Eco-Printing on Textile Materials Using Eucalyptus Globulus Leaves: A Sustainable Botanical Printing Approach

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Abstract
Eco-printing, also known as botanical contact printing, is an environmentally sustainable textile printing technique that utilizes natural pigments present in plant materials to create unique surface designs on fabrics. The present study investigates the application of eco-printing using discarded leaves of Eucalyptus globulus on three textile substrates—khadi cotton, rayon, and mulberry silk. Iron rust solution and vinegar were employed as mordants to enhance dye fixation and color development. The bind-and-steam technique was adopted, with controlled steaming durations based on fiber type. Visual assessment revealed superior print clarity and color intensity on khadi cotton, followed by rayon and mulberry silk. The study demonstrates that eucalyptus leaves, often treated as waste, possess significant potential for sustainable textile printing, supporting eco-friendly fashion and circular material utilization.

Keywords: Eco-printing, Botanical printing, Eucalyptus globulus, Natural dyes, Sustainable textiles, Mordanting

1. Introduction

The contemporary textile and fashion industry is undergoing a significant paradigm shift toward sustainability in response to escalating environmental concerns related to the extensive use of synthetic dyes, toxic chemical effluents, and high water and energy consumption (Fletcher, 2014; Shukla & Vankar, 2017). Clothing not only fulfills the fundamental human requirement of protection but also serves as a powerful medium of cultural identity, aesthetic expression, and socio-economic representation. Conventional textile printing techniques such as batik, screen printing, and stencil printing predominantly depend on petrochemical-based colorants and auxiliaries, which are associated with ecological degradation, occupational health risks, and persistent water pollution (Bechtold & Mussak, 2009).

Eco-printing, also known as botanical contact printing, has emerged as a promising sustainable alternative within textile surface design. This technique enables the direct transfer of natural pigments from plant materials—such as leaves, flowers, stems, and bark—onto textile substrates through the combined action of heat and pressure, thereby eliminating the need for synthetic dyes and complex extraction processes (Kadolph, 2010). Unlike conventional dyeing, eco-printing promotes in-situ pigment migration from botanical sources to fabric surfaces, resulting in minimal chemical usage, reduced wastewater generation, and lower environmental impact (Hwang et al., 2020). Among various botanical resources, Eucalyptus globulus leaves are abundantly available and frequently discarded despite their high content of tannins and natural pigments. The present research investigates the application of eucalyptus leaves in eco-printing across different fiber types to support sustainable textile practices and waste valorization.

2. Materials and Methods

2.1 Fabric Selection

Three textile substrates representing distinct fiber categories were selected to evaluate the influence of fiber chemistry and structure on the eco-printing performance of Eucalyptus globulus leaves. Khadi cotton (KC-01-25), a hand-spun and hand-woven cellulosic fabric, was chosen due to its high porosity, surface roughness, and superior absorbency, which are favorable for natural pigment uptake. Rayon (RC-02-25), a regenerated cellulosic fiber, was included to assess pigment transfer behavior in semi-synthetic textiles with smoother surfaces and uniform fiber morphology. Mulberry silk (MS-03-25), a protein-based natural fiber, was selected to examine the interaction of botanical pigments with amino acid functional groups present in proteinaceous substrates.

All fabric samples were cut into A3 dimensions to maintain uniform surface area and ensure consistency during scouring, mordanting, and printing processes. The selection of these three fabrics enabled a comparative evaluation of eco-printing efficiency across cellulosic, regenerated cellulosic, and protein fibers.

Table 1. Fabric types, sample codes, and fiber nature used for eco-printing experiments

S. No.	Fabric Type	Fabric Code	Fiber Nature
1	Khadi Cotton	KC-01-25	Cellulosic
2	Rayon	RC-02-25	Regenerated cellulosic
3	Mulberry Silk	MS-03-25	Protein

2.2 Plant Material

Fresh leaves of Eucalyptus globulus were collected, washed thoroughly with water to remove surface contaminants, and used immediately for printing. The study aimed to valorize discarded eucalyptus leaves by utilizing their inherent pigment properties for textile applications.

2.3 Mordants

Iron rust solution and vinegar were used as mordants. Iron acts as a metallic mordant forming coordination complexes with plant polyphenols and fiber functional groups, while vinegar functions as a mild acidic modifier enhancing pigment fixation. Both mordants are economical, easily accessible, and environmentally safer compared to synthetic alternatives.

3. Experimental Procedure

3.1 Scouring

All fabric samples were scoured overnight using a soda ash-based detergent solution to remove sizing agents, oils, and impurities. After rinsing and shade drying, fabric weights were recorded:

- Khadi cotton (KC-01-25): 50 g
- Rayon (RC-02-25): 50 g
- Mulberry silk (MS-03-25): 30 g

3.2 Material-to-Liquor Ratio (MLR) Calculation

A standard MLR of 1:50 was maintained for mordant preparation. Mordant concentration was calculated as 20% of the fabric weight to ensure effective pigment fixation and improved color fastness.

3.3 Mordanting

The scoured fabrics were soaked in iron rust solution with vinegar for 24 hours at room temperature. Post-mordanting, samples were shade-dried to preserve fiber integrity and prepare them for printing.

3.4 Printing Process

Washed eucalyptus leaves were arranged on the mordanted fabric surface with the adaxial (upper) leaf surface in contact with the fabric. Butter paper was placed over the arrangement to prevent leaf displacement during rolling.

3.5 Binding

The layered fabric was tightly wrapped around an iron rod and secured with cotton thread to ensure uniform pressure and pigment transfer during steaming.

3.6 Steaming

Steaming was carried out in a stainless-steel steamer using a stand to avoid direct water contact. Steaming durations were optimized based on fiber type:

- Khadi cotton (KC-01-25): 90 minutes
- Rayon (RC-02-25): 90 minutes
- Mulberry silk (MS-03-25): 60 minutes

3.7 Removal of Plant Residues

After steaming, fabric bundles were allowed to cool and partially dry at room temperature. Subsequently, the bundles were opened, and plant residues and butter paper were removed.

3.8 Drying

Printed fabrics were air-dried under shade for 30 minutes to stabilize the prints and prevent oxidation-related color changes.

4. Testing Standards Applied

The printed textile samples were evaluated using standard qualitative and performance assessment parameters commonly employed in studies on natural dyeing and eco-printing. Visual assessment was conducted to examine print clarity, sharpness, and the degree of botanical detail transferred from Eucalyptus globulus leaves onto the fabric surface, as visual aesthetics remain a primary criterion in textile surface design (Kadolph, 2010). Fabric absorbency was assessed to understand the influence of fiber structure and surface characteristics on pigment uptake, as absorbency plays a crucial role in determining print uniformity and depth of color (Bechtold & Mussak, 2009).

Wash fastness was evaluated through hand washing using a mild, non-ionic detergent to simulate domestic laundering conditions and to observe pigment fixation and resistance to color loss, which is particularly significant for naturally dyed and printed textiles (ISO 105-C10). Additionally, color retention was visually observed after washing and drying to assess the stability of the botanical pigments and the effectiveness of the mordanting process (Shukla & Vankar, 2017). These testing parameters collectively provided a comprehensive assessment of the functional and aesthetic performance of the eco-printed fabrics.

5. Results and Discussion

The eco-printed textile samples exhibited distinct and well-defined botanical impressions that closely reflected the natural morphology of Eucalyptus globulus leaves. Visual evaluation revealed clear variations in print quality across different fiber types, highlighting the influence of fiber chemistry and surface characteristics on pigment transfer. Khadi cotton (KC-01-25) demonstrated the highest print clarity, sharpness, and uniform color distribution. This superior performance can be attributed to the porous structure, high amorphous content, and abundance of hydroxyl groups in cellulosic fibers, which facilitate strong coordination bonding with iron–tannin complexes formed during mordanting (Bechtold & Mussak, 2009; Shukla & Vankar, 2017).

Rayon (RC-02-25), although also cellulosic in nature, exhibited slightly reduced print sharpness compared to khadi cotton. This may be due to its smoother and more uniform fiber surface, which limits pigment penetration and mechanical anchoring of botanical dyes (Kadolph, 2010). Mulberry silk (MS-03-25), a protein-based fiber, showed softer and comparatively diffused impressions. Despite its good absorbency, the reduced print intensity may be related to the shorter steaming duration and the interaction of pigments with amino acid functional groups, which differs from cellulose–mordant interactions (Hwang et al., 2020).

All samples showed satisfactory wash and color fastness under mild washing conditions, indicating effective fixation of eucalyptus pigments through iron mordanting. These findings confirm that eucalyptus leaves are a viable and sustainable botanical resource for eco-printing on diverse textile substrates.

Table 2. Comparative performance of eco-printing on diverse textile substrates using Eucalyptus globulus leaves

Fabric Type	Fabric Code	Print Clarity	Color Intensity	Wash Fastness	Observations
Khadi Cotton	KC-01-25	Excellent	High	Very Good	Sharp and well-defined botanical impressions
Rayon	RC-02-25	Good	Moderate	Good	Slightly reduced sharpness due to smooth surface
Mulberry Silk	MS-03-25	Moderate	Soft	Good	Diffused impressions, softer tonal appearance

Overall, the results substantiate the potential of eco-printing with Eucalyptus globulus leaves as an environmentally sustainable textile printing technique applicable across multiple fiber categories.

(a) (b) (c)

Fig. 1 Eco-printing on cotton fabric by Eucalyptus globus leaves
(a) Arrangement of leaves on cotton fabric (b) Unrolling of Steamed Bundle (c) Final print on Cotton fabric

6. Conclusion

The present study demonstrates the successful application of eco-printing on textile materials using Eucalyptus globulus leaves as a sustainable and eco-friendly botanical resource. Among the investigated substrates, khadi cotton exhibited the highest print clarity and color intensity, followed by rayon and mulberry silk, indicating the strong influence of fiber structure on pigment absorption. The use of iron rust solution and vinegar proved effective in achieving satisfactory pigment fixation and wash fastness without generating harmful environmental impacts. Overall, eco-printing with eucalyptus leaves represents a promising approach for sustainable textile design, waste valorization, and eco-fashion development, supporting environmentally responsible manufacturing practices.

7. References

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