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# Color Characteristics of Local Plant-Derived Natural Dyes for Hand-Drawn Batik Using Dip and Brush Dyeing Techniques

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***Abstract***
*The use of synthetic dyes in the batik industry may contribute to environmental pollution due to chemical residues generated during the dyeing process. Therefore, natural dyes derived from local plants have attracted attention as alternative sources of textile colorants. This study aimed to examine the color characteristics of natural dyes derived from five local plant materials when applied to hand-drawn batik using different dyeing techniques. The study employed an exploratory experimental approach, with primary data obtained through natural dye extraction, batik preparation, dyeing, fixation, and preliminary washing evaluation. The natural dye sources consisted of temulawak rhizome (Curcuma xanthorrhiza Roxb.), teak leaves (Tectona grandis L.f.), red cordyline leaves (Cordyline fruticosa), rambutan peel (Nephelium lappaceum), and avocado leaves (Persea americana). The extracted dyes were applied to mori fabric using dip and brush dyeing techniques, followed by fixation with alum. The results showed that the plant-derived dyes produced different observable color characteristics. Temulawak produced yellowish shades, while teak and avocado leaves produced brownish shades. Red cordyline leaves and rambutan peel produced reddish to purplish or brownish tones. Alum-treated samples generally showed brighter and lighter shades based on visual observation. The preliminary washing evaluation showed that most samples maintained their basic color characteristics after water washing, although some samples showed reduced visual color intensity after detergent washing. These findings provide preliminary evidence of the varied color characteristics produced by local plant-derived dyes in hand-drawn batik. Further studies using instrumental color measurement and standardized textile fastness testing are needed to provide quantitative evaluation.*

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## INTRODUCTION

Indonesia is a country with remarkable cultural diversity, one of which is batik. Batik craftsmanship represents a valuable cultural heritage with high artistic and cultural significance. Batik reflects beliefs, traditions, and aspects of past community life (Maghfiroh et al., 2023). One of the batik-making techniques is hand-drawn batik, which involves applying wax patterns onto fabric using a traditional tool called a canting.

Batik was officially recognized by UNESCO as an Intangible Cultural Heritage of Humanity under the title Masterpieces of the Oral and Intangible Heritage of Humanity in 2009 (Oktyajati et al., 2023). Since its recognition as a world cultural heritage, batik development has continued to grow. The Indonesian government has promoted batik among various

communities, encouraging different regions to develop their own distinctive motifs. As a result, the batik industry has gained increasing popularity both nationally and internationally.

The growing popularity of batik has significantly increased market demand. However, behind the production process, the batik industry still faces considerable environmental challenges. Many batik industries continue to rely on synthetic dyes, such as naphthol, indigosol, and remasol, because they are relatively inexpensive and practical to use (Kirana, 2021). Although synthetic dyes provide advantages in terms of color intensity and production efficiency, their usage may negatively affect human health and the environment. The dyeing process requires large amounts of water, and wastewater containing chemical residues may reduce water quality and disrupt aquatic ecosystems. In addition, dyeing activities may contribute to air pollution through the release of potentially harmful emissions (Ayu et al., 2024; Ayu Kusumawardani et al., 2024). Therefore, the transition toward more sustainable production methods has become an important strategy for supporting the long-term development of the creative textile industry.

Indonesia is located in a tropical region with high plant diversity, providing abundant biological resources that can potentially be utilized as natural dye sources (Akbar et al., 2023). This plant diversity offers opportunities for developing natural dyes as environmentally responsible alternatives to synthetic dyes. The utilization of local plants not only supports the concept of a green economy but also provides unique and softer color characteristics that are difficult to replicate using synthetic dyes.

The application of natural dyes in the textile industry has become increasingly important as a response to the environmental impacts associated with synthetic dyes, which may contain hazardous compounds, persist in the environment, and contribute to pollution. Previous studies have reported biodegradability and potential environmental and health benefits for some plant-derived natural dyes, although these characteristics may vary depending on the dye source and processing conditions (Failisnur et al., 2021; Junita et al., 2024). Furthermore, their plant-based sources support sustainable resource utilization and provide opportunities for utilizing local biological resources. However, the major limitations of natural dyes are their relatively lower dye absorption capacity, color stability, and fastness properties compared with synthetic dyes, resulting in less consistent textile quality (Bukhari et al., 2017). Therefore, developing simple, applicable, and locally based processing strategies remains necessary to improve the performance of natural dye applications.

One of the approaches commonly applied to overcome these limitations is the use of mordants, which enhance the interaction between dye molecules and textile fibers, thereby improving color development and stability (Mozaffari & Imam, 2018). Previous studies have demonstrated that different mordants can modify the resulting shades and improve color fastness properties of natural dyes. However, the application of metal-based mordants, such as iron-based compounds, may also raise environmental concerns due to the potential accumulation of metal ions in wastewater (Benli, 2024; Martuti et al., 2020). Consequently, sustainable dyeing strategies are required to balance improved dye performance with environmental considerations.

Recent studies have increasingly explored plant-based materials as sources of natural dyes for sustainable textile applications. Various plant parts, including leaves, roots, fruit peels, and other biomass resources, have been reported to contain pigment compounds such as anthocyanins, tannins, flavonoids, and curcuminoids that contribute to textile coloration (Ariyanti et al., 2023). Furthermore, research has investigated several strategies, including extraction condition modification, dyeing technique variations, and mordant application, to improve the quality of natural dye-based textiles (Adeel et al., 2023; Fadhila et al., 2022).

Previous studies have examined plant-derived colorants from individual plant materials and have explored different extraction, dyeing, and mordant or fixation treatments for textile

coloration (Adeel et al., 2023; Ariyanti et al., 2023; Fadhila et al., 2022). These studies indicate that both the choice of plant material and the processing conditions are relevant to the resulting color characteristics. However, the studies cited above considered particular plant sources or specific processing combinations. The present study extends these investigations by examining five locally available plant materials within a common hand-drawn batik application framework, using dip and brush dyeing techniques and alum as fixatives. The resulting color characteristics and preliminary responses to water and detergent washing were then documented comparatively. This context highlights the need for further research that examines locally available plant materials in practical textile applications to better characterize their potential as natural dye sources for hand-drawn batik.

Therefore, this study addresses the existing research gap by exploring multiple Indonesian local plant resources, including temulawak rhizome (*Curcuma xanthorrhiza* Roxb.), teak leaves (*Tectona grandis* L.f.), red cordyline leaves (*Cordyline fruticosa*), rambutan peel (*Nephelium lappaceum*), and avocado leaves (*Persea americana*), as potential sources of sustainable natural dyes for hand-drawn batik. The contribution of this study lies in the comparative screening of five local plant-derived dyes for hand-drawn batik under different dyeing techniques and fixative treatments using alum, with emphasis on their observable color characteristics.

Therefore, this study aims to explore the potential of Indonesian local plants as sustainable natural dye sources and to evaluate the characteristics of colors produced through different dyeing techniques and fixative treatments in hand-drawn batik. The findings are expected to provide insights into the development of sustainable textile practices and encourage the utilization of local biological resources as alternatives to synthetic dyes.

## METHODS

### Research Design

This study employed an exploratory experimental approach to characterize the observable color characteristics of five local plant-derived dyes applied to hand-drawn batik. The experimental comparison involved five plant-derived dye sources, two dyeing techniques (dip and brush), and alum as the post-dyeing fixative. The resulting color characteristics and preliminary washing responses were documented descriptively. This approach was used to explore the potential of various plant materials as natural dye sources and to evaluate the characteristics of colors produced through different dyeing techniques and fixative treatments.

### Research Time and Location

The research was conducted from December 2025 to January 2026. The preparation of materials and the extraction process were carried out in late December 2025, while the batik-making process, dyeing, fixation, and color evaluation were performed in January 2026. All research activities were conducted independently within the Science Education Laboratory in Universitas Ivet.

### Research Object and Unit of Analysis

The research object was mori fabric treated with natural dyes extracted from local plant materials. The units of analysis included natural dye extracts, fabric samples before and after dyeing, and the resulting color characteristics after fixation and *nglorod* processes. The plant materials used in this study consisted of teak leaves (*Tectona grandis* L.f.), temulawak rhizomes (*Curcuma xanthorrhiza* Roxb.), red cordyline leaves (*Cordyline fruticosa*), rambutan peel (*Nephelium lappaceum*), and avocado leaves (*Persea americana*). These materials were selected based on their natural pigment compounds, including tannins, anthocyanins, curcuminoids, and flavonoids, which have potential applications as textile colorants (Ariyanti et al., 2023).

## Materials and Instruments

The instruments used in this study included a digital scale, blender, cooking pot, stove, filter, canting, pan, fabric frame (*bidangan*), thermometer, measuring cylinder, and cotton buds. The materials consisted of mori fabric, batik wax (*malam*), water, natural dye sources from local plants, and fixative agents consisting of alum. The application of fixatives is important in natural dyeing processes because they improve the interaction between dye compounds and textile fibers, resulting in improved color stability (Damayanti et al., 2024).

## Natural Dye Extraction and Batik Dyeing Process

The extraction process began with the preparation of plant materials by washing, cutting, and grinding the samples to increase the surface area and facilitate pigment extraction. Temulawak rhizomes, teak leaves, and avocado leaves were extracted by heating at 65°C for 20 minutes, whereas red cordyline leaves and rambutan peel were extracted at 90°C for 60 minutes. These plant-specific extraction conditions were adapted from Yuniati et al. (2024) and were predetermined before the comparative dyeing experiment. The extraction temperature and duration were not treated as independent experimental variables. The extracted solutions were subsequently filtered and cooled before being applied to the fabric.

The batik-making process was conducted by designing patterns on mori fabric and applying wax using a *canting* as a color-resist technique. The dyeing process was performed using two techniques: immersion dyeing (*celup*) and brush dyeing (*colet*). The immersion dyeing process was conducted for up to seven cycles on the same fabric sample to facilitate dye uptake, while the brush technique was applied to specific motif details (Khakim & Widagdo, 2024). These cycles represented repeated dye application rather than independent experimental replicates.

Post-dyeing fixation was conducted at 40°C using alum. Alum was applied as post-dyeing fixation treatments to obtain different observable color characteristics. After fixation, the fabric underwent *nglorod* processing to remove batik wax, followed by washing, drying, and finishing. The overall process of producing natural dyes from local plants for hand-drawn batik is presented in Figure 1.

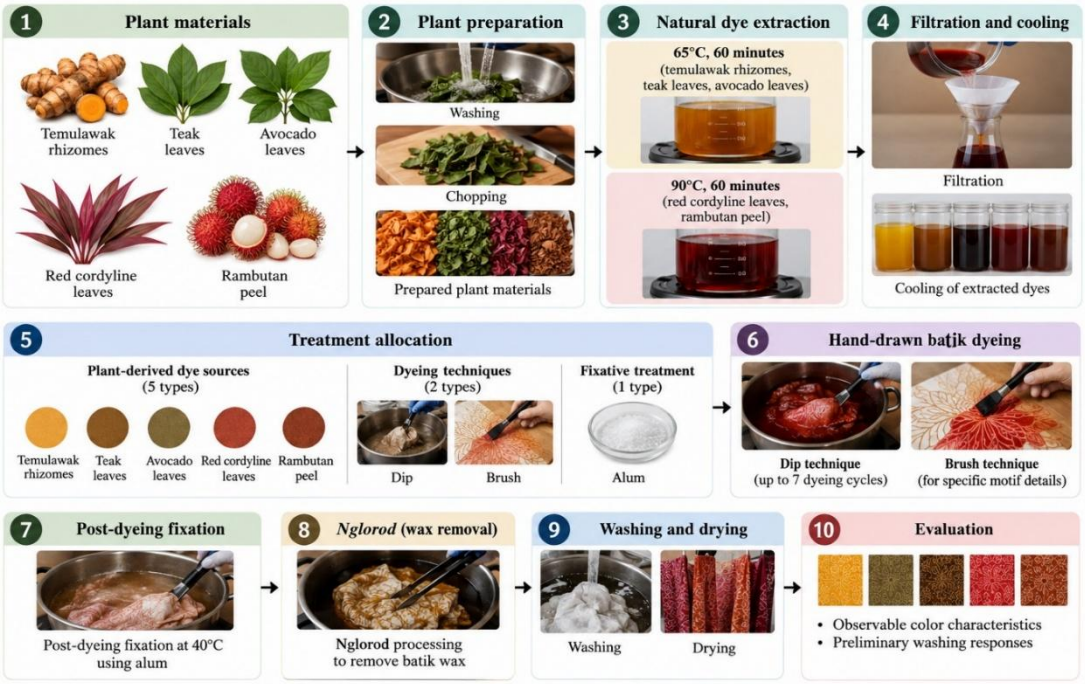


Figure 1. Flow diagram of local plant-based natural dye preparation for hand-drawn batik production

### Color Fastness Evaluation

The preliminary washing evaluation used water and detergent solutions. The samples were washed for 10 minutes using a detergent-to-water ratio of 1:100. The washing response was assessed through visual observation of the samples before and after washing, focusing on whether the basic color characteristics were maintained or whether visible reductions in color intensity occurred. The observations were documented descriptively as preliminary washing responses.

### Research Variables

The variables investigated in this study consisted of independent, dependent, and controlled variables.

### Independent Variables:

1. Natural dye sources:
    - teak leaves (*Tectona grandis* L.f.)
    - temulawak rhizomes (*Curcuma xanthorrhiza* Roxb.)
    - red cordyline leaves (*Cordyline fruticosa*)
    - rambutan peel (*Nephelium lappaceum*)
    - avocado leaves (*Persea americana*)
2. Dyeing techniques:
    - immersion dyeing (*celup*)
    - brush dyeing (*colet*)

### Dependent Variables:

- Color intensity
- Color brightness/darkness
- Color stability after fixation and *nglorod* process

### Controlled Variables:

- Type of fabric (mori fabric)
- Dyeing techniques (dip and brush)
- Fixative treatments (alum)
- Extraction conditions (plant-specific, as described above)

### Material Formulation

The formulation of natural dye extracts and fixative solutions was prepared as follows:

### Natural Dye Extraction:

The plant-to-water ratios used for extraction were plant-specific, as follows: temulawak rhizome, 446 g per 1 L water (1:2.2); teak leaves, 284 g per 1 L water (1:3.5); red cordyline leaves, 100 g per 1 L water (1:10); rambutan peel, 150 g per 1 L water (1:6.7); and avocado leaves, 120 g per 1 L water (1:8.3). These formulations were predetermined for each plant material based on the extraction procedures used in the study. Because the extraction ratios and conditions differed among plant materials, the resulting color characteristics were interpreted descriptively and were not used to infer intrinsic dyeing capacity or relative color strength among the plant sources.

Fixative Solution:

- Alum: 7.5 g per 1 L water

### Data Analysis

The experimental observations were recorded descriptively for each plant-derived dye, dyeing technique, and fixative treatment. The resulting color characteristics were documented through visual observation and summarized according to the observable color shades produced. The washing responses were assessed by comparing the visual appearance of the fabric before and after water and detergent washing, particularly whether the basic color characteristics were maintained or whether visible reductions in color intensity occurred. The observations were compared descriptively across the experimental conditions. No inferential statistical analysis was

performed because the study was designed as an exploratory descriptive experiment without independent experimental replication.

## RESULTS AND DISCUSSION

### Characteristics of Natural Dye Extracts from Local Plants

The extraction process of local plant materials produced different color characteristics depending on the type of plant source and extraction conditions. The differences in color appearance were related to the diversity of pigment compounds contained in each plant material, including curcuminoids, tannins, flavonoids, and anthocyanins, which contribute to variations in textile coloration (Ariyanti et al., 2022).

The natural dye extracts obtained from temulawak rhizome (*Curcuma xanthorrhiza Roxb.*), teak leaves (*Tectona grandis L.f.*), red cordyline leaves (*Cordyline fruticosa*), rambutan peel (Nephelium lappaceum), and avocado leaves (*Persea americana*) showed distinct color characteristics. Temulawak extract produced a yellowish color, while teak leaves and avocado leaves generated brownish shades. Rambutan peel and red cordyline leaves produced reddish to purplish tones. These observed color characteristics may be associated with curcuminoid, tannin, flavonoid, and anthocyanin compounds reported for the respective plant materials in previous studies (Bhandari et al., 2024). However, these compounds were not chemically characterized in the present study.

The extraction process was conducted to obtain colorant extracts from the selected plant materials. Previous studies have reported that extraction conditions can affect the characteristics and stability of plant-derived colorants, particularly heat-sensitive compounds such as anthocyanins (Gecchele et al., 2021; Junita et al., 2024). However, because the present study did not systematically investigate extraction conditions as an independent experimental variable, their specific contribution to the observed color characteristics cannot be determined.

Overall, the color differences observed among the extracts indicate that the selected local plant materials have potential as sources of natural dyes for hand-drawn batik. Nevertheless, the color evaluation in this study was primarily based on visual observation, and the specific chemical composition of the extracts was not quantitatively characterized.

### Color Characteristics of Hand-Drawn Batik Using Local Plant-Based Natural Dyes

The application of natural dyes on mori fabric produced various observable color characteristics across the plant sources, dyeing techniques, and fixation treatments. The observed differences in color appearance indicate variation in the resulting shades under the respective experimental conditions. However, these observations cannot be used to determine differences in dye-fiber binding because binding was not directly measured in the present study.

Temulawak produced yellowish shades, while teak and avocado leaves produced brownish shades. These observed colors may be associated with curcuminoid and tannin compounds reported for the respective plant materials in previous studies (Failisnur et al., 2021). However, the observed color characteristics may also reflect differences in plant material, extraction formulation, dyeing technique, and fixation treatment. Therefore, the present findings should be interpreted as descriptive observations of color characteristics rather than evidence of differences in intrinsic dyeing capacity, pigment concentration, or dye–fiber binding.

The application method was associated with differences in the visual appearance of the batik samples. The immersion technique involved exposing the fabric to the dye solution, whereas the brush technique (*colet*) enabled localized application to specific motifs. In the present study, these differences were observed qualitatively from the resulting fabric appearance rather than evaluated using a standardized measure of color uniformity. Therefore, the comparison between the two techniques is presented as a qualitative observation rather than a demonstrated treatment effect. Similar findings have been reported that dyeing techniques

influence pigment absorption and visual appearance in natural dye-based textiles (Adeel et al., 2023). The process of applying natural dyes to patterned and waxed fabric is shown in Figure 2.



Figure 2. Natural Dyeing Process of Hand-Drawn Batik Using Local Plant Extracts

## Influence of Fixatives on Color Appearance

The fixation process using alum resulted in observable changes in color appearance across the plant-derived dye samples. The alum-treated samples generally showed brighter and lighter shades based on visual observation. Such changes may be related to interactions between the dye components and textile fibers during the fixation process. Previous studies have reported that alum can influence the resulting appearance of natural-dye coloration; however, the present study did not directly examine the chemical interactions between dye components and textile fibers. Therefore, the observed changes are interpreted descriptively rather than as evidence of a specific chemical mechanism. Additionally, the use of mordants can improve dye fixation and color intensity, as seen in studies involving various plant species (Ketapang et al., 2016; Klinpikul et al., 2025). Therefore, future studies should consider environmentally safer mordant alternatives or optimize mordant concentrations to achieve a balance between color performance and environmental sustainability.

Table 1. Comparison of Color Characteristics Before and After Alum Fixation

| No. | Dye Material | Color Before Fixation | Color After Fixation |
|---|---|---|---|
| 1 | Temulawak rhizome | Yellow | Brighter yellow |
| 2 | Red andong leaves | Reddish brown | Brighter reddish brown |
| 3 | Avocado leaves | Batik red | Brighter batik red |
| 4 | Rambutan peel | Brown | Brighter brown |

## Preliminary Color Fastness Evaluation

The preliminary washing evaluation provided qualitative observations of the color appearance after washing. Most samples maintained their basic color characteristics after water washing, although some samples showed visibly reduced color intensity after detergent washing. These observations are considered preliminary and descriptive because no standardized color-fastness measurement or sample-specific scoring procedure was used. The observed reduction in visual color intensity after detergent washing may be related to the removal of loosely retained colorant from the fabric surface, although this mechanism was not directly examined in the present study. Natural dyes generally have lower affinity toward textile fibers compared with synthetic dyes, resulting in limitations in washing fastness and long-term color stability (Bukhari et al., 2017). Nevertheless, the tested plant-based dyes demonstrated potential for application in hand-drawn batik, particularly when combined with appropriate fixation treatments. The use of mordants contributed to improving pigment–fiber interactions, which may enhance color retention during washing (Damayanti et al., 2024).

## CONCLUSION

This study explored the observable color characteristics of natural dyes derived from five local plant materials for hand-drawn batik using dip and brush dyeing techniques and alum as the post-dyeing fixative. The plant-derived dyes produced varied observable color characteristics, including yellowish, brownish, reddish, and purplish tones. Alum-treated samples generally showed brighter and lighter shades based on visual observation. The preliminary washing evaluation indicated that most samples maintained their basic color characteristics after water washing, although some samples showed reduced visual color intensity after detergent washing. These findings provide preliminary descriptive evidence of the potential use of local plant-derived dyes for hand-drawn batik. However, the findings should not be interpreted as quantitative evidence of differences in dyeing performance or color fastness. Further research using instrumental color measurement, independent experimental replication, and standardized textile washing or color-fastness procedures is needed to provide more robust quantitative evidence.

Several limitations should be considered when interpreting the findings of this study. First, the plant-derived extracts were not chemically characterized; therefore, the observed color characteristics cannot be causally attributed to specific pigment compounds. Associations between the observed colors and compounds reported in previous studies should be regarded as possible explanations rather than experimentally verified mechanisms. Second, color characteristics were evaluated through qualitative visual observation without instrumental color measurement or a standardized visual scoring procedure. Consequently, quantitative differences in color intensity or color performance cannot be established. Third, the washing evaluation was preliminary and non-standardized and was not conducted according to a recognized textile color-fastness standard. Therefore, the washing observations should not be interpreted as standardized color-fastness results. Finally, the study did not involve independent experimental replication, limiting the extent to which the findings can be generalized or used to establish treatment effects. In addition, environmental sustainability was not directly evaluated; no assessment of environmental impact, resource consumption, toxicity, wastewater characteristics, or life-cycle performance was conducted.

## AI AND AI-ASSISTED TECHNOLOGIES DECLARATION IN THE WRITING PROCESS

During the preparation of this work, the authors used **Scopus AI and SciSpace AI** to assist in literature exploration, reference identification, and supporting the review of relevant scientific sources. The authors also used **ChatGPT** to assist with language refinement, improvement of academic sentence structure, and the development of illustrative figures for research presentation purposes. After using these tools, the authors thoroughly reviewed, verified, and edited all generated content as needed and take full responsibility for the accuracy, originality, and integrity of the content presented in this publication.

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