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Diversity of natural dye plants in the Taplel waterfall area, Sisimeni Sanam Training forest, Takari district, Kupang regency

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Abstract

The Taplel waterfall area which is in the Sisimeni Sanam Education and Training Forest area is one of the conservation areas in East Nusa Tenggara which has quite high biodiversity, including plants that produce natural colors. However, information on the species diversity of dye plants in the Taplel waterfall area is still lacking. The objective of this study was to uncover the diversity of natural dye plants in the Taplel waterfall area, Sisimeni Sanam Training Forest, Takari District, Kupang Regency. Data collection was carried out by setting sample plots measuring 2 x 2 meters (seedlings), 5 x 5 meters (saplings), 10 x 10 meters (poles), and 20 x 20 meters (trees). Analysis of the importance of species using the Importance Value Index, and species diversity using the Species Diversity Index (Shannon-Wiener Index). Species of natural dye plants found in the Taplel Waterfall Area include Tectona grandis, Cassia siamea, Acacia auriculiformis, Tamarindus indica, Ficus racemosa, Leucaena leucocephala, Schleichera oleosa, Bauhinia purpurea, Cassia fistula, Garuga floribunda, and Annona squamosa L.. Plant species that has the highest important role in the Taplel Waterfall Area is Cassia fistula (sapling), Bauhinia purpurea (pole), and Tectona grandis (tree). Meanwhile, the diversity of natural dye plant species in the Taplel Waterfall Area at the level of seedlings, saplings, poles and trees is in the moderate category.

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INTRODUCTION

The Taplel waterfall is located in the Sisimeni Sanam Education and Training Forest area; one of the conservation areas in East Nusa Tenggara which has a relatively high wealth of natural resources (BKSDA NTT, 2018), including plants that produce natural colors. Information on the species diversity of these plants have been reported from the areas around community settlements, as their use for coloring woven fabrics by the local community. That earlier study showed that there were dozens of natural dye plants used by artisans from East Nusa Tenggara, such as tarum, turmeric, noni, along with color enhancers such as loba and biduri (Sabuna et al., 2018; Sabuna & Nomleni, 2020).

However, information on the species diversity of dye plants in natural area such as in the Taplel waterfall area is still lacking. Thisresults of this study will provide useful information on the occurrence of dye plant species in natural forests. The Sisimeni Sanam Education and Training Forest area is a lowland forest ecosystem, located at an altitude of between 245 – 480 m above sea level. The climate type in the forest area ranges between type D to E according to the climate classification by Schmid and Ferguson. (BKSDA NTT, 2018).

People in the villages areas in East Nusa Tenggara are known for their woven crafts. They use natural dyes taken from dye plants in the forests around their village. This potentially threaten the dye plants in the forest.Hadi et al. (2015) emphasized that human activities can affect species diversity in a forest community. Lani et al. (2021) found that the diversity of natural dye plants in Hundihopo village, East Rote sub-district, which is also a center for the development of natural dye-based ikat, has a moderate level of diversity. Apart from that, one of the plants that used to produce the red color, namely loba, is no longer found in the area. Besides due to human activities, woven craftsmen have switched to

using synthetic dyes to color woven threads, even though ancestral cultural heritage is a characteristic of the people of NTT, which can be a special attraction for local and foreign tourists from a tourism perspective apart from being environmentally friendly and safe.

Maintaining the strategic assets of the Indonesian nation in facing the challenges and opportunities of the globalization era is important (Darajati et al., 2016). The diversity of plants that have the potential as natural dyes in the Taplel waterfall area, the Sisimeni Sanam Education and Training Forest has an important value to support the economy, research and ecotourism in this area. The research objective was to determine the diversity of natural natural dye plant species in the Taplel waterfall area of the Sisimeni Sanam Training Forest, Takari District, Kupang Regency.

METHODS

Location and Time of Research

This research was conducted in October - November 2022 in the Taplel waterfall area, Sisimeni Sanam Education and Training Forest, East Nusa Tenggara which is geographically located between 124010' - 124020' East Longitude and between 9030' - 9040' South Latitude.

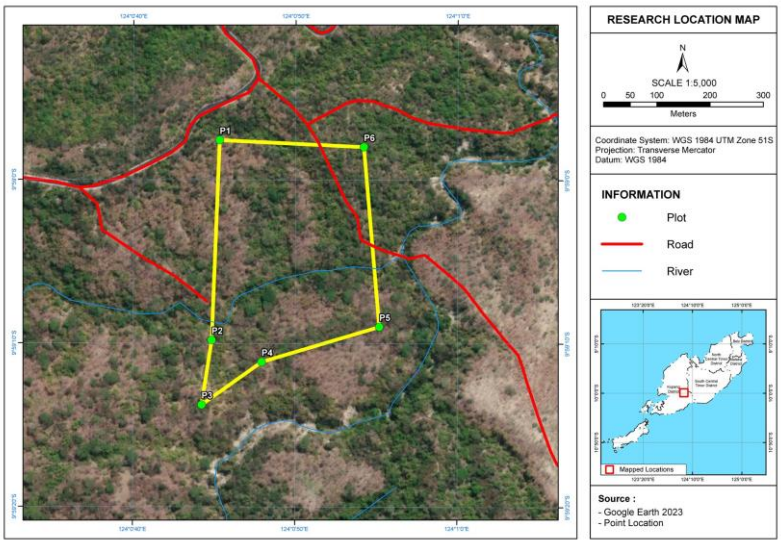

Figure 1. Map of research locations

Tools and Materials

The tools and materials used in this research were GPS (Global Positioning System), camera, digital soil analyzer tester, digger, compass, raffia rope, paper scissors, twig scissors, and machete.

Research Procedures

1. Method determination

Data was collected via the transect method with a sample plot of 20 x 20 meters. In this sample plot, trees of ≥ 20 cm in diameter were measured in the whole 20 m x 20 m plot. subplots are used to analyze vegetation. The poles (individuals with diameter 10 to 20 cm) were measured in the 10 m x 10 m sob plots. Individuals with a height of more than 1.5 m but the diameter less than 10 cm (sapling) were measured in the sub plot measuring 5 m x 5 m. Seedling (less than 1.5 in height) were measured in the sub plot of 2 x 2. The number of individuals of each species was only counted at the seedling level, but the diameter of the stem at breast height and the number of individuals of each species were counted at the tree, pole and sapling level (Usmadi et al., 2018).

2. Retrieval of plant data

Plant species that is potential for natural dyes were listed in advance from libraries such as journals and textbooks. When they were found in the study area, the name of each plant species was recorded. When we could not identify the species name, we asked the staff of the staff Sisimeni Sanam Education and Training Forest who help us in data collection.

3. Collection of physical data

Several physical parameters, such as soil moisture, soil pH, and light intensity, were also collected in each plot. The Digital Soil Analyzer Tester tool is used to measure soil parameters, which are embedded directly on the soil surface in a place that has no shade.

Data analysis

Species diversity index was calculated by the data on the number of individuals of each species

obtained. The species diversity index describes the characteristics of the community level based on its biological structure (Indriyanto, 2006). The Shannon Winner diversity index (H′) was used in this study.

$$H' = -\sum (pi\ (\ln pi)) \qquad (1)$$

$$pi = \frac{ni}{N}$$

Remarks:

H' = species diversity index

pi = number of individuals of species i/total number of individuals of all species (ni/N)
ni = number of individuals of species i

N = total number of individuals of all species
Shannon value definition of species diversity:

1. $H' > 3$: high species diversity.
2. $1 \leq H' \leq 3$: moderate species diversity.
3. $H' < 1$: low species diversity. (Fonge et al., 2013)

In addition, this study also calculates relative density (RDe), relative frequency (RF), relative dominance (RD), and important value index (IVI).

$$IVI = RDe + RF + RD \qquad (2)$$

RESULTS

Based on research conducted in the Taplel Waterfall Area, Sisimeni Sanam Training Forest (Figure 1), eight species of plants were found that have the potential to act as natural dyes from five families at tree level. Fabaceae is the family with the largest number of species; five species. Species from the Fabaceae are *Cassia siamea, Acacia auriculiformis, Tamarindus indica, Leucaena leucocephala*, and *Bauhinia purpurea*. Meanwhile, five species of plants that do not included as natural dye plants are *Acacia leucophloea*, kiuk-ba'i, *Ziziphus timorensis, Strychnos lucida*, and *Ziziphus mauritiana* (Table 1).

Through data processing results from six observation plots, the highest frequency for natural dye plants was *Tectona grandis* which was found in four observation plots with a frequency value of 0.50, and the lowest frequency were *A. auriculiformis, T. indica, Ficus racemosa, L. leucocephala, Schleichera oleosa*, and *B. purpurea* which were only found in one or two observation plots with a frequency value of 0.167 each (Table 1).

The species density at tree level was 216.7 individuals/ha with the highest density found in the *Tectona grandis* at 45.8 individuals/ha. Meanwhile, the species with the highest dominance was *T. grandis* at 4.40368 cm2/m2 (Table 1).

The results of the analysis show that *T. grandis* is a species of dye plant that has the highest role in the research location with an INP

Table 1: Relative density (RDe), relative frequency (RF), relative dominance (RD) and important value index (IVI) at the tree level

No.	Latin Name	Family	Relative density	Relative frequency	Relative dominance	IVI
1	*Acacia leucophloea* (Roxb.) Willd.	Fabaceae	25,00	20	41,76	86,76
2	*Tectona grandis* L.*	Lamiaceae	21,15	12	24,80	57,96
3	*Ficus racemose* L.	Moraceae	13,46	12	9,27	34,73
4	*Cassia siamea* (Lamk.) Irwin et Barneby*	Fabaceae	3,85	8	2,67	14,52
5	*Acacia auriculiformis* A. Cunn. ex Benth*	Fabaceae	1,92	4	0,86	6,79
6	*Tamarindus indica* L.*	Fabaceae	1,92	4	2,65	8,57
7	*Ziziphus timorensis* Lam.	Rhamnaceae	9,62	16	5,04	30,66
8	Kiuk-ba'i *#	-	1,92	4	0,86	6,79
9	*Leucaena leucocephala* de Wit*	Fabaceae	1,92	4	2,06	7,99
10	*Strychnos lucida* R. Br.	Loganiaceae	1,92	4	0,92	6,84
11	*Ziziphus mauritiana* Lam.	Rhamnaceae	1,92	4	0,81	6,74
12	*Schleichera oleosa* (Lour.) Oken*	Sapindaceae	3,85	4	2,60	10,44
13	*Bauhinia purpurea* L.*	Fabaceae	11,54	4	5,69	21,23

Note: * = natural dye plants, # = not yet identified

value of 57.96%. Other species that have an important role in the Taplel Waterfall Area, Sisimeni Sanam Training Forest are *B. purpurea* (21.23%), *C. siamea* (14.52%), *S. oleosa* (10.44%), *T. indica* (8 .57%), *Leucaena leucocephala* (7.99%), *A. auriculiformis* (6.79%), and kiuk-ba'i (6.79%) (Table 1).

At the regeneration level, namely poles, seven species of three tribes were found. At the pole level, the species that has the greatest density is *B. purpurea* at 166.66667 individuals/ha. The species of dye plant that has the greatest role in the forest community in the Taplel Waterfall Area, Sisimeni Sanam Training Forest at pole level is *B. purpurea* with an IVI value of 61.13%. Other types that have an important role are *L. leucocephala* (29.44%), and *Cassia fistula* (26.87%) (Table 2).

Table 2: Relative density (rDe), relative frequency (RF), relative dominance (RD) and important value index (IVI) at the pole level

No.	Latin name	Family	Relative density	Relative frequency	Relative dominance	IVI
1	*Bauhinia purpurea* L.*	Fabaceae	18,52	12,12	30,49	61,13
2	*Tectona grandis* L.*	Lamiaceae	3,70	6,06	3,82	13,58
3	*Ficus racemosa* L.	Moraceae	11,11	9,09	5,56	25,77
4	*Ziziphus mauritiana* Lam.	Rhamnaceae	3,70	6,06	1,23	11,00
5	*Cassia fistula* L.*	Fabaceae	9,26	9,09	8,52	26,87
6	*Ziziphus timorensis* Lam.	Rhamnaceae	20,37	12,12	16,61	49,10
7	Haububut #	-	3,70	3,03	3,22	9,95
8	*Leucaena leucocephala* de Wit*	Fabaceae	9,26	12,12	8,06	29,44
9	*Tamarindus indica* L.*	Fabaceae	3,70	6,06	4,42	14,18
10	*Acacia leucophloea* (Roxb.) Willd.	Fabaceae	5,56	6,06	7,65	19,27
11	*Vitex* sp.	Lamiaceae	3,70	6,06	2,84	12,61
12	*Garuga floribunda* Decne	Burseraceae	1,85	3,03	1,50	6,38
13	*Strychnos lucida* R. Br.	Loganiaceae	1,85	3,03	1,17	6,05
14	*Deris* sp.	Fabaceae	1,85	3,03	1,79	6,67
15	*Schleichera oleosa* (Lour.) Oken*	Sapindaceae	1,85	3,03	3,12	8,00

Note: * = natural dye plants, # = not yet identified

At the sapling level in the Taplel Waterfall Area, Sisimeni Sanam Training Forest, the species that has the highest role is *C. fistula* with an IVI value of 51.04%. At the sapling level, other types that have an important role in the forest community in the Taplel Waterfall Area, Sisimeni Sanam Training Forest are *Annona squamosa* (39.15%), *B. purpurea* (18.93%) and *T. indica* (10.88%) (Table 3).

Table 3: Relative density (RDe), relative frequency (RF), relative dominance (RD), and important value index (IVI) at the sapling level

No.	Latin name	Family	Relative density	Relative frequency	Relative dominance	IVI
1	*Cassia fistula* L.*	Fabaceae	16,22	15,79	19,04	51,04
2	*Tectona grandis* L.*	Lamiaceae	2,70	5,26	3,96	11,93
3	Haububut#	-	8,11	5,26	9,03	22,40
4	*Ziziphus timorensis* Lam.	Rhamnaceae	27,03	21,05	30,94	79,02
5	*Tamarindus indica* L.*	Fabaceae	2,70	5,26	2,91	10,88
6	*Bauhinia purpurea* L.*	Fabaceae	5,41	10,53	2,99	18,93
7	*Strychnos lucida* R. Br.	Loganiaceae	18,92	10,53	14,96	44,41
8	*Annona squamosa* L.*	Annonaceae	13,51	15,79	9,85	39,15
9	*Deris* sp.	Fabaceae	2,70	5,26	3,16	11,13
10	*Schleichera oleosa* (Lour.) Oken*	Sapindaceae	0,00	0,00	0,00	0,00
11	*Acacia leucophloea* (Roxb.) Willd.	Fabaceae	0,00	0,00	0,00	0,00
12	*Ziziphus mauritiana* Lam.	Rhamnaceae	2,70	5,26	3,16	11,13

Note: * = natural dye plants, # = not yet identified

The results of the analysis revealed that at the level of seedlings, saplings, poles and trees the Shannon-Wiener diversity index value was 2.41 (Table 4). The magnitude of the diversity index value indicates that the diversity of plant species in the Sisimeni Sanam Training Forest is moderate.

Table 4: Species Diversity Index

No.	Latin name	Family	Number of individuals	pi	lnpi	pi*lnpi
1	*Acacia auriculiformis* A. Cunn. Ex Benth	Fabaceae	1	0,004329	-5,44242	-0,02356
2	*Annona squamosa* L.*	Annonaceae	17	0,073593	-2,6092	-0,19202
3	*Tamarindus indica* L.*	Fabaceae	4	0,017316	-4,05612	-0,07024
4	*Bauhinia purpurea* L.*	Fabaceae	18	0,077922	-2,55205	-0,19886
5	*Garuga floribunda* Decne	Burseraceae	1	0,004329	-5,44242	-0,02356
6	*Ziziphus timorensis* Lam.	Rhamnaceae	36	0,155844	-1,8589	-0,2897
7	*Tectona grandis* L.*	Lamiaceae	45	0,194805	-1,63576	-0,31865
8	*Cassia siamea* (Lamk.) Irwin et Barneby*	Fabaceae	4	0,017316	-4,05612	-0,07024
9	*Acacia leucophloea* (Roxb.) Willd.	Fabaceae	16	0,069264	-2,66983	-0,18492
10	*Ficus racemosa* L.	Moraceae	13	0,056277	-2,87747	-0,16194
11	*Strychnos lucida* R. Br.	Loganiaceae	41	0,177489	-1,72885	-0,30685
12	Haububut#	-	5	0,021645	-3,83298	-0,08296
13	*Schleichera oleosa* (Lour.) Oken*	Sapindaceae	3	0,012987	-4,34381	-0,05641
14	Kiuk-ba'i*#	-	1	0,004329	-5,44242	-0,02356
15	*Vitex* sp.	Lamiaceae	2	0,008658	-4,74927	-0,04112
16	*Ziziphus mauritiana* Lam.	Rhamnaceae	4	0,017316	-4,05612	-0,07024
17	*Cassia fistula* L.*	Fabaceae	11	0,047619	-3,04452	-0,14498
18	*Leucaena leucocephala* de Wit*	Fabaceae	6	0,025974	-3,65066	-0,09482
19	Semak duri#	-	1	0,004329	-5,44242	-0,02356
20	*Deris* sp.	Fabaceae	2	0,008658	-4,74927	-0,04112
			231	H'		2,41931

Note: * = natural dye plants, # = not yet identified

In addition, the diversity of plants that have the potential to become natural dyes in the Taplel Waterfall area, the Sisimeni Sanam Training Forest is also influenced by environmental conditions. Parameter measurement needs to be done to determine the environmental conditions where natural natural dye plants live. Measurements were made in each plot. Environmental parameters measured in the Taplel Waterfall Area, namely:

Table 5. Environmental Parameters of the Taplel Waterfall Area, Sisimeni Sanam Training Forest

Environmental parameters	Unit	Range
Soil moisture	%	3-5
Soil pH	-	7
Light intensity	Lux	250-300

The results of measuring environmental parameters in the research location include soil moisture values ranging from 3-5%, soil pH values 7, light intensity values ranging from 250-300 Lux (Table 5).

DISCUSSIONS

Based on observations in the Taplel Waterfall Area, Sisimeni Sanam Training Forest, some of the plants with potential for natural dyes found were *T. grandis*, *T.* indicus, and S. *oleosa*. In line with the results of this research, according to the East Nusa

Tenggara Natural Resources Conservation Center (BKSDA NTT) (2018), in Sisimeni Sanam Education and Training there are 104 species of flora from 51 families, some species that are easy to find are *Cassia siamea*, *C. odorata*), *T. indica*, *Z. timorensis*, *T. grandis*, *S. oleosa*), *Dysoxylum* sp. and several species of *Ficus*.

The importance value index is one of the parameters that can provide an overview of the role of the species in question in their community (Soegianto, 1994). The high IVI value of this species is because this species is often found in the research location and has a large stem diameter, so the relative frequency and relative dominance values are high. Apart from that, the high IVI value for teak plants is due to the fact that the area is a former Industrial Plantation Forest (HTI).

Bauhinia purpurea, C. fistula, and *Annona squamosa* L. generally have an important role in the level of seedling, sapling and pole regeneration in the Taplel Waterfall Area, Sisimeni Sanam Training Forest. The ability of a particular species to grow to a higher growth rate illustrates the higher adaptability of that species of vegetation to an ecosystem/forest (Gunawan et al., 2011). These three species will replace the tree community in the Taplel Waterfall Area, Sisimeni Sanam Training Forest in the future. However, unlike the *Tectona grandis*, the density of this species is low in young stage. This is expected to disrupt the regeneration of this plant in the future.

Species diversity index is an index of overall diversity within a community (Odum, 1998). The species diversity index is used to determine the level of species diversity in a forest stand, the higher the value of species diversity, the greater the level of diversity or the more species found (Rikardus et al., 2017). The species diversity index is closely related to the number of vegetation constituent species (in this case plants that have the potential to become natural natural dye plants).

Based on these observations, it can be stated that the environmental conditions in the Taplel Waterfall area, Sisimeni Sanam Training Forest are classified as quite humid with a fairly high light intensity, and a place that is relatively open to light and strong winds. These conditions are very good for the growth and development of natural natural dye plants.

According to Indriyanto (2009), the ability of plant species to adapt to where they grow and their relationship with other plants determines the extent of the spread of these plant species. This species capability is due to the relatively large tolerance to various ecological factors and the nature of cosmopolitan plants such as members of the families Gramineae, Polypodiaceae, and Passifloraceae.

According to Ramadhanil et al. (2008), the dominant herbaceous plant species in the forest were from the famili Urticaceae, Araceae, Hypoxidaceae and Acanthaceae. While Richards (1952), Burtt (1977) in Kiew (1978) mentioned that the dominance of certain families in the forest were Araceae, Begoniaceae, Cyperaceae, Gesneriaceae, and Melastomaceae (also Acanthaceae and Rubiaceae are also common).

Tropical rain forests are characterized by high species diversity, and only certain species are tolerant and able to live in very extreme habitats (open areas, full sun, high temperatures, high rainwater impacts, dense and hard soil textures), and nutrients are still bound to the rocks). Vegetation that is intolerant to the above environmental conditions will not be found, but plants that require such environmental factors will grow well (Resosoedarmo et al., 1989).

CONCLUSION

From the results of research that has been conducted on the Diversity of Natural Dyes Plant species in the Taplel Waterfall Area, Oesusu Village, Takari District, Kupang Regency, it is concluded that the species of natural dye plants found in the Taplel Waterfall Area include *T. grandis, C. siamea, A. auriculiformis, T. indica, F. racemosa, L. leucocephala, S. oleosa, B. purpurea, C. fistula*, *G. floribunda*, and *A. squamosa* L.. The Species of natural dye plants that have the highest important role are *C. fistula* (saplings), *B. purpurea* (poles), and *T. grandis* (trees). The diversity of natural dye plants at the level of seedlings, saplings, poles and trees is in the moderate category.

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AUTHOR CONTRIBUTIONS

Alan Sabuna: research conceptualization, research coordinator, data analysis, data interpretation, manuscript writing; Arnold Hendrik: member contributor, research implementer, data analysis, interpretation, manuscript writing; Andriani Rafael: member contributor, research implementer, interpretation; Sonya Nge: member contributor,

research implementer, interpretation; James Ngginak: member contributor, research implementer, interpretation.

CONFLICTS OF INTEREST

The authors declare there is no conflict of interest related to financial funding and authorship order for this article.

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