



MORPHOLOGICAL CHARACTERS VARIABILITY OF TARO (*Colocasia* spp.) IN KALIMANTAN, INDONESIA BASED ON PHENETIC ANALYSIS APPROACH

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SUMMARY

Taro (*Colocasia* spp.) is an aroid plant which has long been cultivated in Kalimantan. This plant is considered as one of the oldest forms of cultivated plants in the region. Information about its morphological variability is needed to develop taro breeding population as future alternative crop. The aim of this research was to determine the morphological characters variability of taro in Kalimantan, Indonesia based on phenetic analysis approach. Leaf, petiole, stolon and corm samples were collected in all Indonesian provinces of Kalimantan. Similarity index was measured using the gower general similarity coefficient and cluster analysis was carried using the unweighted pair group method using arithmetic average (UPGMA). A dendrogram and principal component analysis (PCA) were constructed using *Multivariate Statistical Program* v.3.1 software. Around 123 accessions had been collected and evaluated using 39 morphological traits. Taro in Kalimantan consists of *C. esculenta*, *C. affinis*, *Colocasia* sp and *Colocasia* wild type. *C. esculenta* is the most widely used as staple food by local residents in Kalimantan. It has two botanical varieties. Fifty two from all the accessions are local cultivars that developed from *C. esculenta* varieties. Cluster analysis revealed Coefficient Similarity of taro ranging from 0.615 to 0.974, and divided into two major clusters. The first cluster has *Colocasia* sp as its single subgroup, while the second cluster has six subgroups including *C. esculenta*, *C. affinis* and *Colocasia* wild type. In Kalimantan, taro leaf especially petiole colour has significant influent in taro grouping.

Key words: *Colocasia* spp, Kalimantan, morphology, phenetic, taro, variability

Key findings: This research provides information about the characteristics of taro that are useful for plant breeding programmes and for developing taro as an alternative crop.

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INTRODUCTION

Taro is a member of the aroid family (Araceae) and is a crop plant of considerable socio-economic importance in Southeast Asia and the Pacific (Kreike *et al.*, 2004). Taro is probably one of the oldest crops on earth, having been first domesticated in Southeast Asia (Lebot, 2009). This cultivation is often regarded as a primitive form of agriculture. Some aroid species, including *C. esculenta*, are cultivated as starch-producing crops and there is great potential to further its use as a subsistence food and in industrial applications (Zhu, 2016).

Borneo is one of the largest islands in the Asia Pacific region and is divided into three political boundaries: Brunei, Malaysia and Indonesia. The largest part of the island is governed by Indonesia and is known as Kalimantan (Galapphatie *et al.*, 2014). The island of Borneo is very rich in aroids (Ridley, 1905) and is arguably one of the richest habitats for these plants worldwide. It is estimated that the total aroid flora in Borneo may exceed 1.000 species, with barely one third of these having been described (Boyce *et al.*, 2010). In Borneo, taro is believed to be the oldest cultivation group on the island (MacKinnon, 2000).

Taro is propagated vegetatively, and is generally accepted to be a polymorphic species (Purseglove, 1972; Dastidar, 2009). Polymorphism is regarded as a characteristic of traditional vegetatively propagated food crops such as *Colocasia* (Matthews and Medhi, 2014). Continuous vegetative propagation and selection have contributed to the phenotypic diversity of taro (Ivancic *et al.*, 1995; Okpul *et al.*, 2004).

The genetic improvement of taro has the potential in the future. The success of such genetic improvement depends on the availability of genetic resources and their diversity (Okpul *et al.*, 2004). Cultivar variation of crops is a source of germplasm, useful for the development of local food supplies. Crops such as taro (*Colocasia* spp.) have the potency to develop as alternative food (Walujo, 2011).

Morphological characters are the important characters to identify, classify and study plants diversity. This characters remain relevant for all diciplines including in plant biological research. This is because of almost all biological science refer to or use morphological concepts and morphological theories (Sattler and Rutishauser, 1997). Morphological characters are needed to prepare digital databases as references for future research. In addition,

morphological characters are very important for rapid and precise identification (Dwari and Mondal, 2011).

Research in the morphological characters of Indonesian taro was carried out on samples collected in West Java by Prana (2000). The results showed leaf variation; especially petiole colour can be used as a diagnostic character to classify taro cultivars. Hartati *et al.* (2001) carried out a study of Indonesian taro based on morphological characters but did not included accessions from Kalimantan. Furthermore, Falah (2015) examined the morphological characteristics of taro in Java and classified the accessions into two major clusters. However, research on taro morphology in Kalimantan has not been carried out so far. For that reason, the objective of this research was to determine morphological character variability of taro in Kalimantan based on phenetic analysis

and to provide initial information for future conservation strategies.

MATERIALS AND METHODS

Plant material

The 123 taro (*Colocasia* spp.) accessions were collected from all provinces in Kalimantan. The representative samples of leaves, petioles, stolons, roots and corms were taken from various habitats in each province (Figure 1) in North, East, South, Central and West Kalimantan. The accession was collected based on phenotypic variations observed and on the traditional knowledge of local inhabitants. The samples were then planted as living collections in an experimental garden. The accessions, vernacular names, origins and morphological characters are listed in Tables 1a–e.

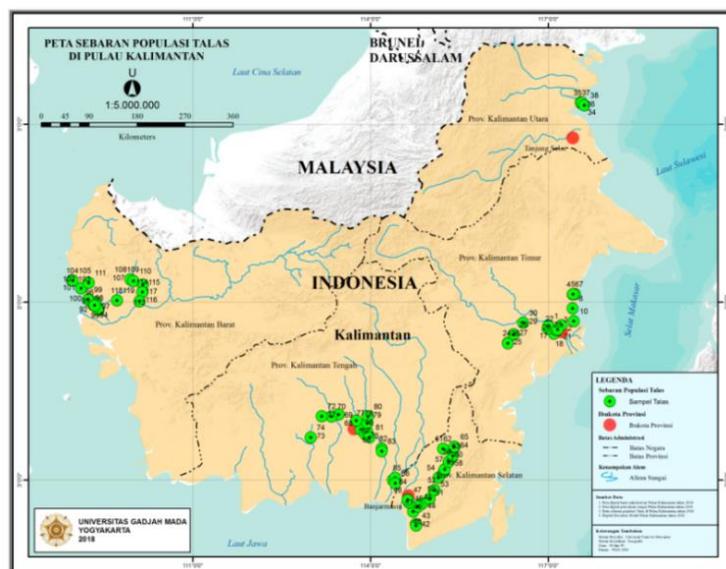


Figure 1. Locations of sample collection in Kalimantan, Indonesia.

(● Location of sampling ● Capital city of province; Source: Personal documentation)

Table 1a. Accession of taro (*Colocasia* spp.) in East Kalimantan.

No.	Accession number	Vernacular name	Origin	Morphological characters (leaf blade margin colour, petiole colour of top third adaxial, leaf main vein colour, spot colour on upper vein, petiole basal-ring colour, corm cortex colour, corm flesh fibre colour)
1.	KT-1	Keladi Gunung	Desa Pinang Seribu Samarinda-East Kalimantan	Green, purple, pink, purple, pink, pink, yellow
2.	KT-2	Keladi Sulur	Desa Pinang Seribu Samarinda-East Kalimantan	Yellow, green light, yellowish-white, yellow, white, white, yellow
3.	KT-3	Keladi Lais	Desa Pinang Seribu Samarinda-East Kalimantan	Yellow, green light, yellowish-white, green, pink, white, yellow
4.	KT-4	Keladi Sayur	Desa Suka Rahmat- East Kutai East Kalimantan	Yellow, yellowish-white, yellowish-white, yellow, white, white, yellow
5.	KT-5	Talas Liar	Desa Talihan- Bontang East Kalimantan	Yellow, yellowish-white, yellowish-white, yellow, white, white, yellow
6.	KT-6	Keladi Hitam	Desa Talihan- Bontang East Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
7.	KT-7	Keladi Hitam	Teluk Pandan-East Kutai East Kalimantan	Yellow, purple, yellowish-white, Purple, pink, white, yellow
8.	KT-8	Keladi Liar	Marangkayu-Kutai Kertanegara East Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
9.	KT-9	Keladi Liar	Desa Sebuntal-Kutai Kertanegara East Kalimantan	Yellow, green light, yellowish-white, green, pink, white, yellow
10.	KT-10	Keladi Liar	Muara Badak-Kutai Kertanegara East Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
11.	KT-11	Keladi Liar	Komp. Kampus UNMUL East Kalimantan	Purple, purple, yellowish-white, purple, pink, white, yellow
12.	KT-12	Talas Liar	Desa Pampang-Samarinda East Kalimantan	Yellow, yellowish-white, yellowish-white, green, pink, white, yellow
13.	KT-13	Talas Malaysia	Desa Pampang-Samarinda East Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
14.	KT-14	Talas Liar	Jl.Juanda-Samarinda East Kalimantan	Purple, purple, yellowish-white, none, white, white, yellow
15.	KT-15	Talas Jahe	Jl.Perjuangan-Samarinda East Kalimantan	Purple, purple, yellowish-white, purple, white, pink, pink
16.	KT-16	Talas Liar	Jl.Wijaya Kusuma Samarinda-East Kalimantan	Green, yellowish-white, yellowish-white, yellow, white, white, yellow
17.	KT-17	Keladi	Loa Bakung -Samarinda East Kalimantan	Green, purple, yellowish-white, purple, pink, white, yellow
18.	KT-18	Keladi	Loa Bakung-Samarinda East Kalimantan	Yellow, yellowish-white, yellowish-white, green, white, white, yellow
19.	KT-19	Keladi	Loa Bakung-Samarinda East Kalimantan	Purple, purple, pink, purple, pink, white, yellow
20.	KT-20	Keladi Liar	Jl.M.Yamin-Samarinda East Kalimantan	Brown, green light, yellowish-white, green, white, white, yellow
21.	KT-21	Keladi Liar	Jl.Perjuangan-Samarinda East Kalimantan	Yellow, yellowish-white, yellowish-white, yellow, white, white, yellow
22.	KT-22	Keladi Gatal	Jl.Belida-Tenggarong East Kalimantan	Brown, green light, yellowish-white, green, green, white, yellow
23.	KT-23	Keladi Liar	Timbau-Tenggarong East Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
24.	KT-24	Keladi	Desa Muara Gusi-West Kutai-East Kalimantan	Green, yellowish-white, yellowish-white, yellow, pink, white, yellow
25.	KT-25	Keladi Gunung	Desa Muara Gusi-West Kutai-East Kalimantan	Pink, pink, pink, purple, white, pink, pink
26.	KT-26	Keladi	Desa Muara Gusi-West Kutai East Kalimantan	Green, yellowish-white, yellowish-white, yellow, pink, white, yellow
27.	KT-27	Keladi Putih	Desa Muara Gusi-West Kutai East Kalimantan	Green, yellowish-white, yellowish-white, yellow, white, white, yellow
28.	KT-28	Keladi	Desa Perian-Kutai Kertanegara-East Kalimantan	Green, yellowish-white, yellowish-white, green, pink, white, yellow
29.	KT-29	Keladi Air	Bangun Rejo-Kutai Kertanegara-East Kalimantan	Purple, purple, yellowish-white, green, white, white, yellow
30.	KT-30	Keladi Air	Bangun Rejo-Kutai Kertanegara-East Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
31.	KT-31	Keladi Akar	Desa Pinang Seribu-Samarinda-East Kalimantan	Yellow, green light, yellowish-white, yellow, pink, pink, yellow

Table 1b. Accessions of taro (*Colocasia* spp.) in North Kalimantan.

No.	Accessions Number	Vernacular Name	Origin	Morphological Character (leaf blade margin colour, petiole colour of top third, leaf main vein colour, spot colour on upper vein, petiole basal-ring colour, corm cortex colour, corm flesh fibre colour)
1.	KU-32	Keladi Gunung	Jl.Kusuma Negara - Tarakan North Kalimantan	Green, purple, pink, purple, pink, pink, yellow
2.	KU-33	Keladi Liar	Jl.Mulawarman-Tarakan North Kalimantan	Yellow, purple, yellowish-white, green, white, white, yellow
3.	KU-34	Keladi Liar	Jl.Akibalak-Tarakan North Kalimantan	Purple, purple, purple, purple, white, pink, yellow
4.	KU-35	Talas Liar	Persemaian-Tarakan North Kalimantan	Green, purple, yellowish-white, green, white, white, yellow
5.	KU-36	Talas Malaysia	Juata Permai-Tarakan North Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
6.	KU-37	Keladi Liar	Juata Kerikil-Tarakan North Kalimantan	Brown, purple, dark brown, purple, white, yellow, yellow
7.	KU-38	Talas Hitam	Kampung satu-Tarakan North Kalimantan	Brown, purple, dark brown, purple, white, white, yellow
8.	KU-39	Talas Ungu	Tarakan - North Kalimantan	Brown, purple, yellowish-white, green, white, white, yellow

Table 1c. Accessions of taro (*Colocasia* spp.) in South Kalimantan.

No.	Accession number	Vernacular name	Origin	Morphological character (leaf blade margin colour, Petiole colour of top third, leaf main vein colour, spot colour on upper vein, petiole basal-ring colour, corm cortex colour, corm flesh fibre colour)
1.	KS-40	Keladi Liar	Desa Liang Anggana-Tanah Laut-South Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
2.	KS-41	Keladi Putih	Desa Liang Anggana-Tanah Laut-South Kalimantan	Yellow, yellowish-white, yellowish-white, yellow, white, white, yellow
3.	KS-42	Talas Liar	Pleihari-Tanah Laut South Kalimantan	Green, green light, yellowish-white, yellow, white, white, yellow
4.	KS-43	Keladi Bentul	Pabaharan- Tanah Laut South Kalimantan	Green, yellowish-white, yellowish-white, yellow, white, white, yellow
5.	KS-44	Keladi Hutan	Desa Tambak Anyar-Martapura-South Kalimantan	Green, green light, yellowish-white, yellow, white, white, yellow
6.	KS-45	Keladi Liar	Banjar Baru- South Kalimantan	Green, purple, yellowish-white, purple, white, white, yellow
7.	KS-46	Keladi Liar	Gambut Kab.Banjar - South Kalimantan	Yellow, green light, yellowish-white, none, pink, white, yellow
8.	KS-47	Keladi Liar	Jl.Pramuka-Banjarmasin South Kalimantan	Green, yellowish-white, yellowish-white, yellow, white, white, yellow
9.	KS-48	Keladi Liar	Jl.Pramuka-Banjarmasin South Kalimantan	Purple, purple, yellowish-white, purple, pink, white, yellow
10.	KS-49	Keladi Liar	Jl.Pramuka-Banjarmasin South Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
11.	KS-50	Keladi Hitam	Mataraman-Kab.Banjar South Kalimantan	Green, green, yellowish-white, green, pink, white, yellow
12.	KS-51	Keladi Hias	Mataraman-Kab.Banjar South Kalimantan	Purple, green, yellowish-white, yellow, white. Orange, orange
13.	KS-52	Keladi Telur	Kec.Binuang-Kab.Tapin South Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
14.	KS-53	Keladi Liar	Kec.Binuang Kab.Tapin South Kalimantan	Green, green light, yellowish-white, yellow, white, white, yellow
15.	KS-54	Keladi Liar	Kota Rantau Kab. Tapin South Kalimantan	Green, yellowish-white, yellowish-white, green, white, white, yellow
16.	KS-55	Keladi Liar	Kandangan-Hulu Sungai Selatan-South Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
17.	KS-56	Keladi Liar	Kandangan-Hulu Sungai Selatan, South Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
18.	KS-57	Keladi Liar	Kandangan-Hulu Sungai Selatan, South Kalimantan	Green, purple, yellowish-white, green, white, white, yellow
19.	KS-58	Keladi Merah	Haruyan-Hulu Sungai Tengah, South Kalimantan	Green, purple, purple, purple, pink, pink, yellow
20.	KS-59	Keladi Putih	Haruyan-Hulu Sungai Tengah, South Kalimantan	Green, yellowish-white, yellowish-white, yellow, white, white, yellow
21.	KS-60	Keladi Hias	Haruyan-Hulu Sungai Tengah, South Kalimantan	Purple, yellowish-white, yellowish-white, yellow, white, orange, orange
22.	KS-61	Keladi Liar	Amuntai-Hulu Sungai Utara South Kalimantan	Purple, yellowish-white, yellowish-white, yellow, white, orange, orange
23.	KS-62	Keladi Liar	Sei.Pandang- Hulu Sungai Utara, South Kalimantan	Green, green, yellowish-white, yellow, white, white, yellow
24.	KS-63	Keladi Liar	Barabai-Hulu Sungai Tengah, South Kalimantan	Green, purple, yellowish-white, purple, white, white, yellow
25.	KS-64	Keladi Liar	Ds.Batu Mandi-Balangan South Kalimantan	Green, yellowish-white, yellowish-white, none, white, white, yellow
26.	KS-65	Keladi Hitam	Des.Hamparan-Balangan South Kalimantan	Green, purple, yellowish-white, purple, pink, white, yellow

Table 1d. Accessions of taro (*Colocasia* spp.) in Central Kalimantan.

No.	Accession number	Vernacular name	Origin	Morphological character (leaf blade margin colour, Petiole colour of top third, leaf main vein colour, spot colour on upper vein, petiole basal-ring colour, corm cortex colour, corm flesh fibre colour)
1.	KH-66	Keladi Liar	Tengkilang-Palangkaraya Central Kalimantan	Purple, purple, yellowish-white, yellow, pink, white, yellow
2.	KH-67	Talas Liar	Tengkilang-Palangkaraya Central Kalimantan	Yellow, green light, yellowish- white, yellow, white, white, yellow
3.	KH-68	Talas Liar	Kab.Katingan-Kasongan Central Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
4.	KH-69	Talas Liar	Kab.Katingan-Kasongan Central Kalimantan	Yellow, green light, yellowish- white, none, white, white, yellow
5.	KH-70	Keladi Merah/Hitam	Kerengpangi-Kasongan Central Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
6.	KH-71	Talas Hitam	Km.30-Kasongan Central Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
7.	KH-72	Talas Putih	Km.30-Kasongan Central Kalimantan	Yellow, green light, yellowish- white, none, white, white, yellow
8.	KH-73	Keladi Hitam	Desa Jemaras-Sampit Central Kalimantan	Purple, purple, yellowish-white, none, white, white, yellow
9.	KH-74	Keladi Putih	Desa Jemaras-Sampit Central Kalimantan	Yellow, green light, yellowish- white, yellow, white, white, yellow
10.	KH-75	Keladi Liar	Jebun Raya-Palangkaraya Central Kalimantan	Yellow, pink, yellowish-white, yellow, pink, white, yellow
11.	KH-76	Keladi Sayur	P. Sebrang-Palangkaraya Central Kalimantan	Yellow, green light, yellowish- white, yellow, white, white, yellow
12.	KH-77	Kujang Bawa	Kahayan Tengah-Pulang Pisau, Central Kalimantan	Yellow, green light, yellowish- white, yellow, pink, white, yellow
13.	KH-78	Kujang Enyuh	Kahayan Tengah-Pulang Pisau, Central Kalimantan	Yellow, purple, yellowish-white, purple, white, white, yellow
14.	KH-79	Kujang Gahuri	Kahayan Tengah-Pulang Pisau, Central Kalimantan	Purple, purple, yellowish-white, purple, green, white, yellow
15.	KH-80	Keladi Liar	Ds.Pamarunan-Kab.Kuala Kurun, Central Kalimantan	Yellow, light green, yellowish- white, none, white, white, yellow
16.	KH-81	Keladi Liar	Sebangau-Palangkaraya Central Kalimantan	Green, yellowish-white, yellowish-white, green, white, white, yellow
17.	KH-82	Keladi Liar	Ds. Pilang-Kab.Pulang Pisau Central Kalimantan	Yellow, light green, yellowish- white, yellow, white, white, yellow
18.	KH-83	Keladi	Jabiran-Kab.Pulang Pisau Central Kalimantan	Purple, purple, yellowish-white, purple, pink, white, yellow
19.	KH-84	Keladi Liar	Kec.Selat-Kab.Kapuas Central Kalimantan	Green, yellowish-white, yellowish-white, yellow, white, orange, orange
20.	KH-85	Keladi Liar	Km 5,5 Kab.Kapuas Central Kalimantan	Purple, green, green, green, white, white, yellow
21.	KH-86	Keladi Habang/Merah	Desa Anjir Mambulau Tengah Kab. East Kapuas Central Kalimantan	Purple, purple, green, purple, pink, white, yellow

Table 1e. Accessions of taro (*Colocasia* spp.) in West Kalimantan.

No.	Accession number	Vernacular name	Origin	Morphological character (leaf blade margin colour, petiole colour of top third, leaf main vein colour, spot colour on upper vein, petiole basal-ring colour, corm cortex colour, corm flesh fibre colour)
1.	KB-87	Keladi Liar	Ds. Arang Limbung Kab. Kubu Raya-West Kalimantan	Purple, yellowish-white, yellowish-white, purple, white, pink, yellow
2.	KB-88	Keladi Liar	Jl.Adisucipto Kab. Kubu Raya West Kalimantan	Purple, purple, pink, purple, pink, pink, yellow
3.	KB-89	Keladi Liar	Kec. Sei.Raya Kab. Kubu Raya West Kalimantan	Purple, purple, yellowish-white, purple, pink, white, yellow
4.	KB-90	Keladi Liar	Ds.Arang Limbung Kab. Kubu Raya, West Kalimantan	Red purple, red purple, red purple, red purple, red purple, white, yellow
5.	KB-91	Keladi Tikus	Kel.Aksaya-Kec. Pontianak Selatan-West Kalimantan	Brown, brown, brown, green, white, white, yellow
6.	KB-92	Keladi Putih	Kel.Aksaya-Kec. Pontianak Selatan-West Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
7.	KB-93	Talas Liar	Jl.K. Bakti-Kec. Pontianak Selatan-West Kalimantan	Yellow, purple, yellowish-white, purple, white, white, yellow
8.	KB-94	Talas Liar	Jl.Surya- Pontianak Selatan West Kalimantan	Purple, purple, yellowish-white, purple, purple, white, yellow
9.	KB-95	Keladi Hitam	Jl.28 Oktober- Pontianak Utara-West Kalimantan	Purple, purple, yellowish-white, green, pink, white, yellow
10.	KB-96	Keladi Kelapa	Jl.28 Oktober- Pontianak Utara-West Kalimantan	Green, purple, yellowish-white, brown, green, white yellow
11.	KB-97	Talas Manis	Jl.28 Oktober- Pontianak Utara-West Kalimantan	Green, green light, yellowish-white, green, white, white, yellow
12.	KB-98	Talas Kelapa	Ds.Wajo -Kab. Mempawah, West Kalimantan	Purple, purple, yellowish-white, purple, pink, white, yellow
13.	KB-99	Keladi Liar	Jungkat-Kab.Mempawah West Kalimantan	Green, purple, yellowish-white, green, white, white, yellow
14.	KB-100	Keladi Liar	Sei.Purun-Kab.Mempawah West Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
15.	KB-101	Keladi Hutan	Sei.Purun-Kab.Mempawah West Kalimantan	Purple, purple, pink, green, white, white, yellow
16.	KB-102	Keladi	Sei.Purun-Kab. Mempawah West Kalimantan	Purple, purple, yellowish-white, none, white, white, yellow
17.	KB-103	Keladi Liar	Kota Mempawah-West Kalimantan	Purple, purple, yellowish-white, green, white, white, yellow
18.	KB-104	Keladi Bangkok	Desa Antibar-Kota Mempawah West Kalimantan	Purple, yellowish-white, yellowish-white, purple, white, white, yellow
19.	KB-105	Keladi Liar	Desa Antibar-Kota Mempawah West Kalimantan	Green, purple, yellowish-white, none, white, white, yellow
20.	KB-106	Keladi Hitam	Kab.Landak-West Kalimantan	Brown, brown, yellowish-white, purple, white, white, yellow
21.	KB-107	Talas Merah	Dusun Tukul, Ngabang Kab. Landak, West Kalimantan	Purple, brown, yellowish-white, purple, pink, pink, pink
22.	KB-108	Talas Putih	Dusun Tukul, Ngabang Kab. Landak, West Kalimantan	Yellow, green light, yellowish-white, yellow, white, white, yellow
23.	KB-109	Keladi Minyak	Dusun Tukul, Ngabang Kab. Landak, West Kalimantan	Pink, yellowish-white, yellowish-white, purple, white, white, yellow
24.	KB-110	Keladi Liar	Ngabang Kab.Landak West Kalimantan	Purple, yellowish-white, yellowish-white, green, pink, white, yellow
25.	KB-111	Keladi Hitam	Desa Purwandalan Kab. Sanggau-West Kalimantan	Brown, brown, yellowish-white, purple, white, white, yellow

Table 1e. (cont'd.)

No.	Accession number	Vernacular name	Origin	Morphological character (leaf blade margin colour, petiole colour of top third, leaf main vein colour, spot colour on upper vein, petiole basal-ring colour, corm cortex colour, corm flesh fibre colour)
26.	KB-112	Talas Malaysia	Desa Purwandalan Kab. Sanggau-West Kalimantan	Green, yellowish-white, yellowish-white, purple, white, white, yellow
27.	KB-113	Keladi Cina	Desa Senyabang Kab. Sanggau-West Kalimantan	Purple, purple, yellowish-white, purple, pink, white, yellow
28.	KB-114	Keladi Mei	Desa Senyabang Kab. Sanggau-West Kalimantan	Green, purple, yellowish-white, purple, white, white, yellow
29.	KB-115	Keladi Mei Hitam	Desa Senyabang Kab. Sanggau-West Kalimantan	Purple, purple, purple, purple, pink, pink, pink
30.	KB-116	Keladi Udang	Ds. Danau Teluk-Kab. Sanggau-West Kalimantan	Red, red, red, red, red, white, yellow
31.	KB-117	Keladi Liar	Ds. Danau Teluk- Kab. Sanggau-West Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
32.	KB-118	Keladi Madura	Desa Teluk Bakung Kab. Kubu Raya-West Kalimantan	Purple, purple, yellowish-white, purple, pink, pink, yellow
33.	KB-119	Keladi Sayur	Desa Teluk Bakung Kab. Kubu Raya-West Kalimantan	Green, yellowish-white, yellowish-white, yellow, white, white, yellow
34.	KB-120	Keladi Liar	Pontianak- West Kalimantan	Green, purple, pink, purple, pink, white, yellow
35.	KB-121	Keladi Liar	Pontianak-West Kalimantan	Green, purple, yellowish-white, green, white, white, yellow
36.	KB-122	Keladi Liar	Pontianak- West Kalimantan	Purple, purple, yellowish-white, purple, white, white, yellow
37.	KB-123	Keladi Liar	Pontianak- West Kalimantan	Brown, brown, dark brown, purple, brown, white, yellow

Data recorded

Morphological characteristics were observed directly in living plants both in the field and 6–8 months after planting. Description was done according to the International Plant Genetic Resources Institute (IPGRI) (1999), Kusumo *et al.* (2002), Prana (2000) and Serviss (2000).

Morphological variability of taro accessions were characterized by using 39 characters, including habit, leaves, petioles, roots and corms, and by applying binary and multistate scoring (Table 2). Operational taxonomic units (OTUs) in this research are 123 accessions. Based on 39 characters, each OTUs was compared to create the present and absent characters between accessions.

Data analysis

Similarity between OTUs was calculated based on gower's general similarity coefficient (Sokal and Sneath, 1963). Cluster analysis was carried out by the unweighted pair group method using arithmetic average (UPGMA). The dendrogram was generated using multivariate statistical package (MVSP) software, version 3.1. (Kovach, 2007) based on morphological characteristic.

Table 2. Scoring of morphological characters for taro OTUs in Kalimantan.

No.	Character	Binary and multistate scoring
1.	Plant span	0 ≤ 100 cm 0 ≥ 100 cm
2.	Plant height	0 ≤ 100 cm 0 ≥ 100 cm
3.	Number of stolons	0 = none 1 = 1-5 2 = 6-10 3 ≥ 10
4.	Stolon length	0 = none 1 = short (≤ 15 cm) 2 = long (≥ 15 cm)
5.	Lamina length/width ratio	0 = ≤1.5 1 = ≥ 1.5
6.	Leaf blade margin	0 = entire 1 = undulate 2 = sinuate
7.	Leaf blade margin colour	0 = yellow 1 = green 2 = purple 3 = brown 4 = pink 5 = red 5 = red purple
8.	Leaf blade texture	0 = opaque 1 = shiny
9.	Leaf blade basal colour	0 = yellowish-white 1 = yellow 2 = green 3 = dark green
10.	Leaf blade upper colour	0 = green 1 = dark green 2 = black patches 3 = black
11.	Leaf main vein colour	0 = yellowish-white 1 = red purple 2 = orange 3 = green 4 = pink 5 = red 6 = brown 7 = purple
12.	Leaf blade symmetry	0 = asymmetry 1 = symmetry
13.	Vein pattern	0 = none 1 = I 2 = Y 3 = V 4 = extending to secondary vein
14.	Petiole junction pattern	0 = none 1 = small 2 = medium 3 = large
15.	Predominant position (shape) of leaf lamina surface	0 = flat 1 = drooping position of anterior and posterior lobes 2 = flat with drooping edge 3 = cup-shape
16.	Leaf blade tip	0 = round 1 = acuminate 2 = acute
17.	Outline sinus	0 = narrow, sharp 1 = wide, sharp 2 = overlapping edge
18.	Petiole junction colour	0 = none 1 = yellow 2 = green 3 = red 4 = purple 5 = red purple 6 = brown
19.	Petiole colour of top third adaxial	0 = yellowish-white 1 = yellow 2 = orange 3 = green light 4 = green 5 = red 6 = brown 7 = purple 8 = pink 9 = red purple
20.	Petiole colour of top third abaxial	0 = yellowish-white 1 = yellow 2 = orange 3 = green light 4 = green 5 = red 6 = brown 7 = purple 8 = pink 9 = red purple
21.	Petiole colour of middle third	0 = yellowish-white 1 = yellow 2 = orange 3 = green light 4 = green 5 = red 6 = brown 7 = purple 8 = pink 9 = red purple
22.	Petiole colour of basal third	0 = yellowish-white 1 = yellow 2 = orange 3 = green light 4 = green 5 = red 6 = brown 7 = purple 8 = pink 9 = red purple
23.	Petiole/lamina length ratio	0 = ≤1.5 1 = ≥1.5
24.	Petiole stripe	0 = none 1 = brown 2 = white 3 = green 4 = purple
25.	Leaf sheath colour on terminal	0 = yellowish-white 1 = Light green 2 = green 3 = red 4 = brownish 5 = purple 6 = pink 7 = red purple
26.	Leaf sheath colour on basal	0 = yellowish-white 1 = light green 2 = green 3 = red 4 = brownish 5 = purple 6 = pink 7 = red purple
27.	Petiole basal-ring colour	0 = white 1 = green 2 = pink 3 = red 4 = purple 5 = red purple 6 = brown
28.	Cross-section of lower part of petiole	0 = open 1 = closed
29.	Leaf sheath/petiole ratio	0 = ≤50cm 1 ≥50cm
30.	Leaf sheath edge colour	0 = purple 1 = white 2 = brown 3 = green 4 = pink 5 = red purple 6 = red
31.	Sap colour of leaf blade tip	0 = white 1 = pink
32.	Length of sheath	0 = ≤50 cm 1 = ≥50 cm
33.	Fleck colour on the upper leaf vein	0 = none 1 = purple 2 = black
34.	Root colour	0 = white 1 = pink 2 = brown 3 = red purple
35.	Uniformity of root colour	0 = no 1 = yes
36.	Corm shape	0 = conical 1 = round 2 = cylindrical 3 = elliptical 4 = dumb-bell 5 = elongated 6 = multifaced 7 = clustered
37.	Corm cortex colour	0 = white 1 = yellow 2 = pink 3 = orange 4 = red
38.	Corm flesh fibre colour	0 = white 1 = yellow 2 = pink 3 = orange 4 = red
39.	Predominant orientation of lamina	0 = semi-vertical with tip pointing upwards 1 = vertical with tip pointing downwards 3 = semi-vertical with tip pointing downwards

RESULTS

Taro distribution in Kalimantan

Kalimantan is located in a tropical humid climatic region which is suitable for taro growth. In Kalimantan, taro grows from lowlands at two m asl on the edge of Mahakam River (East Kalimantan) up to 192 m asl in the Tapin region (South Kalimantan). However, the majority of taro is found from 10 to 100 m ASL and grows in cultivated and wild habitat.

The cultivated habitat included home yards, gardens, ridges of paddy fields and orchards. In this case, taro are grown only for limited scale or for family consumption. Meanwhile, in the wild taro grows in ditches and streams, swamps and on road sides.

Morphological variation

Germplasm characterizations in viable populations are important links between the conservation and utilization of plant genetic resources (Whitkus *et al.*, 1994). Morphological characters are aspects of germplasm and are relevant for all areas of plant biology research. Morphological characterization is the first step in the description and classification of germplasm (Smith and Smith, 1989). Plant breeders can utilize morphological characters and genetic similarity information for phenotypic information for the development of breeding populations (Sari *et al.*, 2016).

The 39 morphological characteristics used for taro identification including habit, leaves, petioles, roots and corms. IPGRI (1999) recommends over 100 characters in total, but not all characters can be used in this study,

especially for taro in wild habitats. This study did not use generative characters. The absence of generative organ reflected that the taro found in the field were not flowering, as taro is a plant that rarely flowers (Cooper, 1969). According to Hartati *et al.* (2001), taro in cultivation and wild habitats rarely produce fertile flowers. In addition, not all taro flowering simultaneously, which lead to the difficulties in the characterization process.

From this research it is found that generally taro plants are over 100 cm tall, with only a few being less than 100 cm, such as the 'Talas Pare', 'Keladi Sulur', 'Keladi Sayur' and 'Keladi Hutan'. Plant span is usually more than 100 cm. This characteristic is important in determining the plant space required and for intercropping (Prana 2000).

Leaf

Observations of the 123 accessions indicated the leaf shape of *Colocasia* spp. is peltate with long erect petioles. Leaf blade is light green or dark green in colour with a smooth and shiny surface, but there are also some leaves with opaque surfaces (Figure 2B). Some taro accessions have variegation on the lamina such as purplish-black or black patches between the main veins on the adaxial leaf blade (KS-51, KS-60, KS-61 and KT-84). These characteristics can be used to differentiate between accessions and are distinctive characters in grouping species.

Leaves variations have been the main character used for the selection process and for interbreeding to obtain cultivars with attractive colours. In South and Central Kalimantan provinces, these accessions are used

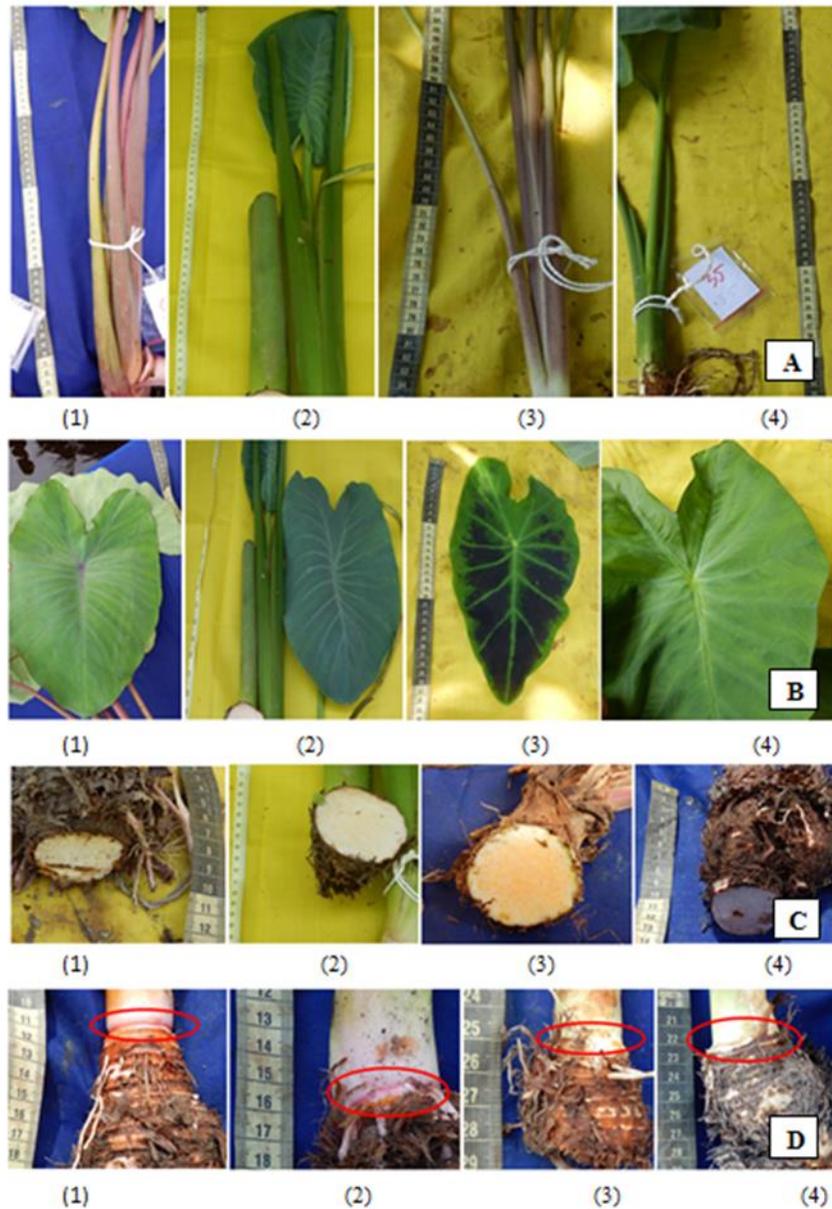


Figure 2. A, B, C, D. Morphological character variations of taro (a.1-5), Petiole colour (b.1-5), Leaf blade (c.1-5), Corm colour (d.1-5), Petiole basal ring colour.

as ornamental plants and are often planted in gardens. This can be seen in "Talas Malaysia" and 'Talas Bangkok" (KT-13, KU-36, KB-104 and KB-112) accessions which have brownish-purple spots on the veins in the adaxial leaf blade. In immature leaves the spots are yellow and turn brownish-purple as the leaves mature.

In "Keladi Mei Hitam" (KB-113), the leaf spot colour is blackish.

The abaxial surface of the leaf blade varies in colour from yellowish-white to light and dark green. Leaf blade margins are undulate, with only a few accessions having entire leaf margins. Leaf blade margin colour also varies from green, purple, yellow,

brown, red and pink. The main vein also has colour variations from yellowish-white, brown, pink and red. The morphological different characters are given in Tables 1a–e.

Petiole

The petiole can be differentiated into three parts: top third, middle third and basal third. Petiole colour varies from green, light green, purplish-green, brown, blackish, pink and red (Figure 2A) and can differ along the petiole, from the top third through the middle third to the basal third. Usually, the colour of each third is different, but in some taro cultivars, such as 'Keladi Udang' (KB-116) and 'Keladi Tikus' (KB-91), the whole petiole is uniformly coloured, red in 'Keladi Udang' and blackish-brown in 'Keladi Tikus'. Some accessions have a white stripe pattern in the basal third, as found in cultivar 'Mei Putih'. The petiole basal-ring is the part of the basal leaf bordering the corm, and is pink or white in colour (Figure 2D). Variation in the leaf sheath includes colour, cross-section of the lower part of the petiole, leaf sheath/petiole ratio and leaf sheath edge colour. The sheath colour variations are green, yellowish-white, pink, red and purple.

Corm

Most of the taro accessions have single corms or large edible main corms with few cormels, and these are known as the 'dasheen' type. The shape of single corms varies from conical, rounded, cylindrical, or elliptical to elongate. In contrast, there are several accessions with small or medium-sized main corms with many side tubers, these being the edible portion and these are

known as the 'eddoe' type. The main differences between these types are in the shape and size of the main corm and cormels. According to Kreike (2004) there are two botanical varieties of taro characterized by their corm shape and described as var. *esculenta* (dasheen type) and var. *antiquorum* (eddoe type).

The colour of the corm can vary from white, orange and pink (Figure 2C), but almost all taro accessions have white corms. Orange corms are only found in accessions that have black patches on their leaves and that are used as ornamental plants. Corm flesh fibre is generally yellow. The character of taro root forms may be uniform or different and roots may have two colour variations, white and pink. Some accessions have uniform roots and other accessions have different roots.

Based on morphological character, taro accessions in Kalimantan are classified as *Colocasia* sp, *C.affinis*, *C. esculenta* and *Colocasia* wild type. *C. esculenta* is generally a cultivated form used by local people in Borneo. This species consists of two varieties: var. *esculenta* (dasheen type) and var. *antiquorum* (eddoe type). However, there are varieties of local cultivars developed from *C. esculenta* that are known by their vernacular names. The taro species in Kalimantan are described in Table 3.

Cluster analysis

Cluster analysis showed that taro have similarity coefficient ranging from 0.615 to 0.974 (61.5–97.4%). This indicates high diversity within Kalimantan taro. Furthermore, there are several accessions with close relationships, indicated by similarity

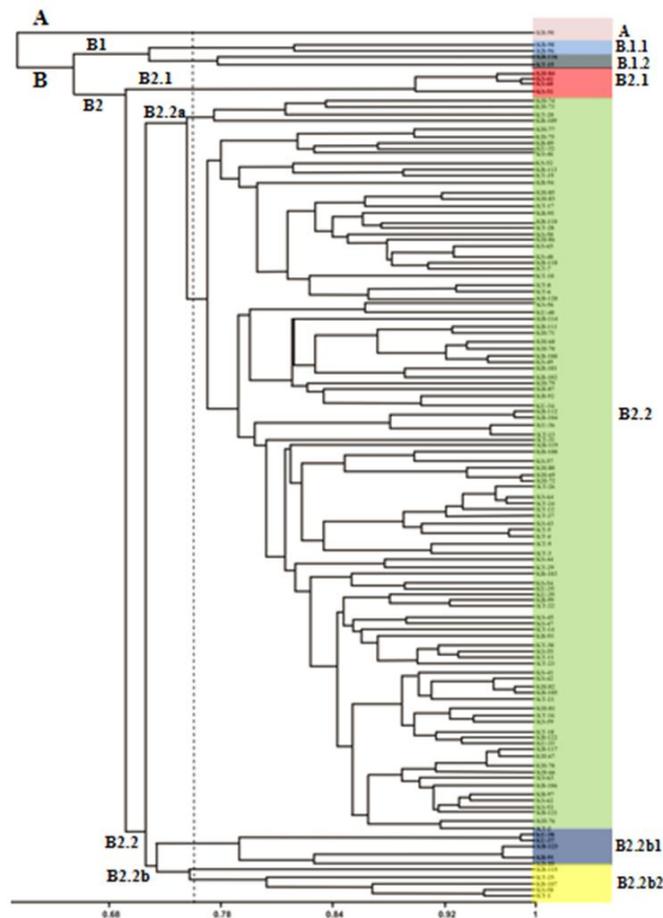


Figure 3. Dendrogram of morphological characters of taro accessions in Kalimantan, Indonesia based on phenetic analysis.

coefficient of above 85% and even reaching as high as 97% (Figure 3). As indicated by the dendrogram, taro in Kalimantan is grouped into two major clusters. Cluster A only has one sub-group containing one member (KB-90), with a similarity coefficient of 0.615 (61.5%). This accession is *Colocasia* sp. and has morphological characteristics for margin leaf blade, petiole junction colour, petiole colour, vein colour and petiole basal-ring colour of purplish-red. This accession was found in wild habitat in West Kalimantan province.

Cluster B consists of 122 taro accessions with a similarity coefficient

of 0.65 and has morphological characteristics for leaf blade colour, petiole junction colour, petiole and vein colours of green to pink. This cluster consists of species *C. esculenta*, *C. affinis* and *Colocasia* wild type. Cluster B can be divided into subgroups B1 and B2. Subgroup B1 is then divided again into sub-group B1.1 with diagnostic characters shiny leaf blades and green abaxial and adaxial leaf surfaces. In addition, the characters used to group these four accessions were leaf symmetry and petiole length ratio to leaf blade length of less than ≤ 1.5 . This sub-group consists of accessions of KB-98 and

Table 3. Species, varieties and characters of classifications taro in Kalimantan.

Species	Varieties	Character
<i>Colocasia</i> sp	-	Leaf blade dark green, colour of petiole and leaf sheath purplish-red. Main veins can be seen on adaxial leaf blade
<i>Colocasia affinis</i>	-	Leaf blade has variegation, such as purplish-black or black patches between the main veins on the adaxial leaf blade
<i>Colocasia</i> wildtype	-	The petiole is uniformly green, leaf sheath green, small corms, causes strong itching and cannot be consumed
<i>Colocasia esculenta</i>	<i>esculenta</i>	The petiole is green, brown, red, leaf sheath green, red, purple, a large edible main corm with few cormels, can be consumed
<i>Colocasia esculenta</i>	<i>antiquorum</i>	The petiole is green, pink, leaf sheath green, pink, small or medium-sized main corm with many side cormels, can be consumed

Table 4. Species, varieties and accessions of taro (*Colocasia* spp.) in Kalimantan.

No.	Species	Varieties	Accessions
1.	<i>Colocasia esculenta</i>	<i>esculenta</i>	KT-1, KT-2, KT-3, KT-4, KT-5, KT-6, KT-7, KT-8, KT-9, KT-11, KT-12, KT-13, KT-14, KT-16, KT-17, KT-18, KT-19, KT-20, KT-21, KT-22, KT-24, KT-26, KT-28, KT-29, KT-30, KT-31, KU-32, KU-33, KU-34, KU-36, KU-37, KU-38, KU-39, KS-40, KS-41, KS-42, KS-43, KS-45, KS-46, KS-47, KS-48, KS-49, KS-50, KS-52, KS-53, KS-54, KS-55, KS-56, KS-57, KS-58, KS-59, KS-62, KS-63, KS-64, KS-65, KH-66, KH-67, KH-68, KH-69, KH-70, KH-71, KH-72, KH-74, KH-75, KH-77, KH-78, KH-79, KH-80, KH-81, KH-85, KH-86, KB-87, KB-89, KB-91, KB-92, KB-93, KB-94, KB-95, KB-97, KB-98, KB-100, KB-101, KB-102, KB-103, KB-105, KB-106, KB-107, KB-108, KB-109, KB-110, KB-111, KB-112, KB-114, KB-115, KB-116, KB-117, KB-118, KB-119, KB-120, KB-121, KB-122, KB-123
		<i>antiquorum</i>	KT-15, KT-23, KT-25, KT-27, KS-44, KS-54, KH-73, KH-76, KH-78, KH-82, KH-83, KB-88, KB-96, KB-99, KB-104, KB-113
2.	<i>Colocasia affinis</i>	-	KS-51, KS-60, KS-61, KH-84
3.	<i>Colocasia</i> wildtype	-	KT-10, KU-35
4.	<i>Colocasia</i> sp	-	KB-90

similarity of morphological features such as wide plant span, green leaf blades, dominant leaf shape, spotted veins, shape of the leaf tip and sinus, colour of petiole basal third, white sap, pink roots, uniformity of root colour and pink corms.

In order to confirm cluster analysis, PCA analysis was performed to show the pattern of accessions grouping and the role of each character in the grouping process (Figure 4). The results show that the characters that are most important in grouping are leaves, especially petioles, displayed in the form of arrows of different lengths. The longer the arrow the higher the character's role in grouping. The longest arrows were for petiole colour, corm colour, leaf sheath colour and corm flesh fibre colour. There are three clear groups of accessions: *Colocasia* sp, *C. affinis* and the major group of *C. esculenta*. *Colocasia* wildtype did not cluster clearly. PCA results showed that *Colocasia* sp (KB-90) was separated apart from other species groups while *C. affinis* also formed a separate group. This was corresponded and supported by the results of the dendogram.

DISCUSSION

There are several species of taro in Kalimantan, such as *Colocasia* sp, *C. esculenta*, *C. affinis* and *Colocasia* wild type. *C. esculenta* has two botanical varieties: var. *esculenta* (dasheen type) and var. *antiquorum* (eddoe type). There are many taro cultivars developed from these varieties, including 'Talas Gunung', 'Keladi Putih', 'Talas Kelapa', 'Talas Hitam', 'Keladi Sayur', 'Keladi Tikus' and 'Keladi Minyak', and worldwide there

are thousands of taro cultivars developed from *C. esculenta* (Plucknet, 1983). In this research there are 52 local cultivars that were developed from *C. esculenta*. The differences between each cultivar can be identified based on the appearance of phenetic and agronomic characteristics, with each having its own leaves, petioles and corms characteristic. According to Quero-Garcia *et al.* (2006), a number of local cultivars have characteristics that vary not only in terms of leaves but also based on the shape and colour of corms. A very large variation of cultivars can be seen based on morphological characters such as leaf shape, leaf colour, plant height and number of stolons (Lebot *et al.*, 2017) and each region or country tends to have its own 'forms' of taro (Ghani, 1984). Among taro species found in Kalimantan, the species *C. esculenta* is the most widely used by local residents as staple food, so this taro has enormous potency to develop in future, whereas *C. affinis* are more generally used as ornamental plants because of their interesting colour pattern.

Colocasia wild type is a group of plants that are not cultivated and are found in habitats that are not farmed by local communities. The term 'wild type' is used to describe plants that have natural genotypes that have not been modified by human activity (Matthews, 1995). In Kalimantan, this taro is used by native people as animal feed, especially as fodder for pigs. It is possible that *Colocasia* wild type is a *C. esculenta* species whose cultivar name is unknown. This was also supported by dendograms and PCA which did not show clear group separation between *Colocasia* wild type and *C. esculenta*. However,

sometimes taro wildtypes have been taxonomically treated as a separate species (Liu *et al.*, 2015).

Taro in Kalimantan are grouped into two major clusters with a similarity coefficient of 61.5%. Based on the similarity coefficient, the KB-90 (*Colocasia* sp) accession in cluster I, assumed is different species. This accession have main vein is clearly visible on adaxial leaf blade and is not used by the local community as food. According to Singh (1999) and based on the phenon auxiliary line in the dendrogram, 65% index of similarity is the threshold for genera. This was also supported by the PCA results which showed that *Colocasia* sp was separated apart from other species. Taro accessions in cluster II are generally those used by the community both as food crops and as ornamental plants.

Taro grouping is strongly influenced by leaf character, especially petiole colour, which differs in each species and cultivar of taro. The petiole colour characteristic is in accordance with the research of Prana (2000) which found that highly variable characters are found in the petiole, making it useful as a diagnostic character for classifying taro cultivars. This is also supported by Strauss *et al.* (1983) and Matthews (2004), that leaves and petioles of taro vary in colour and size.

In food crops, these colour characters are often used and can assist in grouping and classifying intraspecific plants. Indonesian water yam (*Dioscorea alata*) germplasm, based on research by Purnomo *et al.* (2012), can be grouped into two large groups that are intraspecific for green and red-purplish colour of stem nodes, upper and base of leaf petiole, leaf veins, auricle at petiole base, tuber

and tuber shape. In taro, corm colour reflects the genetic structure of the plant (Mergedus *et al.*, 2015).

Based on the similarity index indicates that taro in Kalimantan has high morphological diversity. According to Lebot (2009), the great diversity of Indonesian taro (in this case in Borneo) may reflect the lack of improvements made to this crop. In addition it also indicates that the cultivation of taro in Kalimantan is rare.

CONCLUSION

Based on the research, it concluded that taro in Kalimantan consist of *Colocasia* sp, *C. esculenta*, *C. affinis* and *Colocasia* wild type. *C. esculenta* has two botanical varieties and many cultivars that develop from these varieties. The most variable morphological characters of taro in Kalimantan is found in leaves, and particularly in the petiole. Colour is important in identification of species and cultivars of taro. Taro is divided into two major clusters consisting of seven sub-groups. Group I has one member; *Colocasia* sp, and group II consists of *C. esculenta*, *C. affinis* and *Colocasia* wild type. The morphological similarity coefficient ranges from 0.615 to 0.974 (61.5–97.4%).

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