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Association of sago plants with weeds in agroecosystem in Ambon Island, Maluku, Indonesia

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Abstract. *Uluputty MR, Botanri S, Kamsurya M, Pelu J, Goo N, La Habi M, Umasangadji A. 2025. Association of sago plants with weeds in agroecosystem in Ambon Island, Maluku, Indonesia. Biodiversitas 26: 3105-3112.* Sago plays an important role in maintaining food security in some areas in Indonesia, including in Maluku. Nonetheless, there is limited knowledge regarding weed species in the context of sago agroecology. The research aims to investigate interspecific association between sago plants and various weed species in sago cultivation ecosystem in Ambon Island, Maluku. Data collection was conducted by establishing 100 observation plots in three sampled areas where sago field occurred. Interspecific association was determined through two stages of analysis, namely determining the presence of association between species simultaneously, and continued by measuring the level of association between paired species. The results of pairwise chi-square analysis show that there is negative association within the same sago species and between three sago species of *Metroxylon rumphii*, *M. longispinum*, and *M. sylvestre*, indicating competition among them. Meanwhile, negative association between sago species and non-sago species occur with two species, namely *Nephrolepis exaltata*, and *Homalomena rubra*, suggesting that these two species act as weed in sago agroecology in Ambon Island. The findings of this study emphasize the attention to reducing the competition among sago plants as well as controlling the disturbance from the two weed species to increase sago yield quality and productivity.

Keywords: Ecosystem, Jaccard Index, *Metroxylon*, weed associations

INTRODUCTION

Weeds are wild plants that grow on agricultural land regardless their presence is wanted or not. The presence of weeds is desirable if they provide positive impacts, conversely weeds are undesirable if they cause negative consequences (Yan et al. 2024). In agricultural landscape, the presence of weeds generally has detrimental effect on cultivated plants, while their benefits to the crops are relatively limited, not surprisingly studies relating to weeds mostly conclude that weeds are harmful to plants. Molinari et al. (2020) stated that in agricultural lands there is always competition between weeds and cultivated plants. Mahgoub (2023) argued that the presence of weeds is undesirable because they interfere the growth and production of cultivated plants through the competition in getting water, nutrients, sunlight and growing space, resulting in the crop not being able to achieve the maximal yields. The competition of weeds with crops for resources is generally considered to be the main factor causing agricultural yield loss (Daba et al. 2023; Horvath et al. 2023). Korav et al. (2018) stated that weeds are an important biological factor in crop production which causes a decrease in yield and contributes around 45% to crop loss. For example, Babaei-Ghaghelestany et al. (2022) reported that the presence of creeping perennial weeds has reduced agricultural production in Iran.

In agricultural ecology (agroecology), various types of weeds can grow simultaneously which might interact each other to form association between the same species (intraspecific) and between species (interspecific). Association is a form of interaction that exists between plant species within vegetation community (Hendrayana et al. 2022). Association occurs when two or more species frequently present together in a habitat than by chance as a consequence of biotic interactions such as mutualism, competition and predation. Associations between species can be positive or negative. Positive association occur when both species share the same habitat or have the same environmental requirements. On the other hand, negative association occur when two species have different or opposing environmental needs and imply detrimental interactions, such as competition between species or predation.

Sago (*Metroxylon* spp.) is carbohydrate producing plant species that is widely distributed in Maluku, Papua and several other areas in Indonesia. Abbas et al. (2020) stated that sago is a member of the palm family (Arecaceae) widespread in tropical and subtropical countries and is able to grow in various habitat conditions from dry land to wet land (Botanri et al. 2022). In its natural habitat (not cultivated), sago plants might grow along with other vegetation. For example, Botanri (2010) found that in a sago forest ecosystem in Seram, Maluku, Indonesia, there were 42 plant species which constituted to 50% vegetation community as indicated with an Important Value Index (IVI) that was greater than 10%, including *Homalomena rubra* Hassk. and *Nephrolepis exaltata* (L.) Schott.

In agricultural system, maintenance activities are generally carried out, including weed control. For example, in oil palm plantation, Anggraini and Rizqan (2021) study in Langkat District, North Sumatra, Indonesia, found 23 species of weeds dominated by the *Paspalum conjugatum* P.J.Bergius. Another study by Neyret et al. (2020) in Northern Thailand found the dominant weed was *Antidesma velutinosum* Blume and *Digitaria radicosa* (J.Presl) Miq. However, in sago cultivation system in Maluku, weed control maintenance efforts are rarely or even not carried out. In that context, research is needed to explain the nature of the association between weeds and sago plants. Research on weeds in the cultivated sago ecosystem has never been carried out by researchers before. Therefore, this study aims to explain the interspecific associations of various types of weeds that grow in the sago fields. It is hoped that the results of this research will become input for sago farmers in managing their sago land.

MATERIALS AND METHODS

Study area and period

The research was conducted in Ambon Island, Maluku Province, Indonesia, for 6 months from March to September 2023. Geographically, the island of Ambon is located between 03°29'S-03°38'S and 127°59'E-128°22'E with an extent of 743.4 km^2 and the altitude ranges from 0-1,225 m above sea level. Administratively, Ambon Island is divided into two regions, namely the southern part of the Ambon City area and the northern part of Central Maluku District. The area has climate type B category according to Smith-Ferguson with average rainfall of around 1500-2000 mm per year, average temperature of 25.9°C and average air humidity of 76.37% (MGA Pattimura Ambon 2023). A map of the research location is presented in Figure 1, and the geographical position of the sample points is presented in Table 1. The topographic conditions of the sample area are hilly and sloping, dominated by sago plants mixed with secondary forest vegetation. The adjacent areas are secondary forest and some mixed gardens.

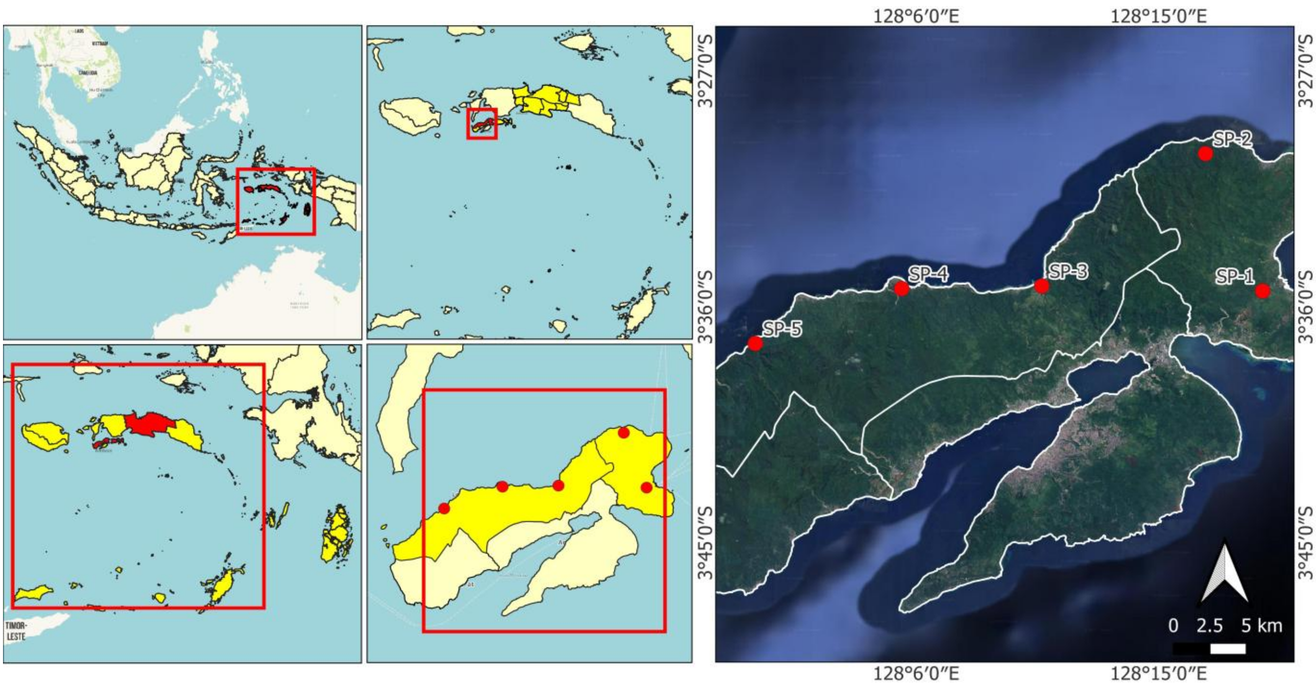

Figure 1. Map of research locations on Ambon Island, Maluku Province, Indonesia

Table 1. Geographical position of sample points in the study area in Ambon Island, Maluku Province, Indonesia

Sample Point (SP)	SP-1	SP-2	SP-3	SP-4	SP-5
Name of sample point	Tulehu*	Liang*	Hitu**	Hila**	Ureng***
Coordinates	3°35'22.83"S	3°30'8.39"S	3°35'11.37"S	3°35'17.45"S	3°37'22.81"S
	128°18'51.52"E	128°16'44.37"E	128°10'39.80"E	128° 5'27.61"E	128° 0'1.95"E
Altitude	8 m asl	44 m asl	12 m asl	8 m asl	18 m asl

Note: *: Salahutu Sub-district; **: Leihitu Sub-district; ***: West Leihitu Sub-district; m asl = Meters above sea level; S: South; W: West

Data collection

Data was collected using field survey on sub-districts and sampling points selected purposively (Mohajan 2018). The selected sub-district areas were Salahutu, Leihitu and West Leihitu due to the presence of sago plantations (Table 2). Ambon bay Sub-district was not chosen because there was extensive damage to sago plants which were converted into residential land and other public facilities. The total sample area covered around 80% of the sago area on Ambon Island. Vegetation data to observe the association of sago plants with weeds was carried out using the plotted line method (Krebs 1999; Kent 2012) on plots measuring 20 × 20 m^2. At each sample point, 20 observation plots were selected, resulted in the total observation plots of 100 plots. Weed species were identified in the field, then weed samples were taken for verification by taxonomists from the Herbarium Bogoriense Bogor, West Java, Indonesia.

Data analysis

The collected data was subjected to analysis of interspecific association to explain the association between sago and weed species in the sago agroecology in Ambon Island. The analysis was carried out based on presence-absence data for all observation plots in three sample areas simultaneously. Interspecific association was determined through two stages, namely determining the presence of association among species simultaneously (comprehensively), and determining the level of association between two species. The entire series of association analyzes was carried out only on the main constituent species, namely species that had an Importance Value Index (IVI)≥10% (Mennan and Zandstra 2005).

The steps of interspecific association analysis are described as follows. First, we created a data matrix to present the presence and absence of a species in each Sampling Unit (SU). The presence of a species is expressed as 1, while its absence is expressed as 0 (Table 3).

Then, we conducted simultaneous species association analysis. Although all combinations of pair of associated species were counted, they will not be independent. Therefore, Ludwig and Reynolds (1988) proposed an approach using the Variance Ratio (VR) derived from the null association model to test the significance of associations simultaneously. The VR association index was derived from the presence-absence data. The steps to calculate the Variance Ratio were as follows:

Calculate the total sample variance for the presence of S species in the sample using the formula:

$$\delta T^2 = \sum_{i=1}^{S} pi\ (1 - pi)$$

Estimating the variance of the total number of species using the formula:

$$ST^2 = \frac{1}{N}\sum_{j=1}^{N} pi\ (T_j - t)^2$$

Where t is the average number of species per sample unit.

Calculate the Variance Ratio (VR) using the formula:

$$VR = \frac{ST^2}{\delta T^2}$$

VR is an index of associations between all species. The criteria are as follows: If: VR = 1 then there is no association; VR>1 for all species shows a positive association; VR<1 for all species shows a negative association.

Third step was conducting pairwise species association analysis using a 2 × 2 contingency table (Table 4). To determine the existence of an association between two species, the Chi-square formula was used:

$$X_i^2 = \sum \frac{(Observation\ value - Ecpectation\ value)^2}{Expectation\ value}$$

Where is the sum of all cells in the 2 × 2 contingency table. The expected value is calculated as follows:

$$E(a) = \frac{mr}{N};\ E(b) = \frac{ms}{N};\ E(c) = \frac{nr}{N};\ E(d) = \frac{ns}{N}$$

Next, the Chi-square statistical test becomes:

$$X_i^2 = \frac{[a - E(a)]^2}{E(a)} + \ldots + \frac{[d - E(d)]}{E(d)}$$

Table 2. Distribution of sago plants on Ambon Island, Maluku, Indonesia and determination of sample areas

City/district	Subdistrict	Sago area (ha)	Percentage (%)
Ambon City	1 Sirimau	0.00	0.00
	2 Ambon Bay	9.47	2.01
	3 Baguala	3.15	0.67
	4 Leitimur	43.59	9.25
	5 Nusanive	0.00	0.00
Amount (A)		56.21	11.94
Maluku Tengah District*	6 Salahutu	168.27	35.73
	7 Leihitu	238.81	50.71
	8 West Leihitu	7.67	1.63
Amount (B)		414.75	88.07
Total (A + B)		470.95	100.00

Note: Data were from Pranata et al. (2018), * sample areas

Table 3. Data matrix for the presence and absence of each species in each sampling unit

Species	Sampling Unit (SU)					Total species
	(1)	(2)	(3)	(...)	(N)	
(1)	1	1	0		0	n_1
(2)	1	0	1		1	n_2
(3)	0	1	0		1	n_3
...	...	...	...			...
...	...	...	...			...
...	...	...	...			...
(S)	0	0	1		1	n_s
Total SU	T_1	T_2	T_3		T_N	

Table 4. 2 × 2 contingency table for pairwise species associations

		Species B		
		There is	There isn't any	
Species A	There is	a	b	m = a+b
	There isn't any	c	d	n = c+d
		r = a+c	s = b+d	N = a+b+c+d

Note: a: Number of plots where species A and species B are found; b: Number of plots where species A is present, but not species B; c: Number of plots where species A is not present, but species B is present; d: Number of plots where species A and B are not present; N: Total number of sampling units (observation plots)

Once the value of X_i^2 is known, it is compared with X^2_{table} with degrees of freedom (df) = (r-1)(c-1), α = 0.05 (5% significance level). Because the test was carried out on two paired species, df = 1. With α = 0.05, we get X^2_{table} = 3.84. If the calculated X^2 is>3.84, then the hypothesis that there is an association between species A and B is accepted, and vice versa is rejected.

Fourth, we determined the type of association using the following criteria: if a>E(a) then the two species have a positive association, whereas a<E(a) then the two species have a negative association. Lastly, we determined the level of association of species in pair using the Jaccard Index (JI) (Ludwig and Reynolds 1988) with the formula:

$$JI = \frac{a}{a+b+c}$$

The Jaccard index value ranges from 0-1, a value of 0 is equivalent to no association, and 1 is equivalent to the maximum level of association. The Jaccard Index was chosen because it is an unbiased index.

RESULTS AND DISCUSSION

Results

This study recorded 22 plant species in the sago agroecology in Ambon Island. The results of the Variance Ratio (VR) analysis obtained a value of 0.831 (VR<1), implying that all plant species that make up the vegetation community in the sago agroecology had a negative association between fellow species. In this regard, to explain the association between one species and another species in the sago community, especially the main constituent species, a chi-square analysis was carried out. Of the 22 plant species that grow in the sago community, there were 13 species as the main constituents with important value index of ≥10% namely *Metroxylon rumphii* (Willd.) Mart., *M. longispinum* (Giseke) Mart., *M. sylvestre* (Giseke) Mart., *N. exaltata*, *H. rubra*, *Leea guinensis* G.Don, *Selaginella ciliaris* (Retz.) Spring, *Pometia ridleyi* King, *Oncosperma tigilarium* (Jack) Ridl., *Limnocharis flava* (L.) Buchenau, *Cordylene terminalis* Kunth, and *Inocarpus fagifera* (Parkinson) Fosberg (Table 5).

Table 5. Chi-square test results for testing interspecific associations of main constituent species

Species A: ***Metroxylon rumphii*** **(Willd.) Mart.**					
Species B	**X^2**	**a**	**E(a)**	**Association type**	**Association level**
M. longispinum (Giseke) Mart.	6.52*	39	44.90	Negative	0.42
M. sylvestre (Giseke) Mart.	5.11*	34	35.12	Negative	0.48
Nephrolepis exaltata (L.) Schott	21.04*	4	6.97	Negative	0.06
Homalomena rubra Hassk.	9.28*	9	13.09	Negative	0.15
Leea guinensis G.Don	0.35ns	5	4.68	Positive	0.68
Selaginella ciliaris (Retz.) Spring	0.37ns	4	2.69	Positive	0.05
Pometia ridleyi King	1.43ns	3	2.78	Positive	0.05
Inocarpus fagifera (Parkinson) Fosberg	0.05ns	1	1.93	Negative	0.03
Oncosperma tigilarium (Jack) Ridl.	0.24ns	1	1.78	Positive	0.03
Limnocharis flava (L.) Buchenau	3.36ns	1	1.79	Negative	0.01
Species A: *Metroxylon longispinum* (Willd.) Mart.					
Species B					
M. sylvestre (Giseke) Mart.	20.72*	12	21.36	Negative	0.16
Homalomena rubra Hassk.	4.35*	4	6.56	Negative	0.09
Nephrolepis exaltata (L.) Schott	4.76*	3	4.61	Negative	0.04
Leea guinensis G.Don	0.06ns	3	2.72	Positive	0.06
Limnocharis flava (L.) Buchenau	1.74ns	2	1.09	Positive	0.05
Pometia ridleyi King.	0.22ns	1	1.61	Negative	0.04
Cordylene terminalis Kunth	0.01ns	1	1.07	Negative	0.03
Selaginella ciliaris (Retz.) Spring	0.58ns	1	1.65	Negative	0.03
Oncosperma tigilarium (Jack) Ridl.	0.02ns	1	1.21	Negative	0.03
Inocarpus fagifera (Parkinson) Fosberg	2.55ns	0	1.11	Negative	0.00
Species A: *Metroxylon sylvestre* (Giseke) Mart.					
Species B					
Leea guinensis G.Don	0.46ns	3	2.27	Positive	0.08
Homalomena rubra Hassk.	4.45*	2	4.72	Negative	0.05
Nephrolepis exaltata (L.) Schott	4.96*	2	5.42	Negative	0.04
Limnocharis flava (L.) Buchenau	2.36ns	2	0.93	Positive	0.05
Oncosperma tigilarium (Jack) Ridl.	1.78ns	0	0.94	Negative	0.00
Selaginella ciliaris (Retz.) Spring	0.51ns	2	1.38	Positive	0.04
Cordylene terminalis Kunth	0.01ns	1	0.92	Positive	0.02
Inocarpus fagifera (Parkinson) Fosberg	0.01ns	1	0.90	Positive	0.03
Pometia ridleyi King.	0.20ns	1	1.38	Negative	0.02

Note: ns: Not significant; *: Significant at the level of 5% (α = 0.05); df = 1; X2 table = 3.84. Association type: a>E(a) positive, a<E(a) negative. Association level based on Jaccard Index (JI): JI = 0 means there is no association between 2 species; JI = 1 means the association between 2 species is maximum

Figure 2. Three sago species and main weeds in the studied area in Ambon Island, Maluku, Indonesia: A. *Metroxylon rumphii*; B. *Metroxylon sylvestre*; C. *Metroxylon longispinum*; D. *Homalomena rubra*; E. *Nephrolepis exaltata*

Discussion

The results of chi-square analysis of pairwise species show that there are associations within the same sago species and between sago species and non-sago species (Table 5). The three species of sago found in the studied area are associated with each other, namely *M. rumphii*, *M. longispinum*, and *M. sylvestre* with X^2 values of 6.25, 5.11, and 20.72. Meanwhile, associations between sago species and non-sago species only occur with two species, namely *N. exaltata*, and *H. rubra*. The association type of most species pairs is significantly negative with the level of association based on the Jaccard index less than 0.5 or weak. There are some weed species whose associations are positive and insignificant. The three types of sago and the main weeds in the studied area are presented in Figure 2.

The main characteristics of *M. rumphii* are that it has a slightly open leaf crown, the angle of the leaf midrib to the stem is approximately 45°, the leaf tip is straight, the shape of the leaflets is parallel pinnate, the tip of the leaflets is upright, and the spines are long, hard, not flexible and breaks easily. The species *M. sylvestre* is almost similar to the *M. rumphii* with differences in the tips of the leaflets which are bent downwards, the angle of the midrib with the stem is approximately 45°, the tip of the leaflets is bent, the base of the midrib is light green from the middle to the tip and the tip of the midrib looked up. The species *M. longispinum* is characterized by a slightly closed leaf crown, the angle of the leaf midrib with the stem is ± 30°, the tip of the leaf is straight, the color of the midrib is greenish red at the base and light green towards the tip, the structure of the spines on the stem line up very irregularly, and the spines are shorter than tuni, soft, irregular and very easy to break (Riry 2022).

Nephrolepis exaltata is characterized by having tapered leaf tips, flat leaf edges, erect leaf petioles, round shape, fine hairs on the young stalks, flat leaf tips and lobes on one side with alternating and opposite leaflets. Anderson (2024) states that the *N. exaltata*, usually known as Boston fern, originates from tropical and subtropical environments. This weed species has the ability to adapt to a wide range of environments under different light intensity conditions. Apart from that, it has the ability to invade and colonize in various habitats outside its natural range. This species has a firm and curved midrib, usually broadly pinnate, graceful and spreading leaves, wider and rounder leaflets, smooth or slightly serrated leaf margins and wider spacing along the ribs. The stipe is generally long and glabrous (without hairs), thus contributing to the plant's elegant appearance. The sori on *N. exaltata* are found on the underside of the leaf and are usually more evenly distributed and found along the leaflet.

Homalomena rubra is generally characterized by oval-shaped leaves, flat leaf edges and a green color. The upper leaf blade is dark green and has a smooth and shiny surface, while the lower part is light green with a smooth surface. Hein and Naïve (2024) states that the Homalomena weed type is generally a herbaceous plant species that is evergreen, aromatic, mesophytic and can reach 45 cm in height with epigeal stem, initially erect, leafy, leafless at the bottom and decumbent with an active ascending tip; leaves 7-8 pieces together spirally arranged; petioles erect, older ones rising to spreading, about 26-34 cm long. Irsyam et al. (2023) stated that other *Homalomena* species (H. Schott) are the most common species originating from Southeast Asia, with the characteristics of heart-shaped leaves, tolerant of shade, grows in terrestrial areas, is upright, up to 1 m high, rhizomatous; rhizome long, slender, reddish brown, segments 6-20 mm; leaves alternate; the scabbard is reddish; petioles are sturdy, green with a reddish tinge, up to 75.5 cm long.

Competition between species occurs in getting light, nutrients and air. The research by Botanri et al. (2022) found that sunlight entering under the sago stands was no more than 12.40%. This shows that most of the sunlight is trapped in the canopy of the sago vegetation. This small amount of light is used by various types of vegetation, resulting in strong competition for sunlight which hinder the growth of other species. A research by Hassan et al. (2024) in Egypt found that most of the coexisting weeds had reduced their cover, diversity and biomass due to the reduction in solar radiation received. Moreau et al. (2021) showed that vertical leaf orientation in certain weed species provides a competitive advantage in obtaining sunlight, especially when grow in fields with shorter cultivated plants that have horizontal leaves. Naibaho et al. (2025) stated that cultivated plants that compete with weeds often experience a reduction in the light intensity received by their leaves, which in turn reduces photosynthesis rates. This situation becomes more severe when weeds have a more vertical leaf orientation, which can capture light more efficiently compared to horizontal leaves in cultivated plants. A'ihi et al. (2017) stated that there is continuous competition between weed species and cultivated plant in the field to obtain growth factors, including sunlight. In sago communities, the canopy usually covers most of the growing space, providing shade to weeds at the ground. Weeds that grow under the sago canopy generally experience growth problems because they cannot compete for sunlight.

In the context of competition between weeds and plants for nutrients, a study by de Vries et al. (2020) in the Netherlands found that there is competition to obtain limited resources such as nitrogen. This competition is strongly influenced by dynamic interactions with biotic and abiotic factors. This interaction continuously influences the balance between growth and defense, which then becomes one of the main challenges in the field of plant evolutionary ecology. Competition for resources has long been considered a primary driver in natural selection. Competition for nutrients has triggered vegetation to adapt to its growing environmental conditions, for example by modifying the root length to be longer and deeper to reduce competition between the same species or between different species. Heuermann et al. (2019) stated that the potential of a plant species to obtain nutrients depends on the ability of each species to explore the soil through its root system. For plant species where the root system is spread at the same depth, the competition for obtaining nutrients is stronger and conversely, if the root distribution of each species is different, the competition between them will of course be smaller. A study by Little et al. (2021) in the United States explained that competition between weeds and plants involves a mutual struggle for nutrients between the two. As the plants and weeds grow bigger, the competition between the two becomes stronger. Hasanuzzaman (2015) states that cultivated plants and weeds usually compete for major nutrients such as nitrogen, phosphorus and potassium. Phosphorus is usually a limiting factor for aquatic ecosystems. Nitrogen is generally a limiting nutrient in terrestrial habitats. Potassium is often overlooked in areas where terrestrial weeds can grow well in soil rich in the nutrient potassium.

Similarly, the competition for obtaining water resources takes place through the root system. Yao et al. (2022) in a study conducted in China where *Broussonetia papyrifera* (L.) L'Hér. ex Vent. and *Platycladus orientalis* (L.) Franco were mixed, it was found that there were benefits from water competition in moderate drought conditions. The species *B. papyrifera* gets an advantage in getting water through the combination of the two species. This shows that there is no detrimental competition between the two species, on the contrary, it gives benefits to *B. papyrifera*, but does not cause losses to *P. orientalis*.

The negative association between species as presented in the table above shows competition between species in the use of resources. The growth or increasing number of individuals of a species will suppress the growth of individuals of other species. Negative interactions indicate that there is no tolerance for living together or there is no reciprocal, mutually beneficial relationship, especially in the division of living space. He et al (2022) stated that a negative association implies that there are species not found simultaneously in one site as they compete each other for food nutrients or get rid of each for growing space. Species that lose in competition both for food nutrients and space will have their growth suppressed, which will eventually die.

The negative association between sago and weeds shows that the two types tend to not live together because of the mutually detrimental influence of one type to the other, implying that the two types have a tendency to cancel each other out. Horvath et al. (2023) stated that direct competition for resources is generally considered to be the main mechanism of yield loss caused by weeds. A study by Perronne et al. (2014) in France found that in agricultural land ecosystems there were interspecific and intraspecific associations of various types of weeds as indicated by the functional characteristics of plants, namely specific leaf area, canopy height and above-ground biomass. Species with high specific leaf area, canopy height and low biomass indicate a shade tolerance characteristic which can be a strategy to win the competition. Negative association between weeds and crop plant can reduce agricultural quality and production as a result of competition (Hasan et al. 2024). Weeds can reduce crop yields, reduce quality, and make harvesting difficult. In addition, weeds can become hosts for pests and diseases, which in turn affect plant health and productivity.

In negative association, one species often releases chemical compounds that can damage other competitor species which is usually known as allelopathy (Khamare et al. 2022). This interaction is often used as a strategy to reduce competition for resources, such as light, water, and nutrients. In allelopathy a plant releases chemicals (allelochemicals) that can change environmental conditions and affect the growth, survival and reproduction of other plants (Başaran 2021; Schulz and Tabaglio 2025). These phytotoxic compounds are mostly secondary metabolites in the form of plant extracts, leachates and other exudates and produced as a sub-branch of the primary metabolic pathway. A large number of plats produce secondary metabolites known as allelochemicals that are capable of inhibiting the germination of competitive species. This process is known as allelopathy and is mediated by several classes of chemicals, among which phenolic compounds are the most frequent. Thus, plant allelochemicals can be used to control weeds in agricultural systems (Mousavi et al. 2021).

Metroxylon rumphii had a fairly strong level of association with *M. longispinum* and *M. sylvestre* which is indicated by a fairly high Jaccard Index of 0.42 and 0.48 respectively. This means that there is mutual pressure or quite strong competition between *M. rumphii* and *M. longispinum* and between *M. rumphii* and *M. sylvestre* in getting resources. Meanwhile, the association between *M. longispinum*, *M. sylvestre*, *H. rubra*, and *N. exaltata* are low as demonstrated by a Jaccard index of less than 0.20. A study by Sharpe (2020) in Canada which studied the association between Kochia (*Kochia scoparia* (L.) Schrad.) and wild oats (*Avena fatua* L.) found serious problems caused by weeds on agricultural land. Kochia populations exhibit evolving survival strategies to become aggressive and resistant to herbicides. This weed has caused interspecific and intraspecific interference between wild oats and kochia. Wild oat biomass was consistently impacted by intraspecific competition, and showed declines of 25 to 50%. Marchelyna et al. (2025) said that intraspecific competition occurs when each individual of the same species competes for the same resources, such as nutrients, water, light and space. This condition can then significantly affect plant productivity. This kind of competition has the potential to lead to reduced growth rates, smaller crop yields, and lower crop quality.

In conclusion, this study revealed significant intraspecific associations between species in the sago agroecology in Ambon Island, Maluku, Indonesia. There was negative association occurred between the sago species *M. rumphii*, *M. longispinum* and *M. sylvestre*, suggesting competition among the sago plants. Two weed species showed negative association with sago plants including *N. exaltata* and *H. rubra*, implying the necessity to control these species to optimize the growth and productivity of sago as the crop species.

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