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From Nature to Fabric: Eco-Printing with Guava and Silver Oak Leaves on Cotton and Mulberry Silk for Sustainable Fashion

Hijam Silvia Chanu[1], Binita B. Kalita[1], Mamoni P. Borah[2], Sunita Boruah[1]*, Bornali Kachari[1] and Meenakshi Sammal[1]

[1]Department of Textiles and Apparel Designing, College of Community Science, Assam Agricultural University, Jorhat, Assam, 785013, India
[2]Department of Textiles and Apparel Designing, College of Community Science, Central Agricultural University, Imphal, India

**Corresponding author*

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ABSTRACT

Textile printing involves using specific machinery and techniques to transfer ink onto fabrics, creating patterns and designs. Eco printing, also referred to as biological printing, is a textile printing technique that involves layering various plant materials between pieces of fabric and steaming them for a specific duration. This method not only creates unique, nature-inspired designs but also emphasizes environmentally friendly practices and promotes ethical behaviour in textile production. This study aimed to assess the colorfastness properties of eco-printed cotton (*Gossypium hirsutum*) and mulberry silk (*Bombyx mori*) fabrics using Guava (*Psidium guajava*) and Silver Oak (*Grevillea robusta*) leaves, along with Marigold and Manjistha dye blankets. The printed samples were assessed for colorfastness properties using the Grayscale, which was employed to determine their resistance to sunlight, washing, crocking (both dry and wet), and pressing (both dry and wet). The evaluations revealed that CGM1 (cotton eco-printed with Guava leaves using Manjistha dye blanket) exhibited the best color fastness performance across all tests, demonstrating superior durability under various conditions.

Introduction

A variety of printing methods are employed in the textile industry, one of the latest being eco-printing, also known as botanical or green-printing (Manuja *et al.,* 2023). Eco-printing offers a sustainable approach to textile design, employing natural plant pigments to create patterns and colors. This method minimizes environmental harm by avoiding harmful chemicals and synthetic dyes, resulting in unique and environmentally conscious designs (Dixit, 2023). This technique utilizes plant materials to imprint designs onto fabrics by placing layers of plants between textiles and using steam to set the prints, thereby extracting pigments that form organic shapes (Pancapalaga *et al.,* 2021). In eco-printing, natural pigments sourced from fruits, flowers, vegetables, insects, and other plant life are used to create unique visual designs on fabric or paper through techniques like hammering, boiling, and steaming (Batham & Mandhary, 2023). Eco-print motifs resemble the shapes of the flowers or leaves used.

Guava leaves, harvested from the tropical guava tree (*Psidium guajava*), offer eco-printing enthusiasts a chance to explore the natural beauty of plant-based designs. Similarly, the leaves of *Grevillea robusta* (Silver Oak) provide a wide range of textures, shapes, and forms, including fern-like, fishbone-like, holly-like, and pinnately divided patterns (Rahman and Akbar, 2006). Silver Oak is particularly valued in eco-printing for its unique characteristics, making it an excellent choice for creating intricate and distinctive fabric prints.

For optimal results in eco-printing, it is recommended to use textiles made from natural fibers, as synthetic fabrics composed of petroleum-based materials generally lack compatibility with natural dyes. Natural fiber fabrics such as bamboo, rayon, cotton, and silk are particularly well-suited for this technique. Cotton stands out due to its softness, absorbency, comfort, chemical resistance, and hypoallergenic properties, which stem from its natural polymer composition (Khanzada *et al.,* 2020). Silk is another preferred choice among eco-printers due to its ability to showcase delicate patterns and vibrant hues. Even eco-printed designs with indistinct leaf shapes can appear visually appealing on silk. Its versatility allows for a broad spectrum of colors and effects, making silk fabrics highly adaptable for eco-printing applications (Sadaf *et al.,* 2022).

The textile industry is presently one of the most environmentally hazardous production systems regarding sustainability, with its effects ranging from raw materials to end products (Oliveira *et al.,* 2021). Sustainability is defined by the use of eco-friendly materials, the reduction of production waste and energy consumption, and the implementation of recycling and upcycling techniques. In textiles, sustainability encompasses practices and materials that aim to lessen environmental impact while ensuring economic viability (Muthu & Gardetti, 2021). This strategy reduces the carbon footprint by utilizing less energy, minimizing material usage, and sourcing native plants locally. Additionally, it promotes slow fashion by producing unique, high-quality items that emphasize craftsmanship over mass production. Eco-printing is gaining importance as a sustainable alternative to traditional textile printing methods (Gunawan *et al.,* 2023). Research into eco-printing is essential for uncovering enhanced and more sustainable printing techniques that leverage natural materials, reduce environmental impact, and improve the overall effectiveness of eco-friendly printing practices.

Materials and Methods

Collection of Materials

The fabrics selected for the study were cotton (*Gossypium hirsutum*) and mulberry silk (*Bombyx mori*). Fabrics were collected from the local market of Jorhat, Assam.

Mature silver oak and guava leaves were chosen for the study due to their easy availability, distinct shapes, and textures, which produce beautiful and detailed patterns when printed onto fabric.

Alum was selected as the mordant for the study.

Pre-treatment of cotton and silk fabrics

Pre-treating cotton and silk fabrics is a vital step in preparing them for eco-printing, as it ensures optimal results. This pre-treatment process includes scouring cotton and degumming silk, both of which involve thoroughly cleaning the fabric to remove impurities and prepare it for effective dye absorption.

Mordanting of the fabrics

Mordanting is the process of treating the fabric with certain chemicals to increase the dye absorbency capacity of the fabric. Pre-mordanting of fabrics with alum was caried out following the technique used by Janani *et al.,* (2014).

Preparation of leaves

A sufficient quantity of fresh guava and silver oak leaves was collected and thoroughly rinsed under running water to eliminate any impurities. At the same time, an iron solution was prepared by dissolving 1 teaspoon of Potassium alum powder in 1 liter of water. The cleaned leaves were then immersed in this iron solution and gently heated on low for 15 minutes. Afterward, the leaves were carefully removed, and any excess iron solution was blotted off with a dry cloth.

Eco-Printing process

Among the various eco-printing methods, the "dye blanket with iron-soaked leaves" was selected for its ability to produce the most defined leaf shapes and vibrant colors on the printed fabrics. Marigold and manjistha were used to dye the blankets for the eco-printing process.

Preparation of dye blankets

In the present study, dye blankets were prepared for eco-printing using marigold dye, and manjistha dye. Marigold dye blanket was prepared following the method outlined by Farooq *et al.,* (2013). Manjistha dye blanket was prepared based on the technique described by Chattopadhyay *et al.,* (2018).

The process of preparing a dyed blanket begins with extracting natural pigments from a fresh dye source. The dye source is cleaned and boiled in water at a material-to-liquid (M:L) ratio of 1:20 for 90 minutes at 100°C to release its pigments. Once boiled, the mixture is cooled and strained to remove solid plant matter, leaving behind a concentrated dye extract. For the dyeing process, the fabric is immersed in a dye bath heated to 90°C, using an M:L ratio of 1:30. The fabric is dyed for one hour, with occasional stirring to ensure uniform absorption and even coloring. This careful process results in a beautifully dyed blanket with vibrant, natural hues.

Eco-printing technique

Pre-mordanted cotton fabric is laid flat on a clean surface, ensuring it is free of creases. Fresh leaves are selected and arranged on the fabric according to the desired design, with their underside (the "moon side") facing downward. Each leaf is gently pressed to adhere to the fabric, securing its position. A dye-soaked blanket is removed from its solution, excess liquid is gently squeezed out to retain dampness, and it is placed over the leaf-covered fabric. A reusable plastic sheet is then layered on top of the dye blanket. All three layers—target fabric, dye blanket, and plastic sheet—are smoothed to eliminate air pockets and pressed lightly to ensure adhesion. The layered materials are tightly rolled into a cylindrical bundle to maximize contact between the leaves and fabric, ensuring crisp print transfer. Once rolled, the bundle was securely tied with fabric strips or ropes, with a tight knot at the end. To steam the bundle the rolled fabric can be placed in a steamer for 2, 4, 6, and 8 hours at temperatures ranging from 60°C, 70°C, 80°C, and 100°C, according to the types of fabric used, allowing the natural dyes to transfer and create the eco-prints.

After steaming, the rolled fabrics were left to cool. Once completely cooled, the roll was unwrapped, and the leaves are removed from the eco-printed fabric. The fabric was then air-dried in the shade.

The same eco-printing method was followed for the silk eco-printing. Both cotton and silk fabrics were printed using the method described above, with marigold and manjistha dye blankets.

The optimized condition for printing the cotton fabric

Temperature = 100ºC

Time = 8 hours

The optimized condition for printing the mulberry silk fabric

Temperature = 80ºC

Time = 6 hours

Nomenclature of the sample

Results and Discussion

Evaluation of color fastness properties of eco-printed fabrics

Colorfastness to sunlight

Table 1 demonstrates that the evaluation of the entire sample revealed superior results in terms of color fastness properties. For the colorfastness of cotton to sunlight, CGM1 and CSM1 both receive a perfect rating of 5, indicating very good fastness property. The eco-printed samples CGM and CSM score 4, meaning they have good resistance to fading but may show some color change over time. Thus, eco-printed samples with manjistha dye blanket perform the best in colorfastness to sunlight, while sample printed with marigold are slightly less resistant, showing some fading.

For silk eco-printed samples SSM, SGM1and SSM1 all have the highest resistance to colour change getting the rating of 5, indicating very good performance. SGM has a slightly lower colour change rating of 4.Silk eco-printed samples show slightly better colorfastness to sunlight than cotton samples.

Colorfastness to washing

In washing fastness assessments, cotton eco-printed sample CGM1 exhibited the best performance among the cotton samples, achieving a rating of 5, which signifies excellent resistance to both color change and color staining. Similarly, silk eco-printed samples demonstrated very good fastness properties, with all samples receiving a rating of 5 and exhibiting negligible color stain, also rated as 5, indicating a strong resistance to fading and staining during washing.

Colorfastness to crocking or rubbing (wet and dry)

In the wet crocking of the eco-printed cotton samples CGM and CGM1 stands out with the best results. Overall, CGM1 performs the best, while the other samples exhibit similar, less ideal performance. The silk samples (SGM, SSM, SGM1, and SSM1) demonstrated varied performance outcomes in color fastness testing. SGM stood out as the top-performing sample, achieving a color change (CC) rating of 5 (indicating very good resistance to fading) and no observable staining (CS = 5).

Samples SSM, SGM1, and SSM1 showed moderate performance, with a color change rating of 4 and slight staining (CS = 4). These results highlight SGM's superior durability compared to the other silk variants, though all samples retained acceptable fastness properties overall.

In the assessment of dry cotton crocking fastness, samples CSM, CGM1, and CSM1 demonstrated excellent performance, achieving negligible or no color staining (CS = 5) alongside very good color change fastness (CC = 5). Meanwhile, the silk samples SSM, SGM1, and SSM1 all showcased very good fastness properties. Overall, the results indicate that while several samples performed well, SSM, SGM1, and SSM1 excelled in maintaining color integrity during dry crocking.

Colorfastness to pressing (wet and dry)

The pressing fastness of wet eco-printed cotton samples CGM, CSM, CGM1, and CSM1 showed consistent very good fastness performance. Wet eco-printed silk samples SGM and SSM demonstrated the best results, achieving a perfect rating of 5 for color change fastness and no staining, while SGM1 and SSM1 received a color change fastness rating of 4 with no staining (CS = 5). Additionally, all cotton and silk samples exhibited excellent dry pressing fastness, scoring 5 in both color change (CC) and color stain (CS), reflecting outstanding color retention and minimal or no staining during the pressing process. These findings emphasize the durability and high-quality performance of both cotton and silk eco-printed fabrics under pressing conditions.

Among all the eco-printed samples CGM1 stands out with consistent ratings of 5 across all conditions, showing excellent color retention. Overall, the eco-printed fabrics show good to very good durability, with minimal staining and color fading, making them suitable for various practical applications. The CGM1 and SSM samples perform the best, maintaining both their color and minimal staining under different conditions. Overall, all the eco-printed samples demonstrated good performance in color fastness properties, possibly due to the effective mordanting process and strong bonding between the natural dyes and the fabric fibers. Overall, the color fastness properties of different eco-printed samples were found to consistently exhibit good performance. Cotton as well as silk samples showed promising resistance against color change and staining under varied circumstances such as sunlight, washing, pressing, and crocking. The findings support that effective mordanting methods and the inherent nature of the eco-printing process play a major role in maintaining the stability of the colors. Of particular interest, certain samples, including CGM and SGM, were remarkable in having better fastness ratings, demonstrating the potential for eco-printing to generate highly colored and long-lasting fabrics. These results point to the feasibility of using eco-printed fabrics in sustainable fashion, highlighting their capacity to retain visual appeal as well as conform to environmental concerns. In general, this study highlights the critical role of both technique and material selection in obtaining favourable color fastness in eco-printed fabrics.

Table.1 The control and eco-printed samples were identified by the following names

Cotton control fabric	**CC**
Cotton eco-printed with guava leaves using Marigold dyed blanket	CGM
Cotton eco-printed with Silver Oak leaves using Marigold dyed blanket	CSM
Cotton eco-printed with Guava leaves using Manjistha dyed blanket	CGM1
Cotton eco-printed with Silver Oak leaves using Manjistha dyed blanket	CSM1
Silk control fabric	SC
Silk eco-printed with guava leaves using Marigold dyed blanket	SGM
Silk eco-printed with Silver Oak leaves using Marigold dyed blanket	SSM
Silk eco-printed with Guava leaves using Manjistha dyed blanket	SGM1
Silk eco-printed with Silver Oak leaves using Manjistha dyed blanket	SSM1

Table.2 Colorfastness of washing, sunlight, crocking and pressing

Sl. No	**Samples**	**Sunlight**	**Washing**		**Crocking**				**Pressing**			
					wet		dry		wet		dry	
		CC	CC	CS	CC	CS	CC	CS	CC	CS	CC	CS
1	CGM	4	4	5	5	4	4	5	5	5	5	5
2	CSM	4	4	5	4	4	5	5	5	5	5	5
3	CGM1	5	5	5	5	4	5	5	5	5	5	5
4	CSM1	5	4	5	4	4	5	5	5	5	5	5
5	SGM	4	5	5	5	5	4	5	5	5	5	5
6	SSM	5	5	5	4	4	5	5	5	5	5	5
7	SGM1	5	5	5	4	4	5	5	4	5	5	5
8	SSM1	5	5	5	4	4	5	5	4	5	5	5

CS: Colour stainCC: Colour Change
CS Ratings: 1= heavily stain, 2= considerably stained, 3 = noticeable stained, 4= slightly stained, 5= negligible or no stained.
CC ratings: 1= very poor, 2= poor, 3= fair, 4 = good, 5= very good.

Figure.1

Figure.1 (a) Placing the leaves face down (moon side) on the target fabric

Figure.1 (b) Covered the leaves and target fabric with the blanket fabric

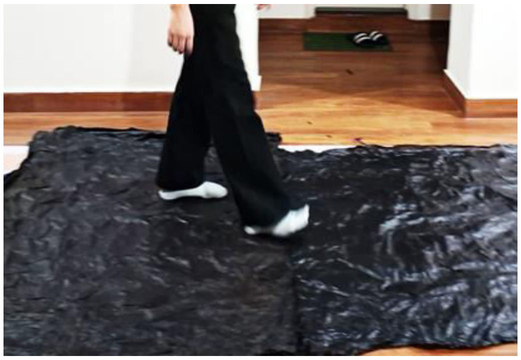

Figure.1 (c) Covered all the layers with plastic sheets and press firmly by walking over.

Figure.1 (d) Steaming the bundle to transfer the leave pigment

Figure.1 (e) Opening and removing the leaves for the final product

Figure.1 (f) Final eco printed fabric

Author Contributions

Hijam Silvia Chanu: Investigation, formal analysis, writing—original draft. Binita B. Kalita: Validation, methodology, writing—reviewing. Mamoni P. Borah:—Formal analysis, writing—review and editing. Sunita Boruah: Investigation, writing—reviewing. Bornali Kachari: Resources, investigation writing—reviewing. Meenakshi Sammal: Validation, formal analysis, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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