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# Eco-Friendly Novel Colours For Cotton Fabric Using Organic Mordant

[1]Rubasri G, [2]Dr S. Lakshmi Manokari,

[1] Ph.D. Scholar, [2]Professor and Head,

[1]Department of Textiles and Apparel Design,
[1]Periyar University, Salem, India

*Abstract:* The growing international awareness of environmental pollution caused by synthetic dyes has promoted the need for green and sustainable substitutes. The present research work deals with the utilisation of natural dyes extracted from turmeric, butterfly peas, and onion peel. For colouration and application on cotton fabric with tannin-based natural mordant such as myrobalan and amalats were used. The dyeing was performed under pre- and post-mordanting conditions at 100°C in relation to the material-to-liquor ratio (1:30). Physical and colour fastness of the dyed samples were examined. The weight has moderately increased without affecting the thickness of the fabric, indicating an enhanced ability to absorb dyes. Among the tested single and double dyeing with mordants, the dyed samples show better fastness to laundering and rubbing. In daylight exposure, the strength of the double-dyeing is moderated. The colour difference between the single and double dyeing with mordanted samples was evaluated using a colorimeter value for both cold washing and hot washing, determining delta E values. The investigation suggests that onion skin, butterfly pea, and turmeric, combined with natural mordant, are an efficient and environmentally beneficial method for textile dyeing. As a result, the current study describes the resurgence of traditional dyeing methods in environmentally responsible textile industries to replace synthetic dyes.

***Keywords:*** Natural mordants, Cotton dyeing, Eco-friendly process, Colour fastness, Sustainable textiles.

## I. INTRODUCTION

The environmental problems associated with textile wet processing have gained a lot of attention lately. The pollution control legislation is now being enforced more strictly by the pollution control board. The textile sector is under a lot of environmental strain because of this procedure. The whole "fall" of natural dyes appears to have been saved by global environmental consciousness. Environmentalists have been compelled to consider natural products due to the dangers posed by the chemical industry and dyes. Consumer interest in textiles made from natural fibers dyed with eco-friendly natural dyes has increased due to growing global awareness of eco-friendly products in daily life.

Natural and synthetic dyes are the two primary types of dyes used in textile dyeing. Synthetic colours made from coal tar and petroleum are used for their vivid hues, stable quality, ease of application, and affordability. However, concerns about the potential risks of synthetic dyes persist, so natural sources like plant roots, stems, leaves, flowers, fruits, animals, and ores are used due to their biodegradability, gentle effect on the skin, and possible health benefits for the wearer. Organic colours extracted from plants are safer and better for young children because of their medicinal properties, which do not contain carcinogenic or dangerous compounds like synthetic dyes.

Food colouring may be created from a wide variety of plant species. One of these is the butterfly pea, also known as Clitoria ternatea. It has white, blue, or purple blooms. In Malaysia, sticky rice is coloured using the butterfly pea bloom's blue hue. Additionally, Kerala, India, and the Philippines each use flowers as veggies. The ternatin-like substance anthocyanin is what gives the butterfly pea blossom its blue colour. Turpentine is used for its anti-inflammatory properties as well as for other health benefits, such as weight loss. A common component of numerous herbal teas, mixed drinks, and cosmetic items is the butterfly pea flower. It is high in antioxidants and may provide several health advantages, including better blood sugar regulation, increased weight loss, and better hair and skin health.

Asian nations frequently utilize the culinary spice turmeric, Curcuma domestica Valeton. It is a member of the family Zingiberaceae. Since ancient times, turmeric's subterranean stems and tuberous rhizomes have been utilized as food, colour, and an aromatic stimulant in many remedies. Turmeric is cultivated in Sri Lanka as well and is a very important spice in India. It has a long history of usage in Ayurveda, an ancient Indian medical practice.

Allium cepa, often known as bulb onions, is a vegetable that is widely cultivated all over the world and is used in culinary preparation. Food-grade onions contain 89 percent water, 4 percent sugar, 1 percent protein, and 2 percent fibre. Additionally, onions include vitamins like Vitamin B1, Vitamin B2, Vitamin B3, and Vitamin C as well as minerals like Iron, Calcium, Magnesium, Manganese, and Zinc. Additionally, they contain compounds like flavonoids and phenols.

Cassia fistula Linn, commonly known as the golden shower tree, is a member of the Caesalpiniaceae family and is extensively recognised for its medicinal properties. The primary characteristic of this product is its effectiveness as a gentle laxative, appropriate for both children and expectant mothers. This tree is grown as an ornamental specimen due to its attractive yellow flowers that bloom in pendant racemes across various regions in India. The pharmacological activities include antimicrobial, antifungal, antipyretic, analgesic, larvicidal, anti-inflammatory, antioxidant, anti-tumour, hepatoprotective, and hypoglycemic properties. Cassia fistula is a flowering plant that belongs to the subfamily Caesalpiniaceae within the leguminous family (Fabaceae) and is commonly known as Amaltas.

Myrobalan (Terminalia cheubula Retz) is a medicinal plant belonging to the Combretaceae family used in Ayurvedic and Thai traditional medicine for wound healing, skin disease treatment, act as a laxative and cardiotonic agent. Gallic and ellagic acids are phenolic compounds that occur in the fruit. It can be prepared with water, alcohol, or low-boiling-point solvents. It has approximately 30–45% tannins in the nut. It used to get a dye uptake from the fabric.

## II. MATERIALS

In this research, 100% cotton fabric has been used due to its absorptive properties, comfort, and compatibility with natural dyes. Cotton cloth procured from Erode (Tamil Nadu) was used for dyeing. The selected natural source for dye is butterfly pea, turmeric
and onion skin. Cassia fistula (Amaltas) bark, and myrobalan (Terminalia chebula) were selected due to their high tannin content and for their ability to yield warm, soft shades on cotton. These substances have been chosen based on their environmentally benign, cost-effective and suitably sustainable coloration accomplishment on the cotton fabric.

## III. METHODS

The experimental procedure consisted of pretreatment, dyeing, mordanting and testing. In pretreatment the cotton fabric was desized (to remove natural impurities, waxes & oils, etc.) and scoured for 30 minutes, then the fabric was brought to boiling water to ensure complete removal of impurities to improve the fabric's absorbency. Single and double dyeing methods were adopted for the dye extraction from onion skin, butterfly pea, and turmeric. For onion skin, amalatas mordant was used as one combination; in the second combination, onion skin was used with myrobalan mordant in single dyeing. For the double dyeing, turmeric and onion skin were used with myrobalan mordant, and butterfly pea and turmeric were used with myrobalan mordant. The butterfly pea, turmeric, and onion skin were shade-dried and powdered. 20% dye powder and mordant were taken on the weight of the fabric. The dye powder was boiled with water at 100ºC for 60 min. The resulting filtrate was treated as a dye bath. For the pre-mordanting process, cotton fabric was mordanted first in a mordant solution and then dyed, while post-mordanting refers to dyeing the fabric with dye and then mordanting. The samples were washed twice in cold water and dried in the shade after dyeing. Finally, the dyed fabrics were evaluated for their physical properties, colour fastness, and colorimetric characteristics to understand the dyeing performances and durability of the dyes.

### 3.1 QUALITY ANALYSIS

A physical test of the dyed sample is an essential criterion for quality measures. With and without mordant-dyed fabrics were tested for physical properties such as, fabric weight, fabric thickness and tearing strength.

#### 3.1.1 Fabric Weight:

The GSM testing is used for determining the weight per square meter of the fabric. The GSM cutter is used to cut a circular sample, which is then weighed using a precision digital balance, and the weight is recorded in grams. The formula GSM=Weight (grams)/Area ($m^2$) is applied to convert the sample into square meters.

#### 3.1.2 Fabric Thickness:

The thickness of woven fabrics was determined by a thickness tester. The dyed samples were cut into 10 cm radius circles free from folds, creases, or wrinkles. With the dial needle positioned at zero, the specimen is placed under the pressure foot with reference to ASTM D 1777. A pressure weight of 4.14 kPa was applied to the specimen, and thickness readings were noted with the dial gauge in millimeters. The process was repeated 10 times to identify the average of the fabric thickness.

#### 3.1.3 Tearing Strength

The term "tearing of the fabric" refers to the required force that initiates the tear. The tearing strength of the fabric is measured in both directions (warp and weft) separately. In this research the falling pendulum type tester method is used; the tester includes a stationary clamp, a clamp carried on a pendulum that is free to swing on a bearing, a mechanism to level, hold and then instantly release the pendulum to measure the force. The test specimen with a precut central slit is held between two clamps, and it is torn through a fixed distance.

### 3.2 Colour Fastness Test

To measure the withstand property of the dye pigment and the fastness of its shade. The following test methods have been used.

1. Colour Fastness to Washing
2. Colour Fastness to Rubbing
3. Colour Fastness to Daylight

### 3.2.1 Colour Fastness to Laundering:

Standard: AATCC Method: AATCC 61

The colour fastness to laundering is tested according to the standard, which evaluates resistance to laundering with a detergent solution for 45 minutes, simulating the effect of five hand or home launderings. The AATCC test method 61, which assesses colourfastness includes five subtest options: 1A, 2A, 3A, 4A, and 5A. In this research, 1A is selected for laundering.

| SAMPLE | SPECIMEN SIZE (cm) | MLR (ml) | TEMPERATURE | DETERGENT LIQUID (ml) | TIME |
|---|---|---|---|---|---|
| 1A | 10×4 | 200 | 40℃ | 0.56 | 45 mins |

### 3.2.2 Colour Fastness to Crocking:

Standard: AATCC Method: AATCC 8.

A crock meter determines the colour fastness of textiles like wool, silk, cotton, etc., against rubbing under wet and dry conditions. A dyed fabric specimen measuring 50 mm by 130 mm was placed without any creases or wrinkles on the emery surface. Thereafter, the crocking cloth (white bleached cloth of 5*5 cm), both in wet and dry conditions, was placed on the surface of the finger by using a spring clip. The traverse process begins with preselected strokes at the rate of 10 strokes per 10 seconds. Once the traverse was completed, the crocking cloth was removed from the finger. The amount of colour transferred from the specimen to the crock cloth in both wet and dry conditions was assessed visually in comparison with the grey scale.

### 3.2.3 Colour Fastness to Light: Outdoor

Colour fastness to light outdoors determines how much the colour will fade when exposed to sunlight. The sample is exposed to direct sunlight in a glass cabinet tilted at a 45° angle. The sample is moved to the side that receives sunlight from morning to afternoon and from afternoon to evening for 3 days to cover 24 hours.

### 3.3 Colorimetric Analysis

The ColorFlex EZ spectrophotometer is used to display results in globally recognized colour spaces like CIE L*a*b* or Hunter Lab, which use numeric values to define colour. In this context, L* represents lightness (0=black, 100=white), a* indicates the green-red axis (where a negative value signifies green and a positive value signifies red), and b* denotes the blue-yellow axis (with negative values representing blue and positive values representing yellow). These values can provide measurements for colour control in production environments, which is useful for calculating the total colour difference (ΔE) between samples in applications such as food, textiles, or plastics.

## IV. RESULTS AND DISCUSSION

The physical and colour fastness of cotton fabric dyed with butterfly pea, turmeric and onionskin using natural mordants was investigated. The results are presented below.

### 4.1 PHYSICAL PROPERTIES

The results of physical tests such as fabric thickness, fabric weight, and tearing strength are discussed below.

### 4.1.1 NOMENCLATURE

The nomenclature for the dyed samples is given in Table 4.1.1.

Table 4.1.1 Nomenclature

| S.NO | Dyeing methods | Name of the samples | Nomenclature of the sample |
|---|---|---|---|
| 1. | Single dyeing | Onion Skin Dyed with Amaltas | OSA |
| 2. | | Onion Skin Dyed with Myrobalan | OSM |
| 3. | Double dyeing | Butterfly Pea, Turmeric Dyed with Myrobalan | BTM |
| 4. | | Turmeric, Onion Skin Dyed with Myrobalan | TOM |
| 5. | Wash type | Cold wash (1st, 2nd and 3rd washes) | C1, C2 and C3 |
| 6. | | Hot wash (1st, 2nd and 3rd washes) | H1, H2 and H3 |

### 4.1.2 FABRIC WEIGHT

Table 4.1.2 Fabric Weight

| S.No. | Samples | Mean Weight Value (GSM) | Gain (GSM) | % Gain |
|---|---|---|---|---|
| 1. | CONTROL | 210 | - | - |
| 2. | OSA | 249 | 39 | 18.6 |
| 3. | OSM | 268 | 58 | 27.6 |
| 4. | BTM | 248 | 38 | 18.1 |
| 5. | TOM | 249 | 39 | 18.6 |

Table 4.1.2 shows that the fabric weight was moderately increased from 18.1% to 27.6% after dyeing which may be due to dyeing and mordant absorption on the fabric.

### 4.1.3 FABRIC THICKNESS

Table 4.1.3 Fabric Thickness

| S.No. | Samples | Mean Thickness Value (mm) | Gain (mm) | % Gain |
|---|---|---|---|---|
| 1. | CONTROL | 0.30 | - | - |
| 2. | OSA | 0.30 | - | - |
| 3. | OSM | 0.30 | - | - |
| 4. | BTM | 0.30 | - | - |
| 5. | TOM | 0.30 | - | - |

Table 4.1.3 shows that the thickness of all the samples has not changed after single and double dyeing.

### 4.1.4 TEARING STRENGTH

Table 4.1.4 Tearing Strength

| S.NO | Sample | Warp (mm) | Loss in Warp direction (mm) | % Loss in warp direction | Weft (mm) | Loss in Weft direction (mm) | % Loss in weft direction |
|---|---|---|---|---|---|---|---|
| 1. | CONTROL | 37 | - | - | 28 | - | - |
| 2. | OSA | 34 | -3 | 8.10 | 23 | -5 | 17.8 |
| 3. | OSM | 34 | -3 | 8.10 | 27 | -5 | 17.8 |
| 4. | BTM | 35 | -2 | 5.40 | 23 | -1 | 3.57 |
| 5. | TOM | 35 | -2 | 5.40 | 27 | -1 | 3.57 |

Table 4.1.4 shows that the tearing strength in the warp and weft direction is decreased from 5.40% to 8.10% (warp) and 3.57% to 17.8% (weft), indicating a moderate reduction in fabric tearing strength after the double dyeing process.

### 4.2 COLOUR FASTNESS:

Colour fastness is a characteristic of the dyed material, rated by the grey scale using the AATCC standard. The greyscale has the 9 possible values: 5, 4–5, 4, 3–4, 3, 2–3, 2, 1–2, and 1. The result of any colour fastness test is a grade given to the tested sample. Grade 5 - No Change, Grade 4 - Slight Change, Grade 3 - Noticeable Change, Grade 2 - Considerable Change, Grade 1 - Severe Change.

Table 4.2.1: Colour Fastness to Laundering.

| **Samples** | **C1** | **C2** | **C3** | **H1** | **H2** | **H3** |
|---|---|---|---|---|---|---|
| OSA | 4-5 | 4-5 | 4 | 4-5 | 3-4 | 3-4 |
| OSM | 4-5 | 4-5 | 4 | 4-5 | 4 | 3-4 |
| BTM | 4-5 | 4-5 | 4-5 | 4-5 | 4 | 3-4 |
| TOM | 4-5 | 4 | 4 | 4-5 | 3-4 | 3-4 |

From Table 4.2.1, the colour fastness to laundering clearly indicates that the samples withstand colour on the fabric after cold washes compared to hot washes.

Table 4.2.2: Colour Fastness to Rubbing

| **Samples** | **Dry rubbing** | **Wet rubbing** |
|---|---|---|
| OSA | 5 | 4 |
| OSM | 5 | 4.5 |
| BTM | 5 | 4.5 |
| TOM | 5 | 4.5 |

Table 4.2.2 shows the colour fastness to rubbing of the dyed fabric with single and double dyeing. The dyed samples with BTM (butterfly pea dyed with myrobalan), TOM (turmeric & onion skin dyed with myrobalan) and OSM (onion skin dyed with myrobalan) were found to have good colourfastness, followed by OSA (onion skin dyed with amaltas).

Table 4.2.3: Colour Fastness to Daylight

| Samples | Before | Daylight fastness |
|---|---|---|
| OSA | 5 | 4 |
| OSM | 5 | 4 |
| BTM | 5 | 4.5 |
| TOM | 5 | 4.5 |

Table 4.2.3 shows the colour fastness to daylight of the dyed fabric, comparing single dyeing with mordant to double dyeing with mordant. The double dye with mordant has good daylight fastness.

## 4.3 COLORIMETRIC EVALUATION: INSTRUMENTAL ASSESSMENT OF COLOUR CHANGE

Table 4.3.1 Onion Skin Dyed with Amaltas

| Wash | L* | | △L | a* | | △a | b* | | △b | △E | Colour fastness grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S | | C | S | | C | S | | | |
| C1 | 33.52 | 36.78 | 3.26 | 15.25 | 11.32 | -3.93 | 17.99 | 12.46 | -5.53 | 7.53 | 1-2 |
| C2 | 33.52 | 43.3 | 7.78 | 15.25 | 11.92 | -3.33 | 17.99 | 14.18 | -3.81 | 11.01 | 1-2 |
| C3 | 33.52 | 44.72 | 11.2 | 15.25 | 12.09 | -3.16 | 17.99 | 14.58 | -3.41 | 12.13 | 1-2 |
| H1 | 33.52 | 42.8 | 9.28 | 15.25 | 13.76 | 1.49 | 17.99 | 15.14 | 2.85 | 9.82 | 1-2 |
| H2 | 33.52 | 40.82 | 7.3 | 15.25 | 14.22 | 1.03 | 17.99 | 27.52 | 9.53 | 12.05 | 1-2 |
| H3 | 33.52 | 39.89 | 6.37 | 15.25 | 3.97 | -11.28 | 17.99 | 15.75 | -2.24 | 13.15 | 1 |

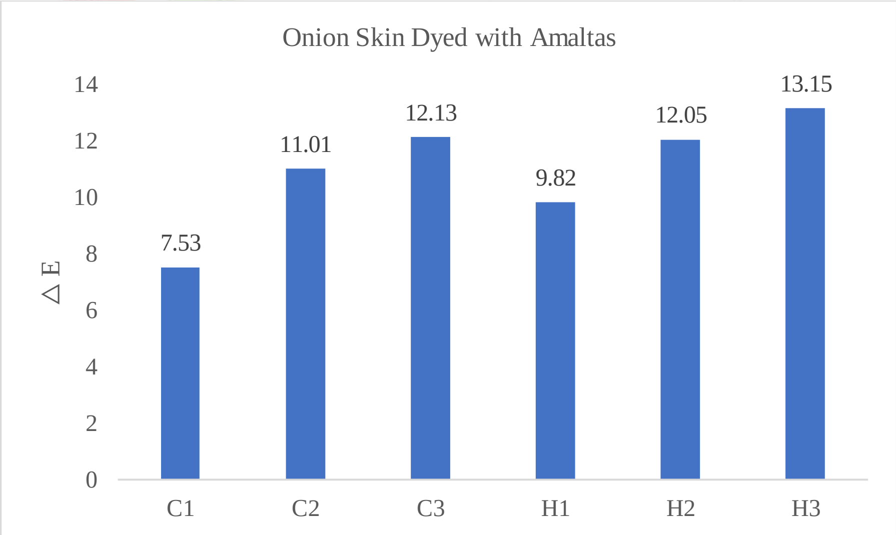


Figure 4.3.1 Onion Skin Dyed with Amaltas

In Figure 4.3.1, the △E value increased in both cold & hot washes, indicating colour difference after each wash, retaining a 1 to 2 colour fastness grade in all washes except in the 3rd hot wash.

Table 4.3.2 Onion Skin Dyed with Myrobalan

| Wash | L* | | △L | a* | | △a | b* | | △b | △E | Colour fastness grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S | | C | S | | C | S | | | |
| C1 | 50.4 | 48.21 | -2.19 | 9.68 | 8.69 | -0.99 | 22.24 | 24.1 | 1.86 | 3.04 | 3-4 |
| C2 | 50.4 | 48.52 | -1.88 | 9.68 | 8.56 | -1.12 | 22.24 | 24.56 | 2.32 | 3.19 | 3-4 |
| C3 | 50.4 | 48.04 | -2.36 | 9.68 | 8.36 | -1.32 | 22.24 | 23.87 | 1.63 | 3.16 | 3-4 |
| H1 | 50.4 | 50.52 | 0.12 | 9.68 | 8.35 | -1.33 | 22.24 | 25.31 | 3.07 | 3.35 | 3-4 |
| H2 | 50.4 | 49.02 | -1.38 | 9.68 | 8.44 | -1.24 | 22.24 | 25.12 | 2.88 | 3.18 | 3-4 |
| H3 | 50.4 | 48.41 | 1.99 | 9.68 | 7.39 | 2.29 | 22.24 | 21.68 | 0.56 | 3.09 | 3-4 |

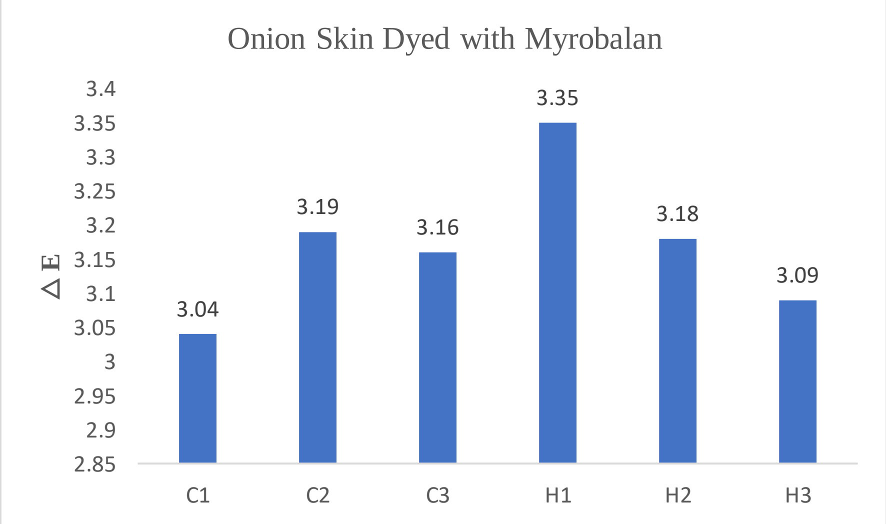


Figure 4.3.2 Onion Skin Dyed with Myrobalan

Figure 4.3.2 shows that the myrobalan mordanted with onion skin sample indicates minimum differences in △E value in 3 hot and cold washes. The colour grade is 3-4 with good fastness in both cold & hot washes.

Table 4.3.3 Butterfly Pea, Turmeric Dyed with Myrobalan

| Wash | L* | | △L | a* | | △a | b* | | △b | △E | Colour fastness grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S | | C | S | | C | S | | | |
| C1 | 57.97 | 53.18 | -4.79 | 1.623 | 3.31 | 1.687 | 37.23 | 36.61 | -0.62 | 5.12 | 2 |
| C2 | 57.97 | 56.29 | -1.68 | 1.623 | 2.9 | 1.277 | 37.23 | 32.17 | -5.06 | 5.48 | 2 |
| C3 | 57.97 | 56.08 | -1.89 | 1.623 | 2.33 | 0.707 | 37.23 | 33.99 | -3.24 | 3.82 | 2-3 |
| H1 | 57.97 | 54.39 | -3.58 | 1.623 | 4.78 | 3.157 | 37.23 | 30.11 | -7.12 | 8.57 | 1-2 |
| H2 | 57.97 | 52.88 | -5.09 | 1.623 | 4.17 | 2.547 | 37.23 | 24.98 | -12.25 | 13.51 | 1 |
| H3 | 57.97 | 54.79 | 3.18 | 1.623 | 3.54 | -1.91 | 37.23 | 22.33 | 14.893 | 15.35 | 1 |

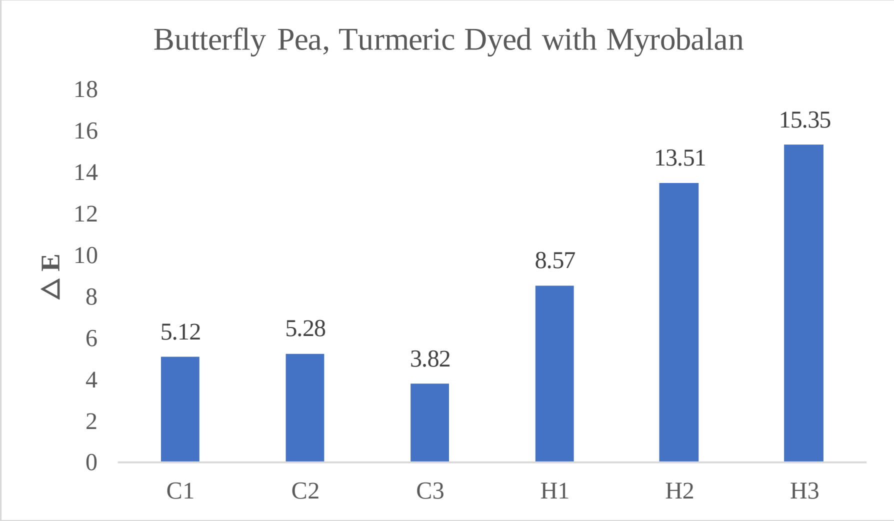


Figure 4.3.3 Butterfly Pea, Turmeric Dyed with Myrobalan

Figure 4.3.3 shows that the △E value is comparatively high in hot wash compared to cold wash, with a fall of colourfastness grade from 2 to 1.

Table 4.3.4 Turmeric, Onion Skin Dyed with Myrobalan

| **Wash** | **L*** | | **△L** | **a*** | | **△a** | **b*** | | **△b** | **△E** | **Colour fastness grade** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S | | C | S | | C | S | | | |
| C1 | 52.62 | 53.99 | 1.37 | 4.88 | 4.60 | -0.28 | 3.24 | 29.89 | -1.35 | 26.69 | 1 |
| C2 | 52.62 | 50.89 | -1.73 | 4.88 | 4.08 | -0.8 | 3.24 | 27.73 | -3.51 | 24.56 | 1 |
| C3 | 52.62 | 54.52 | 1.9 | 4.88 | 3.00 | -1.88 | 3.24 | 27.27 | -3.97 | 24.18 | 1 |
| H1 | 52.62 | 56.36 | 3.74 | 4.88 | 5.06 | 0.2 | 3.24 | 22.76 | -8.48 | 19.88 | 1 |
| H2 | 52.62 | 56.96 | 4.34 | 4.88 | 4.23 | -0.65 | 3.24 | 19.18 | -12.06 | 16.53 | 1 |
| H3 | 52.62 | 59.04 | 6.42 | 4.88 | 3.56 | 1.32 | 3.24 | 17.2 | 14.04 | 15.42 | 1 |

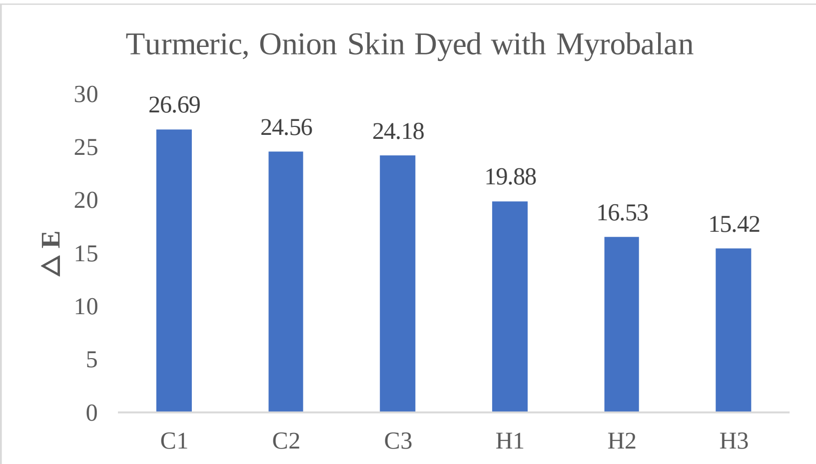


Figure 4.3.4 Turmeric, Onion Skin Dyed with Myrobalan

Figure 4.3.4 shows that the △E value for both hot & cold washes indicate progressive changes. Compared to hot washing, cold washing shows a high fade.

## V. FINDING OF THE STUDY:

Natural dyeing and mordanting resulted in an increase in fabric weight (18.1–27.6%), which can be attributed to the absorption of dye and mordant. No change was observed in fabric thickness for either single or double dyeing. Tear strength declined moderately by 5.40–8.10% in the warp direction and 3.57–17.8% in the weft direction, suggesting that the processing induced stress on the yarn, especially in single-dyed samples.

Colour fastness tests indicated that the dyed fabrics exhibited good resistance to laundering, with only slight fading. Laundering performance was superior to that under hot and cold wash conditions. Rubbing fastness was highest for the Butterfly pea, turmeric dyed with Myrobalan(BTM), Turmeric, onion skin dyed with myrobalan (TOM), and Onion skin dyed with myrobalan(OSM). Light fastness was better in double-dyed mordant samples, indicating a higher degree of resistance to fading from light exposure.

ΔE values increased after both cold and hot washing, reflecting gradual colour changes. Fading was more pronounced after hot washing (moderate to slight change). Among the samples, onion skin dyed with myrobalan mordant (OSM) had low ΔE values and maintained a colour fastness grade of 3–4, demonstrating promising durability and fastness for naturally dyed fabrics.

## VI. SUMMARY AND CONCLUSION:

This study confirms that natural dyeing with appropriate mordants leads to a moderate increase in fabric weight due to effective dye and mordant uptake, without causing any significant change in fabric thickness. Although a moderate reduction in tearing strength was observed, more pronounced in the weft direction, the overall mechanical performance of the fabric remained acceptable for practical use. The dyed fabrics exhibited good colour fastness to laundering and rubbing, with only slight colour changes, indicating stable dye fixation. Double dyeing with mordant enhanced daylight fastness, demonstrating improved resistance to light-induced fading. Colorimetric analysis showed that ΔE values increased after both cold and hot washes, with hot washes causing more severe fading than cold washes; however, the overall colour fastness grade remained at an acceptable level (3–4). Among all samples, onion skin dyed with myrobalan mordant (OSM) showed good durability and fastness, highlighting the effectiveness of natural dyes and mordants in producing sustainable textiles with satisfactory physical and colour fastness properties.

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