Research Article

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

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The development of dyeing from natural substances for silk fabrics has been rapidly growing in recent years. This study aimed to explore the plant species producing 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 lycops (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 Psychotria 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 115,000,000.00 (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 eco-print technique are ginkgo leaves, eucalyptus, willow, teak, and so on. The finding will inform new dyes of bundle dyeing or eco-print 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 karst 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 7th–10th 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(SO4)2·12H2O), 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 “uniformed” 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
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 paconifolius*, *Spigelia, anthelminia*, and *Orozylum 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 uniformed 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 veinsations 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 |
|---------------------------------|----------------|-----------|-------------------|--------------|-----------------|------|
| 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        | II   |
| Muntingia calabura L.           | Muntingiaceae  | tree      | s, m ↑↓           |              | formed          | I    |
| Tricalysia minahassae Comb       | Rubiaceae      | tree      |                   |              | unformed        | III  |
| Mussaenda erythropylla Schum. & Thom. | Rubiaceae    | shrub     | s, m ↑↓           |              | formed          | I    |
| Cananga odorata (L.) Hook.f. & Breckon | Annonaceae    | tree      | s, m ↑↓           |              | formed          | II   |
| R.M.K. Saunders                 | Annonaceae     | tree      |                   |              | unformed        | III  |
| Naboa longifolia (Som.) B. Xue & | Annonaceae     | tree      |                   |              | unformed        | III  |
| Standl.                         | Bignoniaceae   | tree      | s ↑↓              |              | formed          | III  |
| Sporadendron campylura P. Beauv | Bignoniaceae   | tree      | s ↑↓              |              | formed          | I    |
| Podreaea ricasoliana T.         | Bignoniaceae   | shrub     | s, m ↑↓           |              | formed          | VI   |
| Messa ferrea L.                 | Calophyllaceae | tree      | s, m ↑↓           |              | formed          | III  |
| Colophyllum calophyllum L.      | Calophyllaceae | tree      | s, m ↑↓           |              | formed          | III  |
| Casuarina equisiliolit A.        | Casuarinaceae  | tree      | s, m ↑↓           |              | formed          | III  |
| Garcinia celebica (Burms.) L.   | Clusiaceae     | tree      | s ↑↓              |              | formed          | II, IV |
| Vatica flavovirens K.L.         | Dipterocarpaceae| tree | unformed          |              | IV              |
| Lycocepodium 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  | shrub     | s ↑↓              |              | formed          | I    |
| Diopterys macrophylla Blume      | Ebenaceae      | tree      |                   |              | unformed        | III  |
| Mimosa pudica L.                | Fabaceae       | shrub     |                   |              | unformed        | I-VII |
| Callistemon callosusus L.        | Fabaceae       | tree      | s, m ↑↓           |              | formed          | V    |
| Samantha saman (Jacq.) Merr.    | Fabaceae       | tree      | s, m ↑↓           |              | formed          | 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 Duke | Fabaceae     | tree      | s, m ↑↓           |              | formed          | III  |
| Intisia bijuga (Cleve.) Kunth.   | Fabaceae       | tree      | s, m ↑↓           |              | formed          | III  |
| Pericopsis mononiana (Thwaites) T. | Fabaceae     | tree      |                   |              | unformed        | III  |
| Gymnema caulis L.               | Fabaceae       | tree      | s, m ↑↓           |              | formed          | III  |
| Cajanus cajan (L.) Millsp.       | Fabaceae       | tree      | s, m ↑↓           |              | formed          | II   |
| Anadenospermum pavonina L.      | Fabaceae       | tree      | s, m ↑↓           |              | formed          | I    |
| Leucaena leucocephala L.         | Fabaceae       | tree      |                   |              | unformed        | I, IV |
| Vitex cognasch Reinv. ex Blume   | Lamiaceae      | tree      |                   |              | unformed        | I-VII |
| Pogostemon cablin Benthi          | Lamiaceae      | shrub     | s, m ↑↓           |              | formed          | VI   |
| Clerodendrum chinense (Osbeck) Mabb | Lamiaceae     | shrub     | s, m ↑↓           |              | formed          | I, V |
| Clerodendrum thomsonianum Balf.f. | Lamiaceae     | shrub     | s, m ↑↓           |              | formed          | V    |
| Cryptocarya massaia (Okon.) 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 |
| Sandericum 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  |
| Tristani um neriifolia (Sim.) R. Br. | Myrtaceae    | tree      | s, m ↑↓           |              | formed          | III  |
| Xanthostemon pubescens (Brong. & Gris) | Myrtaceae | shrub     | s, m ↑↓           |              | formed          | VII  |
| Syzygium smithii (Poir.) Nied.   | Myrtaceae      | tree      | s ↑↓              |              | formed          | I, V  |
| Syzygium polyanthum (Wight) Walp. | Myrtaceae     | tree      |                   |              | unformed        | II, III, IV |
| Eucalyptus alba Reinv. ex Blume  | Myrtaceae      | shrub     | s, m ↑↓           |              | formed          | III  |
| Eucalyptus deglupta Blume        | Myrtaceae      | tree      | s ↑↓              |              | formed          | I, III |
| Species                                   | Plant families | Life form | Sample & position | Colors group | motif of samples | Site |
|-------------------------------------------|----------------|-----------|-------------------|--------------|------------------|------|
| Olea europaea L.                          | Oleaceae       | shrub     | s ††               | formed       | III              |      |
| Zeuxis mauritiana Lam.                    | Rhamnaceae     | tree      |                   |              |                  |      |
| Macropis emissi Engl.                     | Rhamnaceae     | tree      | s, m ††            | formed       | III, IV          |      |
| Melicope fistulosa (DC.) T.G. Hartley & B. C. Stone | Rutaceae   | shrub     |                   |              | unformed         | III  |
| Citrus maximia (Burm.) Merr.              | Rutaceae       | tree      |                   | unformed     | I-VII            |      |
| Zanthoxylum ricketts (Roxb.) DC.          | Rutaceae       | tree      | s, m ††            | formed       | III              |      |
| Flacourtia ricket Zoll. & Moritz.         | Salicaceae     | tree      | s, m ††            | formed       | III              |      |
| Santalum album L.                         | Santalaceae    | tree      | s, m ††            | formed       | III              |      |
| Euphorianthus venaeczus (Miq.) Leenh.     | Sapindaceae    | tree      |                   | unformed     | I-VII            |      |
| Dimocarpus longan Loui.                   | Sapindaceae    | tree      | s, m ††            | formed       | II, III, IV      |      |
| Palagumum oblongifolium Burck.            | Sapotaceae     | tree      | s ††               | formed       | III              |      |
| Manilkara kanwa (L.) Dubard               | Sapotaceae     | tree      |                   | unformed     | III              |      |
| Manilkara kunanensisii H.J. Lam & B.      | Sapotaceae     | tree      | s ††               | formed       | III              |      |
| Moeceae                                   | Sapotaceae     | tree      |                   | unformed     | VI               |      |
| 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               |      |
| Cynus verticillata L.                     | Vitaceae       | vine      | s, m ††            | formed       | IV               |      |
| Cosmus caudatus Kunth                     | Asteraceae     | shrub     | s, m ††            | formed       | I, IV            |      |
| Tagetes erecta L.                         | Asteraceae     | shrub     | s, m ††            | formed       | I                |      |
| Melampodium divericatum (Rich.) DC.       | Asteraceae     | shrub     | s, m ††            | formed       | III              |      |
| Panicus granatum L.                       | Lythraceae     | shrub     | s, m ††            | formed       | III              |      |
| Daeace Carota L.                          | Apiaceae       | herb      |                   | formed       | III              |      |
| Impatiens pullerianna Hook.f.             | Balsaminaceae  | herb      | s, m ††            | formed       | VII              |      |
| Averrhoa bilimbi L.                       | Oxalidaceae    | tree      | s, m ††            | formed       | I                |      |
| Piperomia Felliida L.                     | Piperaceae     | herb      |                   | unformed     | VI               |      |
| Piperum umbilatum 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 arboreum L.                     | Malvaceae      | shrub     | s, m ††            | formed       | VII              |      |
| Chrysanthemum pulchella (Copper Leaf)     | Geraniaceae    | herb      | s, m ††            | formed       | I                |      |
| Scirpanthus sylvatica (Korth) Baiil        | Geraniaceae    | herb      |                   | unformed     | IV, VII          |      |
| Aquilaria malaccensis Okon                | Thymelaeaceae  | tree      | s ††               | formed       | I                |      |
| Polystylosia opposita (Wallich) Alston    | Celastraceae   | shrub     |                   | formed       | II, IV           |      |
| Bruguiera gymnoorhiza (L.)                | Rhizophoraceae | shrub     |                   | unformed     | V, VI            |      |
| Lygodium microphyllum                    | Schizaceae     | fern      |                   | unformed     | V, VI            |      |
| Acerostichum anurnum L.                   | Pteridaceae    | fern      |                   | formed       | IV, V            |      |
| Epilobium montanum L.                     | Onagraceae     | herb      | s, m ††            | formed       | V, VI            |      |
| Ficus auriculata Loor.                    | Moraceae       | tree      | s, m ††            | formed       | VI               |      |
| Paripartia officinalis L.                 | Urticaeae      | shrub     | s, m ††            | formed       | VI               |      |
| Torenia fournieri L.                      | Linderniaceae  | shrub     |                   | unformed     | I, II, VII       |      |
| Annona muricata L.                        | Annonaceae     | tree      | s, m ††            | green        | formed           | I    |
| Annona squamosa L.                        | Annonaceae     | tree      | s, m ††            | unformed     | I, II, VII       |      |
| Mangifera indica L.                       | Anacardaceae   | tree      |                   | unformed     | I, II, VII       |      |
| Aristolochia scholaris (L.) R. Br         | Acanthaceae    | tree      |                   | formed       | I, II, VII       |      |
| Hygropha auriculata (K. Schum.)           | Acanthaceae    | herb      |                   | unformed     | V-VI             |      |
| Arterbophyllum diversifolium Blume        | Araliaceae     | tree      | s, m ††            | formed       | II               |      |
| Tabea pala L.                             | Bignoniaceae   | shrub     | s, m ††            | formed       | I, III           |      |
| Diospyros celebica Bak.                   | Ebenaceae      | tree      |                   | unformed     | 1-III            |      |
| Senna siamee (Lam.) H.S. Irwin & Barnchey | Fabaceae       | tree      | s, m ††            | formed       | I                |      |
| Senna alata (L.) Roxb.                    | Fabaceae       | shrub     | s, m ††            | formed       | II               |      |
| Senna occidentalia L.                     | Fabaceae       | shrub     | s, m ††            | formed       | VII              |      |
| Bauhinia purpurea L.                      | Fabaceae       | tree      |                   | unformed     | I-VII            |      |
| Casalpinia 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               |      |
| Persoon americana Mill.                   | Lauraceae      | tree      |                   | unformed     | II, VII          |      |
| Laggerstroemia speciosa (L.) Pers.         | Lythraceae     | tree      |                   | unformed     | I-III            |      |
| Species                  | Plant families | Life form | Sample & position | Colors group | motif of samples | Site |
|--------------------------|----------------|-----------|-------------------|--------------|------------------|------|
| *Pisonia grandis* R.B.  | Nyctaginaceae  | tree      | s, m ↑↓             | formed       | III              |      |
| *Durio zibethinus* Merr. | Malvaceae      | tree      | s ↑↓               | formed       | I                |      |
| *Kleinovia hospita* L.   | Malvaceae      | tree      | s ↑↓               | formed       | I                |      |
| *Hibiscus rosa-sinensis* L. | Malvaceae | shrub | s ↑↓                | formed       | I                |      |
| *Urena lobata* L.        | Malvaceae      | shrub     | s ↑↓               | formed       | VI               |      |
| *Broussonetia papyrifera* (L.) | Moraceae | shrub | s, m ↑↓            | formed       | IV               |      |
| *Morus cathayana* Hems.  | Moraceae       | shrub     | s, m ↑↓            | formed       | I                |      |
| *Rosa hipida* L.         | Rosaceae       | shrub     | s, m ↑↓            | formed       | I                |      |
| *Prunus avium* L.        | Rosaceae       | shrub     | s, m ↑↓            | formed       | VI               |      |
| *Syzygium cumini* (L.) Skeels | Myrtaceae | tree | s                        | unformed       | II, IV            |      |
| *Psidium guajava* L.     | Myrtaceae      | shrub     | s, m ↑↓            | formed       | I, II            |      |
| *Piper baccatum* Blume   | Piperaceae     | vine      | s                    | unformed       | IV, VI            |      |
| *Piper betle* L.         | Piperaceae     | vine      | s                    | unformed       | IV, VI            |      |
| *Piper capellibracteum* C,DC | Piperaceae | vine | s                    | unformed       | II, IV            |      |
| *Anthocephalus chinensis* (Lam.) Rich. ex Waip. | Rubiaceae | tree | s                        | unformed       | I, III, V         |      |
| *Morinda citrifolia* L.  | Rubiaceae      | shrub     | s                    | unformed       | I, VII            |      |
| *Gardenia jamassicensis* J. Ellis | Rubiaceae | shrub | s ↑↓                | formed       | II, IV            |      |
| *Lantana camara* L.      | Verbenaceae    | shrub     | s, m ↑↓             | formed       | II               |      |
| *Stackebrandia 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       | I                |      |
| *Leea indica* (Burm.f.) Merr. | Vitaceae | shrub | s                        | unformed       | IV, VI            |      |
| *Ricinus communis* L.    | Euphorbiaceae  | shrub     | s, m ↑↓             | formed       | III              |      |
| *Jatropha curcas* L.     | Euphorbiaceae  | shrub     | s, m ↑↓             | formed       | II               |      |
| *Jatropha gossypifola* L. | Euphorbiaceae  | shrub     | s, m ↑↓             | formed       | I                |      |
| *Jatropha multifida* L.  | Euphorbiaceae  | shrub     | s, m ↑↓             | formed       | II               |      |
| *Acalypha indica* L.     | Euphorbiaceae  | shrub     | s, m ↑↓             | formed       | 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 & I. Rob. | Asteraceae | shrub | s                        | unformed       | I, VII            |      |
| *Diplazium aberrans* Maxon & C. V. Morton | Athyridaceae | fern | s                    | formed       | IV, V            |      |
| *Phyllanthus acidus* (L.) Skews | Phyllanthaceae | tree | s, m ↑↓            | formed       | III              |      |
| *Adiantum raddianum* C. Presl | Pteridaceae | fern | s, m ↑↓            | formed       | III              |      |
| *Aristolochia aureum* L. | Pteridaceae    | fern      | s                    | formed       | III              |      |
| *Betula pubescens* L.    | Betulaceae     | tree      | s                    | unformed       | IV               |      |
| *Amaranthus retroflexus* 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      | s                    | unformed       | IV               |      |
| *Sicyos angulatus* L.    | Cucurbitaceae  | vine      | s                    | formed       | VI               |      |
| *Sphenoclea zeylanica* Gaertn | Sphenocoleaceae | herb | s                    | formed       | V                |      |
| *Aspidistra indica* A. Juss. | Meliaceae | tree | s, m ↑↓           | formed       | I                |      |
| *Ipomea sp*              | Convolvulaceae | vine | s, m ↑↓             | formed       | II, VI            |      |
| *Scirpus atropurpureus* (Blume) Danser | Loranthaceae | vine | s                    | formed       | IV               |      |
| *Pangium edule* Reinw. ex Blume | Araliaceae | tree | s ↑↓                | formed       | III              |      |
| *Monstera delicosa* Liebm. | Araceae        | vine      | s                    | unformed       | II, IV, VII      |      |
| *Agathis alba* (Lamb.) Rich. & A. Rich. | Araucariaceae | tree | s, m ↑↓            | formed       | III              |      |
| *Terminalia mantaly* H. Perrier | Combretaceae | tree | s, m ↑↓            | formed       | III              |      |
| *Theobroma cacao* L.     | Malvaceae      | shrub     | s, m ↑↓             | formed       | I                |      |
| *Tilia platyphyllos* Scop. | Malvaceae | shrub | s ↑↓                | formed       | V                |      |
| *Cinnamomum sp*          | Lauraceae      | tree      | s, m ↑↓             | formed       | II, III           |      |
| *Syzygium aromaticum* (L.) Merr. & L.M. Perry | Myrtaceae | tree | s, m ↑↓           | formed       | II                |      |
| *Callictenon citrinus* (Curti.) Skews | Myrtaceae | tree | s, m ↑↓           | formed       | VI                |      |
| *Neea malaccika cadamba* (Rehb.) Bosser | Rubiaceae | tree | s, m ↑↓            | formed       | III              |      |
| *Ficus carica* L.         | Moraceae       | shrub     | s, m ↑↓             | formed       | III              |      |
| *Pometia pinnata* J. R. Forst. & G. Forst. | Sapindaceae | tree | s, m ↑↓            | formed       | III, III          |      |
| *Sapindus saponaria* L.  | Sapindaceae    | tree      | s, m ↑↓             | formed       | VI               |      |
| *Selaginella tamariscina* (P. Beauv.) Spring | Selaginellaceae | fern | s                    | formed       | II, IV            |      |
| *Schima wallichii* (DC.) Korth. | Theaceae | tree | s                    | unformed       | III              |      |
Table 1: Continued.

| Species                          | Plant families | Life form | Sample & position | Colors group | motif of samples | Site |
|----------------------------------|----------------|-----------|-------------------|--------------|-----------------|------|
| Plectranthus scutellarisoides L. | Lamiaceae      | herb      | s, m ‡           | formed       | I               |      |
| Volkommenia inermis L.           | Lamiaceae      | vine      | s, m ‡           | formed       | VI              |      |
| Ocimum citriodorum L.            | Lamiaceae      | shrub     |                   | uniformed    | II, IV          |      |
| Prenanthes volubilis L.          | Lamiaceae      | shrub     |                   | uniformed    | II, IV          |      |
| Melastoma malabathricum L.       | Melastomataceae | shrub | s, m ‡           | formed       | II              |      |
| Garcinia mangostana L.           | Clusiaceae     | tree      |                   | uniformed    | II, IV          |      |
| Ficus benjamina L.               | Moraceae       | tree      |                   | uniformed    | V, VI           |      |
| Solanum hirtum Vahl.             | Solanaceae     | tree      |                   | uniformed    | VII             |      |
| Eclipta prostrata L.             | Asteraceae     | herb      | s, m ‡           | formed       | I, V            |      |
| Fagus grandifolia Ehrh           | Fagaceae       | tree      |                   | uniformed    | VI              |      |
| Inga senarissa D.                | Fabaceae       | shrub     | s, m ‡           | formed       | II, III         |      |
| Pococannhe parviflora B.         | Fabaceae       | shrub     | s, m ‡           | formed       | VI              |      |
| Barleria cristata L.             | Acanthaceae    | shrub     |                   | uniformed    | V, VI           |      |
| Achyranthes aspera L.            | Amaranthaceae  | shrub     |                   | uniformed    | II, IV          |      |
| Borbermia cylindrica L.           | Urticaceae     | tree      |                   | uniformed    | IV              |      |
| Angelica sylvestris L.           | Apiaceae       | shrub     |                   | uniformed    | IV, VI          |      |
| Rauwolfia caffra S.              | Apocynaceae    | tree      | s, m ‡           | formed       | VI              |      |
| Muchenbeckia complexa A.C.       | Polygonaceae   | vine      |                   | uniformed    | IV, VII         |      |
| Rhizophora mucronata Lamk        | Rhizophoraceae | tree      |                   | uniformed    | VI              |      |
| Tectona grandis L.F.             | Lamiaceae      | shrub     | s, m ‡           | red          | formed          | I, II, III |
| Indigofera tinctoria L.           | Fabaceae       | shrub     |                   | uniformed    | V, VI           |      |
| Begonia spp                      | Begoniaceae    | herb      |                   | uniformed    | V, VI           |      |
| Hemitropis alternata (Burn.f.) T. | Acanthaceae    | herb      |                   | pink         | uniformed       | V, VI |
| Anderson                         | Acanthaceae    | herb      |                   |             |                 |      |
| Eryngium foetidum L.             | Acanthaceae    | herb      |                   |             |                 |      |
| Cleopatra manghaes L.            | Acanthaceae    | herb      |                   |             |                 | V, VI |
| Symplocos ophiophora C.B. Clarke | Symplocaceae   | shrub     | s, m ‡           | grey         | uniformed       | V, VI |
| Syringia guayava L.              | Myrtaceae      | tree      | s, m ‡           | formed       | VI              |      |
| Inga alba (Sw.) W.               | Fabaceae       | tree      | s, m ‡           | formed       | VI              |      |
| Monstera Borsigiana L.           | Araceae        | vine      | s, m ‡           | formed       | I               |      |
| Wringia arbores (Dentist.) Mabb   | Apocynaceae    | tree      | s, m ‡           | formed       | I               |      |
| Acalypha wilkesii Mull. Arg.     | Euphorbiaceae  | shrub     | s, m ‡           | black        | formed          | I     |
| Epiploca cupreata Hamst           | Gesneriaceae   | herb      |                   |             |                 |      |
| Codiaeum variegatum (L.) A. Juss | Euphorbiaceae  | shrub     | s, m ‡           | blue         | uniformed       | VII  |
| Coffee sp                        | Rubiaceae      | shrub     |                   | orange       | uniformed       | VI-VII|
| Nuellea orientalis L.            | Rubiaceae      | tree      |                   | orange       | uniformed       | VI-VII|
| Symlocos opruniflorus DC.         | Symplocaceae   | shrub     |                   | blue         | uniformed       | II-VI |
| Syringia guayava L.              | Myrtaceae      | tree      |                   |             |                 |      |
| Canarium decumatum Gaert (Burs.) | Burseraceae    | tree      | s, m ‡           |              | formed          | I     |
| Aganosma marginata (Roxb.) G. Don | Apocynaceae    | vine      | s, m ‡           |              | formed          | II    |
| Amorpha phylla (Dentist.) Mabb   | Apocynaceae    | tree      | s, m ‡           |              | formed          | I     |
| Nicotiana                      | Araceae        | herb      | s, m ‡           | black        | uniformed       |       |
| Spigenia angustifolia L.          | Loganiaceae    | shrub     | s, m ‡           | blue         | uniformed       | VI-VI |
| Cassia clementiana (L.) Vent.     | Cassia clementiana (L.) Vent. | shrub | s, m ‡           | blue         | uniformed       | V, VI |
| Part used: Flowers               |                |           |                   |              |                 |      |
| Seemannia sylvatica (Kunth) Balli | Gesneriaceae   | herb      |                   |             |                 |      |
| Chrysophyllum pachypodum (Copper Leaf) | Gesneriaceae | herb      |                   |             |                 |      |
| Tagetes erecta L.                | Asteraceae     | shrub     |                   |             |                 |      |
| Spathodea campanulata P. Bearv   | Bignoniaceae   | tree      |                   |             |                 |      |
| Rosa hirsuta L.                  | Rosaceae       | shrub     |                   |             |                 |      |
| Punica granatum L.               | Lythraceae     | shrub     |                   |             |                 |      |
| Musaenda erythrophylla Schum. & Thom | Rubiaceae | shrub |                   |             |                 |      |
| Melastoma malabathricum L.       | Melastomataceae | shrub | s, m ‡           | formed       | II              |      |
| Plumeria rubra L.                | Apocynaceae    | shrub     |                   |             |                 |      |
| Stachytarpheta jamaicensis (L.) Vahl | Verbenaceae | herb      |                   |             |                 |      |
| Hibiscus sabdariffa L.           | Malvaceae      | shrub     |                   |             |                 |       |
| Hibiscus rosa-sinensis L.         | Malvaceae      | shrub     |                   |             |                 |       |
| Barleria cristata L.             | Acanthaceae    | shrub     |                   |             |                 |       |
| Torenia fournieri L.              | Linderniaceae  | shrub     |                   |             |                 |       |
| Cosmos caudatus Kunth             | Asteraceae     | shrub     |                   |             |                 |       |
| Melampodium divaricatum (Rich.) DC. | Asteraceae | herb      |                   |             |                 |       |
| Impatiens balsamina               | Balsaminaceae  | herb      |                   |             |                 |       |
| Senna alata (L.) Rob.            | Fabaceae       | shrub     |                   |             |                 |       |
| Caesalpinia pulcherrima (L.) Sw.  | Fabaceae       | shrub     |                   |             |                 |       |
| Senna siamea (Lam.) H.S. Irwin & Barneby | Fabaceae | tree      |                   |             |                 |       |
| Rauvolfia serpentina L.           | Rubiaceae      | shrub     |                   |             |                 |       |
| Hibiscus tiliaceus L.             | Malvaceae      | tree      |                   |             |                 |       |
| Gossypium arboreum                | Malvaceae      | shrub     |                   |             |                 |       |
| Crossandra infundibuliformis L.   | Cacuminaceae   | tree      |                   |             |                 |       |
| Tabebuia chrysotricha (Matt. ex DC.) | Bignoniaceae | tree      |                   |             |                 | I-VII|
| Sterculia                  | Bignoniaceae   | tree      |                   |             |                 |       |
| Lea guineensis G.Don             | Vitaceae       | shrub     |                   | grey         | uniformed       | V     |
| Eclipta prostrata L.             | Asteraceae     | shrub     |                   |             |                 | V    |
| Macaranga tanarius (L.) Müll.Arg. | Euphorbiaceae | shrub |                   | green        | formed          | II    |
Figure 2: Percentage of colors group expression of leaf samples (a) and vegetation life forms of colored leaves (b).

Figure 3: Continued.
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: anthraquione, to none, indigoid, naphthoquinone, carotenoids, flavones, dihydropryrans, 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, phlophyn, 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 sinensis’ flowers and N. orientalis’ 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 calex [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.

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