting.




2.2 Dye Extraction Experiment

Aqueous extraction method was used to extract colourants from the selected source.

2.2.1 Aqueous Extraction

In this method, 1g of Bovitiya powder was dissolved in 3 different volumes of water. As the dye is highly concentrated, this weight has been determined. The mixture was then heated to 90 °C and maintained at that temperature for 10 minutes (Table 1). Afterwards, the solution was filtered to obtain the extracted dye. A cotton fabric piece was dipped in each dye extract to observe their colors.

Table 1 Conditions used in aqueous extraction

Sample	Weight of the dye powder (g)	Temperature°C	Duration of heating (min)	Volume of water (ml)	Resultant samples
1	1g	90	10 min	20ml	
2	1g	90	10 min	50ml	
3	1g	90	10 min	100ml	

2.3 Mordant Extraction

2.3.1 Bombu Mordant Extraction

For the extraction of mordant from Bombu (*Symplocos cochinchinensis*) powder, 5g of the powder was mixed with 100ml of water, maintaining a liquor ratio of 1:20. The extraction was carried out at a temperature of 90°C for 30 minutes. Finally, the solution was filtered to collect the extracted mordant.

2.3.2 Aloe Vera Mordant Extraction

Aloe vera gel was extracted from the inside of the thick, green outer rind of the plant's leaves. The weight of 5g of aloe vera gel was dissolved in 100ml of water to achieve a liquor ratio of 1:20. The solution was filtered to remove the unnecessary plant particles. The weights of the selected mordants were selected based on the weight of the fabric (Jahangiri, A., et al, 2018).

2.4 Pre-treatment Process

2.4.1 Desizing

DE sizing has been carried out to remove sizing materials from the warp yarn of raw woven cotton fabrics. The major desizing methods include rot steeping, enzymatic steeping and acid steeping. In this case, the method used was rot steeping. The fabric was immersed in water at a temperature of 60°C and allowed to simmer for 4-6 hours at room temperature. After this process, the fabric was dried.

2.4.2 Scouring

Scouring was carried out to clean the cotton fabric using an alkaline medium to remove remaining fats, waxes and other residues after the desizing process. A solution of caustic soda and a compatible detergent was used at high temperatures. A solution containing 10 g/L caustic soda is prepared, with 0.5-1.0 mL/L of detergent added, maintaining a liquor ratio of 1:20. The temperature is then raised to 95-100°C and the scouring process is conducted for approximately 1-2 hours.



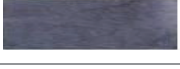
2.4.3 Bleaching

The fabric was immersed in a solution containing 6 mL/L sodium hypochlorite, 2 g/L NaOH and 1 g/L of a wetting agent and the operation was carried out at 90°C for 90 minutes. After this, the temperature of the bath is allowed to drop to room temperature.

2.5 Dyeing Process




The extract that produced the best colour strength was further utilized to optimize the dyeing process for cotton. The parameters adjusted during the dyeing experiments included time, temperature and pH, while the other factors remained stable. The extractions were performed at different liquor temperatures and for varying durations such as 15 minutes, 30 minutes and 45 minutes. Additionally, dyeing was carried out under different pH levels, including acidic (HCl), alkaline (NaOH) and neutral (distilled water) mediums. The duration of the dyeing process was changed three times and the colours of the dyed samples were observed (Table 2).

Table 2 Changing Time

Sample	Weight of the dye powder (g)	Temperature°C	Duration of heating (min)	Volume of water (ml)	Resultant samples
1	2	90	15	100	
2	2	90	30	100	
3	2	90	45	100	


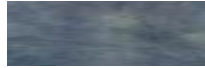

The dyeing process was conducted at three different temperatures: 40°C, 60°C and 80°C and the colours of the dyed samples were observed (Table 3).

Table 3 Changing Temperature

Sample	Weight of the dye powder (g)	Temperature °C	Duration of heating (min)	Volume of water (ml)	Resultant samples
1	2	40	30	100	
2	2	60	30	100	
3	2	80	30	100	

Three different pH levels were adjusted in the dye liquor and the colours of the dyed samples were observed (Table 4).

Table 4 Changing pH

Sample	pH range	Weight of the dye powder (g)	Temperature °C	Duration of heating (min)	Volume of water (ml)	Resultant samples
1	Acid (4) (HCl)	2	90	30	100	
2	Alkali (13) (NaOH)	2	90	30	100	
3	Neutral 6-7	2	90	30	100	

The dye extraction process for Bovitiya powder was optimized based on the desired depth of shades in the dyed samples. The optimal conditions for dyeing were determined to be 40°C for 15 minutes, with a pH of 4. These optimized parameters were used to prepare the dye liquor, which was then employed to evaluate the effects of various mordants and mordanting techniques on cotton fabrics.

2.6 Mordanting Process

Mordanting was carried out in three stages such as pre pre-mordanting, simultaneous mordanting and post-mordanting. In pre-mordanting, the fabric sample was first treated with the mordant and then dyed using Bovitiya extract separately. Simultaneous mordanting combined the dye and mordant into a mixture, which was then applied to the fabric sample that was to be dyed. In post mordanting the fabric samples were mordanted after they had been dyed with the natural dye.

2.6.1 Mordanting with Bombu Extract

The 5 g samples of cotton fabric was immersed in the pre-made mordant solution. The temperature of the solution was raised to 90°C and maintained for 30 minutes. Afterwards, the mordanted fabric samples were thoroughly rinsed with water, squeezed out and dried. These conditions were employed for pre-mordanting and post-mordanting methods. Since the simultaneous mordanting must be done alongside the dyeing process, 5g of ground Bombu powder was added to the dye liquor during dyeing.

2.6.2 Mordanting with Aloe Vera gel

The 5 g samples of cotton fabric was immersed in the mordant solution and the temperature of the solution was raised to 100°C for 30 minutes. After this period, the mordanted material was thoroughly rinsed with water then squeezed and dried. These conditions were applied for pre-mordanting and post-mordanting methods. Since the simultaneous mordanting must occur alongside the dyeing process, 5g of aloe vera gel was dissolved into the dye liquor during dyeing. Aloe vera has been used as an alternative natural mordant for comparison with the Bombyx mordant.

2.6.3 Mordanting with Metallic Salts

Cotton fabric samples were treated with metallic salt mordants, ferrous sulphate (FeSO_4), copper sulphate (CuSO_4) and alum ($\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$), at a concentration of 0.4 g/ml during the mordanting process. The mordant was dissolved in a liquor ratio of 1:20. The temperature of the solution was raised to 90°C, allowing for a pre-mordanting duration of 30 minutes, followed by 50 minutes for both simultaneous and post-mordanting processes. After mordanting, the fabrics were thoroughly rinsed with water, squeezed and then dried.

2.7 Colour Fastness Assessments

The colour fastness of the dyed fabric samples was assessed for light, washing and rubbing.

2.7.1 Light Fastness Test

The dyed samples were evaluated for colour fastness to light using ISO standards (ISO-105 B02). The standard sample size was 1cm x 5cm. This test assesses the extent of colour fading when exposed to a controlled light source. The samples were exposed to light (D65 daylight) inside the light fastness tester for approximately 52 hours and compared to an unexposed sample. Changes were assessed using blue wool scales to determine fading intensity.

To conduct the test, the samples and blue wool references were mounted on a sample card. The middle one-third of the test card was covered during exposure. After exposure under specified conditions, the test sample was compared to the non-exposed areas of the tested samples using a grey scale for assessing change in colour to evaluate the degree of colour change.

2.7.2 Wash Fastness Test

The dyed samples were tested for wash fastness using ISO-105 C03 standards. A sample of the dyed fabric, measuring 4 cm x 10 cm, was prepared and sewn to a multi-fibre fabric of the same size at one corner. A detergent solution was prepared using a standard detergent. The combined specimen was immersed in the solution and subjected to rinsing in hot water, followed by squeezing with cold water. Afterward, the samples were dried.

The test was conducted at 60°C for 30 minutes, with the rota wash washing machine running at 40 rpm. No steel balls were used during the process. The staining on the multi-fibre fabric and the colour changes on the dyed fabric were evaluated using a grey scale to assess the wash fastness.

2.7.3 Rubbing Fastness Test

The dyed samples were tested for rubbing fastness using ISO 105-X12 standards with a crock meter. Two specimens, one for wet and one for dry testing, were prepared, each measuring 5 cm x 11.5 cm. The samples were securely clamped onto the crock meter, and a cotton rubbing cloth was used for the test. The test involved applying a fixed pressure

and rubbing for 10 cycles. The rubbing test was conducted at room temperature. After the test, the colour change on the samples was assessed using a grey scale to determine the level of staining.

3 RESULTS AND DISCUSSION

3.1 Dye Extraction

A range of purple colours were obtained from the aqueous extract of Bovitiya. Several samples were dipped into the extracted liquors to observe the shades produced by the extract. The deepest shade was observed in the dye liquor extracted at a 1:20 liquor ratio, heated to 90°C for 10 minutes.

3.2 Dyeing Process




Based on the visual assessment of the depth of shade in the dyed samples, the conditions that produced the highest depth of shade were a temperature of 40°C, a heating duration of 15 minutes, and a pH level of 4. These conditions produced better results than the other conditions that were tested.

3.3 Mordanting Process

The optimal conditions identified during the dyeing process were selected to prepare a consistent dye liquor and establish the dyeing conditions for fabric samples that were mordanted using various mordants and mordanting techniques. The colour variations in the samples that were dyed and mordanted were noticeable (Table 5).

Table 5 Samples of dyed fabrics at different mordants and different techniques

Sample number	Sample type	Dyed sample
S ₁	Non-mordanted sample	
S ₂	Pre-mordanting with Bombu	
S ₃	Simultaneously mordanted with Bombu	
S ₄	Post-mordanted with Bombu	
S ₅	Pre-mordanted with Aloe Vera	
S ₆	Simultaneously mordanted with Aloe Vera	

S ₇	Post-mordanted with Aloe Vera	
S ₈	Pre-mordanted with FeSO ₄	
S ₉	Simultaneously mordanted with FeSO ₄	
S ₁₀	Post-mordanted with FeSO ₄	
S ₁₁	Pre-mordanted with CuSO ₄	
S ₁₂	Simultaneously mordanted with CuSO ₄	
S ₁₃	Post-mordanted with CuSO ₄	
S ₁₄	Pre-mordanted with Alum	
S ₁₅	Simultaneously mordanted with Alum	
S ₁₆	Post-mordanted with Alum	

3.4 Colour Fastness Assessment

3.4.1 Lightfastness

The light fastness properties of cotton fabric samples were assessed against the blue wool standard. Test samples S₁, S₂, S₃, S₄, and S₅ exhibited a colour change corresponding to a rating of 1, indicating poor light fastness. Similarly, samples S₆, S₇, S₈, S₉, S₁₀, S₁₄, S₁₅, and S₁₆ showed ratings of 1-2 on the blue wool standard, further confirming poor light fastness. In contrast, test samples S₁₁ and S₁₂ demonstrated good light fastness properties, while sample

S₁₃ exhibited very good light fastness (Table 6). The superior performance of S₁₃ was observed in samples dyed using post-mordanting with copper sulphate (CuSO₄).

Table 6 Light Fastness Test - Greyscale values

Sample number	Sample type	Greyscale value
S ₁	Non mordanted sample	1
S ₂	Pre-mordanting with Bombu	1
S ₃	Simultaneous mordanted with Bombu	1
S ₄	Post-mordanted with Bombu	1
S ₅	Pre-mordanted with Aloe Vera	1
S ₆	Simultaneous mordanted with Aloe Vera	1-2
S ₇	Post-mordanted with Aloe Vera	1-2
S ₈	Pre-mordanted with FeSO ₄	1-2
S ₉	Simultaneous mordanted with FeSO ₄	1-2
S ₁₀	Post-mordanted with FeSO ₄	1-2
S ₁₁	Pre-mordanted with CuSO ₄	3-4
S ₁₂	Simultaneous mordanted with CuSO ₄	3-4
S ₁₃	Post-mordanted with CuSO ₄	4-5
S ₁₄	Pre-mordanted with Alum	1-2
S ₁₅	Simultaneous mordanted with Alum	1-2
S ₁₆	Post-mordanted with Alum	1-2

3.4.2 Washfastness

The wash fastness properties of cotton fabric samples were evaluated using the grey scale for colour change and staining on adjacent fabrics. Samples S₂, S₄, S₆, S₈, S₉, S₁₀, S₁₁, S₁₃, and S₁₄ exhibited very poor wash fastness with colour change values in the 1-2 range, indicating poor performance. Sample S₁₅ also showed a 1-2 colour change value, confirming its low wash fastness properties (Table 7). Overall, the data suggest that the washing fastness was poor across all test samples in terms of colour change.

For staining on adjacent fabrics, most samples received ratings of 4-5, demonstrating relatively good performance in this aspect (Table 7). However, sample S₁ on nylon fabric exhibited staining values of 1-2, indicating significant staining.

Table 7 Wash Fastness Test - Greyscale values

Sample number	Sample type	Greyscale rating for change in colour	Greyscale value for staining on the adjacent fabric				
			Cotton	Nylon	Polyester	Acrylic	Wool
S ₁	Non-mordanted sample	1-2	4-5	1-2	4-5	4-5	4-5
S ₂	Pre-mordanting with Bombu	1	4-5	4-5	4-5	4-5	4-5
S ₃	Simultaneously mordanted with Bombu	1-2	4-5	4-5	4-5	4-5	4-5
S ₄	Post-mordanted with Bombu	1	4-5	4-5	4-5	4-5	4-5
S ₅	Pre-mordanted with Aloe Vera	1-2	4-5	4-5	4-5	4-5	4-5
S ₆	Simultaneously mordanted with Aloe Vera	1	4-5	4-5	4-5	4-5	4-5
S ₇	Post-mordanted with Aloe Vera	1-2	4-5	4-5	4-5	4-5	4-5
S ₈	Pre-mordanted with FeSO ₄	1	4-5	4-5	4-5	4-5	4-5
S ₉	Simultaneously mordanted with FeSO ₄	1	4-5	4-5	4-5	4-5	4-5
S ₁₀	Post-mordanted with FeSO ₄	1	4-5	4-5	4-5	4-5	4-5
S ₁₁	Pre-mordanted with CuSO ₄	1	4-5	4-5	4-5	4-5	4-5
S ₁₂	Simultaneous mordanted with CuSO ₄	1-2	4-5	4-5	4-5	4-5	4-5
S ₁₃	Post-mordanted with CuSO ₄	1	4-5	4-5	4-5	4-5	4-5
S ₁₄	Pre-mordanted with Alum	1	4-5	4-5	4-5	4-5	4-5
S ₁₅	Simultaneous mordanted with Alum	2-3	4-5	4-5	4-5	4-5	4-5

S ₁₆	Post-mordanted with Alum	1-2	4-5	4-5	4-5	4-5	4-5
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3.4.3 Rubbing Fastness

The results of the rubbing fastness tests, conducted under both dry and wet conditions, revealed that all samples exhibited excellent dry rubbing fastness with ratings of 4-5. However, variations were observed in wet rubbing fastness. Samples S₁₁ and S₁₂ displayed a poor performance with a rating of 1, while sample S₇ had a slightly better but still poor rating of 1-2. Samples S₁, S₅, S₆, S₁₃, and S₁₅ exhibited moderately low ratings of 2-3, indicating poor wet rubbing fastness. Sample S₁₀ had a rating of 3, while samples S₂, S₃, S₄, S₁₄, and S₁₆ demonstrated good wet rubbing fastness with ratings of 4. Samples S₈ and S₉ showed very good wet rubbing fastness (Table 8).

It was observed that pre-mordanting and simultaneous mordanting with FeSO₄ significantly improved the performance in wet rubbing tests. Additionally, the use of Bombu as a mordant yielded excellent results, achieving consistent dry and wet rubbing fastness ratings of 4-5.

Table 8 Rubbing Fastness Test – Greyscale values

Sample number	Sample type	Greyscale value	
		Wet	Dry
S ₁	Non-mordanted sample	2-3	4-5
S ₂	Pre-mordanting with Bombu	4	4-5
S ₃	Simultaneously mordanted with Bombu	4	4-5
S ₄	Post-mordanted with Bombu	4	4-5
S ₅	Pre-mordanted with Aloe Vera	2-3	4-5
S ₆	Simultaneously mordanted with Aloe Vera	2-3	4-5
S ₇	Post-mordanted with Aloe Vera	1-2	4-5
S ₈	Pre-mordanted with FeSO ₄	4-5	4-5
S ₉	Simultaneously mordanted with FeSO ₄	4-5	4-5
S ₁₀	Post-mordanted with FeSO ₄	3	4-5
S ₁₁	Pre-mordanted with CuSO ₄	1	4-5
S ₁₂	Simultaneously mordanted with CuSO ₄	1	4-5
S ₁₃	Post-mordanted with CuSO ₄	2-3	4-5
S ₁₄	Pre-mordanted with Alum	4	4-5
S ₁₅	Simultaneously mordanted with Alum	2-3	4-5
S ₁₆	Post-mordanted with Alum	4	4-5

4 CONCLUSIONS AND RECOMMENDATIONS

The study investigated the potential of Bovitiya fruit (*Melastoma polyanthum*) as a natural dye and Bombu (*Symplocos cochinchinensis*) as a natural mordant for dyeing cotton fabric, emphasizing their environmental benefits over synthetic alternatives. The deepest shade was observed in the dye liquor extracted at a 1:20 liquor ratio, heated to 90°C for 10 minutes by visual observation. The lowest shade was observed in the dye liquor extracted at a 1:100 liquor ratio, heated to 90°C for 10 minutes. Optimal dyeing conditions were identified, with the cotton samples dyed at 40°C for 15 minutes under a 1:20 material-to-liquor ratio and mordanting achieved at 90°C for 30 minutes.

The fastness properties were thoroughly evaluated. Washing fastness showed significant variations, with most samples achieving 4–5 ratings on the grey scale for staining adjacent fabrics. Light fastness values varied with improved performance observed for post-mordanting with copper sulphate (4–5 on the grey scale). Rubbing fastness results were excellent, with dry rubbing scoring 4–5 across all samples and wet rubbing also demonstrating robust performance for samples treated with Bombu mordant.

Based on the test results, cotton fabric dyed with Bovitiya fruit extract and mordanted with Bombu demonstrates promising qualities for specific applications. While the fabrics exhibit excellent rubbing fastness, their poor wash fastness and light fastness properties suggest they are unsuitable for garments exposed to frequent washing or direct sunlight. However, their durability in terms of rubbing fastness makes them ideal for indoor applications where exposure to light and washing is minimal.

Recommended uses include furniture coverings, floor carpets and decorative mats, where aesthetic appeal and environmental sustainability are prioritized over frequent washing and prolonged light exposure. Further research could focus on enhancing wash and light fastness through mordant optimization or the use of UV stabilizers to expand potential applications.

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