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Article

Biodiversity of SAGO (*Metroxylon* spp.) and Its Understory in Maluku, Indonesia

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Abstract

Sago (*Metroxylon* spp.) is an important agricultural commodity in Maluku. The area of sago plantations in Indonesia is 1,25 million hectares. To conserve Maluku's diverse sago, urgent action is needed for identification and selection of high-yielding varieties. This study was aimed to investigate the diversity of sago palms and the weed surrounding sago groves in Maluku. The research was carried out in six sago areas from September 2015 to October 2016. The sago plant identification was carried out throughout the growth phases of sago, i.e. seedlings, saplings, weaning, trunk growth, and ripening. Vegetation observation was done in a radius of 100 m^2 surrounding sago clumps. The identification results are tabulated in a pivot table and vegetation analysis data includes density, frequency, dominance and important value index. The result shows that 'Tuni', 'Molat', and 'Ihur' sago varieties dominated sago palm areas in Ceram and Ambon Islands, Maluku. There were significant morphological variability among the verietes of sago, especially in stem height, midrib width, leaf midrib color, number of thorns, flower stalk length, and the contrasting carbohydrate contents. The weed within the sago palm study sites exhibited significant diversity, encompassing 15 plant families and 20 distinct species. The dominant understory plant families were Araceae, Thelypteridaceae, and Athyriaceae. The Araceae family was represented by species such as wild taro and broadleaf plants, while Thelypteridaceae and Athyriaceae were predominantly composed of ferns. It is anticipated that the findings of this study will provide valuable insights for developing effective strategies for the sustainable conservation and utilization of sago resources in the Maluku region.

Keywords: biodiversity; Maluku; *Metroxylon* spp; understory

1. Introduction

Sago (*Metroxylon* spp.) is an important socio-economic crop in Southeast Asia [1]. The centres of sago diversity is Papua New Guinea, Indonesian Papua, and Maluku [2]; [3]; [4]. Sago is known as a plant that can grow and thrive in various ecologies, such as in swamps area [5], acidic peat soils, as well as saline and submerged soils [3]; [6]. The plant's robust root system, firmly embedded in the mud, enables it to withstand floods, droughts, fires, and strong winds.

For Eastern Indonesia, Sago is the major source of carbohydrates, especially in Papua and Maluku. The total sago area in Indonesia reached 5,5 million ha in 2014, and the largest sago area is in the province of Papua (**4.749,424** ha), while the sago area in Maluku is in the third position, which is 60,000 ha. Sago palms have higher productivity than other crops containing carbohydrates, such as sweet potatoes, maize, rice and cassava. However, production is still very poor because most of it is still in natural sago forests that have not been cultivated properly and are harvested only from easily available plants. When compared to the area of sago land between 1960-1970 is still wider than

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the existing land. This is due to the transfer of sago land function that is used as rice fields so that the area of land becomes reduced. Land use for the benefit of various other sectors, does not always take into account the consequences that occur in the environment. The change in the natural ecosystem of sago habitat takes place very quickly, so there is a scarcity of many varieties / accessions. Efforts to conserve sago biodiversity that have an indirect impact, such as plant benefits for water regulators, soil cover, healthy air guards and others and documented in writing (Astirin 2000).

Sago's palm grows in swampy, alluvial and peaty soils where almost no other major crops can grow without drainage or soil improvement [7]; [8]. Sago's palm is one of the most important bioresources for sustainable agriculture and rural development in the tropics' swampy areas. *Metroxylon* palms, even sago palm is recognized as an unexploited or underexploited plant. Sago's palms species has been harvested from natural forests and has been semi-cultivated under very simple maintenance.

In freshwater zones as well as in brackish water areas along the coast, Sago palms grow well. [9] stated that the treatment with saline water up to EC 6 to 7 mmho/cm did not affect the sago palm's growth [9]. Recorded that 10 S/m. of salinity tolerant sago palm: Few studies of the salt tolerance system in the sago palm. Due to the low germination percentage of sago palm seeds and wide variation in days for germination, it is usually very difficult to obtain standardized plant materials, often longer than one year necessary [10] and Singhal et al. (2008). One of the main reasons there is no experimentally further information on ecological and physiological growth response regarding salt tolerance in sago palm.

Since sago palms grow in various habitats, genetic variations of sago palms tend to occur according to their ecosystems. The variation in an ecosystem would also decide the understory of the sago stands' vegetation diversity. This research aims to classify the biodiversity around the sago clumps in Maluku of sago palm and weed.

In the eastern Indonesian regions, particularly in Papua and Maluku, sago is a important carbohydrate source for human comsumption. In 2014, Indonesia had a total sago area of 5.5 million hectares. Papua, with 4.7 million hectares, holds the largest area, whereas Maluku ranks third with 60,000 hectares. Sago palms are more productive than other carbohydrate crops like sweet potatoes, maize, rice, and cassava. However, the production remains low due to reliance on natural, uncultivated sago forests and selective harvesting of easily accessible plants. Sago land has decreased since the 1960s due to its conversion into rice fields and other landuses The conversion of sago land for various purposes frequently overlooks environmental consequences. Sago ecosystems are undergoing rapid transformation, resulting in a significant loss of diversity. To address this, conservation efforts, as outlined by Astirin (2000), emphasize the indirect ecological benefits of sago, such as water regulation, soil protection, and air quality improvement.

Sago trees predominantly grow in swampy, alluvial, and peaty soils, where few other major crops can be cultivated without drainage or soil improvement. Sago palms exhibit a high tolerance for soil salinity. They thrive in both freshwater and brackish water environments, such as coastal areas. However, there is a lack of experimental data on the specific ecological and physiological responses of sago palms to salt stress.

Metroxylon palms, including sago palms, are underutilized plant resources with significant potential for sustainable agriculture and rural development in tropical swampy areas. These palm species have tradisionally been harvested from natural forests and semi-cultivated with minimal maintenance. As a result, sago fields usually contain diverse uderstory vegetation. The diverse habitats of sago palms may lead to genetic variations among different populations. The specific ecosystem also affects the diversity of plant species growing beneath the sago canopy. It is important to study vegetation or plant species under sago forests. Understanding these understory plants helps in conserving biodiversity and preserving delicate ecological balance. The vegetation is expected to plays a significant role in maintaining soil health by preventing erosion, improving soil structure, and contributing to nutrient cycling. These plants can help regulate water flow, and prevent soil erosion, especially in sloping areas. They may also contribute to carbon sequestration by absorbing

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carbon dioxide from the atmosphere, mitigating climate change. This research aimed to describe and classify the biodiversity of both sago palms and weed in Maluku.

1.1. Materials and Methods

This research was carried out in several sago regions in Maluku Province. Sago forests were selected as the research sites representing the sago regions in Maluku. They were in six villages, i.e. Rutong and Tawiri villages in Ambon; Tulehu village in Central Maluku Regency; Ariate, Eti, and Waisamu villages in Western Ceram Regency. Vegetation identification was performed at the Maluku Institute for Agricultural Technology Assessment (AIAT) Laboratory, Cibinong Indonesian Institute of Science, and Department of Botany Laboratory, Biology Research Center, Bogor. This stuty was conducted from September 2015 to October 2016.

Plant identification was carried out through the growth phase of sago, i.e. seedlings, saplings, weaning, trunks, and ripening. Vegetation observation was done in a radius 100 m^2 surrounding sago clumps. Observation data included the growth phases of sago (type, number, height, and circumference of trunks) and the weed (type and numbers of vegetation). Sago clumps growth consists of five phases, namely: a) stolon phase, which is the smallest sago tiller or called a seedling, b) sago seedling phase, usually used as sago seedling propagules, c) weaning phase, starting forming trunks, d) tree phase, and e) ripening phase, when sago trees are ready to be harvested. Observations were carried out both in the dry season (April-Mei) and rainy season (October-November).

1.2. Data Analysis

The identification results are tabulated in a pivot table in Microsoft Excel 2007. Veg- etation analysis data includes density, frequency, dominance and important value index (INP) using Microsoft Excel 2007 program.

Density (density = D) is the number of individuals per unit area or per unit volume.

The density of the i-th species can be calculated by:

$$D - i = \frac{Number\ of\ individuals\ (i)}{Unit\ area} \quad (1)$$

$$D\ relative\ \text{-}i = \frac{D\ each\ species}{D\ total\ species\ per\ unit} \quad (2)$$

The frequency of plant species is the number of plots where a species is found from the number of plots made. Frequency is the intensity of the species found in the observa- tion of the presence of organisms in the community or ecosystem. For a plant communityanalysis, the species frequency (F), the frequency of the i-th species (F-i), and the relative frequency of the i-th species (FR-i) can be calculated using the following formula:

$$F\text{ - }i = \frac{number\ of\ plots\ occupied\ by\ vegetation}{number\ of\ plots} \quad (3)$$

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$$F \rightarrow relative \cdot - \cdot i \cdot = \frac{Frequency \cdot of \cdot vegetation \rightarrow type \cdot (i)}{Total \cdot of \cdot frequency} x100\% \quad (4)$$

The Important Value Index (IVI) is an index that describes the important role of veg- etation in its ecosystem. The higher the value of each vegetation, the greater of its effect on the ecosystem stability. The index value at the understory level was calculated from the relative density (DR) and relative frequency (FR):

$$IVI = DR + FR \quad (5)$$

2. Results and Discussion

2.1. Distribution and Diversity of Sago Type

Maluku's sago range ranges through coastal areas, rivers and medium lowlands at an altitude of 700 m above sea level, while this plant is found at the height of 1000 msl. However,[12] stated that sago growth could be slower at an altitude above 400 msl. Sago evolves well in humid tropical lowland areas. At a minimum temperature of 26 ^{o}C, a relative humidity of 90 per cent and light radiation of 9 MJ/m2 per day [6], the ideal conditions for increasing sago are. Sago also develops in the saline region [13]; the salinity, however, does not exceed 10 S/m [10];[11].

In Maluku, we found six sago forests in six villages reflecting the distribution and variety of the sago type based on the distribution. Five forms of sago, namely the genus *Metroxylon*, are found and dominate the sago region on Ceram and Ambon's islands; including *Metroxylon rumphii.* (Tuni sago), M. sagus Rottb. (Molat sago), *M. silvester* Mart (Ihur sago), *M. longispium* Mart (Makanaru sago), and *M. micracantum* Mart (Rotan sago). [14]. Significant morphological differences between the five types of sago have been recorded, particularly in the stem's height, a width of the midrib, the colour of the leaf midrib, number of thorns, and length of the flower stalk. The branches of the Tuni sago, Molat sago, Ihur sago, Makanaru sago, and Rotan sago are 25 m, 16 m, 20 m, 10 m and 9 m, respectively, whereas the width of the base of the fronds is 25 m and 20 m respectively. 19 m, 8 m and 20 m, respectively. *M. rumphii* Mart. (sagu Tuni) has fewer saplings, more frequent drooping tips of the leaflets and rarely grows around the main tree. Species of Ihur sago have more tillers, grow irregularly, the leaves' tips are upright, and around the main tree grow more tillers. For the five forms of sago found in Maluku during the dry and rainy seasons, the presence of each growth stage of sago (Table 1).

The five types of sago also contain different carbohydrates. [15] reported that the car- bohydrate content in Tuni Sago, Molat sago and Sago Ihur were respectively 89.13%, 88.6% and 76.03%, while two others are lower. Therefore, economically, these three types of sago are more widely used and processed by the community [16].

The yield potentials of various sago types in Indonesia is shown in Table 2. Sago in Papua and Maluku are found growing wild in swamps, lowlands with large areas (Bintoro 2010). According to Ruddle (1977), sago plants grow well naturally on marshy clay and are rich in organic materials such as mangrove forests or nipah. In addition sago can grow on volcanic soils latosol, andosol, podzolic red yellow, alluvial hydromorphic gray. Based on the altitude factor of the place, Maluku has a high potential as a place to grow sago. Sago plants in Maluku are commonly found in areas near streams, coastal areas, and flat land. Botanri (2010) states that sago plants in Maluku are spread on land conditions with characteristics namely: 1) flat-steep land, 2) near the coast, 3) near rivers, 4) on alluvial lands (Entisol and Inceptisol), and 5) at an altitude of 0-250 m above sea level. Gosleana (2012), generally sago plants in Ceram Island Maluku found in areas with characteristics such as: 1). altitude of the place between 0-250 meters above sea level. 2). The slope of the slope is flat which is 0 - 8%. 3). on alluvial soil type. 4). the distance from the river < 300 m. 5), with an estimated sago area of 617,500.31 ha based on logistics regression analysis

The diversity of sago found at the six research sites are as follows;

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In Maluku, we chose six sago forests in six villages reflecting the distribution and variety of sago types based on the distribution. Five types of sago, namely the genus *Metroxylon* Mart, are found and dominate the sago region on Ceram and Ambon's islands. *Metroxylon rumphii.* (Tuni sago), M. sagus Rottb. (Molat sago), *M. silvester* Mart (Ihur sago), *M. longispium* Mart (Makanaru sago), and *M. micracantum* Mart (Rotan sago). [14]. Significant morphological differences among the five types of sago have been recorded, particularly in the stem's height, a width of the midrib, the colour of the leaf midrib, number of thorns and length of the flower stalk [14]. The branches of the Tuni sago, the Molat sago, Ihur sago, Makanaru sago, and Rotan sago are 25 m, 16 m, 20 m, 10 m and 9 m, respectively, and the width of the base of the fronds are 25 m and 20 m, 19 m, 8 m and 20 m, respectively. Tuni sago has fewer saplings, more frequent drooping tips of leaflets and rarely grows around the main tree. There are more tillers, uneven growth, the leaves are upright, and several tillers grow around the main tree. The appearance of each sago growth for the five sago types found in Maluku during the dry and rainy seasons are presented in Table 1.

- **Sago area at Eti Village**

Eti Village is located in Western Ceram Regency, Ceram Island, the Maluku Province. The observation sites is located at an average height of 2 m above sea level. The first sago grove observation point is in the coordinate of E: 128 ° 12,794 and S: 03 ° 05.974, the second sago grove is E: 128 ° 12.832 and S: 03 ° 05.978, and the third sago grove is at E: 128 ° 12.861 and S: 03 ° 06.017. In lowland areas, sago forest ranges on river watershed areas, dry land, and flooded ground. The sago population's composition is clustered (30-50 clumps of sago plants) or spotted (5-10 clumps of sago plants). The dominant sago types are Tuni sago, Ihur sago and Rotan sago. Sago area in this village also have a diverse flora beyond the weed, including species such as sugar palm, coconut, langsat, durian, cloves, bananas, and cassava. To ensure a consistent supply of sago for consumption as papeda and sago flour, local communities actively engage in intensive sago processing. Furthermore, the sago stem waste, known as 'ela,' serves as a valuable feed source for livestock.

- **Sago area at Waisamu Village**

Waisamu Village is located in Kairatu Barat District, Western Ceram Regency, Ceram Island , the Maluku Province. The sago forest extends in lowland areas, wetlands and inundated fields. Thye Sites of observation are situated at an average height of 4 m asl. The first sago grove is located at the coordinate of: E: 128 ° 19,498 'and S: 03 ° 16,949', the second sago grove: E 128 ° 19.510 'and S: 03 ° 16.945', and the third sago grove: E 128 ° 19.502 'and S: 03 ° 16,957'. The sago population structure is clustered (80 - 100 sago clumps of sago plants) or spotted (5 - 10 sago clumps of sago plants). The dominant sago types are Tuni sago), Molat sago, Ihur sago, Makanaru sago and Rotan sago. The sago plant canopy is closed, and the sago region is bordered by paddy fields; and the sago forests become a source of irrigation water for the irrigation of rice fields. This region is dominated by lower vegetation and sago groves. Sago starch is extracted from sago trunks and the starch is utilized as papeda and plate sago as a staple food, local people. There is also a factory for processing sago stalks for the extraction of sago starch in this village.

- **Sago area at Rutong Village**

Rutong village is at an average height of 2 m above sea level, where the three observation points for the sago grove are located. Rutong Village is situated within the South Leitimur District of Ambon Island, Maluku Province. The village lies at a low elevation, approximately 2 meters above sea level. This low-lying area is also the location of the three observation points established for monitoring the sago grove. The first sago grove is E: 128 ° 16.055 'and S: 03 ° 42.327', the second sago grove is E: 128 ° 16.077 'and S: 03 ° 42.295', and the third sago grove is E: 128 ° 16.080 'and S: 03 ° 42.296'. In lowlands and coastal areas, wetlands and inundated lands, Sago forests spread. The sago population structure is clustered (100 - 150 sago clumps) and spots are spotted (5 - 10 sago clumps). The dominant sago forms are *M. Mart rumphii* (Tuni sago), *M. Rottbsagus* (Molat sago). Uh, and *M. Mart silvester*. (Sago Ihur). This region is dominated by the closed sago canopy, lower vegetation and sago groves. To be utilized as papeda and plate sago as a staple meal, local people intensively process sago for consumption as sago starch.

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- **Sago areal at Tawiri Village**

Tawiri Village is located within Teluk Dalam District on Ambon Island. The three observation sites in this village are situated at an altitude of 3 m asl. The first is at a coordinate of E: 128 ° 06.331 'and S: 03 ° 41.372', the second at E: 128 ° 06.321 'and S: 03 ° 41.379', and the third at E: 128 ° 06.320 'and S: 03 ° 41.395'. In the lowland areas, sago forests spread along the river watershed, on dry land and wetlands. The sago population structure is clustered (20 - 40 sago clumps) or spotted (5 - 10 sago clumps). The dominant sago types are Tuni sago), Molat sago and Ihur sago. Intercropping sago palm trees with other cash crops such as coconut, langsat, durian, clove, banana, and cassava, is found on the sites. Sago has been intensively processed into starch for consumption by local people and used as *papeda* and sago meal as a staple food.

- **Sago area at Tulehu Village**

Tulehu Village, situated in Salahutu District on Ambon Island, has three observation sites located at an altitude of 3 meters above sea level. The geographic coordinates of these sites are as follows: Site 1: E: 128° 18.542', S: 03° 35.449'; Site 2: E: 128° 18.576', S: 03° 35.471'; and Site 3: E: 128° 18.556', S: 03° 35.440'. The lowland areas surrounding these sites are characterized by the presence of sago forests, on dry land and wetland areas along a river watershed. Sago palm populations within these sites exhibit two distinct distribution patterns: clustered (80-100 clumps) and scattered (5-10 clumps). The sago varieties encountered in these sites include Tuni sago, Molat sago, Ihur sago, Makanaru sago, and Rotan sago. In addition to sago palms, the vegetation within these areas includes a diverse range of plant species, such as coconut, langsat, mango, clove, durian, cocoa, banana, cassava, beans, and corn. Sago starch, obtained through processing of the sago palm, constitutes a staple food for the local population, commonly consumed as papeda and sago meal

2.2. Understory Vegetation of Sago Palms

Tables 3, 4, 5, 6, 7, and 8 present the results of weeds in the sago area vegetation surveys conducted at six observation areas of this dtudy. The species composition and abundance of weed varied across the different areas. In Ariate Village, plant species belonging to 15 families were identified. These plant families demonstrate a high degree of shade tolerance, thriving under the canopy of the sago palms. The weed exhibits diverse ecological functions. Several species possess ethnobotanical value, including *Typhonium flagelliforme*, *Piper betle*, and *Cissus sicyoides*, which are utilized as medicinal plants [17–19]. *Pandanus amaryllifolius* is commonly used as a culinary spice [20]. Furthermore, *Etlingera coccinea* is known to produce essential oils [21]. However, certain species, such as *Cissus sicyoides*, can exhibit invasive growth characteristics, potentially hindering the growth and development of the sago palms."

During the dry season, according to the essential vegetation value index, more vegetation plays an important role in preserving the stability of the ecosystem, such as *Christellaparasitica*, *Etlingera coccinea* (Blume) S. *Typhoniumflagelliforme*L, Sakai &Nagam, and *Bridelia* sp. Willd.-Willd. The meaning index of important shifts in the rainy season, where *Typhoniumflagelliforme* L and *Bridelia* sp. Will and *Etlingera coccinea* (Blume) S. have a higher IVI than *Christellaparasitica*. Nagam& Sakai. Other vegetation, both in the dry season and the rainy season, has lower relative density and IVI values.

The relative density of each vegetation type is related to the vegetation's morphological characteristics, such as the requirements for plant height, sunlight, and habitat. The foliage of large trees is usually lower in density than that of shrub vegetation. This condition is consistent with [22] findings, where the ecosystem's small vegetation appears to be denser than large trees.

In the villages of Eti, Waesamu, Tulehu, Rutong and Tawiri, respectively, where the number of families and species is 15 families and 20 species, 14 families and 20 types of vegetation, 13 families and 15 types of vegetation, 14 families and 14 types of vegetation, and 15 families and 17 types of vegetation, tables 3, 4, 5, 6 and 7 identify the diversity of weed and around sago clumps. The high number of families and species of vegetation shows that the environment is still natural. [22] stated that natural habitats appear to have an increased number of vegetation types, while damaged ecosystems, on the other hand, experience a decline in the number of the kinds of vegetation.

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Three plant families dominate the sago palms' weed, namely Araceae, Thelypteridaceae, and Athyriaceae. Groups of plants include taro and broadleaf plants in the family Araceae, while ferns are Thelypteridaceae and Athyriaceae. In terms of forest survival and nutrient availability, weed plays an important role and is also an important component of forest aesthetics [23]. The structure of the vegetation includes 1) the vertical system of the foliage, classifies the vegetation layers largely according to the different heights at which their plants grow, i.e. the layers of trees, poles, weaning, seedlings and herbs that make up the vegetation, 2) the horizontal distribution that defines the spread of each vegetation, and 3) the abundance of each population species [24]. The observation site tends to have distinct vegetation forms and structures.

A significant quantitative understanding of a plant population's nature and composition is examining the collected vegetation index value. The quantitative estimate of the vegetation population consists of (1) estimating the composition of the vegetation species in the region as opposed to other areas, or the same place with different observation times, (2) assessing the diversity of the species within the region, and (3) correlating the diversity of the vegetation with environmental factors [25];[26].

Plant community ecological study employs quantitative parameters, including density, frequency, and dominance, to assess species abundance and importance within the community. Dominance, a key ecological parameter, reflects the relative influence of a species within the plant community. Several metrics, such as biomass, crown cover, basal area, and the Importance Value Index (IVI), are used to quantify species dominance [27];[28];[29]. The IVI integrates density, frequency, and relative dominance to provide a comprehensive measure of a species' ecological significance within the community. In this study, the fern species *Christella parasitica* exhibited the highest dominance in both the rainy and dry seasons, characterized by high relative density of 26.80) and a significantly high IVI of 34.69. Other notable plant species observed in the sago region included *Etlingera coccinea* S. Nagam & Sakai, *Bridelia sp*. Willd,- , *Typhonium flagelliforme* L., *Diplazium dietrichianum* (Luerss.), *Colocasia* sp. Chr., and *Colocasia esculenta* L. Cissus sicyoides L. is known as a medicinal herb, but this plant interferes with sago growth because of its growth character. Observation and analysis of the weed revealed that ferns exhibited the highest dominance among the understory plant species. This dominance was evident in their high density, frequency of occurrence, and overall importance within the ecosystem, as indicated by the high Importance Value Index (IVI) [25]. The IVI is a crucial ecological metric that quantifies the relative significance of a plant species within a given community. Higher IVI values suggest that the species plays a more significant role in maintaining ecosystem stability.

Future research efforts should prioritize the conservation and enhancement of sago species in the Maluku Islands. Sago holds immense potential as a crucial source of food security, particularly for communities residing on small islands. Furthermore, research is essential to empower local communities in the Maluku Islands to sustainably manage and utilize sago as a staple food source, thereby improving their livelihoods and ensuring food security for future generations.

3. Conclusion

The sago fields and forests of Ceram and Ambon islands, Maluku Province, is primarily dominated by three species: *Metroxylon rumphii* (Tuni sago), *M. sagus* (Molat sago), and *M. silvester* (Ihur sago). These species exhibit significant morphological variability, with notable differences observed in stem height, leaf midrib width, leaf midrib color, thorn density, flower stalk length, and carbohydrate content.

The weed within the sago forests exhibited significant diversity, encompassing 15 plant families and 20 distinct species. The dominant understory plant families were Araceae, Thelypteridaceae, and Athyriaceae. The Araceae family was represented by species such as taro and broadleaf plants, whereas Thelypteridaceae and Athyriaceae were predominantly composed of ferns. Furthermore, the weed also included a variety of plants with ethnobotanical significance, serving as medicinal plants, culinary spices, and sources of essential oils.

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