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# A Review of the Taxonomy and Taxonomic Characters of Philippine *Alocasia* (Schott) G. Don (Araceae)

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**This study was conducted to provide insights in the taxonomy of Philippine *Alocasia* by investigating the morphology, anatomy and pollen characters of the component species. Results showed that morphological characters can be used to a certain extent in delimiting taxa, while leaf anatomical characters showed continuous variation between species and are not of much use for taxonomic recognition when used alone. The combined morphology, anatomy and pollen characters showed a clear distinction on the 'heterophylla', 'longiloba', 'macrorrhizos', 'odora', 'princeps' and 'scabriuscula' groups, which agree with the classification of *Alocasia* proposed by Hay in 1991, 1998, 1999. The distribution and ecology of the species were also reported. The center of diversity of *Alocasia* in the Philippine archipelago is in Luzon and the Visayan regions. All of the species, except *A. macrorrhizos*, are endemic to the country. This study shows that the Philippines now ranks second, next to Borneo, in terms of species diversity of *Alocasia*.**

Key Words: *Alocasia,* Araceae, biogeography, palynology, Philippines, plant anatomy, raphides, collenchymas cells, spathe, infructescence

## INTRODUCTION

Araceae is one of the most ecologically and structurally diverse family of monocots occupying a wide variety of habitats and display a notable diversity of life forms from geophytes, climbers, epiphytes, helophytes to free-floating aquatics (Croat 1998, Grayum 1990, Mayo et al. 1997). The family is represented by 114 genera and 3,750 species (Boyce 2004, Croat 1988). In the Philippines, it is represented by 25 genera and *ca*. 150 species, with *Alocasia* having the most number of species (see also Merrill 1923).

*Alocasia* (Schott) G.Don is a genus of major horticultural importance and agricultural significance in tropical and subtropical Asia (Manner 2011). *Alocasia macrorrhizos* (L.) G.Don, for example, is an important food plant in the Visayan region particularly in Samar and Leyte. The rhizome of many *Alocasia* species is a good source of starch and the leaves are used as feed for animals, while several species, such as, *A. clypeolata* A. Hay, *A. sanderiana* W. Bull., *A. sinuata* N.E. Brown, *A. scalprum* A. Hay and *A. zebrina* Schott ex van Houtte are grown as ornamental plants (Steiner 1960). The genus comprises more than 110 species distributed from Sri Lanka through Indochina to China, southern Japan, the Malesian region, Oceania and Australia (Nauheimer et al. 2012). It is most diverse in Borneo (*ca*. 50 species), the Philippines (*ca*. 15), and New Guinea (*ca*. 12). Apparently, the Philippines is the second most species-rich area in Malesia next to Borneo (Hay 1999). However, the species report is based mainly on herbarium specimens and horticultural records. Field data as well

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as assessments of ecological and distributional patterns are needed to confirm this report.

The taxonomic revision of *Alocasia* was first made by Engler and Krause (1920). Regional revisions were also done by several taxonomists, e.g., Sri Lanka (Nicolson 1987), East Malesia and Australasia (Hay & Wise 1991), Himalaya (Noltie 1994) , West Malesia and Sulawesi (Hay 1998), Philippines (Hay 1999) and Thailand (Boyce 2008). The taxonomic revisions were done, however, mostly at 'alpha-level' taxonomy. Hay & Wise (1991) divided the Australasian *Alocasia* species into five groups. The West Malesia and Sulawesi species fall into six groups (Hay 1998), but no formal grouping is proposed yet for Philippine species. Some Philippine species showed affinities with the West Malesian "longiloba group" (*A. sanderiana* and probably *A. boyceana*), West Malesian "puber group" (*A. maquilingensis*) , Bornean "scabriuscula" group (*A. sinuata*) and Australasian "macrorrhizos" group (*A. macrorrhizos* and *A. portei). Alocasia atropurpurea*, *A. clypeolata* and *A. micholitziana* is perhaps allied to continental Asian *A. odora* (Lodd.) Spach. Other species, especially the "heterophylla group" showed no particular affinities, thus, it needs further study (see Hay 1998, 1999).

There is no modern monograph of the genus *Alocasia* in the Philippines to date and this work endeavors to contribute towards this goal. The Philippine species have not been well studied taxonomically. According to Hay (1999) there are six species of Philippine *Alocasia* known from very few botanical collections and have restricted distributions. He recommended that the actual conservation status of these species be verified by local botanists who have access to field conditions. Thus, this study attempts also to assess the conservation status of the species in their natural habitat in order to establish measures for protection and conservation.

In essence, this paper presents a review of the taxonomy and taxonomic features of the species of *Alocasia* based on external morphology, internal anatomy (leaves), and palynological (pollen) characters. It also provides the information of the species geographic distribution in the country.

## MATERIALS AND METHODS

The study was based on herbarium specimens as well as living materials. Morphological, anatomical and palynological studies were conducted. Type specimens of Philippine *Alocasia* were loaned from major herbaria (K, L, MO and GH). Local herbaria like CAHUP, CMU and PNH were also visited.

For anatomical investigation, Johansen's (1940) free hand sectioning technique was employed. The anatomical structures of the leaf petiole and midrib were described following the terminology of French & Tomlinson (1981) and Keating (2000, 2003, 2004). Paraffin method, clearing and epidermal peels used by Johansen (1940) were also employed in observing the stomatal distribution and epidermal pattern.

For examination of pollens, the procedure of Erdtman (1966) was followed. Pollens were examined and observed using Light Microscope (LM) and Scanning Electron Microscope (SEM).

## RESULTS AND DISCUSSION

**Morphology**

Philippine *Alocasia* exhibits four types of growth forms. It can be grouped into: (1) very massive pachycaul herb, (2) robust caulescent herb, (3) moderately robust herb, and (4) small or diminutive herb. Species characterized by a very massive pachycaul growth habit are *Alocasia macrorrhizos* (L.) G. Don and *A. portei* Schott. These two species are trunk forming reaching up to 6 m tall and the mature plant develops a tessellated grayish brown bark. The trunk, however, is not so woody. *Alocasia atropurpurea* Engl. and *A. maquilingensis* Merr. are examples of robust caulescent herbs having a massive growth form reaching a height of up to 1.5 m tall. Most other species of the moderately robust herbal growth form in the Philippines reach a height of up to 70 cm with erect to decumbent stems. These include *A. boyceana* A. Hay*, A. culionensis* Engl.*, A. micholitziana* Sander*, A. nycteris* M.P. Medecilo, Yao & Madulid*, A. sanderiana* and *A. zebrina*. *Alocasia clypeolata, A. heterophylla* (Presl.) Merr., *A. ramosii* A. Hay*, A. scalprum* and *A. sinuata,* are categorized as small to diminutive herbs reaching a height of up to 40 cm.

Lamina shape is highly variable in *Alocasia*. The species can be grouped according to the shape of the blade. *Alocasia culionensis* has a narrowly hastate to sagittate blade. *Alocasia atropurpurea* is characterized to have a cordato-sagittate blade. *A. boyceana*, *A. heterophylla*, *A. ramosii* and *A. zebrina* have narrowly triangular to hasto-sagittate leaves. The species with broadly ovato-sagittate blade include *A. clypeolata*, *A. macrorrhizos*, and *A. maquilingensis*. *A. sinuata* has narrow ovato-sagittate leaves and is the only species having a bullate and deeply coriaceous blade. *Alocasia portei* and *A. sanderiana* have sagittate to deeply-pinnatifid blade, while *A. scalprum* is the only species with falcate, narrowly lanceolate blade.

Seven types of leaf margins are found in Philippine *Alocasia*. Species with entire leaf margins are *A. atropurpurea, A. clypeolata, A. scalprum* and *A. zebrina*.

*Alocasia boyceana* is the only species with a slightly undulate to entire leaf margin. *Alocasia culionensis* has a shallow sinuate to undulate margin. Species with entire to shallowly sinuate margins are *A. heterophylla, A. macrorrhizos, A. maquilingensis,* and *A. ramosii*. *Alocasia micholitziana* has a strongly undulated leaf margin. *Alocasia nycteris* and *A. sanderiana* have deeply undulate to subpinnatifid leaf margin, while *A. portei* has a strongly crispate to deeply-lobed margin (Figure 1).

*Alocasia* inflorescence is composed of spathe and spadix. The spathe is divided into a thicker convolute thicker lower portion called the lower spathe and the upper thinner open limb. These two portions are differentiated by a constriction. The shape of the lower spathe can be globose, funnel-form to cucullate and/or tubular at maturity and wraps all around at least the lower portion of the spadix. Species with globose lower spathes are *A. atropurpurea, A. clypeolata* and *A. sanderiana.* In some species, the shape of the lower spathe is subglobose, e.g., *A. boyceana, A. culionensis, A. heterophylla, A. maquilingensis, A. micholitziana, A. nycteris, A. ramosii, A. scalprum* and *A. sinuata*, and in few species it is ovoid, e.g., *A. macrorrhizos, A. portei* and *A. zebrina*.

The female zone of the spadix is at the base below the sterile instertice, male zone and the appendix. Most species have a cylindric female zone consisting of unisexual flowers with only up-turned flask-shaped, globose and subglobose, naked pistils. The gynoecium in *Alocasia* is unipistillate with a short style (sometimes absent) and a thick to conical, discoid stigma (sometimes

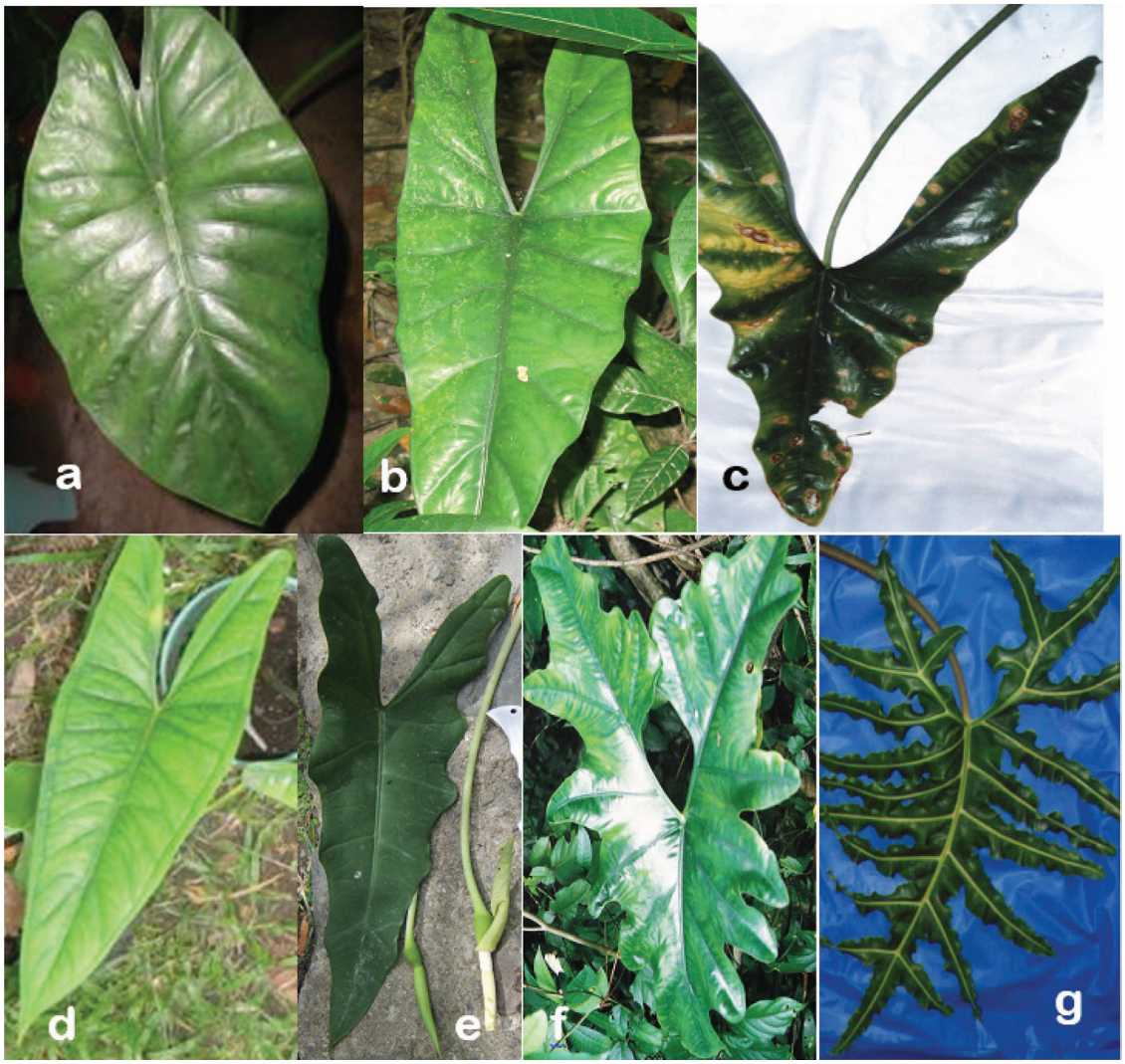


**Figure 1.** Seven types of leaf margins found in Philippine *Alocasia***.** (**a**). *A. sp. nov***.** with an entire margin; (**b**). *A. boyceana* with slightly undulate to entire margin; (**c**). *A. culionensis* with shallow sinuate to undulate margin; (**d**). *A. heterophylla* with entire to shallowly sinuate leaf; (**e**). *A. micholitziana* with a strongly undulate leaf margin; (**f**). *A. nycteris* with deeply undulate to subpinnatifid leaf; and (**g**). *A. portei* with a strongly crispate to deeply lobed leaf margin.

sessile, if style is absent). Some ovaries are closely-spaced (*A. atropurpurea, A. macrorrhizos, A. maquilingensis* and *A. portei*) while majority of the species, such as *A. boyceana, A. clypeolata, A. culionensis, A. heterophylla, A. micholitziana, A. sanderiana, A. scalprum* and *A. sinuata*, the ovaries are widely-spaced. The stigma can be 2-3 lobed (*A. heterophylla, A. culionensis* and *A. scalprum*), 3-lobed (*A. clypeolata, A. maquilingensis, A. sinuata* and *A. nycteris*), 3-5 lobed (*A. macrorrhizos*), or weakly lobed (*A. micholitziana, A. portei, A. sinuata* and *A. zebrina*), but in some species, it is inconspicuous and may or may not have a style (Figure 2).

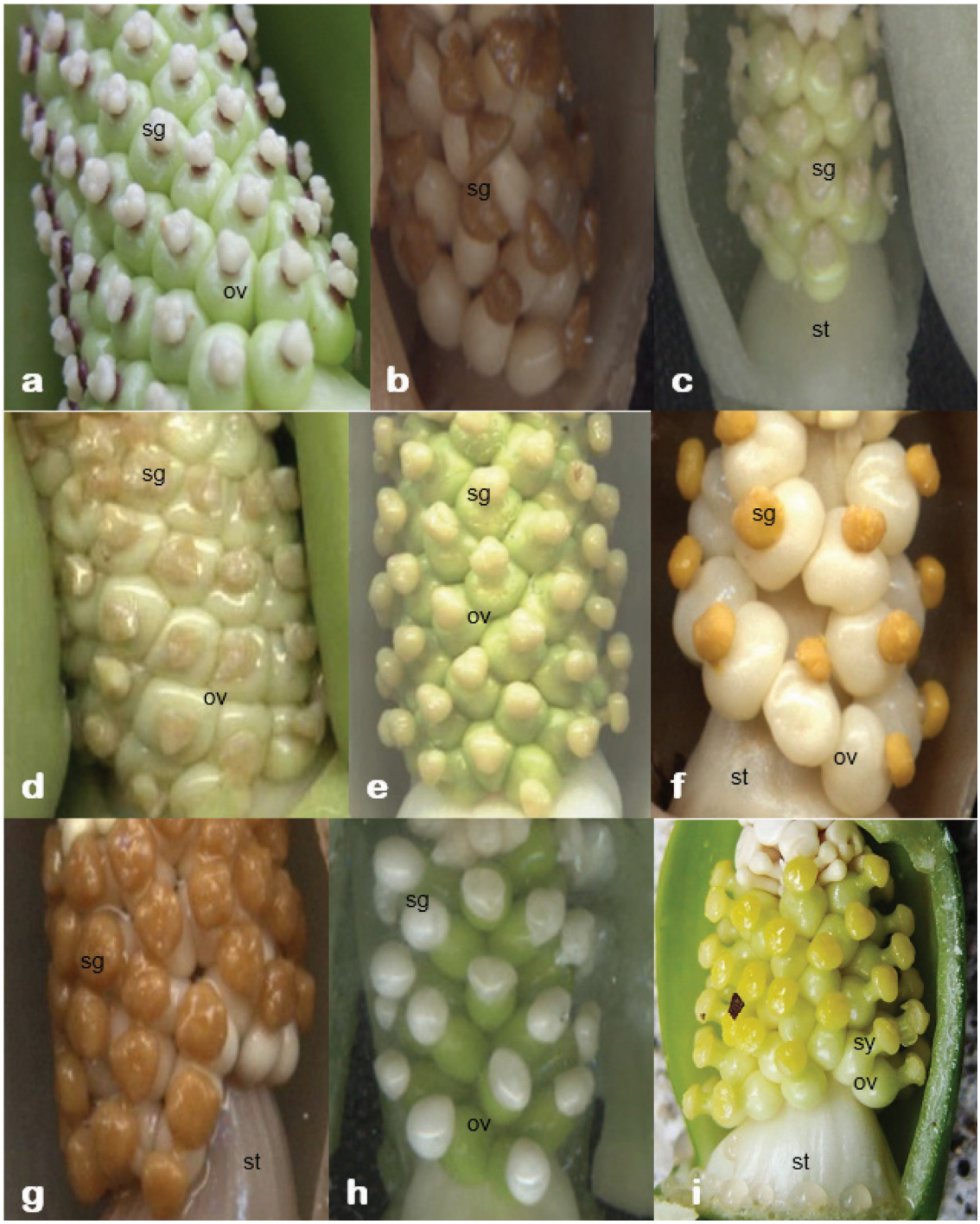


Figure 2. Female flower zone of Philippine *Alocasia* showing the arrangement of the ovaries (ov), appearance of stigma (sg) and presence of style (sy) and stipe (st). (**a**). *A. atropurpurea*; (**b**). *A. clypeolata*; (**c**). *A. heterophylla*; (**d**). *A. macrorrhizos*; (**e**). *A. maquilingensis*; (**f**). *A. micholitziana*; (**g**). *A. sanderiana*; (**h**). *A. sinuata*; and (**i**). *A. zebrina*.

The shape of the ovary may be subglobose (*A. atropurpurea, A. boyceana, A. maquilingensis, A. macrorrhizos, A. nycteris, A. portei, A. ramosii* and *A. scalprum*), subspheroidal (*A. sanderiana*), globose (*A. clypeolata*, *A. micholitziana* and *A. zebrina*), or upturned flask-shaped (*A. culionensis, A. heterophylla* and *A. sinuata*).

The synandria of Philippine *Alocasia* differs in shape with or without a synconnective. *Alocasia atropurpurea* is irregularly-shaped (4-5 merous) with indistinct stamens. In some species (*A. macrorrhizos* and *A. portei*) the vertical pollen thecae are attached throughout the length to its flanks. The thecae reach the top of the synandrium and open through apical pores. The synconnective is expanded on the top of the thecae so that pollen is release in the apical slits into the spaces between the synandria. The appendix of some species is smooth (*A. boyceana*, *A. heterophylla* and *A. ramosii*), in other species it is sinuously, longitudinally and forms a finely channeled irregular compressed synandrodia (Hay 1998). In Philippine *Alocasia,* the texture of the appendix varies. *A. atropurpurea* has a strong stony or rocky-like texture, blunt and white in color, while *A. sanderiana* has a slight stony texture or brain-like pattern. *Alocasia clypeolata*, *A. culionensis,* and *A. micholitziana* have smooth texture with longitudinal slits. The species with sinuous appendix are *A. macrorrhizos*, *A. maquilingensis*, *A. nycteris* and *A. portei*.

After pollination, only the female part of the spadix and the lower spathe remain and the lower spathe enlarges to accommodate the developing fruits. The spathe varies in color from ivory white (*A. maquilingensis*), green to dark green (*A. boyceana, A. heterophylla, A. macrorrhizos, A. nycteris, A. ramosii, A. scalprum, A. sinuata* and *A. zebrina*), or purplish green (*A. atropurpurea*, *A. portei* and *A. sanderiana*). It splits longitudinally later to expose the ripe fruitlets of the infructescence, which are ovoid (*A. macrorrhizos, A. maquilingensis, A. portei, A. zebrina*) to globose (*A. micholitziana, A. sanderiana, A. ramosii, A. heterophylla, A. scalprum*, and *A. sinuata*) (Figure 3). The fruits are berry, yellowish to reddish orange when ripe, odorless, fleshy, and contain one to several seeds which are a few millimeters in diameter.

**Anatomy**

The anatomical structure of the petiole of *Alocasia* consists of the epidermis, collenchyma strands, peripheral and central vascular strands, parenchyma ground tissues, and air chambers. Most of the petiole is circular in cross sectional view. It has thin distinct continuous layer of epidermis of squarish, oblong and rectangular cells with thin wall. Inner to the epidermis there are several large masses of collenchyma cells forming collenchyma strands, and inner to them are compacted, fairly wide, parenchymatous ground cells. In the central portion, there are wide circular air chambers scattered among the parenchymatous ground tissues. The vascular system consists of peripheral and central vascular strands; the peripheral strands are located opposite to collenchyma strands, and the central strands are more or less scattered in between the wide air chambers. The epidermis of all the species are glabrous except in *A. maquilingensis* which has trichomes (Fig. 4e). Grayum (1990) reported that trichomes and other ornamentation occur in Araceae, but is rare. He further added that this character is of no phylogenetic significance in the family.

The cross section of petiole exhibits six shapes, e.g., oval, semi-circular, circular, semi-circular with one groove, semi-circular with two grooves, and wavy semi-circular shape. Oval shape occurs in *A. macrorrhizos* only. Species with circular shape are *A. clypeolata*, *A. maquilingensis*, *A. micholitziana, A. portei*, *A. ramosii* and *A. tigrina*, Most of the species, such as *A. atropurpurea, A. heterophylla, A. nycteris, A. scalprum* and *A. sinuata*, have semicircular shape with one groove, while *A. boyceana* is the only species having a semi-circular shape with two grooves.

Collenchyma cells are considered as supporting tissue (Esau 1977). These cells are grouped into multicellular strands or bands that are well-demarcated from adjacent parenchyma ground tissues. It is characterized as more elongated than adjacent ground tissues, angularly thickened, non-lignified and found at or near the perimeter of midrib and petioles (Keating 2000). Most species (*A. boyceana, A. heterophylla, A. portei, A. ramosii* and *A. sanderiana*) have the collenchyma strands located one cell layer from the epidermis. *Alocasia macrorrhizos* and *A. nycteris* have them 1-2 cell layers from the epidermis. A. *atropupurpurea, A. sinuata, A. scalprum,* and *A. micholitziana* (velvet var.) have them 2 cell layers from the epidermis, while *A. maquilingensis* has the strands 3-4 cell layers from the epidermis. Keating (2004a, 2004b) and Goncalvez et al (2004) reported that collenchyma strands in the genus *Alocasia* are of Sv type. This type has the collenchyma cells which form the circular or semi-circular strands that are aligned or located on the same radii as the perimeter vascular bundles. Collenchyma strands are either located proximally to the phloem or more distant, but not directly contiguous with perimeter vascular bundles.

Vascular bundles may be scattered in the petioles of *Alocasia*, but majority are concentrated in the center or pith. The bundles are completely surrounded by parenchymatous ground tissues and are not in direct contact with air cavities**.** Grayum (1984) observed that each vascular bundle may or may not be accompanied by groups of fibers in the petioles of many species in Colocasioideae. Sometimes the bundles in the periphery

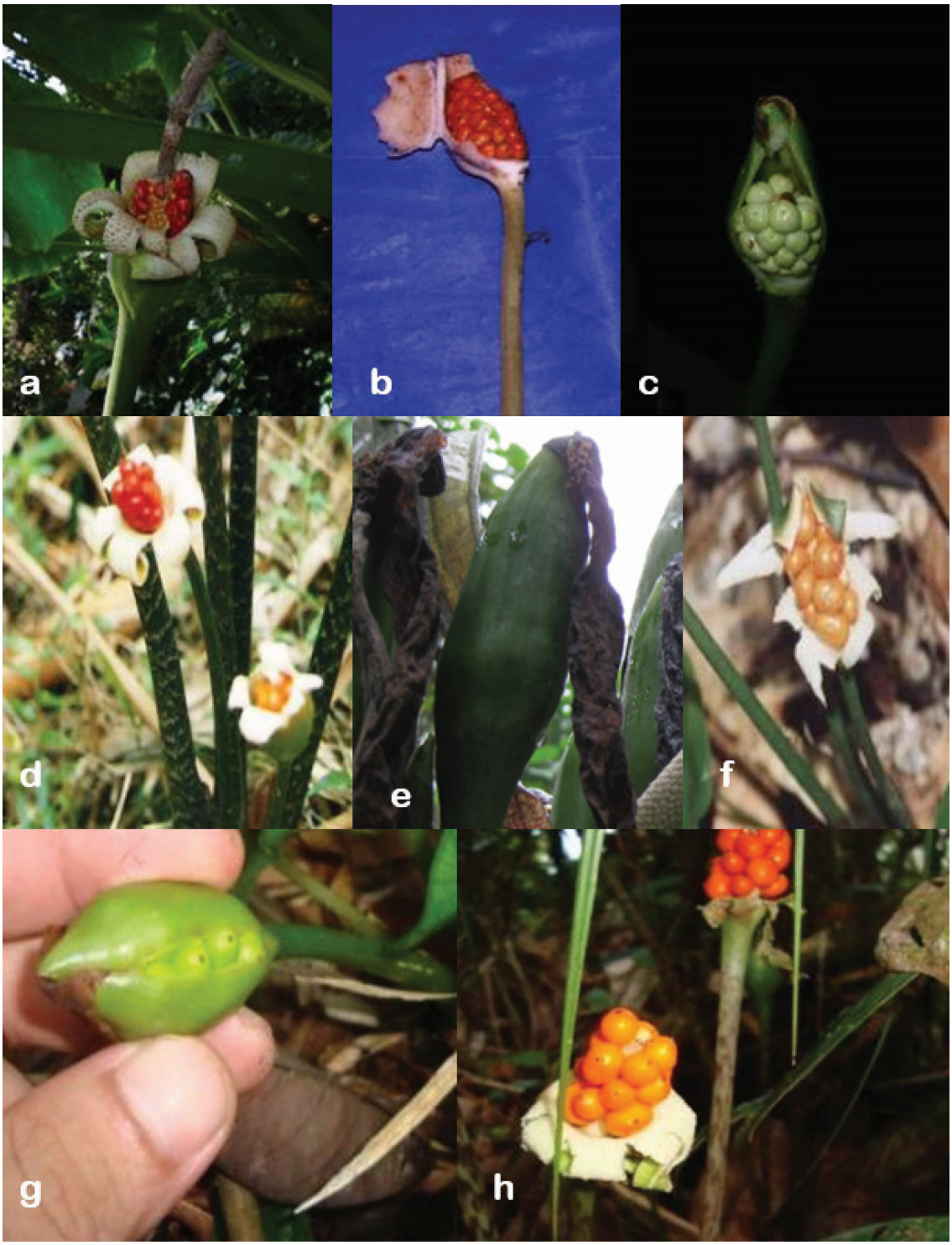


**Figure 3**. Infructescence and fruits of Philippine *Alocasia.* **(a)** *A. macrorrhizos*; **(b)**. *A. maquilingensis*; **(c)**. *A. micholitziana*; **(d)**. *A. nycteris*; **(e)**. *A. portei*; **(f)**. *A. ramosii*; **(g)**. *A. scalprum*; and **(h)**. *A. zebrina.*

are accompanied by collenchymatous sheath or strand. This is found in the petioles of *Alocasia*.

Aroids possess calcium oxalate crystals in every organ of the plant. All genera of aroids have a simple raphide cell of an irregularly-shaped and thin-walled cell forming a single raphide bundle (Keating 2003). The number of raphides in one secretory cavity varies. *Alocasia heterophylla, A. ramosii, A. scalprum* and *A. sanderiana* have only one raphide crystal located at the edges of secretory

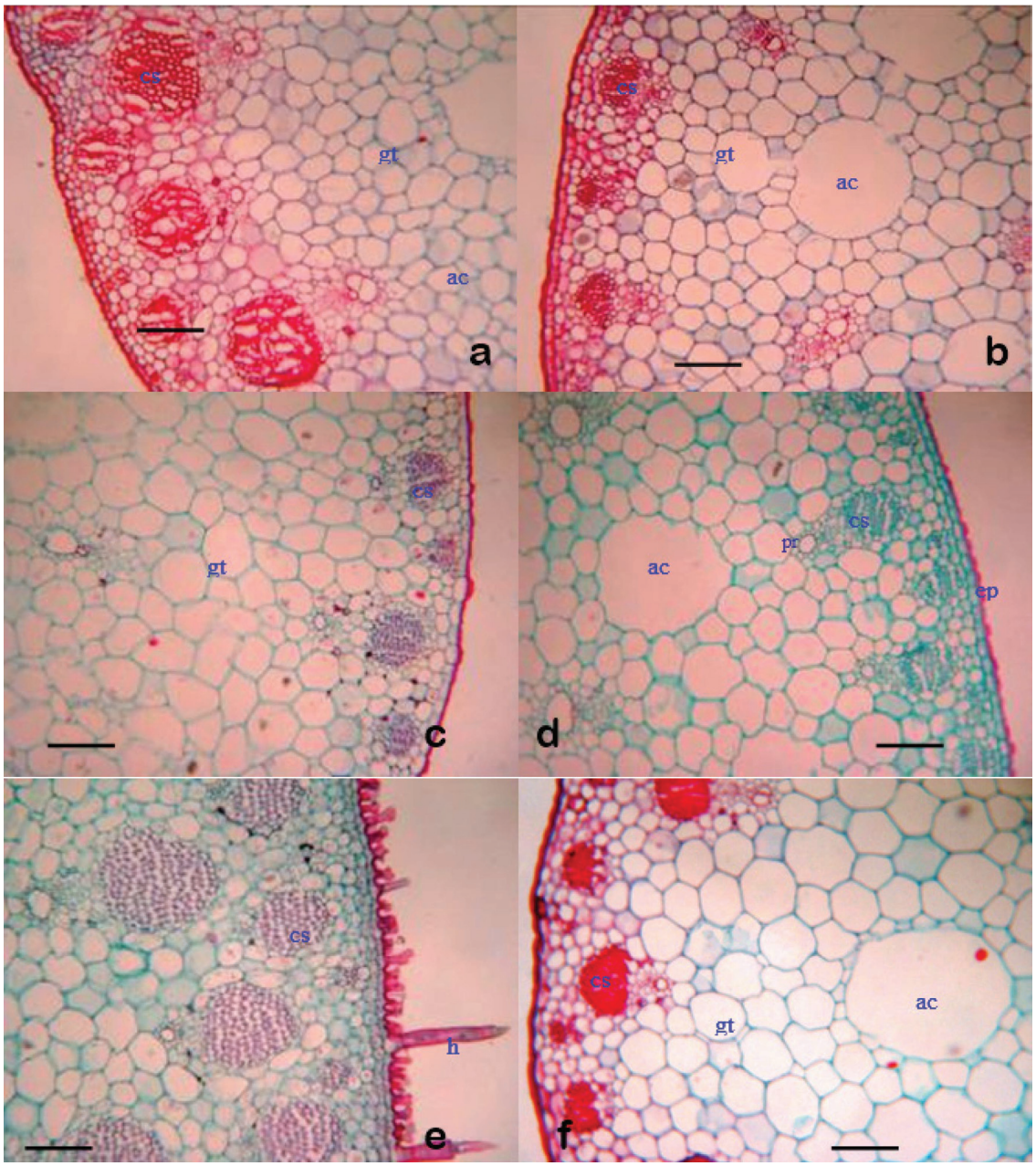


**Figure 4**. Petiole transverse section of some species of Philippine *Alocasia*. (**a**). *A. boyceana* with circular collenchyma strand (cs) and polygonal air cavities (ac); (**b**). *A. clypeolata* with circular air cavities (ac); (**c**). *A. heterophylla* with rough epidermis; (**d**). *A. macrorrhizos* with polygonal air cavities and circular protoxylem (pr); (**e**). *A. maquilingensis* showing the trichomes (t) in the epidermis. and (**f**). *A. zebrina* showing the ground tissues (gt) and large air cavities (ac) Scale bar = 140 µm.

cavities. 1-2 raphides per cell occur in *A. atropurpurea*, *A. boyceana, A. macrorrhizos, A. maquilingensis*, *A. micholitziana* and *A. nycteris.* The species with more than 5 raphides in one secretory cavity are *A. maquilingensis* and *A. scalprum*.

Raphides length ranges from 50-125 µm. The species with the shortest length is *A. boyceana* (50 µm), followed by *A. maquilingensis* with 62.5 µm. *Alocasia zebrina* and *A. heterophylla* have the longest raphide (125 µm). The width of raphides also varies between species. The shortest width is 25 µm in *A. cf. maquilingensis* and *A. heterophylla*, while most species have a raphide width of 50µm.

Raphide cell types in petiole and leaf tissues of Araceae were identified by Keating (2004a, 2004b). Nine types occur in the family, namely, unmodified (U), wide (W), elongate (E), tubular (T), articulate (Ta), spindle-shaped (Sb), and biforine (B). In *Alocasia*, only 4 types occur,

namely, tubular, spindle-shaped, elongate and wide. Most species have tubular (T) cell type and this occurs in *A. boyceana, A. culionensis, A. micholitziana* (velvet var.), *A. nycteris, A. ramosii, A. sinuata, A. scalprum, A. sanderiana* and *A. zebrina,* while *A. heterophylla* have elongate raphide crystal. *Alocasia clypeolata*, on the other hand, has wide raphide cell type. Some species has more than one raphide cell type. *A. atropupurea* and *A. maquilingensis* have both elongate and spindle-shaped types.

The transverse section of leaf shows dorsiventral nature with prominent midrib and lamina attached on the adaxial part spreading laterally. The midrib has thin epidermal layer of circular to rectangular cells with thin walls, wide air cavities or chambers in the center, thick masses of collenchyma strands, parenchymatous ground tissues and vascular bundles. The air chambers are circular, semicircular or angular wavy in shape varying from narrow to wide being located in the central part.

Venation in most aroids leaves is characterized by a distinct midrib. The midrib shape and size show systematically useful variations in a few genera of aroids (Keating 2003). Adaxial (upper) and abaxial (lower) midrib surfaces are described as convex, rounded or ridged, flat or concave. Five midrib types occur in Philippine *Alocasia*. These are slightly convex adaxially and deep rounded abaxially, i.e., *A. atropurpurea, A. boyceana* and *A. macrorrhizos*; slightly convex adaxially and abaxially, e.g., *A. clypeolata, A.micholitziana* and *A. zebrina*; flat adaxially and deep rounded abaxially, as in the case of *A. culionensis, A. portei* and *A. ramosii*; slightly convex adaxially and rounded/ridged abaxially, i.e., *A. heterophylla*, *A. maquilingensis* and *A. scalprum*; and flat adaxially, slightly convex abaxially, i.e., *A. nycteris, A. sanderiana* and *A. sinuata*).

Midrib size or thickness range from 1062.50 µm (lowest) to 10,000 µm (highest). The species with the smallest size is *A. sinuata*, while *A. macrorrhizos* has the biggest midrib (10,000 µm). Most species have medium midrib size ranging from 2000 to 3000 µm. Midrib has columnar parenchyma cells in the adaxial region while collenchyma strands are abundant in the abaxial side. Collenchyma strands are semicircular to circular in shape similar with petiole transaction. Vascular bundles are few to abundant and scattered in the central part.

The cross section of lamina is composed of the cuticle, upper and lower epidermis, bundles of collenchyma strands, ground tissues, secretory cavities and vascular bundles. These structures are also found in the petiole. The pattern of distribution in the petiole as well as in leaves does not change quantitatively with the age of the plants. The distribution of collenchyma strand formation in the leaves of *Alocasia* is of Colocasioid pattern. This pattern is characterized by rounded strands of collenchyma cells concentrically disposed. The thickness of collenchyma strands is a variable feature among species. In the present study, *Alocsia macrorrhizos* and A. *atropurpurea* have the greatest width which ranges from 210-230 µm. Other *Alocasia* species have width ranges from 150-200 µm (*A. boyceana, A. clypeolata*, *A. heterophylla* and *A. maquilingensis*), while the rest of the species has the width ranges from 80-125 µm (*A. culionensis, A. nycteris, A. portei, A. ramosii, A. scalprum, A. sinuata* and *A. zebrina*).

The usual epidermal cell outline is polygonal in many genera of aroids, including *Alocasia*. Anticlinal cell walls maybe straight-sided, undulate or deeply sinuous. Species with wavy cell walls of epidermal pattern are *A. culionensis, A. heterophylla, A. maquilingensis* and *A. zebrina*. Species like *A. atropurpurea, A. boyceana, A. portei, A. macrorrhizos,* and *A. maquilingensis* have polygonal epidermal walls, while *A. clypeolata, A. micholitziana, A. nycteris*, *A. ramosii, A. sanderiana* and *A. sinuata* have sinuous cell walls.

The length of stomata varies from species to species of *Alocasia*. *A. boyceana* has a length of 1.0 µm (being the shortest), followed by *A. clypeolata* (1.3 µm), while *A. zebrina* has the longest length of 4.55 µm. The number of stomata (abaxial side) in one microscopic field was also counted. The species with lesser number of stomata (6-8) are *A. heterophylla*, *A. micholitziana*, and *A. sanderiana*, while *A. clypeolata*, *A. portei* and *A. sinuata* have more than 20 stomata in one microscopic field. Grayum (1990) pointed out that most genera of aroids have hypostomatic or amphistomatic leaves with more stomata on the lower surface, which we also find in the present study.

**Palynology**

All pollen grains of Philippine *Alocasia* are of echinate type which is considered by Grayum (1990) as the most highly derived condition. These spinose exines are specialized for pollen dispersal by insects, such as beetles and flies. The pollen grains of *Alocasia* species are inaperturate, bilaterally symmetrical, monad, apolar and monosulcate. Inaperturate pollens are characterized by a constantly thick endexine and intine throughout the pollen grain. Three shapes of pollen were observed in *Alocasia* and based on P/E ratio or the ratio between the polar axis (P) and the maximum length of equatorial size axis. These are spherical/globular (P/E approximately equal to1), oblate (P/E less than 0.8), and prolate or elongate (P/E is greater than 1.2). Most species of *Alocasia*, such as *A. atropurpurea*, *A. boyceana*, *A. clypeolata*, *A. culionensis, A. heterophylla, A. macrorrhizos, A. micholitziana, A. portei, A. ramosii, A. sanderiana, A. scalprum, A. sinuata,* and *A. nycteris* are spherical or globose in shape (Figure 5). The only species having an oblate shape is *A. zebrina* while *A. maquilingensis* has prolate or elongate shape.

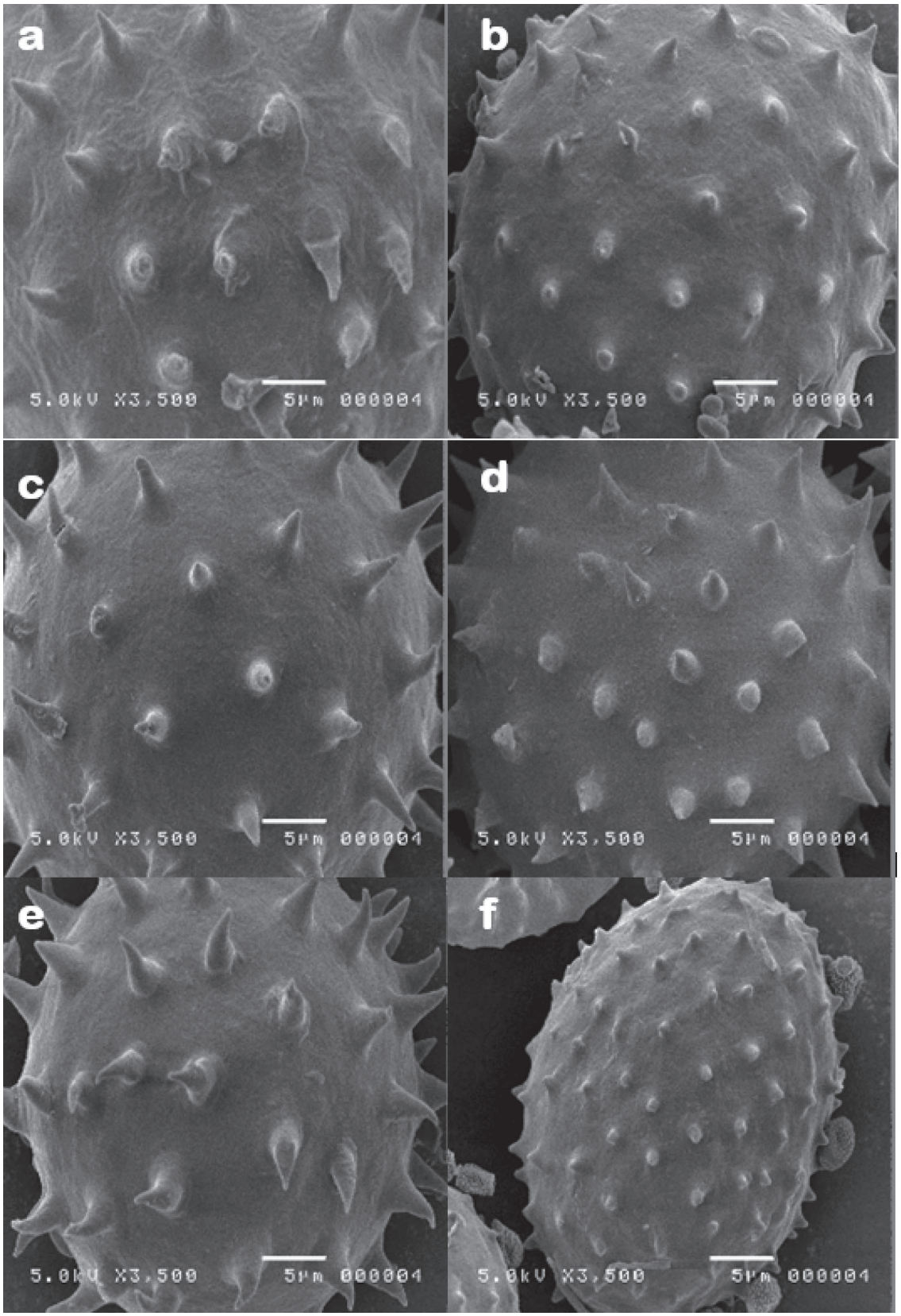


**Figure 5**. Scanning Electron Micrograph of pollens of Philippine *Alocasia* showing the pollen surface and spinuous ornamentation, (**a**). *Alocasia culionensis*, (**b**). *A. macrorrhizos*, (**c**). *A. portei*, (**d**). *A. sinuata*, (**e**). *A. zebrinam*, (**f**). *A. sp. nov. prop*. All scale bars are 5 µm.

Based on Erdtman's (1966) criteria of pollen size, there are six ranges in Philippine *Alocasia*. The size ranges from very small grains (<10 µm), small grains (10-25 µm), medium-sized grains (25-50 µm), large grains (50-100 µm), very large grains (100-200 µm) and gigantic grains (>200 µm). However, in the Philippine specimens examined only three sizes occur. *Alocasia sanderiana* is the only species having the smallest grain (25 µm). Ten species has medium-sized grains. These are *A. atropurpurea*, *A. boyceana*, *A. culionensis*, *A. heterophylla*, *A. macrorrhizos*, *A. maquilingensis*, *A. nycteris, A. scalprum* and *A. sinuata*. Five species, namely, *A. clypeolata*, *A. macrorrhizos*, *A. micholitziana*, *A. portei*, *A. ramosii* and *A. zebrina* have very large grains. As discussed above, all species of *Alocasia* are of echinate type. Variation occurs in the size and shape of the spines. *A. sanderiana* has short (1-2 µm) spines; *A. clypeolata*, *A. micholitziana*, *A. ramosii* and *A. scalprum* have an elongate (2-3 µm) spines. The species with spines length of 3-4 µm are *A.atropurpurea*, *A. maquilingensis*, and *A. portei*. Species with spines length of 4-5 µm are *A. culionensis* and *A. heterophylla*. *Alocasia zebrina* has the spine length of 5-6 µm; *A. ramosii*, *A. nycteris* and *A. sinuata* have spines length of 2-4 µm, and *A. macrorrhizos* has the longest length of spines (6-7 µm), while *A. boyceana* has a variable length of spines ranging 2-6 µm.

**Geographic Distribution**

*Alocasia* occurs in all parts of the Philippines. Nearly all species are endemic in the country, except *A. macrorrhizos*, which is widespread and occurs in Indo-Malesia and Oceania. One endemic species, *A. zebrina*, is found in Luzon, Visayas and Mindanao islands. Another species which is of wider distribution is *A. boyceana*. It is found in Visayas (Cebu, Negros, Samar and Leyte), Mindanao (Jolo, Camiguin, Cotabato) and Luzon (Bataan). *Alocasia micholitziana* is found in Rizal, Laguna, Benguet and Ifugao provinces. Four species of *Alocasia* occur in Samar and Leyte islands, a Pleistocene island complex. These are *A. boyceana A. sinuata, A. scalprum* and *A. zebrina*. These two islands are remarkable in having rich species although they have relatively small land areas. Natural populations of *A. sanderiana* are confined to Mindanao island only. It is found in the provinces of Bukidnon, Agusan, Lanao, Butuan, Surigao and Misamis Occidental. Based on the findings, it is apparent that Luzon and Visayas islands are the centers of distribution of *Alocasia* in the Philippines, having 10 species each, while Mindanao with 8 species.

Habitat-wise, several species, such as *A. sinuata, A. clypeolata* and *A. heterophylla* are restricted to limestone areas. *Alocasia sinuata* grows in limestone areas near beaches and at lower elevation between 29-200 masl. Most other species are confined to well-drained sites in non-limestone areas, i.e., *A. culionensis, A. ramosii*, *A. scalprum, A. sanderiana* and *A. zebrina*, These species are in association with other aroid herb species in primary and secondary forests. Some species grow in lowland secondary forest patches on well-drained soils and old reforested, generally dry areas with thick leaf litter. *Alocasia sanderiana* grows well in primary forest with an altitudinal range of 500-800 masl. Species that are found in open field or in gap spaces are *A. portei*, *A. macrorrhizos* and *A. zebrina. Alocasia nycteris* occur in disturbed areas near rice fields and along roadsides and occurs outside primary forest and in lower elevation at 0-5 m. *Alocasia micholitziana* occurs along roadsides in open areas.

**Conservation Notes**

Most of the Philippine *Alocasia* species are of ornamental or of potential ornamental value and are presently threatened by over-collection and habitat destruction. There are several species of Philippine *Alocasia*, i.e., *A. atropurpurea, A. nycteris, A. scalprum, A. sinuata* and *A. sanderiana* that are restricted in their distribution and are known only from few natural localities today. They are presently threatened in various degrees and in need of protection. However, they are not in the CITES list, whereas *A. sanderiana* and *A. zebrina* are included in the National List of Threatened Species of the Department of Environment and Natural Resources (DENR).

Three species of Philippine *Alocasia* have been evaluated and included in the 2008 IUCN Red List of Threatened Species (Medecilo & Ong 2008a, 2008b, Medecilo et al. 2008). Based on the 2001 Criteria (v3.1) all three were categorized as critically endangered (CR). They are *A. atropurpurea, A. sinuata*, and *A. sanderiana* (see www.iucnredlist.org).

## CONCLUSIONS

The combined uses of characters of morphology, leaf anatomy and palynology are best in defining and identifying the species of Philippine *Alocasia* and this observation conforms with the classification of Hay (1991, 1999).

Based on habit and morpho-anatomical characters of the leaves, Philippine *Alocasia* species consists of 15 species constituting seven distinct species groups (see Table 1).

**Table 1**. Tentative grouping of Philippine species of *Alocasia* based on external morphology, internal anatomy and pollen characters.

| Species Group | Taxa | Characters Distinct to the group |
|---|---|---|
| Heterophylla | *A. boyceana*, *A. heterophylla*, *A. ramosii* | Small herb up to 50 cm tall; stem erect to decumbent, sheathing in the lower third; blade narrowly sagittate, margins shallowly sinuate; opening by apical pores in the synandria not capped by synconnective, appendix up to 2 cm long, ivory white and tapering; petiole and leaf internal anatomy consists of 1 layer of collenchyma strand; pollen globose |
| Longiloba | *A. sanderiana* | Seasonally dormant; cataphylls thinly membranaceous, degrading into sparse fibers; blades always 2-together, peltate and pendulous, purple abaxially with white major venation; spathe limb opening wide and deciduous, whitish green flushed with purple; appendix ivory white, larger than the male zone, stony-like texture and blunt tip. |
| Macrorrhizos©© | *A. macrorrhizos*, *A. portei* | Very massive pachycaul herb; stem erect, trunk-forming tessellated with grey bark,; inflorescence pairs mostly interspersed with foliage leaves sometimes clustered in the crown; spathe constriction corresponding with the male zone; thecae of synandria in the male zone overtopped by synconnective; appendix more than 5 cm long; presence of raphides in air chambers and absence of trichosclereids |
| Odora | *A. atropurpurea*, *A. clypeolata*, *A. micholitziana* | With membranous, peltate leaves, cordato-sagittate, except *A. micholitziana*; spathe constricted about 1/5 away from the base; spadix shorter than spathe, sessile to shortly stipitate. |
| Princeps | *A. culionensis*, *A. nycteris*, *A. zebrina* | Moderately robust lithophytic or terrestrial herb; stems erect to decumbent; petioles smooth, sheathing in lower 1/8 – 1/3, bright grebe to purple brown, or marked with obliquely streaked brownish or dark green; blade triangular to narrowly triangular, rich glossy green, very dark green adaxially; posterior lobes about 1/3 to subequalling the length of the anterior lobe, except *A. zebrina* |
| Puber | *A. maquilingensis* | Massive arborescent plant; Leaves several together, often hairy; inflorescence numerous in succession, not interspersed with foliage leaves usually with horizontal elliptic often dark red glands on the lower spathe; male zone of spadix held partly within the lower spathe chamber; fruiting spathe white; pollen grain prolate. |
| Scabriuscula | *A. scalprum*, *A. sinuata* | Diminutive to small lithophytic or terrestrial herbs; leaves coriaceous, succulent, thick textured, secondary venation flush with the lamina abaxially and adaxially; lower spathe 1.1-1.5 cm long; spathe constriction corresponding above the base of the male zone of the spadix; ovary dark green, presence of pollen thecae in the synandria and slightly pointed, ivory white appendix |

**A key to the species identification of Philippine *Alocasia* based on the combined taxonomic characters discussed above is presented below.**

1a. Plants robust to very massive pachycaul 50 cm to 5 m tall . . . . . 2

1b. Plants diminituve to small herb, 20 cm to 50 cm tall . . . . . 10

2a. Leaf blade not peltate to very slightly peltate . . . . . 3

2b. Leaf blade slightly peltate to distinctly peltate . . . . . 8

3a. Inflorescence in numerous pairs clustered in the centre of the leaf crown; appendix more than 6 cm long, yellow . . . . . 4

3b. Inflorescence in pairs not clustered in the centre of the leaf crown; appendix less than 6 cm long, ivory white . . . . 6

4a. Stem not trunk forming; leaves pubescent; thecae of synandria in the male zone not overtopped by synconnective; fruting spathe white . . . ***A. maquilingensis***

4a. Stem trunk-forming; leaves glabrous; thecae of synandria in the male zone overtopped by synconnective; fruiting green to purplish green . . . . . 5

5a. Blade ovato-sagittate, with entire to very slightly sinuate margin; primary lateral veins up to 11 pairs; spathe limb green . . . . . ***A. macrorrhizos***

5b. Blade hasto-sagittate with deeply pinnatifid margin; primary lateral veins up to 9 pairs, yellowish; spathe limb purplish green . . . . . ***A. portei***

6a. Posterior lobes about 1/3 to subequalling the length of the anterior lobe . . . . . 7

6b. Posterior lobes shorter that the anterior lobe . . . ***A. zebrina***

7a. Lamina with deeply undulated to subpinnatifid margin; spathe up to 10 cm; spadix partly adnate to the lower

spathe at 1.5 mm . . . . . ***A. nycteris***

7b. Lamina with faintly undulate margin; spathe less than 10 cm; spadix free but obliquely inserted to the lower spathe . . . . . ***A. culionensis***

8a. Costae and primary lateral veins green; blade green, ovato-sagittate . . . . . 9

8b. Costae and primary lateral veins white; blade rich velvety matt deep green adaxially, paler abaxially, sagittate . . . . . ***A. micholitziana***

9a. Petiole up to 20 cm long; lower spathe spherical, asymmetric; limb cucullate, dark purplish brown; appendix with strongly-stony texture, tip blunt. . . . . ***A. atropurpurea***

9b. Petiole less than 60 cm long; lower spathe ovoid, symmetric; limb broadly lanceolate, whitish green; appendix smooth, tip tapering . . . . . ***A. clypeolata***

10a. Leaves pendulous, purple abaxially with white to yellow major venation; spathe limb opens-wide, deciduous, purplish red . . . . . ***A. sanderiana***

10b. Leaves slightly pendulous to erect, green abaxially with green major venation; spathe limb light green, slightly opens, not deciduous . . . . . 11

11a. Stems erect from 2cm to 5 cm long; leaves coriaceous, thick textured; stigma white. . . . . 12

11b. Stems decumbent to creeping up to 20 cm long; leaves membranous to slightly coriaceous. . . . . 13

12a. Plant with narrowly to broadly lanceolate blade, slightly falcate; stigma discoid, weakly lobed . . . . . ***A. scalprum***

12b. Plant with ovato-sagittate leaves, dark green, bullate with blackish green in the anterior costa; stigma triangular, 3-lobed . . . . . ***A. sinuata***

13a. Anterior costa of the blade not prominent abaxially; blade with 3-4 primary lateral veins diverging at 45-60º, distally deflected towards the leaf tip forming a submarginal veins . . . . . ***A. heterophylla***

13b. Anterior costa of the blade prominent abaxially; blade with 4-5 primary lateral veins diverging at 45-85º, not forming submarginal veins . . . . . .14

14a. Posterior lobes slender with blunt points, naked in sinus for 1-2cm; stigma with 3-4 lobed . . . . . ***A. boyceana***

14b. Posterior lobes narrow to broad, tapering to blunt point, sinus naked for 1-3 cm; stigma button-like . . . . . ***A. ramosii***

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