Hindawi
International Journal of Forestry Research
Volume 2022, Article ID 4971977, 12 pages
https://doi.org/10.1155/2022/4971977

Research Article

Exploring the Flora of South Sulawesi, Forest Vegetation, and Karst Areas as Bundle Dyeing on Silk Fabrics

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Received 31 December 2021; Revised 15 May 2022; Accepted 2 June 2022; Published 31 August 2022

Academic Editor: Ahmad A. Omar

The development of dyeing frm natural substances for silk fabrics has been rapidly growing in recent years. This study aimed to explore the plant species prodsucing unique dyes and patterns on silk fabrics. The flowers and leaves of some plant species found at the research sites were assayed for their color and shape expression on the fabrics. The dyeing technique applied was the bundle dyeing or ecoprinting technique on the fabric's surface with mordant alum and myrobalan. We obtained 297 plants consisting of 95 families and 181 genera. The plant species producing colors were trees (48.4%), shrubs (30.5%), and herbs, vines, ferns, and lycopods (21.1%). The plant species samples obtained were 213 (71.7%) producing color and 84 (28.3%) species not expressing color. The leaves and flowers producing colors and patterns on the fabrics suitable for bundle dyeing were 126 species and 19 species, respectively. The leaves produce colors without shape patterns; thus, they have potential roles as dyes for the dipping technique.

1. Introduction

Natural dyes for fabrics are dyeing substances extracted from natural resources, such as plants, animals, and minerals. Most natural dyes are vegetable dyes from plants' parts, that is, roots, rinds, seeds, bark, flowers, and wood, as well as other organic resources, such as fungi, lichens [1], and *Serratia marcescens* SB08 bacterium [2]. Even with organic waste, living organisms, and by-products from food, beverage, wood, agricultural, and other industries can be utilized as natural dyes [3]. These natural dyes then go through several processes, namely, boiling, burning, bruising, pounding, or being directly used.

The communities in developed countries and their textile industries have widely acknowledged the utilization of natural dyes for fabrics. Examples of plants for natural dyes are *Indigofera* or *Isatis tinctoria* in North Europe and England. Red colors on the textile are from madder (*Rubia tinctorum*), Manjistha or Indian madder (*Rubia cordifolia*), Brazilwood (*Caesalpinia echinata*), Sappan wood (*Caesalpinia sappan*), and Indian mulberry (*Morinda citrifolia*) [4]. Natural dyes can be easily obtained locally from several plant parts, such as leaves, bark, wood, or roots, so the cost is very cheap with several advantages [5]. Likewise, Indonesian tribes have been using natural materials for years as yarn dyes for woven fabrics. The Iban Dayak tribe in Kapuas Hulu Regency, Kalimantan, uses plants as natural dyes: *M. citrifolia* L., *Pandanus amaryllifolius*, *Curcuma domestica*, *Morinda tinctoria*, and *Psychtoria* sp. [6]. In Sintang and Sambas Regencies, West Kalimantan, the traditional cloth weavers generate natural dyes from 36 plant species [7]. Additionally, some tribes in Indonesia have used these substances for dyeing the weave and batik fabrics that they become local wisdom. However, they have only applied dipping techniques for yarn and finished fabrics.

Fabric dyeing using natural dyes has undergone some developments, including direct contact dyeing techniques, better known as bundle dyeing or contact dyeing or ecoprint techniques. It is a simple technique by applying the plant part directly to the pretreated fabric. Contact dyeing is a

creative method widely exerted by graphic art designers, textile designers, and artists [3]. This technique can be performed on fabrics; natural fibers: cotton, canvas, linen, and silk [3, 8], and synthetic fibers: viscose, tencel, and polyester [3]. It also can be combined with the batik dyeing technique using plant leaves [9]. The silk dyeing raises the exclusive value of the artwork, and eventually, the purchase price will be very high. The prices of plain silk fabric range from IDR 60,000.00 to 115,000.00 (the equivalent of 4.24–8.13 USD in 2019) per meter, depending on the silk fibers. Nevertheless, after dyeing and patterning the bundle dyeing technique, the price will reach IDR 1,500,000.00 for 2.5 meters per piece of silk fabric [10]. Thus, it might be a profitable business opportunity.

Natural dyeing with bundle dyeing has become very popular because of its unique aesthetic value and limited product. The plant species are still limited to those that can express colors well. The most commonly used plant species in the ecoprint technique are ginkgo leaves, eucalyptus, willow, teak, and so on. The finding will inform new dyes of bundle dyeing or ecoprint for the practitioners.

2. Materials and Methods

2.1. Flora Sampling. The samples were collected from leaves and flowers from all plant species found at the research sites. The collection locations were Hasanuddin University area, Makassar (site I); the educational forest of Hasanuddin University area, Maros (site II); the nursery of the Second Region of Forest Seed/Seedling Office, South Sulawesi, Gowa (site III); Special Purpose Forest Area, Tabo-Tabo Forestry Education and Training, Pangkep (site IV); Rammang-Rammang Tourism Karst, Maros (site V); Leang Kado Karst, Maros (site VI); and Kahu Village Forest, Bontocani, Bone (site VII; Figure 1).

Samples were collected using the exploration method: exploring the entire forests and karsts areas and selecting representative plant species. The samples were trees, shrubs, bushes, vines, ferns, and herbs that had grown and/or were saplings. The selected leaves are shoots and mature leaves but before turning yellow. Flower samples were found according to flowering time. The collected plants were recorded with their scientific names, and the identification was performed for unknown species. The selected parts of the plant were from the shoot up to the 7^{th}–10^{th} leaves and flowers (if available). All plant parts were taken if it is the herb, sapling, or bush. The samples were immediately assayed before they were wilt. Samples assayed at the previous site were not reassayed at the following site but were recorded.

2.2. Preparation of Silk Fabric and Mordanting. The silk fabric used was 150 × 200 cm. The fabric was soaked for 30 minutes in a 14 g/l TRO (Turkish Red Oil) solution. The fabric was rubbed, rinsed, and then squeezed. The fabric was drained until the water was no longer dripping, and then it was ready to be mordanted. The mordant solution consisted of 17 g/l alum ($KAl(SO_4)_2{\cdot}12H_2O$), 7 g/l myrobalan tannins, and 3 ml/l vinegar. The silk fabric was soaked in the mordant solution for 30 minutes. After that, the fabric was wrung out and drained until there was no more dripping solution.

2.3. Sample Arrangement on Silk Fabric. The approach method used is to directly print the patterns using the shapes of plants on fabrics [11]. A damp fabric that has been mordant spread out on a flat surface. Samples of leaves/flowers were arranged on the fabric and sorted according to the code. Each sample species was tested for mature shoots and leaves. The position of the leaf stomata was placed facing the fabric and vice versa. Samples that have been arranged were covered with plastic and then rolled and tied. Samples were steamed for two hours.

2.4. Data Collection. Each plant sample was observed to express the color of the leaves or flowers on the fabric. The resulting colors were grouped without distinguishing the strength of the color. The leaf/flower motif depicted was described as "formed" or "unformed" on the silk fabric. Leaf samples consist of shoots and mature leaves but are not yet yellowed. The leaf sample is placed on fabric with the stomata facing down and vice versa The leaf sample is placed on fabric with the stomata facing down and vice versa.

3. Results and Discussion

3.1. Plant Species That Produce Color. Samples collected from the educational forest of Hasanuddin University (site II) had more plants (97 plants) than other sites. This site has an area of 1,300 ha comprising natural forest with original vegetation. Kara and Lhotka [12] stated that unmanaged forests or natural forests possess higher biodiversity levels than managed forests, such as planted forests. As many as 53 species were found at site I in Hasanuddin University and its surroundings. At site III, the samples found were 92 species. Site IV–VI are karst areas with vegetation of no more than 60 species at each site. Most of the species at site VII were already found at the other sites.

The samples obtained were 297 species consisting of 213 (71.7%) producing color and 84 (28.3%) species not expressing color. There are 95 families, 181 genera, 213 species of colored leaves, and 29 species of 16 families of colored flowers (Table 1). Exploration by Prigioniero et al. [13] in Southern Italy, Mediterranean Basin, identified 64.31% of plant species producing colors that were 25.2% of leaves and 18.5% of flowers. The expressed colors were divided into groups based on the percentage producing yellow, green, brown, orange, grey, red, black, faded blue, and pink (Figure 2(a)), and the life-forms were trees, bushes, herbs, vines, ferns, and lycopods that produce colors from their leaves (Figure 2(b)). The leaves and flowers that produced colors and patterns on the fabrics were 126 (59, 15%) species and 19 species, respectively. Eighty-four species that do not produce color in leaves and flowers are the families Poaceae, Arecaceae, Pinaceae, and Arecaceae.

The families with leaves that expressed the greenest color and formed patterns were Euphorbiaceae, Fabaceae, and Malvaceae. The other seven families only had one species

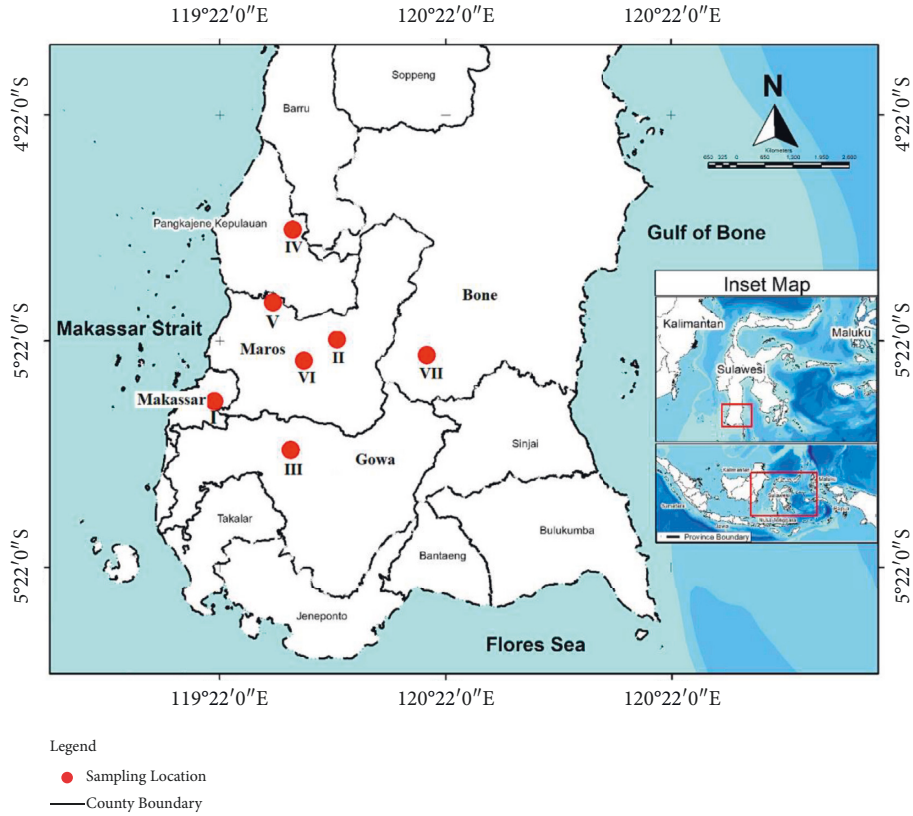

Figure 1: Sampling location (sites I–VII).

whose leaves produced green color. Genus of Malvaceae expressed green only in its shoots (genus *Senna*). The leaves of families Fabaceae, Myrtaceae, Lamiaceae, Bignoniaceae, Vitaceae, Asteraceae, and Meliaceae produced yellow color and patterns. The Dayak Randu tribe in Melawi, West Kalimantan, utilizes *Mucuna* sp. (family Fabaceae) for producing yellow dye and *Daemonorops* (family Araceae) for red dye for yarns or fabrics [14]. The Dayak Bidayuh tribe, Sanggau, West Kalimantan, uses *Aglaia odorata* Lour (Meliaceae) leaves to produce purple dye [15]. The yellows for dyeing are common and abundant in natural dyes, particularly from Fabaceae and Euphorbiaceae [16]. Prigioniero et al. [13] stated that in addition to leaves, other parts of the plants also produce yellow colors, such as roots, fruit peduncles, and flowers (54%). Some species that also produce yellow color on fabrics are *Garcinia dulcis* (Roxb.) [17], *Cinnamomum camphora* [18], and *Manilkara zapota* (Sapotaceae) [19].

Three species from the families Fabaceae, Euphorbiaceae, and Lamiaceae expressed brown rust color. *Syzygium guajava*, *Canarium decumanum*, *Aganosma marginata*, *Amorphophallus paeoniifolius*, *Spigelia, anthelmia*, and *Oroxylum indicum* were the species from different families that produced orange color and patterns on the fabric of their leaves. Two species from the family Rubiaceae, *Coffea* spp., and *Nauclea orientalis* were also generated orange color, but the motif unformed on the fabric. Thus, those species are potential as dipping dyes. Family Rubiaceae generates reddish to dark orange dyes in the dipping technique [16]. Moreover, the flowers generally used in dyeing are *Cosmos* sp. for orange dye [20] and *Tagetes erecta* for light brown [21].

3.2. The Color Expression on the Fabric. The printed samples formed the leaf shapes and even showed clear leaf venations were *Wrightia arborea*, *Gossypium arboreum*, *Acalypha wilkesiana*, *Polygonum barbatum*, *O. indicum*, *Antigonon leptopus*, and *Tecnona grandis* (Figures 3(a)–3(g)). The well-printed samples but unformed leaves or flowers according to the sample, such as the flowers of *Hibiscus rosa sinensis* L. and leaves of *N. orientalis* L. (Figures 3(h) and 3(i)). Bundle dyeing is a natural technique that transfers colors and shapes to produce patterns from natural substances, such as leaves or flowers, to the fabric. Transferring colors and shapes to the fabric works well if it can display the original color and texture of the natural substance's surface in detail. The natural substances used must have sensitive pigments that can be expressed with the help of specific triggers. The trigger in the fabric dyeing is called the mordant. Özen et al. [22] explained that the mordants that can be applied are potassium aluminum sulfate (alum), iron (II) sulfate, copper (II) sulfate, and tin chloride. In this research, we utilized alum and added myrobalan tannin to strengthen the color expression of the tested samples. Myrobalan is a plant species containing high tannin content, so it is used as a natural mordant [5]. Myrobalan will increase the affinity

Table 1: List of flora, shoot (s), mature of the leaf (m), the color from the lower surface of the leaf to the fabric (↑), the color from the lower and upper surface of the fabric (↑↓), Hasanuddin University area, Makassar (I), the educational forest of Hasanuddin University area, Maros (II), the nursery of the Second Region of Forest Seed/Seedling Office, South Sulawesi, Gowa (III), Special Purpose Forest Area, Tabo-Tabo Forestry Education and Training, Pangkep (IV), Rammang-Rammang Tourism Karst, Maros (V), Leang Kado Karst, Maros (VI), and Kahu village forest, Bontocani, Bone (VII).

Species	Plant families	Life form	Sample & position	Colors group	motif of samples	Site
Part used: leaves						
Antigonon leptopus Hook. & Arn	Polygonaceae	vine	s, m ↑	yellow	formed	V, VII
Polygonum barbatum	Polygonaceae	herb	s, m ↑↓		formed	VI
Anacardium occidentale L.	Anacardiaceae	tree			unformed	I, II, III
Lannea grandis (Dennst.) Engl	Anacardiaceae	tree	s, m ↑↓		formed	I, V
Mangifera caesia Jack.	Anacardiaceae	tree			unformed	III
Muntingia calabura L.	Muntingiaceae	tree	s, m ↑↓		formed	I
Tricalysia minahassae Comb	Rubiaceae	tree			unformed	III
Mussaenda erythrophylla Schum. & Thonn	Rubiaceae	shrub	s, m ↑↓		formed	I
Cananga odorata (Lam.) Hook.f. & Thomson	Annonaceae	tree	s, m ↑↓		formed	II
Monoon longifolium (Sonn.) B. Xue & R.M.K. Saunders	Annonaceae	tree			unformed	III
Tabebuia chrysotricha (Mart. ex DC.) Standl.	Bignoniaceae	tree	s ↑↓		formed	III
Spathodea campanulata P. Beauv	Bignoniaceae	tree	s ↑↓		formed	I
Podranea ricasoliana T.	Bignoniaceae	shrub	s, m ↑↓		formed	VI
Mesua ferrea L.	Calophyllaceae	tree	s, m ↑↓		formed	III
Calophyllum inophyllum L.	Calophyllaceae	tree	s, m ↑↓		formed	III
Casuarina equisetifolia L.	Casuarinaceae	tree	s, m ↑↓		formed	III
Garcinia celebica (Burm.) L	Clusiaceae	tree	s ↑↓		formed	II, IV
Vatica flavovirens L.f.	Dipterocarpaceae	tree			unformed	IV
Lycopodium clavatum L.	Lycopodiaceae	lycopod	s, m ↑↓		formed	IV
Aleurites moluccana L.	Euphorbiaceae	tree			unformed	II, III
Euphorbia pulcherrima Willd. ex Klotzsch	Euphorbiaceae	shrub	s ↑↓		formed	I
Hura crepitans L.	Euphorbiaceae	tree			unformed	I, III
Macaranga tanarius (L.) Müll.Arg.	Euphorbiaceae	tree	s ↑↓		formed	I
Diospyros macrophylla Blume	Ebenaceae	tree			unformed	III
Mimosa pudica L.	Fabaceae	shrub			unformed	I-VII
Calliandra calothyrsus	Fabaceae	tree	s, m ↑↓		formed	V
Samanea saman (Jacq.) Merr	Fabaceae	tree			unformed	I
Delonix regia (Bojer ex Hook.) Raf.	Fabaceae	tree	s, m ↑↓		formed	I, III
Parkia speciosa Hassk	Fabaceae	tree	s, m ↑↓		formed	III
Schizolobium amazonicum Huber ex Ducke	Fabaceae	tree	s, m ↑↓		formed	III
Intsia bijuga (Colebr.) Kuntze	Fabaceae	tree			unformed	III
Pericopsis mooniana (Thwaites) Thwaites	Fabaceae	tree			unformed	III
Cynometra cauliflora L.	Fabaceae	tree	s, m ↑↓		formed	III
Cajanus cajan (L.) Millsp.	Fabaceae	vine	s, m ↑↓		formed	II
Adenanthera pavonina L	Fabaceae	tree	s, m ↑↓		formed	I
Leucaena leucocephala L	Fabaceae	tree			unformed	I, IV
Vitex cofassus Reinw. ex Blume	Lamiaceae	tree			unformed	I-VII
Pogostemon cablin Benth	Lamiaceae	shrub	s, m ↑↓		formed	VI
Clerodendrum chinense (Osbeck) Mabb	Lamiaceae	shrub	s ↑↓		formed	I, V
Clerodendrum thomsoniae Balf.f.	Lamiaceae	shrub	s, m ↑↓		formed	V
Cryptocarya massoia (Oken) Kosterm.	Lauraceae	tree			unformed	I, II, VII
Cinnamomum burmannii (Nees & T. Nees) Blume	Lauraceae	tree	s, m ↑↓		formed	III
Swietenia macrophylla King.	Meliaceae	tree	s ↑↓		formed	II, III
Sandoricum koetjape (Burm.f.) Merr.	Meliaceae	tree	s ↑↓		formed	I, III
Toona sureni (Blume) Merr.	Meliaceae	tree	s ↑↓		formed	I, III
Myristica fatua Houtt.	Myristicaceae	tree	s ↑↓		formed	III
Tristania neriifolia (Sims) R.Br.	Myrtaceae	tree	s, m ↑↓		formed	III
Xanthostemon pubescens (Brongn. & Gris)	Myrtaceae	shrub	s, m ↑↓		formed	VII
Syzygium smithii (Poir.) Nied.	Myrtaceae	tree	s ↑↓		formed	I
Syzygium polyanthum (Wight) Walp.	Myrtaceae	tree			unformed	II, III, IV
Eucalyptus alba Reinw. ex Blume	Myrtaceae	tree	s, m ↑↓		formed	III
Eucalyptus deglupta Blume	Myrtaceae	tree	s ↑↓		formed	I, III

Table 1: Continued.

Species	Plant families	Life form	Sample & position	Colors group	motif of samples	Site
Olea europaea L.	Oleaceae	shrub	s ↑↓		formed	III
Ziziphus mauritiana Lam.	Rhamnaceae	tree			unformed	III, IV
Maesopsis eminii Engl.	Rhamnaceae	tree	s, m ↑↓		formed	III
Melicope latifolia (DC.) T.G. Hartley	Rutaceae	shrub			unformed	III
Melicopa obovata (H. St. John) T. G. Hartley & B. C. Stone	Rutaceae	shrub			unformed	III
Citrus Maxima (Burm.) Merr.	Rutaceae	tree			unformed	I-VII
Citrus aurantifolia Swing.	Rutaceae	tree			unformed	I-VII
Zanthoxylum rhetsum (Roxb.) DC	Rutaceae	tree	s, m ↑↓		formed	III
Flacourtia rukam Zoll. & Moritzi	Salicaceae	tree	s, m ↑↓		formed	III
Santalum album L.	Santalaceae	tree	s, m ↑↓		formed	III
Euphorianthus euneurus (Miq.) Leenh.	Sapindaceae	tree			unformed	I-VII
Dimocarpus longan Lour.	Sapindaceae	tree	s, m ↑↓		formed	I
Palaquium obtusifolium Burck.	Sapotaceae	tree			unformed	II, III, IV
Manilkara kauki (L.) Dubard	Sapotaceae	tree	s ↑↓		formed	III
Manilkara kanosiensis H.J. Lam & B. Meeuse	Sapotaceae	tree	s ↑↓		formed	III
Mimusops elengi L.	Sapotaceae	tree			unformed	VI
Passiflora edulis	Passifloraceae	vine	s, m ↑↓		formed	III
Leea aculeata Blume ex Spreng.	Vitaceae	shrub	s, m ↑↓		formed	II
Leea guineensis G. Don	Vitaceae	shrub	s, m ↑↓		formed	VI
Cissus verticillata L.	Vitaceae	vine	s, m ↑↓		formed	IV
Cosmos caudatus Kunth	Asteraceae	shrub	s, m ↑↓		formed	I, IV
Tagetes erectus L.	Asteraceae	shrub	s, m ↑↓		formed	I
Melampodium divaricatum (Rich.) DC.	Asteraceae	shrub	s, m ↑↓		formed	I
Punica granatum L.	Lythraceae	shrub	s, m ↑↓		formed	III
Daucus Carota L.	Apiaceae	herb	s, m ↑↓		formed	III
Impatiens walleriana Hook.f.	Balsaminaceae	herb	s, m ↑↓		formed	VII
Averrhoa bilimbi L.	Oxalidaceae	tree	s, m ↑↓		formed	I
Peperomia Pellucida L.	Piperaceae	herb			unformed	VI
Piper umbellatum L	Piperaceae	vine	s, m ↑↓		formed	V
Datura metel L.	Solanaceae	shrub			unformed	VII
Ipomea batatas (L.) Lam	Convolvulaceae	vine	s ↑↓		formed	II, IV
Gossypium arborium L.	Malvaceae	shrub	s, m ↑		formed	VII
Chrysothemis pulchella (Copper Leaf)	Gesneriaceae	herb	s, m ↑↓		formed	I
Seemannia sylvatica (Kunth) Baill	Gesneriaceae	herb			unformed	IV, VII
Aquilaria moluccensis Oken	Thymelaeaceae	tree	s ↑↓		formed	I
Pleurostylia opposita (Wallich) Alston	Celastraceae	shrub			unformed	II, IV
Bruguiera gymnorrhiza (L.)	Rhizophoraceae	shrub			unformed	V, VI
Lygodium microphyllum	Schizaeaceae	fern			unformed	V, VI
Acrostichum aureum L.	Pteridaceae	fern			unformed	IV, V
Epilobium montanum L	Onagraceae	herb	s, m ↑↓		formed	V, VI
Ficus auriculata Lour.	Moraceae	tree	s, m ↑↓		formed	VI
Parientaria officinalis L	Urticaceae	herb	s, m ↑↓		formed	VI
Torenia fournieri L.	Linderniaceae	shrub			unformed	III
Annona muricata L.	Annonaceae	tree			unformed	I, II, VII
Annona squamosa L.	Annonaceae	tree	s, m ↑↓	green	formed	I
Mangifera indica L.	Anacardiaceae	tree			unformed	I, II, VII
Alstonia scholaris (L.) R. Br	Apocynaceae	tree			unformed	I - III
Hygrophila auriculata (K. Schum)	Acanthaceae	herb			unformed	V-VI
Arthrophyllum diversifolium Blume	Araliaceae	tree	s, m ↑↓		formed	II
Tabebuia pallida L.	Bignoniaceae	shrub	s, m ↑↓		formed	I, III
Diospyros celebica Bakh.	Ebenaceae	tree			unformed	I - III
Senna siamea (Lam.) H.S. Irwin & Barneby	Fabaceae	tree	s, m ↑↓		formed	I
Senna alata (L.) Roxb.	Fabaceae	shrub	s, m ↑↓		formed	II
Senna occidentalis L	Fabaceae	shrub	s, m ↑↓		formed	VII
Bauhinea purpurea L.	Fabaceae	tree			unformed	I-VII
Caesalpinia pulcherrima (L.) Sw.	Fabaceae	shrub			unformed	I, II, VII
Gmelina arborea Roxb.	Lamiaceae	tree	s, m ↑↓		formed	I, II
Vitex trifolia L.	Lamiaceae	shrub	s, m ↑↓		formed	II
Persea americana Mill.	Lauraceae	tree			unformed	II, VII
Laegerstroemia speciosa (L.) Pers	Lythraceae	tree			unformed	I-III

Table 1: Continued.

Species	Plant families	Life form	Sample & position	Colors group	motif of samples	Site
Pisonia grandis R.Br.	Nyctaginaceae	tree	s, m ↑↓		formed	III
Durio zibethinus Murr.	Malvaceae	tree	s ↑↓		formed	I
Kleinhovia hospita L.	Malvaceae	tree	s ↑↓		formed	I
Hibiscus rosa-sinensis L.	Malvaceae	shrub	s ↑↓		formed	I
Urena lobata L	Malvaceae	shrub			unformed	VI
Broussonetia papyrife (L.)	Moraceae	shrub			formed	IV
Morus cathayana Hemsl.	Moraceae	shrub	s, m ↑↓		formed	I
Rosa hiproida L	Rosaceae	shrub	s, m ↑↓		formed	I
Prunus avium L.	Rosaceae	shrub			unformed	VI
Syzygium cumini (L.) Skeels	Myrtaceae	tree			unformed	II, IV
Psidium guajava L.	Myrtaceae	shrub	s, m ↑↓		formed	I, II
Piper baccatum Blume	Piperaceae	vine			unformed	IV-VI
Piper betle L.	Piperaceae	vine			unformed	II, IV-VI
Piper caducibracteum C.DC.	Piperaceae	vine			unformed	II, IV-VI
Anthocephalus chinensis (Lam.) Rich. ex Walp.	Rubiaceae	tree			unformed	I, III, V
Morinda citrifolia L.	Rubiaceae	shrub			unformed	I-VII
Gardenia jasminoides J. Ellis	Rubiaceae	shrub	s ↑↓		formed	II, IV
Lantana camara L.	Verbenaceae	shrub	s, m ↑↓		formed	II
Stachytarpheta jamaicensis (L.) Vahl	Verbenaceae	herb	s, m ↑↓		formed	II
Terminalia catappa L.	Combretaceae	tree	s, m ↑↓		formed	I
Cayratia trifolia L.	Vitaceae	shrub	s, m ↑↓		formed	II
Leea indica (Burm.f.) Merr.	Vitaceae	shrub			unformed	IV-VI
Ricinus communis L.	Euphorbiaceae	shrub	s, m ↑↓		formed	III
Jatropha curcas L.	Euphorbiaceae	shrub	s, m ↑↓		formed	II
Jatropha gossypifolia L.	Euphorbiaceae	shrub	s, m ↑↓		formed	I
Jatropha multifida L.	Euphorbiaceae	shrub	s, m ↑↓		formed	II
Acalypha indica L.	Euphorbiaceae	shrub			unformed	I
Acalypha hispida L	Euphorbiaceae	shrub	s, m ↑↓		formed	I
Euphorbia hirta L.	Euphorbiaceae	herb	s, m ↑↓		formed	I, II
Chromolaena odorata (L.) R.M. King & H. Rob.	Asteraceae	shrub			unformed	I-VII
Diplazium aberrans Maxon & C. V. Morton	Athyriaceae	fern			unformed	IV-V
Phyllanthus acidus (L.) Skeels	Phyllanthaceae	tree	s, m ↑↓		formed	III
Adiantum raddianum C. Presl	Pteridaceae	fern	s, m ↑↓		formed	II, I
Acrostichum aureum L.	Pteridaceae	fern			unformed	IV-V
Betula pubescens L.	Betulaceae	tree			unformed	IV
Alternanthera sessilis L.	Amaranthaceae	bush	s, m ↑↓		formed	III
Celosia argentea L	Amaranthaceae	bush	s, m ↑↓		formed	III
Passiflora foetida L	Passifloraceae	vine	s, m ↑↓		formed	II
Salix caprea L.	Salicaceae	bush			unformed	IV
Sicyos angulatus L.	Cucurbitaceae	vine	s, m ↑↓		formed	VI
Sphenoclea zeylanica Gaertn	Sphenocleaceae	herb			unformed	V
Azadirachta indica A. Juss.	Meliaceae	tree	s, m ↑↓		formed	I
Ipomea sp	Convolvulaceae	vine	s ↑↓		formed	II, VI
Scurrula atropurpurea (Blume) Danser	Loranthaceae	vine			unformed	IV
Pangium edule Reinw. ex Blume	Achariaceae	tree	s ↑↓	brown rust	formed	III
Monsterra deliciosa Liebm.	Araceae	vine			unformed	II, IV, VII
Agathis dammara (Lamb.) Rich. & A. Rich.	Araucariaceae	tree	s, m ↑↓		formed	III
Terminalia mantaly H. Perrier	Combretaceae	tree			unformed	III
Theobroma cacao L.	Malvaceae	tree	s, m ↑↓		formed	I
Tilia platyphyllos Scop	Malvaceae	shrub			unformed	V
Cinnamomum sp	Lauraceae	tree	s, m ↑↓		formed	III
Syzygium aromaticum (L.) Merr. & L.M. Perry	Myrtaceae	tree	s, m ↑↓		formed	II
Callistemon citrinus (Curtis) Skeels	Myrtaceae	tree			unformed	VI
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	tree	s, m ↑↓		formed	III
Flacourtia inermis Roxb.	Salicaceae	tree			unformed	III, V
Pometia pinnata J. R. Forst. & G. Forst.	Sapindaceae	tree	s, m ↑↓		formed	I, III
Sapindus saponaria L.	Sapindaceae	tree	s, m ↑↓		formed	VI
Selaginella tamariscina (P. Beauv.) Spring	Selaginellaceae	fern			unformed	II, IV
Schima wallichii (DC.) Korth.	Theaceae	tree			unformed	III

Table 1: Continued.

Species	Plant families	Life form	Sample & position	Colors group	motif of samples	Site
Plectranthus scutellarioides L.	Lamiaceae	herb	s, m ↑↓		formed	I
Volkameria inermis L	Lamiaceae	vine	s, m ↑↓		formed	VI
Ocimum citriodorum L.	Lamiaceae	shrub			unformed	II, IV
Prunella vulgaris V.	Lamiaceae	shrub			unformed	II, IV
Melastoma malabathricum L.	Melastomataceae	shrub	s, m ↑↓		formed	II
Garcinia mangostana L.	Clusiaceae	tree			unformed	II, IV
Ficus benjamina L.	Moraceae	tree			unformed	V, VI
Solanum hirtum Vahl.	Solanaceae	shrub			unformed	VII
Eclipta prostrate L.	Asteraceae	herb	s, m ↑↓		formed	I, V
Fagus grandifolia Ehrh	Fagaceae	tree			unformed	VI
Inga sarmentosa D.	Fabaceae	shrub	s, m ↑↓		formed	II, III
Poecilanthe parviflora B.	Fabaceae	shrub	s, m ↑↓		formed	VI
Barleria cristata L.	Acanthaceae	shrub			unformed	V, VI
Achyranthes aspera L.	Amaranthaceae	shrub			unformed	II, IV
Boehmeria cylindrica L.	Urticaceae	tree			unformed	IV
Angelica sylvestris L.	Apiaceae	shrub			unformed	IV, VI
Rauvolfia caffra S.	Apocynaceae	tree	s, m ↑↓		formed	VI
Muchlenbeckia complexa A.C.	Polygonaceae	vine			unformed	IV, VII
Rhizophora mucronata Lamk	Rhizophoraceae	tree			unformed	V, VI
Tectona grandis L.f.	Lamiaceae	tree	s, m ↑↓	red	formed	I, II, III
Indigofera tinctoria L.	Fabaceae	shrub			unformed	I
Begonia spp	Begoniaceae	herb			unformed	V, VI
Hemigraphis alternata (Burm.f.) T. Anderson	Acanthaceae	herb		Pink	unformed	V, VI
Eryngium foetidum L.	Apiaceae	herb		grey	unformed	V, VI
Cerbera manghas L.	Apocynaceae	tree			unformed	V, VI
Cleome rutidosperma Dc.	Cleomaceae	shrub	s, m ↑↓		fermod	VI
Erythina variegata L.	Fabaceae	tree	s, m ↑↓		formed	VI
Inga alba (Sw.) W.	Fabaceae	tree	s, m ↑↓		formed	II
Monstera Borsigiana L.	Araceae	vine	s, m ↑↓		formed	I
Wringtia arborea (Densst.) Mabb	Apocynaceae	tree	s, m ↑↓		formed	I
Acalypha wilkesiana Mull. Arg.	Euphorbiaceae	shrub	s, m ↑↓	black	formed	I
Episcia cupreata Hanst	Gesneriaceae	herb			unformed	II
Codiaeum variegatum (L.) A. Juss	Euphorbiaceae	shrub		faded blue	unformed	VII
Coffea sp	Rubiaceae	shrub			unformed	VII
Nauclea orientalis L.	Rubiaceae	tree		orange	unformed	VI
Symplocos ophirensis C.B. Clarke	Symplocaceae	shrub			unformed	II, IV
Syzigium guajava L.	Myrtaceae	tree	s, m ↑↓		formed	I, II
Canarium decumanum Gaertn (Burs.)	Burseraceae	tree	s ↑↓		formed	I
Aganosma marginata (Roxb.) G. Don	Apocynaceae	vine	s, m ↑↓		formed	II
Amorphophallus paeoniifolius (Dennst.) Nicolson.	Araceae	herb	s, m ↑↓		formed	VI
Spigelia anthelmia L.	Loganiaceae	herb	s, m ↑↓		formed	VI
Oroxylum indicum (L.) Vent.	Bignoniaceae	tree	s, m ↑↓		formed	IV, V
Part used: flowers						
Seemannia sylvatica (Kunth) Baill	Gesneriaceae	herb			formed	VII
Chrysothemis pulchella (Copper Leaf)	Gesneriaceae	herb		orange	formed	I
Tagetes erectus L.	Asteraceae	shrub			formed	I
Spathodea campanulata P. Beauv	Bignoniaceae	tree			unformed	VI
Rosa hiproida L.	Rosaceae	shrub			unformed	I
Punica granatum L.	Lythraceae	shrub		pink	unformed	III
Mussaenda erythrophylla Schum. & Thonn	Rubiaceae	shrub			formed	I
Melastoma malabathricum L.	Melastomataceae	shrub			formed	II
Plumeria rubra L.	Apocynaceae	shrub			unformed	VI
Stachytarpheta jamaicensis (L.) Vahl	Verbenaceae	herb			unformed	V
Hibiscus sabdariffa L	Malvaceae	shrub		red	unformed	I-VII
Hibiscus rosa-sinensis L.	Malvaceae	shrub			formed	I
Barleria cristata L.	Acanthaceae	shrub		blue	unformed	VI, VI
Torenia fournieri L.	Linderniaceae	shrub			unformed	III
Cosmos caudatus Kunth	Asteraceae	shrub			formed	I
Melampodium divaricatum (Rich.) DC.	Asteraceae	herb		yellow	formed	I
Impatiens balsamina	Balsaminaceae	herb			formed	I
Senna alata (L.) Roxb.	Fabaceae	shrub			formed	II
Caesalpinia pulcherrima (L.) Sw.	Fabaceae	shrub			formed	I
Senna siamea (Lam.) H.S. Irwin & Barneby	Fabaceae	tree			formed	I
Bauhinea purpurea L.	Fabaceae	shrub			formed	I
Hibiscus tiliaceus L.	Malvaceae	tree			formed	II, IV
Gossypium arborium	Malvaceae	shrub			formed	VII
Crossandra infundibuliformis L.	Acanthaceae	herb			formed	I
Tabebuia chrysotricha (Mart. ex DC.) Standl.	Bignoniaceae	tree			unformed	I-VII
Cerbera manghas L.	Apocynaceae	tree		grey	formed	I
Leea guineensis G.Don	Vitaceae	shrub			unformed	VI
Eclipta prostrata L.	Asteraceae.	shrub		green	formed	V
Macaranga tanarius (L.) Müll.Arg.	Euphorbiaceae	tree			formed	I

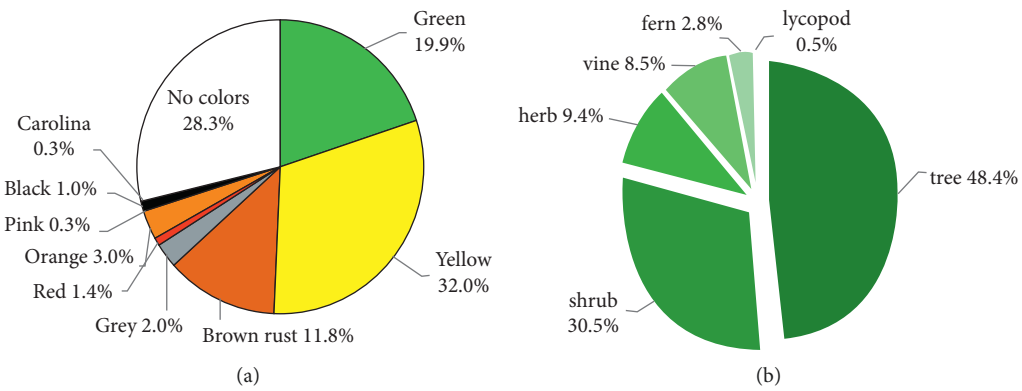

Figure 2: Percentage of colors group expression of leaf samples (a) and vegetation life forms of colored leaves (b).

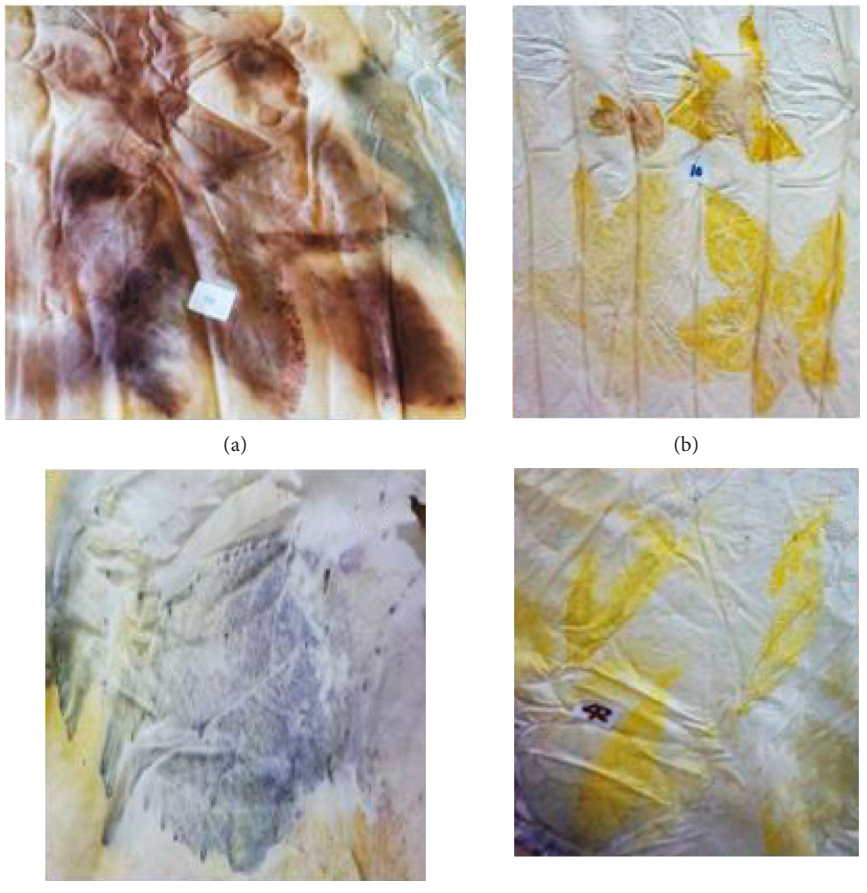

Figure 3: Continued.

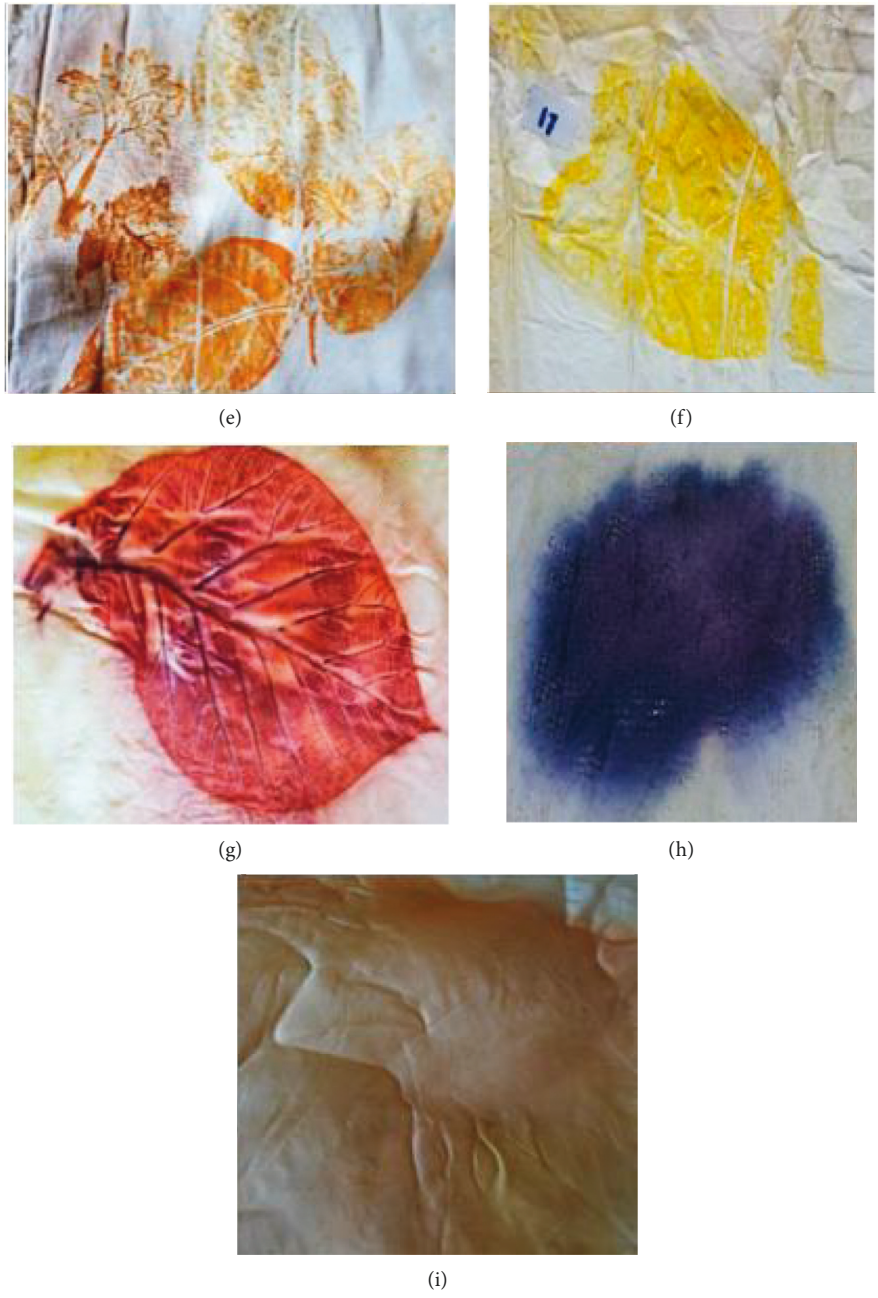

Figure 3: The samples that produce color: (a) *Wrightia arborea* (Dennst.) Mabb, (b) *Gossypium arboreum* L., (c) *Acalypha wilkesiana* Mull. Arg., (d) *Polygonum barbatum* L. (e) *Oroxylum indicum* (L.) Vent., (f) *Antigonon leptopus* Hook. & Arn., (g) *Tecnona grandis* L., (h) *Hibiscus rosa-sinensis* L., and (i). *Nauclea orientalis* L.

of natural dyes on fabrics [23]. The application of alum mordant and natural myrobalan mordant is still relatively safe or nontoxic [24].

The color of each plant on the fabric may differ from the original color due to the used mordant types. The option of using alum as the mordant produces a color that is stronger and closer to the color without the mordant, as in *G. dulcis* produces a beige shade if without mordant and becomes a yellow shade using alum [17]. The iron (II) sulfate as mordant generates the natural color becoming darker (dark brown, grey, or even black) [17, 25–27]. It is the main reason for alum mordant and tannin application as preliminary research on natural substance dyeing.

There is no visual indication of plant species that can be used as a fabric dye base. Morphologically, there are no definite indications that the leaves can be used as fabric dyes. Leaf shape, rough or smooth leaf surface, many or few trichomes, and producing a sharp odor are not good indicators of color production. No characteristic of the life-form groups (trees, shrubs, vines, or herbs) can be used as

dyes. Likewise, under the position of the leaves on the surface of the fabric, two species of upper surface leaves produce color (*A. leptopus* and *G. arboreum*), and twenty-four species produce color in shoots. The printed color variations are highly dependent on the color pigments contained in the dyes used. The phytochemicals responsible for the dyeing are from the flavonoid group [20, 28, 29]. Organic dyes are divided into chemical classes: anthraquinone-to none, indigoid, naphthoquinone, carotenoids, flavones, dihydropyran, anthocyanidin, and flavonol [16]. The colors produced by teaks' (*Tectona grandis*) leaves are orange, red, bloody red, and dark brown with very strong and bright venation due to β-carotene pigment, pheophytin, pelargonidin 3-glucoside, pelargonidin 3,7-diglucoside, and anthocyanin [30]. At the same time, the green color is expressed from leaves rich in chlorophyll and other colors from indigotin [13].

The strength of the sample colors on the fabrics also depends on the presence of hydroxyl or carbonyl groups in the structure of the color pigment, which can be bound by the positively charged metal complex of the mordant. The dyes' metal anions and cations have a strong affinity for positively charged amino groups on the negatively charged carboxyl groups of silk fiber. Thus, ionic bonds are formed between the dye with the mordant and fiber, between metal and fiber, and eventually between the dye and metal ions. A dye molecule can only form a fabric fiber bond, while a mordant molecules bond with two or more plant color pigment molecules [25]. In addition to the pigment bonding to the mordant, the mordants' type and concentration also determine the color strength [31] and are not determined by the temperature at the time of dying [32].

The natural dyeing of the fabric depends on not only the mordant used but also the dyeing technique [33]. The highly vivid, sharp, and impressive visual effects are produced using a minimum amount of mordant plants for optimal application to obtain unique and non-repeatable results [22]. The contact dyeing technique tends to produce random patterns or high concentrations of color in particular areas. These unique colors and/or patterns cannot be duplicated, resulting in highly creative products. Preparation of substances is from various plants for dyes and patterns. The dyes' substances and textile types produce a variation in color strength in the contact dying technique [34]. Plant parts expressing strong color and providing detailed visualization of leaf venation are the best material for the bundle dyeing technique. The genus Leea, *G. arboreum*, *A. leptopus*, and *O. indicum* produce strong colors from yellow to orange groups. Young teak (*T. grandis*) leaves have the most robust red color and clear venation in the red group.

The dye leaves with a clear venation pattern can also be used as dyes for the dipping technique. Natural dyeing with the dipping technique can be implemented as a basic dye on fabrics as a combination before bundle dyeing. Fresh or dried coffee leaves can be a suitable fabric dye by extracting dyeing solution [35]. Eighty-seven species that produced colors but were unformed can produce color by dipping technique, for example, *H. rosa sinensiss*' flowers and *N. orientaliss*' leaves. As the Bidayuh Dayak Tribe, Sanggau, West Kalimantan, uses the ground flower of *H. rosa sinensis* (Malvaceae) and produces green color with the addition of calx [15]. Meanwhile, *H. sabdariffa* contains anthocyanin pigment, an important dye-producing plant [36]. Anthocyanins give red, purple, and blue colors produced by flowers or fruits [37].

4. Conclusion

This study expects to find alternative dyes for silk fabrics to meet the consumer demand for environmentally friendly products increasing lately. Exploration of the color-producing plant species that are found around us has not been revealed yet. Several species of plants can be an alternative to dye silk cloth, especially the leaves. There are 126 species of plants that can be used as dyes using the bundle dyeing technique and 87 species that produce colors without patterns formed but have the potential as dyes for yarn or fabric. The colors investigated in this study can still be described differently by trying other types of mordant.

Data Availability

The vegetation-enumerated data used to support the findings of this study are included within the article.

Disclosure

The funding agency did not influence the design of the study; the collection, analyses, or interpretation of data; and the writing of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

Research grant funds received from the Directorate of Research and Community Service Director General of Higher Education (DRPM, Dirjen Dikti) are acknowledged by the authors.

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