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The diversity, ethnobotany and nutrient contents of *Dioscorea* for post-disaster food security in Lombok, Indonesia

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[4]Tropical Biopharmaca Research Center, Institut Pertanian Bogor. CRC Building, 2nd Floor, STP Area, Taman Kencana Campus, Taman Kencana St. No. 3, Bogor 16128, West Java, Indonesia. Tel.: +62-251-8373561, Fax.: +62-251-8347525, ♥♥♥email: ime@apps.ipb.ac.id

[5]Department of Chemistry, Faculty of Mathematics and Natural Sciences, Institut Pertanian Bogor. Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia

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Abstract. *Indriyatno, Wijayanto N, Batubara I, Supriyanto. 2024. The diversity, ethnobotany and nutrient contents of* Dioscorea *for post-disaster food security in Lombok, Indonesia. Biodiversitas 25: 553-564.* Earthquakes caused damage to infrastructure, houses, and roads in Lombok in 2018. After the earthquake, there was a shortage of food. Adaptation to address food shortage can be overcome by using local food sources, including those from the *Dioscorea* genus. The study aims to analyze the diversity and distribution, ethnobotany and nutrient contents of the *Dioscorea* genus in Lombok Island. Botanical explorations were conducted to identify the intraspecific varieties in the form of local types/names complemented with ethnobotanical study through structured interviews. The nutrient contents were determined using a standardized method in proximate analysis. The study found 12 local types of *Dioscorea* belonging to four species which are used by the community for adaptation after earthquake disaster, namely: *D. bulbifera* (*kentang*), *D. bulbifera* (*engal*), *D. alata* (*uwi sawa*), *D. alata* (*lami*), *D. alata* (*uwi kuning ampenan*), *D. alata* (*uwi putih ampenan*), *D. alata* (*uwi ungu dara kunci*), *D. alata* (*uwi putih batu layar*), *D. alata* (*uwi ungu batu layar*), *D. esculenta* var. *apiculata* (*surak*), *D. esculenta* var. *spinosa* (*gembili*) and *D. pentaphylla* (*buyut*). The highest diversity of *Dioscorea* is found in climate type C3 (8 local types), followed by climate type E (5 local types), climate type D4 (4 local types), climate type B2 (3 local types), and climate type C2 and D3 (1 local type). The local community utilizes the *Dioscorea* genus in several cultural events including when celebrating the Prophet Muhammad's birthday. The nutritional value of *Dioscorea* genus is high due to its carbohydrate content (66,09-76,96%), protein content (3.79-10.84%), fat content (1.70-9.58 %) and fiber content (0.32-6.81%). This study shows the potential of *Dioscorea* to be used as food sources that are cheap, easy to grow, and more adaptive to different environmental conditions to help post-earthquake communities.

Keywords: *Dioscorea*, earthquakes, ethnobotany, local food, Lombok, proximate

INTRODUCTION

Geologically, Indonesia lies on three boundaries of tectonic plate, resulting in the emergence of a series of volcanoes in the ring of fire (Kaban et al. 2019; Firdaus et al. 2022; Kurniawan et al. 2022). These geological conditions imply that Indonesia is among the countries with the highest threat of disasters related to earthquake and volcanic activities with one of the disaster-prone regions are Lombok Island and the surrounding small islands (Nugroho et al. 2022). The vulnerability of Lombok Island to geological disasters can be seen from the series of earthquake, i.e. in 1257, 1979, and 2018, that have paralyzed the economy due to infrastructure damage (Pradjoko et al. 2018; Ferrario 2019; Zhao et al. 2021; Lines et al. 2022; Malawani et al. 2022). Besides, Lombok Island is also threatened with meteorological disasters amplified by climate change, resulting in some events of flood and landslides, such as in 2022 in the Meninting River flow area. Both types of disasters caused damage to infrastructure, changes in surface water flow, sedimentation, and disruption in food production and distribution (Rodriguez et al. 2015).

Disasters can cause food vulnerability (Jackson et al. 2020). During the disaster events, food vulnerability is often overcome by communities by consuming non-common staple foods such as tubers which are locally obtained from agroforestry lands and forests. Such foods are essential to substitute a more common foods such as rice which are usually grown on fields and might be affected by disasters such as floods. Not only to produce foods in the form of fruits, crops and tubers, forests and agroforestry systems also provide medicines, and serve as habitat of animal and plant diversity (Juliarti et al. 2021; Susilowati et al. 2021; Octavia et al. 2022). In particular, tubers in agroforestry play a role in improving food security and sustainability (Nankaya et al. 2021; Kassa et al. 2023) as reflected in the menus of consumed foods (Sukenti et al. 2016;

Jannaturrayyan et al. 2020), as well as in their ritual and cultural activities.

Rituals and cultures are related to many human activities on Lombok Island, including indigenous knowledge related to landscape management and agricultural practices. For example, the presence of a well-known volcano on the island, Mount Rinjani, is associated with the myth of the mountain guardian called "sebawe" (Koopman 2023). The eruption of Mount Samalas (or ancient Rinjani) in 1257 buried nearly half of Lombok under 50 meter deep pyroclastic deposits and destroyed vegetation (Mutaqin et al. 2019). Oral and written records, such as the Babad Lombok, Babad Suwung, and Babad Sembalun, mentioned the conditions before, during, and after the eruption (Malawani et al. 2022). Interestingly, the Babad Lombok also mentions tuberous plants, like the *Dioscorea* genus, as alternative food sources.

While classical literatures have recorded the importance of biological diversity for human life including during the events of disasters, such biodiversity has been degraded due to changes in social and economic aspects (Díaz et al. 2019; Booth et al. 2022). Plant species with low economic value experience a decrease in population number. For instance, the tubers which were previously common, are now becoming difficult to obtain because people prefer other types of crops that are more valuable economically. Considering that historically tubers such as *Dioscorea* were consumed in the moment of disasters, these plants have the potential to be re-developed as safeguard of food security during unfortunate events or food depletion as a substitute of rice. These plants have advantage of being able to grow in various different environmental conditions and can be developed in agroforestry systems.

Dioscorea genus grow widely in tropical and subtropical areas (Mat Lazim et al. 2021) including in Indomalaya ecoregion (Evans et al. 2020). This plant group is therefore deemed suitable to be developed in Lombok Island since this island is biogeographically situated in the Wallace Line with ecologically resembling Australasia ecoregion. Also, the climate is within the suitable range of *Dioscorea* since according to Oldeman climate classification, the climate in Lombok is divided into six types of climate (B2, C2, C3, D3, D4 and E) (Baihaqi et al. 2020). In Lombok, *Dioscorea* can be cultivated in agroforestry land which is a common agricultural practice in several regencies including in North Lombok, East Lombok, Central Lombok, and Mataram City.

Dioscorea genus has different local names in the Lombok community due to its colors, tastes, forms or other important characters. Therefore, the local names of this plant vary according to the local communities. The type of *Dioscorea* used by society requires scientific name information, which is still very limited up to date. Mapping scientific name of *Dioscorea* genus is needed as basic data, which is important information for post-earthquake food resilience. The analysis of identification, morphological characteristics, and nutritional content of *Dioscorea* genus in Lombok or in Indonesia is very crucial. Therefore, the study aimed to assess the diversity of *Dioscorea* and their ethnobotanical uses by Lombok community as a post-earthquake food resilience strategy. In doing so, the study will identify their scientific name, their distribution in various agroforestry systems and in different climate types, and nutrient contents with descriptive method and proximate analysis approaches.

MATERIALS AND METHODS

Study area

Dioscorea genus was collected from the study area of the entire Lombok Island, West Nusa Tenggara Province, Indonesia (Figure 1). Administratively, it encompassed several regencies including East Lombok, North Lombok, West Lombok, and Mataram City. Geographically, it is located at 08°55'20" LS and 116°00'08 BT. The average temperature and humidity of the study area are 26.8°C and 83%.

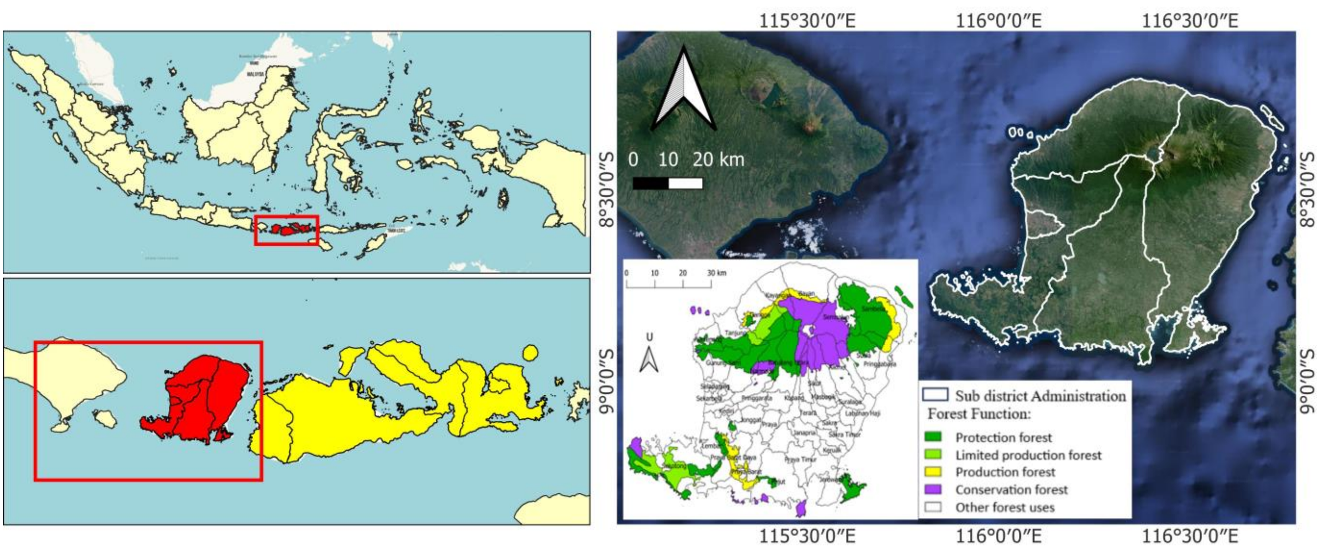

Figure 1. Map of the study area showing the entire Lombok Island, West Nusa Tenggara Province, Indonesia where data was collected

Data collection

Ethnobotany

In ethnobotanical studies, structured interviews were conducted to obtain local names of plants and plant parts used (Phatlamphu et al. 2021; Amrul et al. 2022). The snowball sampling technique was used to select 30 people for interview (Navia et al. 2021; Susandarini et al. 2021). The questions to respondents were about the plant species used as an alternative food source in the post-disaster period, plant locations, and how to cultivate them. The interview results were used for botanical exploration, especially tubers of the *Dioscorea* genus and the tuber types, and plant materials were collected as herbarium specimens. Each specimen consisted of four samples of vegetative parts (leaf), generative (fruit and flower) organs, and bulbs (Supiandi et al. 2019).

Herbarium specimens were made from plant collection, and then the plant samples were dried, labeled, identified, and stored. Information such as scientific names, families, and local names was compiled and tabulated in database (Manzanero-Medina et al. 2020). In addition, water, protein, fat, fiber, and carbohydrates contents were analyzed from the tuber parts (Mat Lazim et al. 2021).

Specimen documentation and identification

Herbarium specimens were identified at the Laboratory of the Forestry Program of Forestry Studies, Faculty of Agriculture of the University of Mataram. The results of the scientific name identification were updated based on Plants of the World Online (https://powo.science.kew.org/) (Navia et al. 2022).

Proximate analysis

Water content

To analyze the water content in *Dioscorea* flour, samples were dried in an oven at a temperature of 105°C. Water content evaporation was done for 5 hours (Mat Lazim et al. 2021). Water content was calculated using the equation below.

$$\text{Water content (\%)} = 100 - \frac{\text{dry weight}}{\text{wet weight}} \text{ x } 100\ \%$$

Ash content

About 2 g of *Dioscorea* flour was burned in a furnace at 550°C for 5 hours (Mat Lazim et al. 2021). This burning caused organic compounds of C, H, O, N to burn out. Ash content was calculated following the equation below.

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of starch}}\ x\ 100\ \%$$

Protein content

About 0.25 g of *Dioscorea* flour was mixed with 1.5 g ($CuSO_4$ and $NaSO_4$), poured into a Kjeldahl flask, and 7.5 mL of concentrated sulphuric acid was added. The flask was deconstructed in a fume hood until clear. The result of the deconstruction was diluted with 100 mL of cold aquadest, then it was added with 50 mL of cold NaOH 40%. The Kjeldahl flask was mounted on a distiller device equipped with an Erlenmeyer tube containing 250 mL H_3BO_3 3% as much as 25 mL. Distillation was stopped when the Erlenmeyer tube reached 100 mL; it was distilled with a standard solution of H_2SO_4 0.1 N, and the titration was stopped when the solution turned to pink or red origin (Maser and Sinaga 2021). The raw protein content is based on nitrogen content multiplied by a conversion factor 6.25 (Ahmadu et al. 2018; Omohimi et al. 2018). Crude protein content was calculated following the equation below.

$$\text{Crude protein} = \frac{\text{mL titration x 0,1 x 0,014 x 6,25}}{\text{sample weight}}\ x\ 100\ \%$$

Fat content

About 1.5 g of *Dioscorea* flour was wrapped in paper and oven-dried for 8 hours at a temperature of 105°C. The fat was dissolved with chloroform for 3-8 hours using a soxhlet extractor. The extracted fat in the solvent is separated by heating in an oven at a temperature of 105°C. Crude fat content was calculated following the equation below. Crude fat content was calculated following the equation below.

$$\text{crude fat (\%)} = \frac{\text{Weight of fat}}{\text{Weight of starch}}\ x\ 100\ \%$$

Fiber content

Raw fibers and ash, which belong to non-soluble components were heated/boiled with acid and base for 30 minutes. The raw fiber values were obtained from the ashes resulting from the combustion of residues of insoluble materials (Mat Lazim et al. 2021). Fiber content was calculated following the equation below.

$$\text{Fiber} = \frac{\text{Weight of fiber}}{\text{weight of starch}}\ x\ 100\ \%$$

Carbohydrate content

Carbohydrate = 100 %-(% water content + % fat + % protein + % fiber + % ash) (Elmi Sharlina et al. 2017; Mat Lazim et al. 2021).

RESULTS AND DISCUSSION

Diversity and distribution of *Dioscorea* in Lombok Island

Climatically, Lombok Island is divided into 6 climate types, namely B2 (7-9 wet months and 2-3 dry months), C2 (5-6 wet months and 2-3 dry months), C3 (7-9 wet months and 4-6 dry months), D3 (3-4 wet months and 2-3 dry months), D4 (3-4 wet months and 7-9 dry months) and E (0-2 wet months and 0-1 dry months), as shown in Figure 2 (Baihaqi et al. 2020). The climate type in the western and southern parts is E, which has relatively low rainfall (Baihaqi et al. 2020).

This study recorded 12 local types of *Dioscorea* across 6 climate types in Lombok Island. The most abundant *Dioscorea* local types were found in climate type of C3 (7-9 wet months and 4-6 dry months). In fact, these *Dioscorea* types are consumed as food sources after the earthquake disaster. The distribution of *Dioscorea* local types is shown in Figure 2 and Table 1. It is possible that each climate type will form a specific ecological condition which is suitable for the growth of certain *Dioscorea* varieties. Limiting ecological factors, such as water availability, will influence the *Dioscorea* genus to grow as good as possible for being adaptive to be drought tolerance species.

Table 1. Distribution of *Dioscorea* local types in different climate types in Lombok Island, West Nusa Tenggara Province, Indonesia

Scientific name	Local name	Climate types						Frequency of distribution
		B2	C2	C3	D3	D4	E	
Dioscorea bulbifera	*Kentang*			√				1
D. bulbifera	*Engal*				√	√	√	3
D. alata	*Uwi sawa*			√				1
D. alata	*Lami*			√			√	2
D. alata	*Uwi kuning ampenan*						√	1
D. alata	*Uwi putih ampenan*						√	1
D. alata	*Uwi ungu dara kunci*				√	√		2
D. esculenta var. *spinosa*	*Gembili*	√		√	√	√	√	5
D. alata	*Uwi putih batulayar*			√				1
D. alata	*Uwi ungu batulayar*			√				1
D. esculenta var apiculata	*Surak*	√		√	√	√		4
D. pentaphylla	*Buyut*	√	√	√				3
Number of local types		3	1	8	4	4	5	

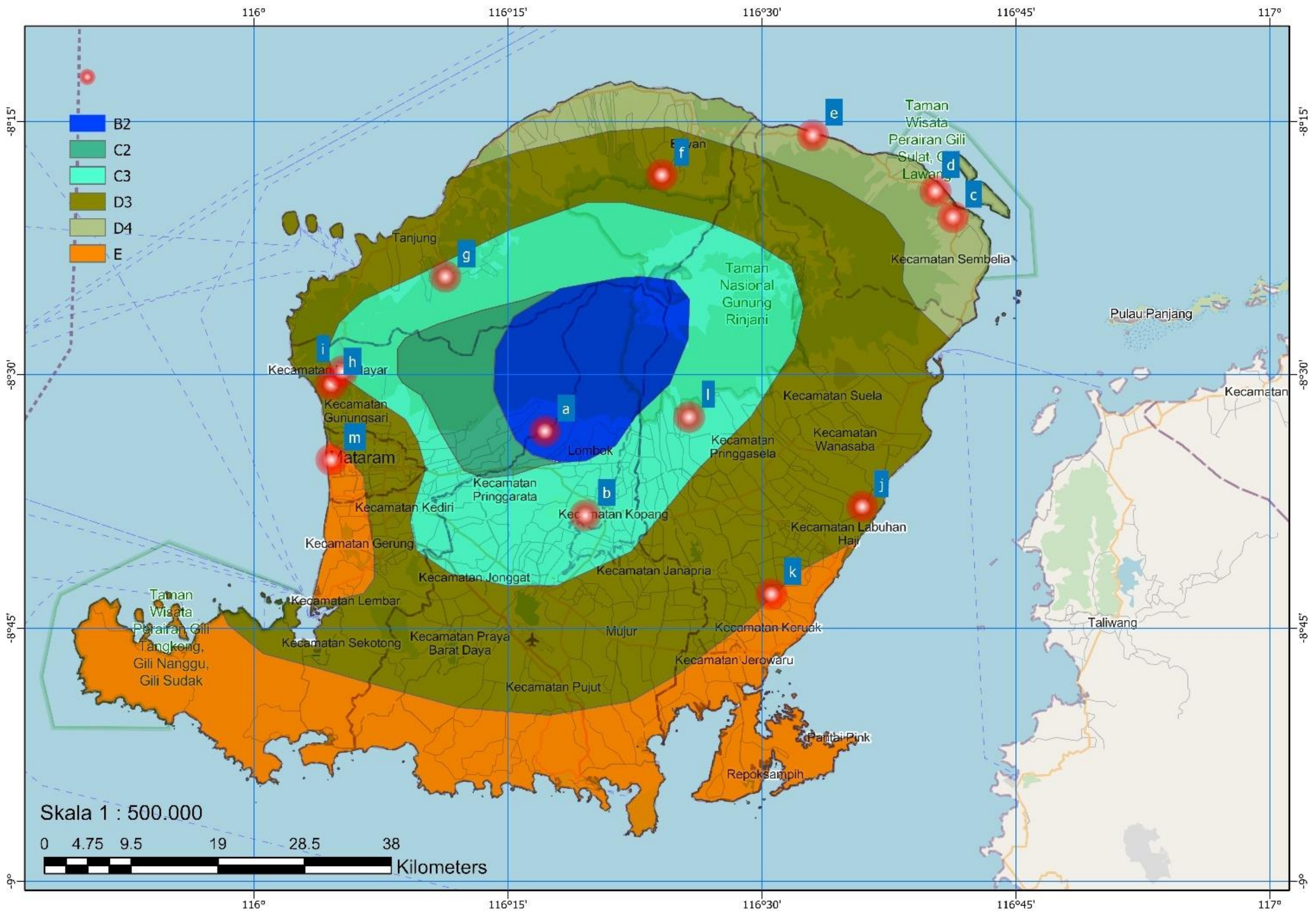

Figure 2. The distribution of *Dioscorea* local types in six different climate tipes in Lombok Island, West Nusa Tenggara Province, Indonesia. A. *Dioscorea alata* (*uwi ungu*), *D. esculenta var apiculata* (*surak*). B. *Dioscorea bulbifera* (*kentang*), *D. alata* (*lami*), *D. esculenta var spinosa* (*gembili*), *D. esculenta var apiculata* (*surak*), *D. pentaphylla* (*buyut*). C. *Dioscorea alata* (*uwi putih*). D. *Dioscorea esculenta var spinosa* (*gembili*) and *Dioscorea alata* (*uwi ungu dara kunci*). E. *Dioscorea esculenta var spinosa* (*gembili*). F. *Dioscorea alata* (*uwi ungu*). G. *Dioscorea esculenta var spinosa* (*gembili*). H. *Dioscorea bulbifera* (*engal*), *D. alata (uwi sawa*), *D. alata* (*uwi putih batu layar*), *D. alata* (*uwi ungu batu layar*), *D. esculenta var apiculata* (*surak*), *D. pentaphylla* (*buyut*), *D. esculenta var spinosa* (*gembili*). I. *Dioscorea pentaphylla* (*buyut*) and *D. esculenta var apiculata* (*surak*). J. *Dioscorea bulbifera* (*engal*), *D. alata (uwi sawa*), *D. alata* (*lami*), *D. alata* (*uwi kuning ampenan*), *D. alata* (*uwi putih ampenan*), *D. esculenta var spinosa* (*gembili*), *D. esculenta var apiculata* (*surak*) and *D. pentaphylla* (*buyut*)

Table 1 shows the most abundant *Dioscorea* local types were found in climate type C3 (8 types), followed by climate type E (5 types), climate type D4 (4 types), climate type B2 (3 types), climate type C2 and D3 (each 1 type), respectively. It is also shown that *D. esculenta* var. *spinosa* (*Gembili*) is the most adaptive species that grows in 5 climate types, followed by *D. esculenta* var. *apiculata* (4 climate types), *D. bulbifera* and *D. pentaphylla* (3 climate types), respectively. The species adaptability to the climate type and market preference may lead to this distribution pattern. *Gembili* may important to be developed across the region for food security in post-earthquake disasters. Species adaptability could be affected by the number of precipitation, temperature, and soil types (Adewumi et al. 2021).

Morphology of *Dioscorea* in Lombok Island

The *Dioscorea* genus is easily differentiated based on the morphology of the leaves, tubers, hairs, and the direction of growth of the host tree vines. Compound leaves are shown by *D. pentaphylla*, while the others are shown with single leaves. *D. alata* has several genetic variations. Based on the color of the tuber, it consists of 4 variants, i.e. white color (*D. alata* (*uwi sawa*), *D. alata* (*lami*), *D. alata* (*uwi putih ampenan*), *D. alata* (*uwi putih batu layar*)), yellow color (*D. alata* (*uwi kuning ampenan*)), purple color (*D. alata* (*uwi ungu dara kunci*)), and purple withies color (*D. alata* (*uwi ungu batu layar*). There are two local varieties of *D. bulbifera* found, namely *engal* and *kentang*, both are the hanging and soil tuber types. The *engal* variant of *D. bulbifera* is not consumed, while the *kentang* variant is consumed.

Moreover, the tuber shapes vary widely among them. Different environmental conditions may affect phenotypic adaptations by plants, such as shape, size, root, and leaf color (Table 2). There are 3 prominent morphological variations, namely the ovoid tuber shape that can reach a weight of 50 kg (Figure 3D), the *sawa* variety with a round shape extending up to 1 m at 4 years after planting, and the *lami* variety with a round shape weighing approximately 1 kg. *D. alata* has a variety of elongated moon shapes, purple or white tuber color, or both. *D. esculenta* var. *spinosa* is easily distinguished by the tuber's characteristics, which can reach 10 per plant with a weight of up to 200 g/tuber. Similarly, *D. esculenta* var. *apiculata* is easily recognized because it has one tuber, many spines at the top of the tuber stalk, and many root fibers (Antonio and Buot 2021). The growth of *D. alata* tuber at 2 years after planting reaches 10.5 kg and 39 cm in length (Figure 3). Gigantic tuber development may be affected by species, age, soil structure and fertility.

The hairs is one of the characteristics that are also easy to distinguish. The type of *D. esculenta* has many sparse pubescent hairs, and *D. pentaphylla* has pubescent hairs on the leaf surface. In contrast, the types of *D. alata* and *D. bulbifera* are bare between the leaf surfaces.

Cultivation of *Dioscorea* in agroforestry systems

In Lombok Island, *Dioscorea* tubers are generally planted in October. *Dioscorea* growth begins with a shoot that emerges from the tuber. The shoots develop into stems that extend into the host tree. The direction of their growth can distinguish these species. *Dioscorea esculenta* grows around the host plant to the right, while *D. alata* grows around the host plant to the left.

The *Dioscorea* genus as climber can grow up to 20 m in height, depending on the height of the host trees (Kamaruddin et al. 2020; Mat Lazim et al. 2021). In Lombok, the genus *D. alata* grows by climbing on host trees up to 10 m. The host trees used for creeping are *banten* (*Lannea coromandelica*), *sengon* (*Falcataria moluccana*), *gamal* (*Gliricidia sepium*), eucalyptus (*Melaleuca leucadendra*), and moringa (*Moringa oleifera*). The host tree, *banten* (*L. coromandelica*), is found to be more common for *gembili* (*D. esculenta* var. *spinosa*). This tree is selected because it has the advantages of being easy to cultivate, adaptable to dry land, light canopy, and a source of forage for livestock.

Flowers are produced as part of the life cycle of this genus. Flowers appear on the tips of leaves, especially at the tip of the plant. Flowering phenology starts in February for *gembili* (*Dioscorea esculenta* var. *spinosa*), in March for *engal* (*D. bulbifera*), in April for *buyut* (*D. pentaphylla*), and in May for *uwi* (*D. alata*). The tubers are generally harvested during the dry season from June to August. People start harvesting the tubers when the leaves start to turn yellow. Especially for *gembili* (*D. esculenta*), which people harvest every year; this species tuber will be damaged naturally if it is not harvested.

In general, tubers in Indonesia are cultivated in various agroforestry systems (Imanuddin et al. 2020), including the *Dioscorea* genus in Lombok (Table 4). Simple agroforestry systems are applied on coffee, cacao, eucalyptus, and sengon (*F. moluccana*) in the yard, and complex agroforestry on sugar palms. In the agroforestry system in the Gangga Sub-district area, cacao is combined with *G. sepium* (*gamal*) and coconut plants. *G. sepium* (gamal) can be used as a host for *gembili* (*D. esculenta*), while in areas with an altitude of 0 to 300 m above sea level, such as in the Batulayar Sub-district of North Lombok District, *L. coromandelica* (*banten*) is used as the host. The combination of cashew and eucalyptus plants in the Sambelia Sub-district has the potential to be a host of *D. alata*.

Concerning disaster, cultivating the *Dioscorea* genus in different agroforestry systems is one of the preparedness strategies for food security to face natural disasters because Lombok Island is a disaster-prone area. This species has the advantage of growing at altitudes ranging from lowlands to highlands and is found in various climates. The tubers can be stored during the dry and rainy seasons.

Ethnobotany of *Dioscorea* on Lombok Island

Lombok Island is frequently affected by food shortages due to natural disasters, floods, and droughts. Several tubers belong to *Dioscorea* genus, such as *D. esculenta*, *D. alata, D. bulbifera,* are common alternative foods to address the food shortage problems. Among them, the most marketable tuber is *D. esculenta* due to its sweet taste, but it is easily rotten if the tuber is wounded. The taste of *D. alata* is a little bit chewy and bland, while the taste of *D. bulbifera* is fully bland or no taste but acceptable for staple food. Lombok communities generally grow the *Dioscorea* genus in fields and gardens under agroforestry systems. The result of this study is in line with other studies in which the *Dioscorea* genus is generally used for food security during long drought season and earthquake disaster (Obidiegwu and Akpabio 2017; Semwal et al. 2021; Kumar et al. 2022). This kind of traditional knowledge is already inherited from generation to generation (Susandarini et al. 2021).

Table 2. Morphological characteristics of *Dioscorea* genus in Lombok Island, West Nusa Tenggara Province, Indonesia

Scientific name	Local name	Tuber cross-section	Tuber shape	Leave shape
D. bulbifera	*Kentang*			
D. bulbifera	*Engal*			
D. alata	*Uwi sawa*			
D. alata	*Lami*			
D. alata	*Uwi kuning ampenan*			
D. alata	*Uwi putih ampenan*			
D. alata	*Uwi ungu dara kunci*			
D. esculenta var. *spinosa*	*Gembili*			
D. alata	*Uwi putih batu layar*			
D. alata	*Uwi ungu batu layar*			
D. esculenta var. *apiculata*	*Surak*			
D. pentaphylla	*Buyut*			

Table 3. Morphological comparison among the *Dioscorea* local type in Lombok Island, West Nusa Tenggara Province, Indonesia

Scientific name	***Dioscorea bulbifera***	***Dioscorea bulbifera***	***Dioscorea alata***	***Dioscorea alata***	***Dioscorea alata***	***Dioscorea alata***	***Dioscorea alata***	***Dioscorea esculenta* var. *spinosa***	***Dioscorea alata***	***Dioscorea alata***	***Dioscorea esculenta* var. *apiculata***	***Dioscorea pentaphylla***
Local name	*Kentang*	*Engal*	*Sawa*	*Lami*	*Uwi kuning ampenan*	*Uwi putih ampenan*	*Uwi ungu dara kunci*	*Gembili*	*Uwi putih batu layar*	*Uwi ungu batu layar*	*Surak*	*Buyut*
Juvenile branch	Green	Green	Green, purplish	Green, purplish		Green, purplish	Green, purplish	Green			Green	Green
Petiole	Grooved at the top, rounded at the bottom	Grooved at the top, rounded at the bottom	Grooved at the top, almost round at the bottom	Grooved at the top, almost round at the bottom	6-sided	6-sided	6-sided	Round	6-sided	6-sided	Round	Round
Bristles on the stalk	Bald	Bald	Bald	Bald	Bald	Bald	Bald	Bushy star hair, 2 spines	Bald	Bald	Furry	Sparsely hairy in the center, dense at the base, 2 spines
Leave shape	Hanging	Hanging	Hanging	Hanging	Hanging	Hanging	Hanging	Hanging	Hanging	Hanging	Hanging	Fingered, 5 leaflets
Leave size	18-22 x 18 - 21	18,50-22,50 x 18,50-21,50	10-14 x 6-13	4,50-9,50 x 5,40-9,30	9-15 x 12-15	9,50-16,50 x 11-18	9-16 x 12-16	7 -8,50 x 12,50-16	8,10-14 x 12,30-15,50	8-13 x 10-16,50	9-11 x 14-16	8-13 x 2-3
Leave tip	Tapered	Tapered	Tapered	Tapered	Tapered	Tapered to prickly	Tapered	Tapered	Tapered	Tapered	Tapered	Tapered
Leaf base	Heart-shaped	Heart-shaped	Heart-shaped	Heart-shaped	Heart-shaped	Heart-shaped	Heart-shaped	Heart-shaped	Heart-shaped	Heart-shaped	Heart-shaped	Tapered
Leaf edge	Flat	Flat	Flat	Flat	Flat	Flat	Flat	Flat	Flat	Flat	Flat	Flat
Secondary leaf blade	Ladder-shaped	Ladder-shaped	Ladder-shaped	Ladder-shaped	Ladder-shaped	Ladder-shaped	Ladder-shaped	Ladder-shaped	Ladder-shaped	Ladder-shaped	Ladder-shaped	Pinnate
Leaf stalk	Flat at the top, rounded at the bottom	Flat at the top, rounded at the bottom	Pentagonal shape	Pentagonal shape	Ladder-shaped	Pentagonal shape	Pentagonal shape	Round, spiny	Pentagonal shape	Pentagonal shape	Round	Round
Flower		None	None	None	None	None	None	None	None	None	None	None
Flower position	Not yet appeared	Appearing in leaf axils	Not yet appeared	Not yet appeared	Not yet appeared	Not yet appeared	Not yet appeared	Not yet appeared	Not yet appeared	Not yet appeared	Not yet appeared	Not yet appeared
Upper tuber	Round	Round	Elongated round	Ovoid	Ovoid	Ovoid	Ovoid	None	Ovoid	Ovoid	None	None

Table 4. Agroforestry system used for the cultivation of *Dioscorea* in Lombok Island, West Nusa Tenggara Province, Indonesia

Agroforestry system	The definition of a system	Host plant species	Crop species	Location
Complex agroforestry and simple agroforestry (Sari et al. 2023)	Combination of tree crops and agricultural crops	*Arenga pinnata, Dracontomelon dao, Aleurites moluccana*	*Piper betle, Vanilla planifolia* (*Vanili*), *D. alata, D. esculenta*	Bayan Sub-district, North Lombok District
Aren agroforestry system (Plieninger et al. 2020)	Combination of tree crops and agriculture	*Arenga pinnata, Tamarindus indica, Michelia champaca, Baccaurea racemosa, Gnetum gnemon, Durio zibethinus, Artocarpus heterophyllus, Mangifera indica, Lansium parasiticum, Pterospermum javanicum, Cocos nucifera*	*D. alata, D. esculenta*	Batulayar Sub-district, West Lombok District
Cocoa agroforestry system	A simple agroforestry system dominated by brown guava	*Theobroma cacao, Cocos nucifera, Gliricidia sepium*	*Vanilla planifolia* (*Vanili*), *D. esculenta*	Gangga Sub-district, North Lombok District
Coffee agroforestry system (Plieninger et al. 2020; Sari et al. 2023)	A simple agroforestry system dominated by cashew nuts	*Coffea canephora, Persea americana, Erythrina variegata*	-	Sembalun Sub-district, East Lombok District
Fruit agroforestry system	Combination of trees and agriculture	*D. zibethinus, Garcinia mangostana, B.racemosa*	*Vanili, P. betle, D. esculenta*	Narmada Sub-district, West Lombok District
Cashew agroforestry (Sari et al. 2023)	A simple agroforestry system dominated by cashew nuts	*F. moluccana, Anacardium occidentale*	*D. alata* (*uwi putih* and *uwi ungu*)	Sugian village, Sambelia sub-district, East Lombok District

Figure 3. A. Tubers of the *Dioscorea* genus are consumed and sold to Batu Layar sub-district, West Lombok district markets, B. *D. alata* reached 39 cm length or 10.5 kg at 2 years after planting, C and D. Digging the biggest *Dioscorea* genus at 50 kg weight

The knowledge of ethnobotany on *Dioscorea* genus is documented in the form of storytelling and in *Babad Lombok* depending on the geographical location (Obidiegwu and Akpabio 2017; Oktavia et al. 2022). The difference in climate type affects the distribution of species from *Dioscorea* genus. Morphologically, *D. esculenta* appears more vigorous in dry climate areas (C3, D3, D4, and E), where it is easily found, while in wet climates (B2 and C2), it is harder to find. According to interviews with the local community, the rarity of this species is due to insect pests that feed on the tubers.

Dioscorea genus is spatially distributed on Lombok Island and varies geographically. In the western part of Lombok Island, *Dioscorea* plants are found in Batu Layar Sub-district, West Lombok District, a hilly area with very limited water sources. Therefore, the community planted sugar palm as another income and in the meantime the water resources is improved. In this region, some individuals cultivate the *Dioscorea* genus beneath sugar palm plantations, practicing palm sugar-based agroforestry. Six species of the *Dioscorea* genus have been identified in this particular area. The community utilizes these tubers to fulfill their daily needs as staple food and sold to the market (Figure 3).

In the southern and eastern part of Lombok Island, *D. alata* and *D. esculenta* are planted to anticipate food insecurity during rice crop failure. This is similar with *D. praehensilis* which is used to anticipate hunger in the lean season in Ghana (Adewumi et al. 2021). In the southern region, especially in Sedau Village, Narmada Sub-district, West Lombok District, the *Dioscorea* genus is used when commemorating the 9^{th} day of the death ritual, in which the family provides a decoction of the tuber as a provision for the spirit to heaven. Tubers used in various daily activities, and indirectly it become a post-disaster adaptation strategy for food security; when natural disasters such as earthquakes occur, the tubers are used as the main food source. When there is no disaster, it is used as a complementary food or substitute for rice and a carbohydrate source.

Local knowledge of indigenous people in the North Lombok District, particularly the Bayan Sub-district, has used *Dioscorea* for religious rituals, cultural activities, and post-disaster adaptation (Figure 4). Religious rituals are performed in the months of *Muharram, Safar, and Rabi'ul Awwal* (the name of the months in the Islamic calendar). In the month of *Muharram*, *Dioscorea* tuber is processed into white porridge. According to traditional knowledge, white porridge is considered a symbolic representation of the process of human creation.

The community's religious ritual activities depend on the forest's resources (Obidiegwu and Akpabio 2017). Forests as a source of life are characterized by food crops, including mountain rice (*Oryza sativa*), nuts, and tubers (Chikmawati et al. 2023). In the studied area, the community presents the crop harvest and livestock during the commemoration of Prophet Muhammad. They offer their best harvest as gratitude to the God. Their local wisdom on natural resource management is shown in their forest zonation system. Bayan communities divide the forest into three groups: the livelihood forest (*hutan penguripan*), the forests for hunting, and the forbidden forests. The livelihood forest is managed to produce foods and previously it was land for shifting cultivation. The community jointly clear the land to cultivate mountain rice (*O. sativa*), *komak* beans (*Delicos lablab*), and *Dioscorea* seedlings. The purpose of the earthly ritual is to appeal to the Almighty for salvation and bliss. The forest designated for hunting is an area where hunting activities are permitted and managed. The community utilizes the forest area for wildlife hunting, conducted annually as a cultural activity to commemorate Prophet Muhammad. The following day, the community continues with land clearing to prepare a suitable area for agricultural activities. The forbidden forest is managed as a conservation area and serves as a source of water. The grouping of forest areas provides an overview of the close relationship between communities and forest resources in fulfilling the needs of life and the indigenous communities' actualization. The interaction between individuals, societies, and environments is a biocultural approach (Buenavista et al. 2022). Therefore, the *Dioscorea* genus has important functions in societies' social, economic, religious, and cultural structures (Obidiegwu and Akpabio 2017).

Figure 4. A. Religious ritual activities of *Maulud* event in 2022. B. Houses destroyed by an earthquake in 2018 in Bayan Sub-district of North Lombok District, West Nusa Tenggara Province, Indonesia

Table 5. The nutritional contents of *Dioscorea* local types in Lombok Island, West Nusa Tenggara Province, Indonesia based on proximate analysis

Species name (local type)	Water (%)	Ash (%)	Crude fiber (%)	Fat (%)	Crude protein (%)	Carbohydrate (%)
D. bulbifera (*kentang*)	8.99	6.85	0.92	8.40	7.90	66.94
D. bulbifera (*engal*)	12.50	1.57	0.86	6.97	7.93	70.18
D. alata (*uwi sawa*)	9.77	2.29	0.35	5.82	6.93	74.85
D. alata (*lami*)	9.81	5.94	0.87	4.08	10.84	68.47
D. alata (*uwi kuning Ampenan*)	10.57	4.81	0.50	9.58	8.45	66.09
D. alata (*uwi putih Ampenan*)	10.33	3.99	0.41	6.39	7.87	71.01
D. alata (*uwi ungu dara kunci*)	12.07	4.16	0.99	6.66	6.78	69.34
D. esculenta var. *spinosa* (*gembili*)	11.07	2.72	0.64	2.77	5.84	76.96
D. alata (*uwi putih batu layar*)	12.94	2.33	0.40	7.62	7.63	69.08
D. alata (*uwi ungu batu layar*)	12.32	1.60	0.42	4.83	6.86	73.73
D. esculenta var. *apiculata* (*surak*)	11.35	2.81	0.32	7.29	4.50	71.45
D. pentaphylla (*buyut*)	14.53	2.95	6.81	1.70	3.79	70.21

Nutritional contents of *Dioscorea* in Lombok Island

Dioscorea nutrients are good for health (Chandrasekara and Kumar 2016; Rinaldo et al. 2022). *Dioscorea* genus have macro-nutrients of carbohydrates and protein when processed into chips, flakes, and flour (Omohimi et al. 2018). The results of proximate analysis of *Dioscorea* spp. in Lombok is presented in Table 5. Generally, it can be observed that high carbohydrates dominate all local types. Carbohydrates provide energy (Frías-Gómez et al. 2023). Carbohydrate sources are commonly obtained from rice, corn, and sago, and rice as staple food (Nath et al. 2022). In the event of disaster, rice-based food is difficult to access. *Dioscorea* tubers might substitute the rice as carbohydrate sources (Buenavista et al. 2022). In general, rice contains 70-80% of carbohydrates, corn (*Zea mays*) contains 85.42%, and sago (*Metroxylon sago*) contains 86.28% (Elmi Sharlina et al. 2017; Verma and Srivastav 2017; Mat Lazim et al. 2021). The highest carbohydrate content is found in *D. esculenta* var. *apiculata* at 76.96%, while the lowest is 66.09% in the local type of *D. alata* of Ampenan. In general, it has an average carbohydrate content of 77.53%. The carbohydrate content is similar to *Dioscorea* genus planted in Chinese region, which is 75-84% (Liu and Lin 2009; Xiong et al. 2020), but it is generally smaller than the carbohydrate content of *Dioscorea* grown elsewhere that is 78.15-92.73% (Senanayake et al. 2013; Elmi Sharlina et al. 2017; Mat Lazim et al. 2021).

Furthermore, the protein functions for cell and tissue repairing (Mbatchou and Dawda 2013; Verma and Srivastav 2017). The highest protein content is found in *Dioscorea alata*, which was collected from Mataram City. The protein content in *D. alata* is high (between 3.79-10.84%) compared to rice, which has a protein content of 7.33%-9.93% (Nath et al. 2022). Previous research mentioned *Dioscorea* contains protein between 3.59%-8.93% (Aminah et al. 2021). Based on the description above, this study found that one type of *Dioscorea* in Ampenan with the local name *lami* has the highest protein content of 10.84%. This species has a different morphology from other species. The shape of the tuber is rounded, relatively smaller, and weighs up to 0.5 kg; this difference is thought to be due to the influence of the variants.

Fiber helps improve digestion and prevents constipation (Verma and Srivastav 2017; Stribling and Ibrahim 2023). Fiber content is the highest in *Dioscorea pentaphylla* (buyut) with 6.81%. Therefore, *D. pentaphylla* is less desirable to cultivate because it has a lot of fiber (Mat Lazim et al. 2021). Other local types have fiber content below 1%; which is comparable to well-milled rice's with standard fiber content of 0.5%-1.0% (Verma and Srivastav 2017). *Dioscorea* local types which are within the standard range are *D. alata* (*uwi ungu dara kunci*) of 0.99%, *D. bulbifera* (*kentang*) of 0.92%, *D. alata* (*lami*) of 0.87%, *D. bulbifera* (*engal*) of 0.86%, *D. esculenta* var. *spinosa* (*gembili*) of 0.64%, *D. alata* (*uwi kuning ampenan*) of 0.50%. In comparison, those with values below 0.5% are *D. alata* (*uwi ungu batu layar*) of 0.40%, *D. alata* (*uwi putih ampenan*) of 0.41%, *D. alata* (*uwi putih batu layar*) of 0.40%, *D. alata* (*uwi sawa*) of 0.35%, *D. esculenta* var. *apiculata* (*surak*) of 0.32%.

A high percentage of ash content affects sensory quality, especially color (Verma and Srivastav 2017). The types of *D. alata* and *D. bulbifera* have varying color variations that tend to have high ash content, *D. bulbifera* (*kentang*) of 6.85%, *D. alata* (*lami*) of 5.94%, *D. alata* (*uwi kuning ampenan*) of 4.81%, *D. alata* (*uwi ungu dara kunci*) of 4.16%, *D. alata* (*uwi putih ampenan*) of 3.99%, while *D. pentaphylla* (*buyut*) of 2.95%, *D. esculenta* var. *apiculata* (*surak*) of 2.95%, *D. esculenta* var. *pentaphylla* (buyut) of 2.95%, *D. esculenta* var. *apiculata* (*surak*) of 2.81%, *D. esculenta* var. *spinosa* (*gembili*) of 2.72%, *D. alata* (*uwi putih batu layar*) of 2.33%, *D. alata* (*uwi sawa*) of 2.29%, *D. alata* (*uwi ungu batu layar*) of 1.60%, *D. bulbifera* (*engal*) of 1.57%. The ash content value commonly found in rice is 0.5% (Verma and Srivastav 2017).

In conclusion, ethnobotanical study revealed 12 local types of *Dioscorea* genus in Lombok Island in which 11 types are edible and used as local food sources and one type is not edible. The most abundant *Dioscorea* genus was found in climate type C3 (8 species), followed by E (5 species), D4 (4 species), B2 (3 species), C2 (1 species) and D3 (1 species), respectively. It shows the adaptability of *Dioscorea* genus in different climate types. *Dioscorea* genus are planted in various agroforestry system in Lombok for food security adaptations during the post-earthquake disaster. The nutritional value of *Dioscorea* genus is important due to its carbohydrate content (66.09-76.96%), protein content (3.79-10.84%), fat content (1.70-9.58 %) and fiber content (0.32-6.81%). *Dioscorea* as local food help post-earthquake communities to have access to food sources that are cheap, easy to grow, and more adaptive to different environmental conditions.

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