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Diversity and ethnobotany of plants used as natural dye in traditional woven by local community in Belu District, Indonesia

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Abstract. *Seran W, Kaho LMR, Pellondo′u ME, Mau AE, Aini Y, Kaho NPLBR, Soimin M. 2024. Diversity and ethnobotany of plants used as natural dye in traditional woven by local community in Belu District, Indonesia. Biodiversitas 25: 4415-4424.* Natural dye plants used by indigenous people for coloring woven fabrics are considered an important and unique Traditional Ecological Knowledge (TEK), especially in East Nusa Tenggara, Indonesia, which has high biodiversity and endemicity. This study is aimed to document the diversity, conservation status and ethnobotanical knowledge of dye-producing plant species used by local community in Belu District, East Nusa Tenggara Province. We used in-depth interviews with local weavers to collect data on plants used as natural dyes and observed the processes of extracting dyes and coloring the yarn. We documented 18 plant species used as dye for traditional *tenun ikat* (tied woven). The coloring process includes oiling the yarn, tying, measuring, dyeing, and drying, followed by weaving process. Stems and leaves are the most used part for producing dyes (each with 39%), followed by rhizomes (11%), fruits (6%) and roots (5%). Based on conservation status, only one species is conservation concern with status of endangered, i.e., *Tectona grandis* L.f., which produce purple and red colors. This study is useful as a record to preserve the rich ethnobotanical knowledge on the use of plants for coloring materials in the eastern region of Indonesia, and to raise awareness of the importance of documenting and conserving traditional plant-based practices.

Keywords: Conservation, dye plant, ethnobotany, local weaver

INTRODUCTION

East Nusa Tenggara Province is a region in Indonesia famous for producing tied woven fabric (*tenun ikat*) that still uses plants as a source of natural dyes. The skills and knowledge of the making of *tenun ikat* in East Nusa Tenggara are inseparable cultural heritage which are passed down from the ancestors, particularly through mother to daughter, and characterized by unique design and their use of natural dyes (Langi et al. 2016; Muchtar et al. 2018; Agustarini et al. 2022).

Every plant has a natural dye source because it contains pigments. However, the potential of natural dye source is determined by the intensity of the color produced and the type of dye present in each plant. Even the color intensity of dye derived from an identical plant substance varies depending on the medium's pH (Arora et al. 2017). Natural dyes from plants are generally easy to obtain. Despite continuous use, natural dyes are not toxic and safe for human health, have a more natural color and give the impression of cold, soft and comfortable, while the waste from weaving dyeing is considered environmentally friendly and does not cause pollution (Jordeva et al. 2020; Tamilarasi and Banuchitra 2021; Bakar et al. 2023; Atav et al. 2024). Fabrics colored with natural dyes generally have a higher value compared to synthetic dyes (Purwar 2016). According to Li et al. (2022) natural dyes are widely found on land and in the sea. Dyes can be extracted from plants (flowers, seeds, leaves, wood, bark, roots, and other parts), animals (insects that can produce red and purple colors), minerals (metals, metal salts, oxides, red dyes, and dark yellow) and other materials (Elsahida et al. 2019).

Natural dyes used in East Nusa Tenggara Province are produced from plants predominantly collected from gardens and yards, while a small portion is obtained from forest areas. For example, Sabuna and Nomleni (2020) recorded six species of plants collected from gardens and yards, namely turmeric (*Curcuma longa* L.), tarum (*Indigofera tinctoria* L.), noni (*Morinda citrifolia* L.), wild gooseberry (*Phyllanthus reticulatus* Poir), lima bean (*Phaseolus lunatus* L.), dan teak (*Tectona grandis* L.). On the other hand, Leki et al. (2023) documented three species of dye plants, namely noni (*M. citrifolia*), candlenut (*Aleurites moluccanus* (L.) Willd.), and tarum (*Indigofera spicata* Forssk.). Dye-producing plants are found at different altitudes and slopes. According to Seran and Hana (2018), dye plants can be found at altitudes ranging from 0 to 1000 masl with slopes of 0-8% (flat), 8-15% (sloping), 15-25% (rather steep) and 25-45% (steep).

Belu is a district in East Nusa Tenggara, a province historically known as one of the centers for the production of *tenun ikat* with distinctive patterns and motifs using natural dyes. However, over time, there has been a shift in weaving practices where many weavers have begun to switch to using synthetic dyes as an alternative due to the difficulty of obtaining natural dyes and their time-consuming and labour-intensive processing. The indigenous knowledge of dye plants in Belu District is important to preserve as conservation efforts on cultural and biological diversity of the region.

Given the importance of preserving the tradition of natural dyeing in *tenun ikat* weaving, the local government of Belu District has recently endeavored to increase the interest of the weavers by establishing weaving houses. The aim of this initiative is to maintain the use of natural dyes in the production of *tenun ikat* weaving without threatening the population of dye-producing plants. To support such an initiative, this study aimed to investigate the diversity of natural dye plants utilized by the local community in Belu District and to document the ethnobotanical knowledge of local weavers on how to use these plants. The results of this study can inform the use of natural dyes in a sustainable manner and conservation measures needed to ensure the availability of natural dye plants in the future.

MATERIALS AND METHODS

Study period and area

This study was performed in January-March 2024 in the Sub-districts of Rai Manuk, Tasifeto Timur (East Tasifeto), Kakuluk Mesak, and Atambua of Belu District, East Nusa Tenggara Province, Indonesia (Figure 1).

Procedures

We gathered data on plant dyes, including local and scientific names, plant parts used, colors and shades obtained through dyeing, method of preparation, and the traditional knowledge of dyeing. Information about plant parts used, colors and shade through dyeing was obtained through interviews with the local community selected using snowball sampling. The procedures started by selecting respondent and determining the person who is considered to use the most plants as medicine, namely healers or shamans (*dukun*) and the community around the forest, then it rolled to the next respondent based on information from the initial respondent. The rationale for selecting traditional healers (*dukun*) as respondents is that they often possess extensive knowledge of local plants, including their medicinal and other practical uses. Since many dye plants are also used for medicinal purposes, these healers are likely to have valuable insights into the traditional knowledge regarding the use of plants for dyeing in their community.

A non-formal interviews with the community were also conducted to find out the types of dye plants used and then matched with literature/various books about coloring plants, which include local names, species names, families, and their benefits. In addition to questions to the local community, data collection on plant parts that are often used by asking directly to weavers who use dye plants species. Data on the processing mode of dyeing plants was carried starting from taking raw materials to the processing of plants used.

Information on dye-producing plant species in the field was collected with assistance from a key informant. Specimens were collected, photographed and identified. We performed vegetation inventories in areas where natural dyeing plants were found and commonly obtained by indigenous weavers. The inventory used the double plot method at areas with natural dye plants. The plot size was 20 × 20 m for mature trees (>20 cm in diameter), 2 × 2 m for seedlings (saplings up to <1.5 m in height), 5 × 5 m for saplings (saplings with a height of >1.5 to young trees with a diameter of <10 cm), and 10 × 10 m for poles (young trees 10 to 20 cm in diameter) (Kusmana 2017).

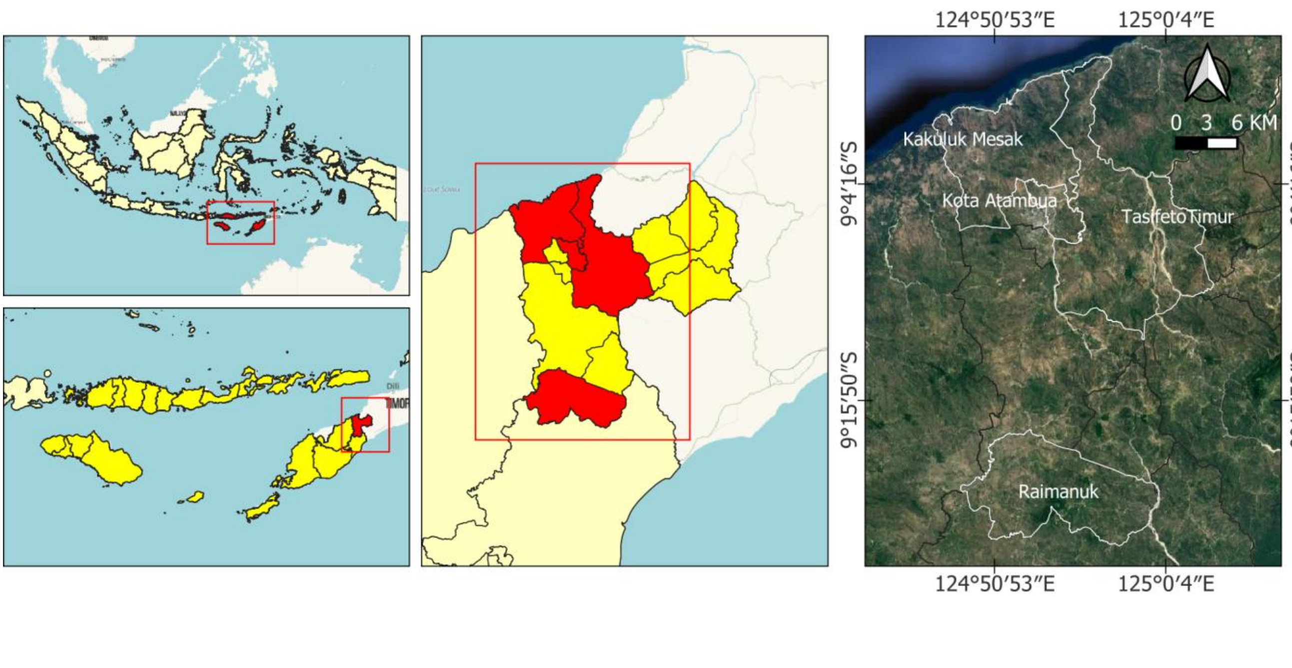

Figure 1. Map of study location in the Rai Manuk, Tasifeto Timur, Kakuluk Mesak, and Atambua Sub-districts of Belu District, East Nusa Tenggara Province, Indonesia

Identification the types of dye plants were observed in the field by direct observation and then recorded in a tally sheet including their coordinates with Garmin GPS. Collecting data on plant parts that are often used by asking directly to the weavers who use the dye plants. For habitus type data collection, medicinal plant data found at the research site are classified based on taxon. For the conservation status, we used IUCN Red List and national regulations concerning protected plant and animal species (P106/2018).

Data analysis

The result of interview was analyzed using simple statistics. We calculated the percentage of each habitus compared to all habitus, which consisted of trees, bushes, shrubs, lianas and herbs. To investigate the structure of vegetation, we divided tree vegetation into four growth stages: tree, pole, sapling, and seedling. We also calculated the percentage of plant part utilized including leaf, fruit, stem, root and rhizome.

For the vegetation analysis, we calculated the Importance Value Index (IVI) based on Kusmana (2017) and (Kissinger et al. 2024) as follows:

$$Relative\ density = \frac{number\ of\ individuals\ of\ species}{total\ number\ of\ individuals} x\ 100$$

$$Relative\ dominance = \frac{dominance\ of\ species}{dominance\ of\ all\ species} x100$$

$$Relative\ frequency = \frac{frequency\ of\ species}{sum\ frequency\ of\ all\ species}\ 100$$

Importance value = Relative density + relative dominance + relative frequency

We calculated the diversity indexes with Shannon's diversity index (H'), Evenness Index (E), and Margalef's diversity index (Dmg):

$$H' = -\sum pi \ln pi$$

$$H' = -\sum ({ni}/_{N}) \ln({ni}/_{N})$$

Where: H': Diversity index; ni: Number of individuals of species i; N: Number of individuals of all species

$$E = {H'}/_{\ln S}$$

Where: E: Evenness index; S: Number of species; H': Species diversity index

$$Dmg = {S-1}/_{\ln N}$$

Where: Dmg: Margalef richness; N: number of individuals; S: Number of species observed; ln: Natural logarithm

RESULTS AND DISCUSSION

Diversity of dye producing plants in Belu District

The people in Belu District use dye plants to color the *tenun ikat* (tied woven). Local weavers collect natural dye plants from the forest around their house. We documented a total of 18 dye producing plant species used by traditional weavers in Belu District (Table 1). The species belong to 11 families, namely Rubiaceae, Sapindaceae, Meliaceae, Fabaceae, Euphorbiaceae, Phyllanthaceae, Asparagaceae, Symplocaceae, Zingiberaceae, Lamiaceae and Anacardiaceae. Fabaceae contributed the largest number of species (45%).

Based on the results of interviews, dye plants are cultivated by weavers in the yard and some are taken from the forest and some are purchased, such as *Symplocos* Jacq., which is bought from traders or collectors. The natural dye plants are found scattered across the studied locations in the sub-districts of Raimanuk, East Tesifeto, Kakuluk Mesak and Atambua. Some dye plants are commonly found across the four locations, including *T. grandis, I. tinctoria, Swietenia mahagoni* (L.) Jacq., *M. citrifolia, Dracaena angustifolia* (Medik.) Roxb., *Bauhinia purpurea* L., *Schleichera oleosa* (Lour.) Oken, and *Mangifera indica* L. There are also dye plants that are only found in one location, such as *Biancaea sappan* (L.) Tod., *A. moluccanus* and *Eleutherine bulbosa* (Mill.) Urb. which are only found in Raimanuk Sub-district, *Cassia siamea*, *Gliricidia sepium* (Jacq.) Kunth and *C. longa* only found in Tasifeto Timur Sub-district and *Sesbania grandiflora* (L.) Poir., *Lannea coromandelica* (Houtt.) Merr., *Phyllanthus reticulatus* only found in Atambua Sub-district.

Based on altitudes, dye plants are found on five land slope classes, namely 0-8% (flat), 9-15% (gentle), 16-24% (slightly steep), 25-45% (steep) and >45% (very steep). This is in accordance to the research of Seran and Hana (2018), which states that the natural dye plants of tied woven (*tenun ikat*) grow on varying slopes. Dye plants that grow on the 0-8% slope class (flat) are *I. tinctoria, S. mahagoni, M. citrifolia, P. reticulatus, T. grandis, S. grandiflora*; on the slope class of 9-15% (sloping) are *T. grandis, M. indica, L. coromandelica, C. longa, G. sepium, M. citrifolia, C. siamea, B. purpurea, S. oleosa, D. angustifolia*, and *A. moluccanus*; on the 16-24% slope class (slightly steep) are *M. indica, B. purpurea, T. grandis, and S. oleosa*; on the 25-45% slope class (steep) are *T. grandis, D. angustifolia, E. bulbosa*; and on the >45% slope class (very steep) are *T. grandis, B. purpurea*, and *B. sappan*. *Tectona grandis* was the only plant found in all five slope classes (Figure 2).

The dye producing plants in four locations are generally found in several ranges of altitude, from <250, 250-500 and 500-750 masl, with the greatest number of plants are found in the 250-500 masl altitude. This shows that there is a relationship between the height of the place where the tied woven dye plants grow as explained by (Bakar et al. 2023).

(Rozak and Gunawan 2015) stated that altitude can affect tree density.

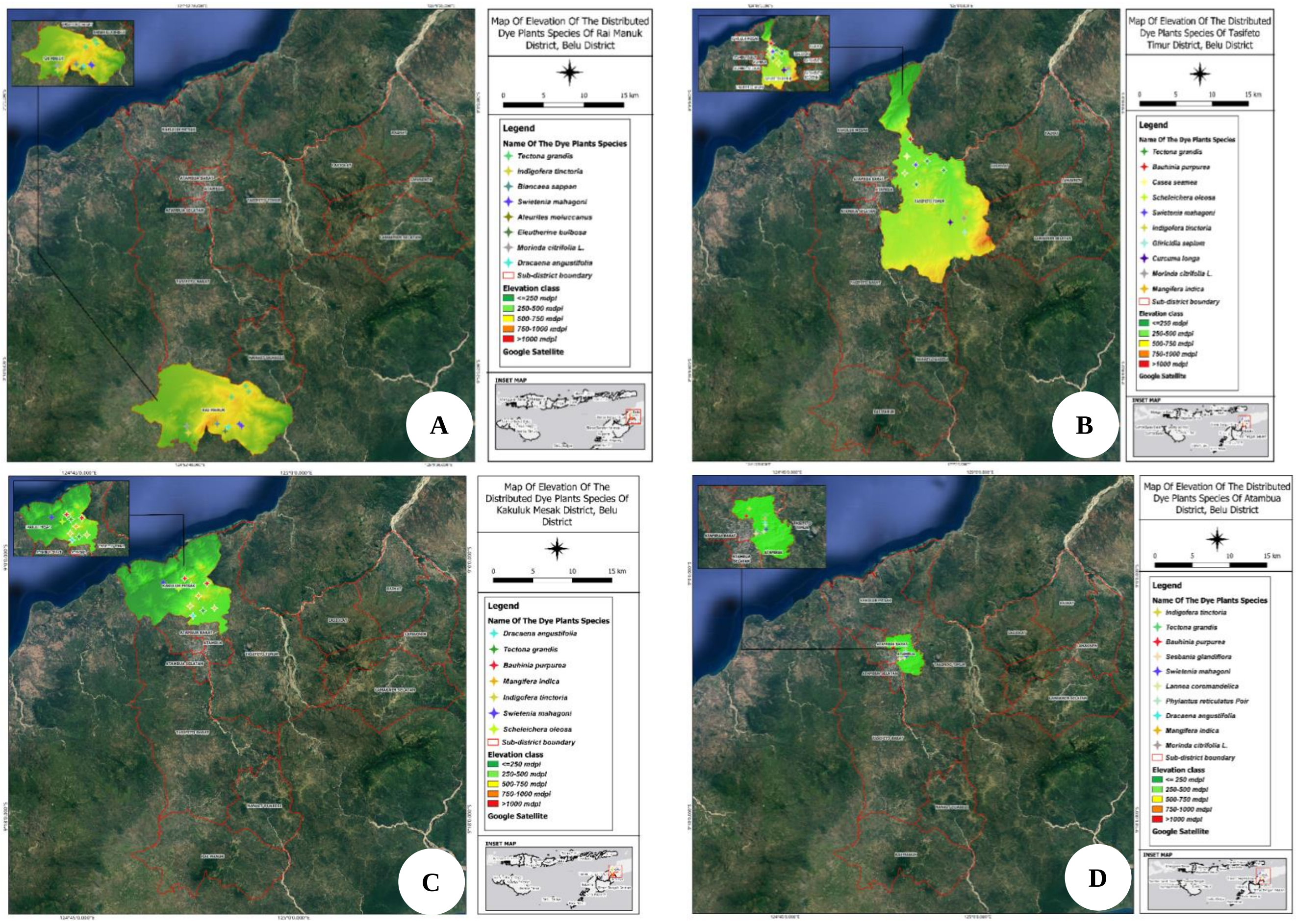

Figure 2. Distribution of dye producing plants in Belu District, East Nusa Tenggara Province, Indonesia: A. Rai Manuk; B. Tasifeto Timur; C. Kalukuk Mesak; and D. Atambua

Table 1. List of natural dye plants used by local weavers in Belu District, East Nusa Tenggara Province, Indonesia

Local name	Indonesian name	Scientific name	Family	Color	Part of plant used	Life form
Ai dois	*Gamal*	*Gliricidia sepium*	Fabaceae	Green	Leaf	Tree
Ai ktarak	*Secang*	*Biancaea sappan*	Fabaceae	Red	Stem	Shrub
Ai maro	*Johar*	*Cassia siamea*	Fabaceae	Orange – Dark brown	Stem	Tree
Baur uru	*Mengkudu*	*Morinda citrifolia*	Rubiceae	Maroon	Root	Tree
Bawang hutan	*Bawang hutan*	*Eleutherine bulbosa*	Iridaceae	Pink	Stem	Herb
Jati	*Jati*	*Tectona grandis*	Lamiaceae	Purple, brown, red	Leaf	Tree
Kala	*Turi*	*Sesbania grandiflora*	Fabaceae	Green	Leaf	Tree
Kanfaek	*Bauhinia*	*Bauhinia purpurea*	Fabaceae	Brown	Stem	Tree
Kmi	*Kemiri*	*Aleurites moluccanus*	Euphorbiaceae	Light beige	Fruit	Tree
Kunyit	*Kunyit*	*Curcuma longa*	Zingiberaceae	Yellow orange	Rhizome	Herb
Mahoni	*Mahoni*	*Swietenia mahagoni*	Meliaceae	Brownish red-brown	Stem	Tree
Mangga	*Mangga*	*Mangifera indica*	Anacardiaceae	Yellow orange	Stem	Tree
Meko	*Buah tinta*	*Phyllanthus reticulatus*	Phyllanthaceae	Black	Fruit	Bush
Nobah	*Loba*	*Symplocos* sp.	Symplocaceae	Yellow and mordant for red color	Leaf	Tree
Reo	*Kudo*	*Lannea coromandelica*	Anacardiaceae	Pink	Stem	Tree
Sekabi	*Kesambi*	*Schleichera oleosa*	Sapindaceae	Golden yellow	Stem	Tree
Suji	*Suji*	*Dracaena angustifolia*	Asparagaceae	Green	Leaf	Shrub

Taun	*Tarum*	*Indigofera tinctoria*	Rubiceae	Blue, black	Leaf	Bush

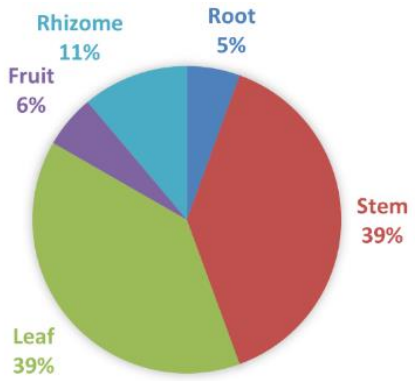

Figure 3. Percentage of natural dye plant parts used by local weavers in Belu District, East Nusa Tenggara Province, Indonesia

The dye producing plants which occur at altitude of <250 masl include *S. mahagoni, S. oleosa* and *T. grandis*; at altitude 250-500 masl include *I. tinctoria*, *T. grandis, S. mahagoni, M. indica, M. citrifolia*, *B. purpurea, D. angustifolia, S. grandiflora, C. longa, L. coromandelica, P. reticulatus*, *S. oleosa*, *G. sepium*, *C. siamea* and *A. moluccanus*. At the altitude of 500-750 masl, plants that are found include *M. indica, T. grandis, S. mahagoni, D. angustifolia, B. sappan* and *E. bulbosa*. *I. tinctoria* is one of the dye plants found in the 250-500 masl across four different locations. This shows that *I. tinctoria* grows in open conditions with full sunlight as described (Agustarini et al. 2021), although it is quite tolerant of shade. *T. grandis* is found at three different altitude classes.

The percentage of plant part used is presented in Figure 3. The most widely used parts are stems and leaves with 39% followed by rhizomes with 11%, fruits with 6% and roots with 5%. This is in accordance with the research of Agustarini et al. (2022) which states that dyes produced from plants come from flowers, fruits, seeds, leaves, wood, bark, roots and other parts. Different plant parts within the same species might produce different colors.

Processing dye producing plants in Belu District

We documented the dyeing process of yarn using natural dye plants by local weavers in Belu, which resulted different colors from each species as presented in Figure 4. The color in Figure 4.A is obtained from processing *B. sappan* with *A. moluccanus* as a mordant. Both plants are ground together, put into a container and squeezed for the extract. The yarn is then soaked in extracted water and dried in the sun. The color in Figure 4.B is obtained by dipping the yarn from Figure 4.A into a mixture of *M. citrifolia* with *Symplocos* sp. as a mordant. *Morinda citrifolia* is mashed until crushed, then put into a container and mixed with *Symplocos* sp. The dried yarn from 4.A is soaked in a container containing a mixture of *M. citrifolia* and *Symplocos* sp. for two nights and dried in the sun.

The color in Figure 4.C is obtained from processing the bark of *S. oleosa* which is cleaned, washed thoroughly and then pounded. Water is added, boiled and then filtered. The yarn is soaked in boiled water, allowed to stand for approximately 30 minutes and then put into alum water and dried in the sun. The color in Figure 4.D is produced from processing the bark of *M. indica* which is ground until smooth, put into a container and add water as much as 2-3 dippers according to the number of threads and then soaked for a day. It is then washed, rinsed with alum water and dried in the shade until dry.

The color in Figure 4.E is produced from processing *C. longa* which is peeled, washed thoroughly and then grated. It is added with water, squeezed the extract and filtered. The yarn is put into the turmeric juice, soak for about three hours, then remove the thread from the turmeric bath, transfer to alum water, rinse and dry. The color in Figure 4.F is produced from processing the bark of *B. purpurea* which is pounded, cleaned and then boiled with enough water until boiling. The water is then filtered, cooled and put in the yarn then soaked for about 3 hours. The yarn is then rinsed in alum water and dried in the sun. Besides producing an orange color, *B. purpurea* also produces a brown color if soaked for a longer time.

The color in Figures 4.G, 4.H, and 4.I are obtained from processing the leaves of *S. grandiflora*, *G. sepium* and *D. angustifolia*. The leaves are washed thoroughly and then pounded, chopped and crushed, boiled and then filtered. The yarn is put into boiled water, let it sit for about 30 minutes and transferred into alum water and dried in the sun for a maximum of 2-3 weeks for better results. The color in Figure 4.J is produced from processing the bark of *E. bulbosa* and *L. coromandelica*. The bark of *E. bulbosa* is peeled, washed thoroughly and grated. The water is added to the grater, squeeze the water then filtered. The thread is put into the juice and soak for about 3 hours. The yarn is then squeezed then put it in fresh water and dried. To obtain maximum color, the process is repeated several times until the color turns pink. Meanwhile, for the bark of *L. coromandelica*, the processing is done by pounding until smooth, cleaning and boiling with enough water until boiling. Strain the boiled water then cooled, put the thread in the water and soak. Then, the yarn is rinsed in alum water and then dried in the sun. This process is repeated 3-4 times if the color is not visible.

The color in Figure 4.K is the result of processing of *I. tinctoria* with whiting as dormant. The leaves of *I. tinctoria* are cleaned, washed and then soaked in a container for 1 night (12 hours). The next day, the leaves are removed, and the water is filtered, then three packets of whiting are added and stirred while boiling until white foam and dark blue in color. To produce a color in Figure 4.L, the soaking needs to be done longer before drying in the shade or in a place that is not exposed to direct sunlight. The color in Figure 4.M is the result of processing *P. reticulatus* leaves which are washed thoroughly, mashed and crushed. It is added with water and then boiled until boiling then the water is filtered. Next, the yarn is put into the boiled water, keep in the water for about 30 minutes and then transfer it to alum water and dried in the sun for a maximum of 2-3 weeks for good results. The color in Figure 4.N is produced from processing young *T. grandis* leaves which are picked, crushed, mixed with water and the yarn is immersed in the liquid to produce a purple color. If soaked longer, the result is as in Figure 4.O.

Figure 4. Type of color produced from natural dye plants in Belu District, East Nusa Tenggara Province, Indonesia. A. *Biancaea sappan* with *Aleurites moluccanus* as a mordant, B. a mixture of *Morinda citrifolia* with *Symplocos* sp. as a mordant, C. *Schleichera oleosa,* D. *Mangifera indica,* E. *Curcuma longa,* F. *Bauhinia purpurea,* G. *Sesbania grandiflora,* H. *Gliricidia sepium* I. *Dracaena angustifolia,* J. a mixture of *Eleutherine bulbosa* and *Lannae coromandelica*, K. *Indigofera tinctoria,* L. *Indigofera tinctoria*, M. *Phyllanthus reticulatus*, N. *Tectona grandis,* O. *Tectona grandis*, P. *Cassia siamea*

Important value index, diversity indices and conservation status of dye-producing plants

The Importance Value Index (IVI) of dye-producing plants for each growth stage (trees, pools, saplings, and seedlings) is presented below. IVI is a measure used to assess the ecological importance of a species within a particular habitat. It combines data on species frequency, density, and dominance, providing a comprehensive understanding of its role in the ecosystem. The important value index of dye producing plants for each growth stage is presented in Table 2.

The analysis on important value index show that at tree level, *S. mahagoni* dominates with an importance value index of of 82.29%, while *M. citrifolia* dominates at the sapling level with important value index of 88.42%, *I. tinctoria* dominates at pole and seedling levels with importance value index of 92.26 and 80.30% respectively. Despite having the highest important value index at tree level, *S. mahagoni* was not found at the pole, sapling and seedling levels. This indicates that *S. mahagoni* is not regenerating well, so efforts are needed enhance its population. The important value index of a vegetation can be high or low. The value would be highest for species with high density, dominance, and frequency, suggesting that the species has a higher number of individuals, a wider spread, and greater control over habitat than other species.

The indices for three biodiversity metrics (i.e., species diversity index, species evennes index and species richness index) are presented in Figure 5. Species diversity index at tree, pole, sapling and seedling levels is classified as medium as indicated with index which ranges from 1.24-2.07. The value of species diversity index of 1-3 is classified medium.

Figure 5 also shows that the evenness index at tree, pole, sapling and seedling levels is evenly distributed with an evenness index ranging from 0.83-0.93. The highest evenness index is found at seedling level of 0.93, followed by the tree level of 0.83 and at the pole and sapling levels with the same value of 0.89. This illustrates that the distribution of species at both levels is balanced. Species richness index at the tree, pole, sapling and seedling levels is low because it has a value below 3.4 with a range of 0.81-2.14. The low species richness of dye producing plants is thought to be due to the lack of efforts to preserve these plant species. This is in accordance with the opinion of (Sabuna et al. 2023), which says that the limited diversity of dye plants likely attributed to insufficient conservation efforts to these plant species.

The conservation status of dye producing plants is presented in Table 3. All of dye producing species documented in this study are not protected by national regulation (P.106/2028). Based on IUCN Red List, 44.4% of dye producing plants are categorized as least concern, 22.2% data deficient and not evaluated, 5.6% near threatened and one species (i.e., *T. grandis*) is endangered.

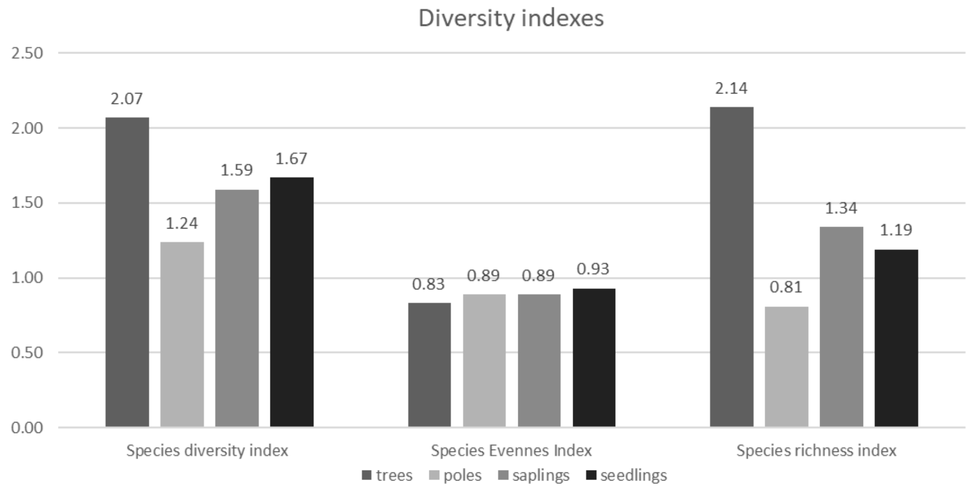

Figure 5. Diversity indices for each growth stage: tree, pole, sapling and seedling for all the natural dye plants in Belu District, East Nusa Tenggara Province, Indonesia

Table 2. Importance Value Index (IVI) of the natural dye plants in each growth stage

Species	Importance Value Index (IVI) (%)
Trees	
Swietenia mahagoni	82.29
Tectona grandis	25.01
Casea seamea	24.31
Scheleichera Oleosa	22.35
Sesbania grandiflora	21.96
Lannea coromandelica	21.08
Morinda citrifolia	20.92
Aleurites moluccanus	19.96
Gliricidia sepium	19.37
Biancaea sappan	17.26
Bauhinia purpurea	12.80
Mangifera indica	12.68
Poles	
Indigofera tinctoria	92.26
Morinda citrifolia	87.22
Sesbania grandiflora	62.18
Gliricidia sepium	58.54
Saplings	
Biancaea sappan	30.30
Bauhinia purpurea	30.30
Lannea coromandelica	22.26
Morinda citrifolia	7.42
Gliricidia sepium	6.80
Sesbania grandiflora	2.92
Seedlings	
Indigofera tinctoria	80.30
Curcuma longa	28.62
Morinda citrifolia	39.03
Dracaena angustifolia	26.02
Eleutherine bulbosa	13.01
Phyllanthus reticulatus	13.01

Table 3. Conservation status of dye producing plants in Belu District, East Nusa Tenggara Province, Indonesia

Species	Local name	IUCN Redlist	P.106/2018
Aleurites moluccanus	Kemiri	LC	Not Protected
Bauhinia purpurea	Bahuinia	LC	Not Protected
Biancaea sappan	Secang	LC	Not Protected
Cassia siamea	Johar	LC	Not Protected
Curcuma longa	Kunyit	DD	Not Protected
Dracaena angustifolia	Suji	NE	Not Protected
Eleutherine bulbosa	Bawang hutan	NE	Not Protected
Gliricidia sepium	Gamal	LC	Not Protected
Indigofera tinctoria	Tarum	NE	Not Protected
Lannea coromandelica	Reo	LC	Not Protected
Mangifera indica	Mangga	DD	Not Protected
Morinda citrifolia	Mengkudu	NE	Not Protected
Phyllanthus reticulatus	Buah tinta	LC	Not Protected
Schleichera oleosa	Kesambi	LC	Not Protected
Sesbania grandiflora	Turi	DD	Not Protected
Swietenia mahagoni	Mahoni	NT	Not Protected
Symplocos sp.	Loba	DD	Not Protected
Tectona grandis	Jati	EN	Not Protected

Note: LC: Least Concern, NE: Not Evaluated, DD: Data Deficient, NT: Near Threatened, EN: Endangered

Discussion

Dye used in *tenun ikat* (tied woven) in Belu District originates from plants extracts from various parts, including stems, roots, flowers, leaves, fruits, and bark (Che and Yang 2022). Natural dye produced from plants is not only a single structure but a mixture of chemical compounds (Kusumastuti et al. 2021). Local community in East Nusa Tenggara is known for their sophisticated weavings, which are practiced in their daily lives and still exist now. The weavings from Belu District (Timor) are known for their patterns and hues that are similar to those of nature, with light base colors like red, yellow, green and orange with little color changes.

When natural dyes are used for coloring, less waste produced, which might harm the environment. The local weaver in Belu District using natural dye plant from the forest around their house, thus the weaving processes are delayed when materials are not available. All processes for dyeing woven fabrics are done traditionally. The process of making woven fabrics in Belu District can categorized as a local wisdom related to natural dyeing techniques, fostering a profound connection with nature (Junsongduang et al. 2017; Theeramongkol et al. 2023).

The weaving tradition in Belu District has been present for a long time. The methods and colors used have been learned from one generation to another. The same thing also happens in East Lombok (Rahayu et al. 2020), where the local weaver utilizes natural dye plants to make woven fabric, using 13 plant species as dyes and 9 species as color binders. Naisumu et al. (2022) recorded 8 species of plants that serve as natural dyes in Manikin Village, East Noemuti District, North Central Timor District. Ndamunamu et al. (2019) reported 13 spesies of medicinal plants that can be used as natural dyes from East Sumba. Also in Belu, few dye producing plants are used by local community as medicinal plants such as *C. longa* (Chengaiah et al. 2010). This plant has high economic and cultural values and is widely cultivated (Sathi 2017), and is culturally important for producing yellow color. This species is widely used for traditional medicine for treating 71 symptoms of disease (Subositi and Wahyono 2019).

One of the dye plants is an endemic plant of East Nusa Tenggara, i.e., *Symplocos* sp. (loba) which is reported only distributed in Timor Tengah Selatan, Rote, Flores and Sumba (Bako et al. 2020). Difference from other dye plants, the local community in Belu District purchases Loba for coloring (Sholikhah et al. 2022). Loba serves as a mordant and acts as a binding agent in the dyeing process of yarn. Traditional weavers in Indonesia use *Symplocos* sp. species as supplementary plants mixed with *M. citrifolia* and *I. tinctoria* which serve as natural dyes and mordants (Schmitt et al. 2016). Loba also can be used as a natural color enhancer because it has a high content of Aluminium (Al). This content is found in leaves, bark and roots. There are several factors that are thought to cause the absence of loba including climatic conditions, soil or special ecosystems in Belu District. According to (Seran and Hana 2018; Seran et al. 2022) Loba was also found in East Sumba and Malacca Districts. Loba and candlenut besides functioning as natural dyes can also be used as mordants. Natural dye plants need a mordant to bind the color so that it does not fade. Ashrafi et al. (2018) found myrobalan extract as a natural mordant (biomordant) and can be a renewable sources of natural dye color. This natural mordant can serve as an alternative to metal mordant. Another yellow color can be produced from *C. longa* (Hu et al. 2022) and *M. indica* (Ayele et al. 2020; Ayale et al. 2020). The dyeing process will be more cost-effective and produce unique, elegant colors if mordants derived from natural sources are used. The selection of the type of mordant and the mordanting process greatly influences the success of dyeing (Nurmasitah et al. 2022).

Dyes and coloring methods have been known since the beginning of textiles found. Nature is plentiful with plants that can generate a variety of colors for the dyeing process. While most organic matter can create color when prepared in a dyeing solution, only some plants could. The production of colors also follow the standards for colorants. Natural colors are derived from plant parts such as leaves, stems, fruits, flower petals, bark, and roots. For coloring, there are plants used as mordant in Belu District, i.e., *S. oleosa* and *A. moluccanus*. These plants are also used as biomordant in West Amarasi (Taimenas et al. 2021). Information of plant species, mordants, and the mordanting process of the woven fabrics from Timor Island limited and not well documented untill now.

Among plant species used as dyes by local weavers in Belu District, *T. grandis* is classified as EN and *S. mahagoni* is classified as NT. Bakar et al. (2023) and Mia et al. (2023) reported that extracted dyes from *S. mahagoni* bark, fruits and wood waste provide a good to excellent color. These species are obtained by the community directly from the forest. The collection of dye producing plants by the community from the forest is directly feared to result in the loss of a species. Efforts are needed to cultivate the species to sustain the existence of these species in the long term. Furthermore, the sustainable utilization of natural dye plant should be concern because the demand for natural dyes nowadays is increasing day by day.

In conclusion, this study documented 18 plant species used as dyes in tenun ikat (tied woven) in Belu District, namely *M. citrifolia*, *S. oleosa*, *S. mahagoni*, *S. grandiflora*, *G. sepium*, *A. moluccanus*, *P. reticulatus*, *B. sappan*, *C. siamea*, *Indigofera tintoria* L., *D. angustifolia*, Symplocos sp., *T. grandis*, *M. indica*, *C. longa*, *L. coromandelica*, *E. bulbosa* and *B. purpurea*. The dye producing plants spread across various locations, namely Raimanuk Sub-district, Tasifeto Timur Sub-district, Kakuluk Mesak Sub-district, and Atambua Sub-district in varying altitudes and topography from 0-8% (flat), 9-15% (gentle), 16-24% (slightly steep), 25-45% (steep) and more than 45% (very steep). Plant with the highest Important Value Index (IVI) at tree level is *S. mahagoni* with 82.29%, sapling is *M. citrifolia* with 88.42%, and pole and seedling is *I. tinctoria* with 92.26 and 80.30%, respectively. The dyes are processed by milled, pounded, grated, chopped and soaked. The conservation status of dye producing plants falls into 5 categories, namely LC (Least Concern), NE (Not Evaluated), DD (Data deficient), NT (Near Threatened) and EN (Endangered).

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REFERENCES

Agustarini R, Heryati Y, Adalina Y, Adinugroho WC, Yuniati D, Fambayun RA, Sabastian GE, Hidayat A, Tata HL, Ingram W, Perdana A. 2022. The development of *Indigorefa* spp. as source of natural dyes to increase community incomes on Timor Island, Indonesia. Economies 10 (2): 49. DOI: 10.3390/economies10020049.

Agustarini R, Heryati Y, Adalina Y. 2021. The Effort to Cultivate Natural Dyes (*Indigofera* sp.) in Timor Region, NTT. IOP Conf Ser: Earth Environ Sci 819: 012080. DOI: 10.1088/1755-1315/819/1/012080.

Arora J, Agarwal P, Gupta G. 2017. Rainbow of natural dyes on textiles using plants extracts: Sustainable and eco-friendly processes. Green Sustain Chem 7 (1): 35-47. DOI: 10.4236/gsc/2017.71003.

Ashrafi N, Gharanjig K, Hosseinnezhad M, Khajeh Mehrizi M, Imani H, Razani N. 2018. Dyeing properties and color fabrics using natural dye and mordant. Prog Color Colorants Coat 11 (2): 79-83. DOI: 10.30509/pccc.2018.75742.

Atav R, Soysal S, Hajı A. 2024. Environmentally friendly coloration of polyamide fabrics with the use of natural dyes: A study including results of industrial scale applications. Fibers Polym 25 (6): 2223-2232. DOI: 10.1007/s12221-024-00576-7.

Ayele M, Tesfaye T, Alemu D, Limeneh M, Sithole B. 2020. Natural dyeing of cotton fabric with extracts from mango tree: A step towards sustainable dyeing. Sustain Chem Pharm 17: 100293. DOI: 10.1016/j.scp/2020.100293.

Bakar MA, Islam MI, Mia R, Ahmed T, Mahmud ST, Toki GF, Haque MA. 2023. Exploring the potential of mahogany extract as a natural dye for the coloration of jute fabric. Heliyon 9 (9): e19464. DOI: 10.1016/j.heliyon.2023.e19464.

Bako NA, Sabuna AC, Daud Y. 2020. Identification of biomordant in Hundihopo Village, East Rote District, Rote Ndao Regency. IOP Conf Ser: Mater Sci Eng 823: 012009. DOI: 10.1088/1757-899X/823/1/012009.

Che J, Yang X. 2022. A recent (2009-2021) perspective on sustainable color and textile coloration using natural plant resources. Heliyon 8 (10): e10979. DOI: 10.1016/j.heliyon.2022.e10979.

Chengaiah B, Rao KM, Kumar KM, Muthumanickam A, Madhusudhana C. 2010. Medicinal importance of natural dyes-a review. Intl J Pharmtech Res 2 (1): 144-154.

Elsahida K, Fauzi AM, Sailah I, Siregar IZ. 2019. Sustainability of the use of natural dyes in the textile industry. IOP Conf Ser: Earth Environ Sci 399 (1): 012065. DOI: 10.1088/1755-1315/399/1/012065.

Hu R, Li T, Qin Y, Liu Y, Huang Y. 2022. Ethnobotanical study on plants used to dye traditional costumes by the Baiku Yao nationality of China. J Ethnobiol Ethnomed 18 (1): 1-17. DOI: 10.1186/s13002-021-00497-2.

Junsongduang A, Sirithip K, Inta A, Nachai R, Onputtha B, Tanming W, Balslev H. 2017. Diversity and traditional knowledge of textile dyeing plants in Northeastern Thailand. Econ Bot 71 (3): 241-255. DOI: 10.1007/s12231-017-9390-2.

Kissinger K, Yamani A, Pitri RMN, Nasrulloh AV. 2024. Impacts of forest farmers management on *Lepironia articulata* Retz.: Conservation based on utilization of peat ecosystem biodiversity in South Kalimantan. Pol J Environ Stud 33 (2): 1203-1213. DOI: 10.15244/pjoes/172040.

Kusmana C. 2017. Survey Methods and Vegetation Data Interpretation. IPB PRESS, Bogor. [Indonesian]

Kusumastuti A, Fardhyanti DS, Anis S, Kamis A. 2021. Production of *Brachiaria mutica* as natural dyes powder for textile application: Characterisation study. IOP Conf Ser: Earth Environ Sci 700: 012033. DOI: 10.1088/1755-1315/700/1/012033.

Langi KC, Park S. 2016. An analysis on characteristics of ancient Indonesian Textiles (I) - Focus on Period, Religion, Region, and Color of the 'Sacred Cloths'. J Korean Soc Costume 66 (6): 67-78. DOI: 10.7233/jksc/2016.66.6.067.

Leki BY, Seran W, Kaho NR. 2023. Identification of natural dye plant fabrics around the Sonmahole Bifemnation production forest. Jurnal Kehutanan Papuasia 9 (1): 61-68. [Indonesian]

Li N, Wang Q, Zhou J, Li S, Liu J, Chen H. 2022. Insight into the progress on natural dyes: Sources, structural features, health effects, challenges, and potential. Molecules 27 (10): 3291. DOI: 10.3390/molecules/27103291.

Mia R, Bakar MA, Islam MR, Ahmed T. 2023. Eco-friendly coloration from mahogany wood waste for sustainable dyeing of organic nonwoven cotton fabric. Results Eng 17: 101032. DOI: 10.1016/j.rineng.2023.101032.

Muchtar H, Ramli A, Amirulloh M. 2017. The benefits of indication of source protection on ikat natural dyeing for small-sized enterprises in Sumba. In International Conference on Law, Governance and Globalization 2017 (ICLGG 2017). Atlantis Press. DOI: 10.2991/iclgg/17.2018.16.

Naisumu YG, Bria EJ, Kasse WH. 2022. Utilization of natural dyes of futus woven fabric as an alternative to dye plant tissue preparation. Bioeduscience 6 (1): 96-107. DOI: 10.22263/j.bes/618079.

Ndamunamu M, Batubara I, Sundawati L. 2019. Medicinal plants in East Sumba that potential as natural dyes for ikat weaving. Jurnal Kimia Valensi 5 (2): 149-158. DOI: 10.15408/jkv/v5i2.9249.

Nurmasitah S, Solikhah R, Widowati, Milannisa AS. 2022. The impact of different types of mordant on the eco-print dyeing using tingi (*Ceriops tagal*). IOP Conf Ser: Earth Environ Sci 969: 012046. DOI:10.1088/1755-1315/969/1/012046.

Purwar S. 2016. Application of natural dye on synthetic fabrics: A review. Intl J Home Sci 2 (2): 283-287.

Rahayu M, Kuncari ES, Rustiami H, Susan D. 2020. Utilization of plants as dyes and natural color binder in traditional pringgasela woven fabric, East Lombok, West Nusa Tenggara, Indonesia. Biodiversitas 21 (2): 641-646. DOI: 10.13057/biodiv/d210228.

Rozak AH, Gunawan H. 2015. Altitudinal gradient affects on trees and stand attributes in Mount Ciremai National Park, West Java, Indonesia. Jurnal Penelitian Kehutanan Wallacea 4 (2): 93-99. DOI: 10.18330/jwallacea/2015.vol4iss2pp93-99.

Sabuna A, Hendrik AC, Rafael A, Nge ST, Ngginak J. 2023. Diversity of natural dye plants in The Taplel Waterfall Area, Sisimeni Sanam Training Forest, Takari District, Kupang District. Jurnal Penelitian Kehutanan Wallacea 12 (2): 47-53. DOI: 10.24259/jpkwallacea/v12i2.27966.

Sabuna AC, Nomleni FT. 2020. Identification of plants natural dye by Meto tribe in South Central Timor. IOP Conf Ser: Mater Sci Eng 823: 012037. DOI: 10.1088/1757-899X/823/1/012037.

Sathi AS. 2017. A review on pharmacological and cosmeceutical properties of *Curcuma longa*. Intl J Pharm Sci Res 2 (1): 9-16.

Schmitt M, Boras S, Tjoa A, Watanabe T, Jansen S. 2016. Aluminium accumulation and intra-tree distribution patterns in three *Arbor aluminosa* (*Symplocos*) species from Central Sulawesi. PLoS One 11 (2): e0149078. DOI: 10.1371/journal.pone/0149078.

Seran W, Hana YW. 2018. Weaving cloth coloring plant identification in Kaliuda Village Pahunga Lodu East Sumba. Jurnal Agribisnis Perikanan 11 (2): 1-8. DOI: 10.29239/j.agrikan/11.2.1-8.

Seran W, Kaho LMR, Mau AE, Nomleni BB. 2022. Identification and distribution of plants that have the potential as natural dyes for ikat weaving in Malaka District. Agrikan: Jurnal Agribisnis Perikanan 15 (2): 621-628. DOI: 10.52046/agrikan.v15i2.1312.

Sholikhah R, Widowati, Nurmasitah S, Nafi'Ah R. 2022. The impact of the use of different mordantt types on the ecoprint dyeing using tegeran (*Cudraina javanensis*) dye on primisima fabric. IOP Conf Ser: Earth Environ Sci 969: 012049. DOI: 10.1088/1755-1315/969/1/012049.

Subositi D, Wahyono S. 2019. Study of the genus Curcuma in Indonesia used as traditional herbal medicines. Biodiversitas 20 (5): 1356-1361. DOI: 10.13057/biodiv/d200527.

Taimenas AK, Ngginak J, Sabuna AC. 2021. Identification of biomordant in Merbaun Village, West Amarasi District, Kupang Regency. IOP Conf Ser: Mater Sci Eng 1143: 012024. DOI: 10.1088/1757-899x/1143/1/012024.

Tamilarasi A, Banuchitra M. 2021. Classification and types of natural dyes: A brief Review. Intl J Creative Res Thoughts 9 (11): 527-532.

Theeramongkol P, Kee-Ariyo C, Soteyome T, Mongkholrattanasit R. 2023. Knowledge management in local wisdom of mor hom natural dyed. J Educ Learn 12 (5): 42-51. DOI: 10.5539/jel/v12n5p42.