A COMPARATIVE ECOLOGICAL STUDY OF THE AROIDS IN HAU RIVER, VIETNAM AND PERAK RIVER, MALAYSIA

DUONG MINH TRUYEN

UNIVERSITI SAINS MALAYSIA

2015

A COMPARATIVE ECOLOGICAL STUDY OF THE AROIDS IN HAU RIVER, VIETNAM AND PERAK RIVER, MALAYSIA

By

DUONG MINH TRUYEN

Thesis is submitted in fulfillment of the requirements for the

Degree of Master of Science

AUGUST 2015

ACKNOWLEDGEMENTS

I wish to say thank you to the following people who contributed to the completion of my thesis in fulfillment of the requirement for the degree of Master of Science. First, I would like to express my deepest gratitude and sincere appreciation to my main supervisor, Prof Mashhor Mansor and my co-supervisor, Dr Amir Shah Ruddin for their guidance, constant encouragement, invaluable suggestions, generous help and support from the beginning until the end of the research and the writing of the thesis. Special thanks go to Mohamad Fikri bin Samsudin, Muzzalifah Abd Hamidsy, Norasikin Ismail, Phan Huynh Anh, Nguyen Trung Toan, Huynh Thao Tien and Nguyen Minh Chi for their advice and constructive suggestions. My sincere appreciations also go to all my colleagues who helped me during the sampling, analyses and writing. Thanks also go to the staff in School of Biological Sciences, Universiti Sains Malaysia for their help and moral encouragement. I am thankful to my parents and my sister for their immense help and encouragement, which inspired and motivated me during the duration of my study. I am very appreciative of all the support, commitment, facilities and trainings from all the parties above, which made me able to conduct and complete this study. I also place on record, my sense of gratitude to all who, directly or indirectly, have lent their helping hand in this venture.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

KAJIAN PERBANDINGAN EKOLOGI AROID DI SUNGAI HAU, VIETNAM DAN SUNGAI PERAK, MALAYSIA

ABSTRAK

Araceae termasuk dalam kumpulan tumbuhan monokot iledon dan merupakan salah satu famili terbesar di dunia selepas orkid, rumput dan rusiga. Spesies aroid memainkan peranan penting dalam kehidupan manusia sebagai sumber makanan, pokok hiasan dan ubatan. Oleh yang demikian kajian mengenai taburan Araceae dilakukan di Sungai Hau, Vietnam dan Sungai Perak, Semenanjung Malaysia. Sungai Perak berada di Pentas Sunda manakala Sungai Hau berada di dalam bio kawasan Indochina. Persampelan dilakukan pada April hingga Mei dan September hingga November 2013 di Sungai Perak dan dari Jun hingga Ogos 2013 di Sungai Hau. Stesen-stesen persampelan telah dipilih berdasarkan penzonan mengikut kepadatan penduduk serta guna tanah. Kaedah tinjaun berstratum di gunakan untuk menilai komposisi. Sejumlah 35 spesies dari 23 genera telah dikenalpasti dalam kajian ini. Daripada jumlah ini, 22 spesies dikelaskan sebagai pokok hiasan, 13 spesies adalah rumpai dan 3 spesies merupakan makanan manusia. Sebanyak 27 spesies telah direkodkan di Sungai Hau manakala 24 spesies direkodkan di Sungai Perak. Enam belas spesies direkodkan di kedua-dua sungai. Hanya 11 spesies direkodkan secara eksklusif di Sungai Hau, manakala 8 spesies hanya eksklusif di Sungai Perak. Tiga spesies endemik, iaitu *Cyrtosperma merkusii*, *Homalonema pontederifolia* dan *Scindapsus pictus* direkodkan di Sungai Perak manakala tiada spesies endemik direkodkan di Sungai Hau. *Colocasia esculenta*, merupakan spesies yang paling kerap ditemui di kedua-dua sungai kerana spesies ini adalah makanan biasa bagi masyarakat tempatan di kedua-dua sungai. Spesies aroid

yang lain ada kepentingan dalam perubatan dan pokok hiasan. Kesimpulannya, taburan spesies aroid di Sungai Hau dipengaruhi oleh aktiviti manusia bagi tujuan makanan, hiasan dan perubatan. Taburan spesies di Sungai Perak pula adalah lebih bersifat semulaja di disebabkan keadaan persekitaran yang kurang mengalami gangguan manusia. Kewujudan tiga spesies endemik di Sungai Perak membuktikannya.

A COMPARATIVE ECOLOGICAL STUDY OF THE AROIDS IN HAU RIVER, VIETNAM AND PERAK RIVER, MALAYSIA

ABSTRACT

The Araceae is a monocotyledonous family and is one of the largest families in the world after the orchids, grasses and sedges. The aroids play important roles in human life such as supplement of food source, ornamentals and medicine. Hence, a study was conducted on the distribution of aroids along the Hau River in the Mekong Delta, Vietnam and the Perak River, Peninsular Malaysia. The Hau River is in the Indochina while the Perak River is in the Sunda Shelf. Field surveys were conducted from April to May and from September to November 2013 in the Perak River and from June to August 2013in the Hau River. The sampling stations were selected from zones based on human population density and land use for both the Hau River and Perak River. A stratified sampling method was used in the study. A total of 35 aroid species from 23 genera were identified from both study areas. Out of this number, 22 species are classified as ornamentals, 13 species as weeds and 3 species as food crops. A total 27 species were recorded along the Hau River as compared to 24 species along the Perak River. Sixteen species are recorded present at both the Hau and Perak Rivers. Eleven species were recorded present exclusively in the Hau River, while only eight species occur exclusively in the Perak River. Three endemic species, namely *Cyrtosperma merkusii*, *Homalonema pontederifolia* and *Scindapsus pictus* were found in the Perak River while no endemic species were recorded in the Hau River. Among the aroid species, *Colocasia esculenta* was commonly recorded at the Hau and Perak Rivers. It isused as food by the local communities along both rivers. In conclusion, the aroid distribution along the Hau River is influenced by

human activities and the use of aroid species for food, ornamental and medical uses. In contrast, the distribution of aroid species at Perak River is more natural and less influenced by human activities. The present of three endemic aroid species in the Perak River proves this point.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The Araceae is one of the common monocotyledonous plants in the world and has a total of about 117 genera and more than 3790 species (Nauheimer, 2012). According Mansor *et al.,* (2012), Araceae is also one of the largest plant families in the world after the orchids, grasses and sedges. Most of the species are found in tropical areas.

Research on Araceae has been conducted since 15thcentury (Croat, 1998; Mayo, 1989; Nicolson, 1984). Although Croat (1988) collected many new of aroids, the early research had been conducted by Ridley (1885). Ridley (1885) had produced the name lists of the species and genera while Mayo *et al.,* (1997) produced the latest reference which summarizes our knowledge on aroids. Hay (1994) displayed a complete name lists of aroid in Australia. According to Hay, more than 1400 species were identified and published. Sulaiman and Boyce (2010) studied the Homalomeneae while Bogner (1980) conducted a study on Indochinese aroids and found some endemic aroids in these countries.

Although Araceae has a worldwide distribution, tropical Asia and tropical America are the centers of aroid diversity in the world. According to Croat (1998), the Neotropics has two-thirds of aroid species, although it has only 36 genera compared to 60 genera of the Paleotropics. Research on Neotropical Araceae tends to focus on particular areas in the Americas (Croat, 1997). For example, Central America is more well known for its aroid flora compared the rest of South America because of the greater number of taxonomists who studied the flora there (Croat, 1997). In the

Neotropic, the aroids are generally found in the tropical forests. They are found in terrestrial, aquatic and habitats within the forest ecosystem. A study in Peru on the altitudinal range of aroids distribution, found that they occur from sea level to more than 3000 meters, but with the highest concentration of the aroids on the middle elevations.

In the Paleotropics, Sulaiman and Boyce (2010) made the observation that the aroids generally occur along the riverbanks, wetlands where the environmental conditions are wet, with high humidity and shade. Dajdok and Kacki (2001) also showed that aroid habitats are often in damp and humid places, such as rivers and lakes. They asserted that these environmental factors are most suitable for the growth of aroids. Boyce *et al.,* (2002) recorded species of the Araceae in mountainous forests from 300m to 800m above sea level.

Nowadays, Araceae is becoming more familiar to humans and recognized as an important source of food, ornamental plants and medicine. *Colocasia* has been used in fermenting vegetables for human food as well as food for fish and pigs (Nunes *et al.*, 2012). In addition, species of Araceae has been utilized for medicinal purposes, as mentioned by Chilpa and Estrada (1995). For example, pregnant women have used *Homalonema sagittifolia* for various ailments.

There are many factors affecting the current distribution of aroid plants. The first factor is growth of human population on a large scale and the migration to new areas as population pressures build up (Khang, *et al*., 2011). With a high human density occupying the land, the land use changes invariably takes place as natural ecosystems are converted or modified for agriculture and human settlements. Secondly, aroid distribution is also largely determined by their economic values as cultivated aroids are found in human settlements. Species with commercial values are

cultivated or collected in the wild. This action changed their natural habitats and distribution pattern. Finally, climate and topography influence aroid distribution when the aroid species are introduced into new areas and only those aroids adapted to the new habitats will thrive. Humid climate generally promotes aroid growth while too dry climate restricts species growth. Topography of flood plains and the low lands in Mekong Delta are suitable for some species and their distribution expands for some particular species, such as *Colocasia esculenta.* Nevertheless, mountains, hills and highland are suitable for the climbing group or special groups (*Amorphophallus*).

Through the survey of aroids distribution in Hau and Perak Rivers for this study, the species presence and the habitats in surveyed areas are recorded and assessed. Moreover, common species such as *C. esculenta* is expectedly found in all types of land-use in both river basins as this species has a cosmopolitan distribution and adaptable and is commonly used as food. It would be of interest to study the distribution of two contrasting areas with different population densities to see how this could affect the distribution of aroids. This will provide a supplement checklist and plant uses to future research in Mekong Delta and Perak plain in the next years.

1.2 Objectives of the study

The main objectives of this study are to address the following aspects:

i. To study the aroid distribution in the two eco-regions of two different countries.

ii. To determine the conservation status of aroids in Hau and Perak Rivers.

iii. To compare the ethnobotanical use and socio – cultural values of Araceae in Hau River, Vietnam and Perak River, Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 Taxonomy

Systematic research on the Araceae has been conducted since the 15th century (Nicolson, 1984). Historically, many eminent botanists contributed on the taxonomy of the aroids. Linnaeus (1750) while studying the family added the aquatic genus *Pistia* into the group. Hooker (1851) described two genera *Alocasia* and *Pistia*. He also discovered the *Amorphophallus* (Hooker, 1860a). Later botanical research had been conducted by Ridley (1885). Ridley had compiled the name lists of the then known species and genera. According to Croat (1998), Leonhart and John were the earliest botanists to describe the Araceae in the 17th century. Croat (1998) stated that in the 19th century, Schott was the earliest botanist to work on the Araceae. He described a large number of genera. In addition, Croat (1998) stated that Schott recognized sectional and subfamilies levels of 40 aroid genera. Following Schott's steps, Engler emphasized the anatomy, morphology and developmental processes in the classification of the Araceae (Croat, 1988). One of Schott's contemporaries was Kunth. He described 90 new taxa. According to Croat (1998), another botanist with significant information on Araceae was Koch. Koch's study was based on cultivated materials, which were often of unknown origins and he described 156 taxa.

An important early scientist of the 20th century who dealt with the taxonomy of Araceae was Brown (1901). Goyder (1995) did excellent work in the floristics of the Araceae and focused his work on one geographic area or specific taxa (Mayo *et al.*, 1997). Subsequently, more studies were undertaken from different geographical

areas. Bogner (1980) conducted a study on the aroids in Indochina and found some of the endemic aroids recorded in Vietnam, Cambodia and Laos.

The essential concepts of relationship of the Araceae and some definitions of classification of species in the family was reviewed by Nicolson and Sivadasan (1981). In addition, Araceae had been studied by Nicolson (1984), Mayo (1989) and Mayo *et al.,* (1997). In more recent years, Croat (1988) collected many new specimens of aroids. Hay (1994) made a complete name lists of aroids in Australia. According to Hay, more than 1400 species were identified and published. Mayo *et al.,* (1997) produced the latest reference which summarizes the taxonomy on aroids. Based on Sulaiman and Boyce (2010), studies on aroid were carried out in Malaysia particularly on the Homalomeneae.

In the last 10 years, botanists had revised the classification of aroid species to complete its taxonomic relationships. To date, taxonomists have identified 3790 species of aroids (Nauheimer, 2012). It should be noted that the more recent aroid classifications has been reviewed by Mayo *et al.,* (2013).

The taxonomy of the aroids was also studied by the more modern approach of molecular biology and genetics. In 2008, the most recent and comprehensive family-wide molecular phylogeny was published which include species from 102 genera (Sedayu *et al.,* 2010). According to Sedayu *et al.,* (2010), sequences of three different genes in 69 taxa of *Amorphophallus* were combined to reconstruct the molecular phylogeny of this species-rich aroid genus. The molecular data with a more complete genera sampling were reanalyzed and the resulting phylogeny were compared with the taxonomic relations based on morphological and anatomical data. With a view in contributing to a new formal classification of the Araceae (Cusimano *et al.*, 2011), the classification based on various lines of evidences, such as molecular genetics to

supplement the traditional morphology was reviewed by Mayo *et al.,* (2013). Perhaps this is the most reliable reference currently. Based on molecular and cladistic studies (Mayo *et al.*, 1997) and the fossil record from the early Cretaceous (Cusimano *et al.*, 2011), Araceae were found to belong to an ancient family with seven subfamilies. Besides, Araceae has numerous herbaceous species having rhizome or tuber. Furthermore, there are a few aroids in the woody or climbing group (Yusof, 2011). Most plants in the aroid group are amphibious. Some contains a white liquid in their leaves and trunks and often have a bitter taste. Some tuber plants contain calcium oxalate which can cause mouth inflammation when chewed (Bown, 2000). Bown also stated that aroids produce tuber in cold and dry environmental conditions and can lie dormant for several months.

2.2 Ecology

2.2.1 Morphology and life form

Indentifying aroid species based on its morphology is relatively easy. A plant has a basal bunch of leaves, corm, rhizome and tuber. Sometimes, it is without conspicuous bunch of leaves. In general, the monocotyledonous plant, which Araceae belongs, the leaves are very diverse, varying from thin venation parallel to bigger form. However, aroids do not follow the typical general shape. Aroid leaves are very diverse, from small to very large with trichomes, papillea on the petiole. They are alternate, spiral or distichous. Leaves are often petiolate and sessile (*Pistia*), simple or compound. The leaf' shapes are ligulate or eligulate, cordate, hastate or sagittate with pinnated, palmated and parallel veins. Leaves have dorsiventral lamina with randomly presented stomata (Watson & Dallwitz, 1992). Bown (2000) pointed out that the changes in leaf types depend on the habitat. He showed this with one

example of *Cryptocoryne*. The leaves are thin and long because the species have adapted to rapid flow of water in their habitat. In *Amorphophallus* and other species, the leaves are complex. Therefore, the plants do not display the ornamental foliage until they are trulymatured. The habits of most aroid species are self-supporting, epiphytic, or climbing. Climbing group includes climbing stem twiners, root climbers or scramblers. Some species are free-floating (*Pistia*), submerged (*Cryptocoryne*) or emergent (*Colocasia*). Aroids in climbing group have small stems while woody plants have thick stems. Plants living on terrestrial and dry areas have erect stems. Generally, aroid stems are aerial and erect with short or long internodes. Stems do not branch off. Roots have velamen or without velamen (Watson & Dallwitz, 1992).

With such a diversity of vegetative forms, the classification of aroid has been based on their floral characteristics rather than vegetative features. In Araceae, six subfamilies with 31 genera have bisexual flowers. The species are more basic, while, the Aroideae with 74 genera is considered the largest subfamily and has unisexual flowers. In unisexual flowers, the male flowers location is on the part upper in the inflorescences while the female flowers are at lower parts. Both male and female flowers are located in the middle zone of the inflorescence. In this unisexual group, the colours of the spadix vary from white to green. Some species in Araceae have very large flowers. For example, the largest unbranched inflorescence found in the world is *Amorphophallus titanum* (titan arum), a species of the *Amorphophallus* (Patel, 2012) which have attract the world attention because of its large size and is found in some botanic gardens. The flower can reach two meters in height. However, *Wolffia* is one of the smallest flowering plants and smallest fruit such as *W. globosa* (Lock, 2013). Flowering features is one of the common characteristics used to indentify aroids. Aroid plants are recognized easily when blooming, but the flowering process is

difficult to see in certain habitats. Most aroid flowers are monoecious. Some plants produce stinking smells. Aroid flowers do not have sheath and circle the spadix. Aroid stamens are from two to eight hypogeneous segments while ovary has various locules or only one. Another inside stamens is independent or in-group. Ovule in ovary is only one or more.

The flower includes an unbranched inflorescence that condensed numerous small flowers (Gottsberger *et al.*, 2013). The ultimate inflorescence units are seemingly racemes. Flowers are spiral, whorls, pedunculate, spathed, or espathed (except *Orontium*). Flowers sometimes have perianth of 'tepals' (Watson & Dallwitz, 1992). Inflorescence consists of specialized spikes ('spadices'). One of special characteristics of Araceae is the arrangement of inflorescence in a spathe. The spathe is variable in shape and colour. Its colour and form is usually green, reflexed or spreading, often showy and coloured, centrally to form a basal tube and an apical limb with a tube that enclosed the female zone of the spadix (Mansor *et al.*, 2012).

Spadix is described as very fleshy, thick, sessile and erectwith short or long stipitate. Flowers are bisexual or unisexual, often small, protogynous, numerous and lacking floral bracts that are generally found in *Pistia* (Thompson, 2014). In addition, the spadix consists of a fleshy axis (spike) carrying bunches of sessile, apetalous, unisexual flowers. The small unisexual flowers are together along the lower area. The flowers are not found in the upper area of the spadix. The upper part of the spadix is lengthy in different forms. On the spadix, there are seeds around the structure. Male flowers consist of numerous stamens group together, while female flowers consist of numerous individual pistils (Olson, 2013). The spadix is often brightly coloured and fragrantor malodorous. However, some emits a putrid odour

that attracts carrion flies for pollination (Broderbauer *et al.*, 2013). Some spadices produce a certain amount of heat in cold weather. The temperature of the spadix can be up to 30^{o}C although cool air temperature around it may be about 10^{o}C (Seymour, 1997).

According to Blendinger *et al.,* (2011), the fruit is a special part of aroids. Fruits are formed from the dry and small flower. Aroid's fruit is a berry and colourful with red, orange, purplish red, white and yellow (*Amorphophallus*) and green (*Typhonium*, *Lasia*, *Pycnospatha*). Fruits are normally fleshy or non-fleshy; an aggregate, or not an aggregate. One of the interesting features of Araceae is the seed. Fruits have numerous thin and curved seeds. Many seeds in one fruit testa are thick to thin, smooth, rough, verrucose or striate, costate. Seeds are found in special different ways, such as rarely operculate (*Pistia*) or highly developed plumule (*Cryptocoryne ciliata*). Blendinger *et al.,* (2011) worked on the seed of the *Anthurium.*The seedling is generally not conspicuous (Watson & Dallwitz, 1992).

2.2.2 Habitat

While comprising over a hundred genera with a sub-cosmopolitan distribution, the aroid group include shrubs, herbs, laticiferous and non laticiferous arborescence (Watson & Dallwitz, 1992). The habits of the aroid are one most diverse family in tropical regions (Mayo *et al.*, 1997). Araceae are frequently distributed in the humid lowland, montane forests (Acebey *et al.*, 2010), moist, ever wet or humid lowland and various types of forest on limestone (Mansor *et al.*, 2012). *Philodendron* is a large genus with 500–700 species (Croat, 1997). *Philodendron radiatum* and *Anthurium clavigerum* (two common species of hemi-epiphytic Araceae) are found in lowland tropical moist forest, and growth and survival is facilitatedby the presence of aerial roots (Meyer & Zotz, 2004).

The Araceae are very adaptable and found in many different ecological habitats. The suitable habitats for this family include peat swamp forests, mangrove forests, lowlands, hills and upper hill forests. The correlation between vessel elements in their morphology, ecology and habit are often reported. All of the genera have vessel elements not only in roots but also in stems (Carlquist & Schneider, 1998). Aroids are also abundant and diverse on steep slopes above streams and small rivers. They occur in cool and constantly humid habitats that are directly found in the forests above the streams to warmer conditions on the upper parts of the slope and ridge (Mansor *et al.*, 2012).

Epiphytie species are also observed growing on trunks under canopy covers. Its abundance was more closely related to soil pH, canopy cover, and phorophyte height as pointed out by Haro-Carrion *et al.,* (2009). Another genus with clear habitat preferences is *Heteropsis*, which is reflected in site differences of soil fertility (Knab-Vispo *et al.*, 2003). Studying the holo-epiphyte *Anthurium* tanatomy in relation to various features such as stomata and epidermal conductance, leaf succulence, sclerophylly, leaf nitrogen content and retranslocation, showed how the aroid species have successfully adapted to the epiphytic habitat (Lorenzo *et al.*, 2010).

In tropical humid forests, a great number of Araceae found are terrestrial mesophytes. Aroid species are described with aerial, decumbent and erect stem and stems of other plants, produce enormously long, pendent and flowering growing high into the forest canopy (Ohi-Toma *et al.*, 2010; Hamzah, 2011). Hemiepiphytic aroids with anchor roots belong to climbing groups are divided into primary and secondary hemiepiphytes (Irume *et al.*, 2013).

Araceae is the most prevalent family in the epiphytic community occurring in a terra firma forest (Irume *et al.*, 2013). Opposite to hemiepiphytes, epiphytes are not

connected to the ground (Annaselvam & Parthasarathy, 2001) and are found rarely in genera such as *Anthurium*, *Philodendron* and *Stenospermation* (Mansor *et al.*, 2012). Another type of aroids with seasonally associating tuberous stems in flooded habitats and dry season (Zulha *et al.*, 2011) are *Amorphophallus* and *Typhonium* (Mendez, 1999).

2.2.3 Native and introduced species

In Araceae, species can be distinguished between native or indigenous species and introduced species. Native species are defined in biogeography as species that appear in a region or ecosystem in nature. The species only grow by natural processes, with no intervention from humans. Another group called non-native, non-indigenous, exotic or introduced species are species occurring outside their distributional range. They have occurred in areas due to human activities. Some species are introduced to the agro - ecosystems by humans deliberately because of their beneficial values. These are the economic species cultivated in traditional agriculture. However, some non-native species can cause negative effects on the environment and local ecosystem when introduced. They are known as invasive species and they often displaces the native species (Yusof, 2011).

According to Mayo *et al.,* (1997), aroid genera and species are also grouped based on their origins. For example, the *Dieffenbachia* and *Spathiphyllum* are native species in Tropical America. Because of their attractive foliage and adaptability, they are often planted in the gardens or in pots for their ornamental value and they are known as evergreen perennials. On the other hand, *Philodendron* is a native climbing plant found under natural conditions but may also be used as ornamentals. Another native species found in South America and Latin America is the *Caladium.* This species is dominant in some habitats. *Monstera* originates from South America and

belong to the climbing group of aroids found in tropical rainforests. In Central America, *Syngonium podophyllum* is native. This species can adapt and grow in acidic soils. Another native species found in wet mountainous forests in North and South America is *Anthurium.*

In Southest Asia and Malesia, *Homalonema* and *Schismatoglottis* are native to these areas. *Typhonium* is a weedy species, which occurs widely in Southeast and East Asia. The genus *Aglaonema* is native in Southeast Asia. Nowadays, species in the *Aglaonema* are cultivated for decoration and horticulture and some are hydridised in the horticulture industry (Mayo *et al.*, 1997). *Alocasia* is native in Tropical and Subtropical Asia while *Colocasia* is native in Southeast Asia. Both genera consist of rhizomatous, tuberous and herbaceous plants growing on and below the ground surface (Mayo *et al.*, 1997).

2.3 Geographic distribution

2.3.1 Distribution in the world

Araceae has one of oldest fossil records among angiosperms. Although there are nearly equal number of genera occurring in the tropics and subtropics, the majority of species are distributed in the tropics.

This family is also found in many regions of the Old World. Araceae were found in tropical evergreen forest at the Indian Western Ghats (Annaselvam & Parthasarathy, 2001). Humidity and altitude were main factors in explaining Araceae diversity patterns.

In the America, Araceae richness was highest in South America, with a secondary centre on the Andean foothills of northwestern Ecuador (Leimbeck *et al.*, 2004). The species of the Araceae was well-distributed over the main landscape units

in the area of Colombian Amazonia (Benavides *et al.*, 2005). This family is one of the largest herb families in tropical America.

In addition, Araceae includes thousands species with their distribution in New World. For example, one species of Araceae, namely *Heteropsis* was reported to be widely distributed and have a high density in a tropical lowland rainforest in southern Venezuela. (Knab-Vispo *et al.*, 2003). Besides that, *Monstera praetermissa* and *M. obliqua* are two known species in the wet seasonal forests of Chiapas, Tropical America, in southern Mexico (Wolf & Alejandro, 2003) and other *Monstera* are found in Brazil (Goncalves & Temponi, 2004). The diversity, altitudinal and geographical distribution of Araceae were recorded in the region of Vera Ceruz (Acebey & Kromer, 2008). This family is also distributed in potentially different ecologically regions (Bin Asad *et al.*, 2011). In addition, *Montrichardia linifera*, commonly known as aninga, forms large populations on the banks of rivers and streams of the Amazon, especially in white water rivers (muddy) (Amarante *et al.*, 2011). Araceae was also reported in various locations in Mexico (Toledo-Aceves *et al.*, 2012). Genera of this family includes free-floating aquatics plants such as *Pistia* and *Lemna laurasia* persists as early lineages, with several relatively recent entries reported in Africa, South America, South-East Asia and Australia (Nauheimer, 2012), and regions in Bolivia at 350 – 4000 meters above sea level (Quilichini *et al.*, 2010). Another species of Araceae, *Rhodospatha arborescens* was found in a semi-deciduous seasonal forest of Minas Gerais state, Brazil (Temponi *et al.*, 2012). At the family level, the epiphyte composition was roughly found in the northwestern Andean, the northern and southern Mesoamerican regions and the Caribbean region (Marin & Ruiz, 2013). Another example is the genus *Anthurium*. Some *Anthurium* are endemic and are found in large areas of Amazonian lowlands and also at the borders of Guyas, Canar, Bolivar,

and Chimborazo, as well as sites along the border with Peru (Vargas *et al.*, 2004). In addition, *A. clavigerum* was found in a lowland tropical moist forest in Panama (Vargas *et al.*, 2004). *Anthurium* are differently distributed in Ecuador (Vargas *et al.*, 2004), Eastern Brazil, Western South America and Central America (Poli *et al.*, 2012). One of richest member of Araceae, *Xanthosoma daguense*, terrestrial aroid was found in the Andes of Colombia (Garcia-Robledo *et al.*, 2005). The *Xanthosoma* has a high number of 26 endemic species and no native species has been found in Venezuela (Berlingeri & Crespo, 2012). Taro species is also grown in Brazil and many local varieties are grown to avoid the loss of genetic diversity of the local varieties (Nunes *et al.*, 2012).

In Bangladesh, many species of Araceae were reported, *Caladium bicolor* was reported for the first time recently (Ara *et al.*, 2004). The discovery of *Typhonium* in Bangladesh throws new light on the geographic history of Araceae (Renner & Zhang, 2004). Species such as *T. blumei* and *T. cochleare* were recorded in Bangladesh by Knudsen *et al.,* (2006). Moreover, *Steudnera gagei*, *Aglaonema modestum*, *Colocasia lihengiae* and *C. virosa* are also cultivated in Bangladesh (Ara *et al.*, 2004; Knudsen *et al.*, 2006). Three of the few north temperate genera of the primarily tropical Araceae are *Symplocarpus*, *Lysichiton*, and *Orontium* (Orontioideae). The Orontioideae fossil evidence suggests the presense of aroids in the late Cretaceous in the temperate Northern Hemisphere. Moreover, *Symplocarpus* has been found in eastern Asia (Nie *et al.*, 2006). Some of Araceae are discovered in Pakistan. New species continue to be discovered in the aroid group. One example is *Carlephyton darainense* a new endemic aroid species had been described and illustrated by Bogner and Nusbaumer (2012) from northern Madagascar.

Some genera can be found in both Old World and New World. For example, another noticeable genus in this family is *Philodendron* (Mayo *et al.*, 1997). *Philodendron* with cordate leaves occurs in North America and Europe. *P. radiatum* and *A. clavigerum* was found in a lowland tropical moist forest in Panama (Vargas *et al.*, 2004). Some *Philodendron* are rare and possibly extinct in the Atlantic Forest (Mayo & Sakuragui, 2011). Moreover, *Philodendron* thrives in the Caribbean sub region (Echeverry & Morrone, 2013). Some examples of aroid species in the Old World, such as *P. bipinnatifidum*, is one of the best-known plants of the ornamental group with large leaves and has been found in Brazil (Gottsberger *et al.*, 2013; Mayo, 1989). The *Philodendron* with the highest epiphytic importance values occur in Brazil particularly in the Amazon region (Irume *et al.*, 2013).

Pistia stratiotes is the most important aquatic floating weed species which is invading water surfaces in the whole tropical world, was orginally found in the north of Togo Republic (Akpagana, 1993). The oldest fossils of the *Pistia* leaves were found to be from Germany and also, a few species in Florida, the Mediterranean, Europe, Kazakhstan, North Dakota, and Tennessee (Renner & Zhang, 2004). At present *Lemna minuta* has been noticed in Europe and Asia according to Iberite *et al.,* (2011) while *L. valdiviana* expanded in the Sardegna and Agro Pontino regions. *Xanthosoma undipes* is a new record in Bangladesh (Ara & Hassan, 2012).

Amorphophallus has wide distribution in Asia, largely consisting of a mainly continental South East Asian clade and one centered in Malaysia. This genus provides a valuable contribution towards understanding pollen ornamental (Van der Ham *et al.*, 2005). In India, Bangladesh and Myanmar, some other species of *Amorphophallus* has been recorded (Jaleel *et al.*, 2012). *A. carnosus*'s first discovery and collection has been after more than 100 years later in India (Jaleel *et al.*, 2012).

Symplocarpus has been found in eastern Asia and eastern North America while *Lysichiton* has an intercontinental discontinuous distribution in eastern Asia and northwestern North America. The monotypic *Orontium* is restricted to eastern North America Eastern Asia (Nie *et al.*, 2006). Similarly, *Monstera praetermissa* and *M. obliqua* are known new species of *Monstera,* are found in the wet seasonal forests of Chiapas, Tropical America, in southern Mexico (Wolf & Alejandro, 2003) and in Brazil (Goncalves & Temponi, 2004)

The evolution of *Arisaema* is reconstructed in East African and North American by Kim *et al.*, (2010).*A. triphyllum*, *A. dracontium* or *A. macrospathum* occurred in eastern North America. *A. triphyllum* fossil infructescences were deposited in Washington State. *Arisaema* species has been studied in East Africa, Arabia, the Himalayan region, China, and North America (Kim *et al.*, 2010).

Lemna valdiviana and *L. minuta* often considered an invasive alien species are native species of the Americas (Iberite *et al.*, 2011). *Laurasia* persists as early lineages, with several relatively recent entries into Africa, South America, South-East Asia and Australia (Nauheimer, 2012).

2.3.2 Distribution in Malaysia

In recent years, a number of scientists have worked intensively in the aroid group and discovered new species in Malaysia. This provides more information about aroid taxonomy in Malaysia. Mansor *et al.,* (2012) published the checklist of Araceae in Malaysia with 165 species, including 140 indigenous and 25 endemic species from 28 genera. Hotta (1965) worked with aroid species in West Malaysia and found a new species *Phymatarum borneense* while *Furtadoa sumatrensis* was studied by Nicolson (1968).

In the 18th century, *Spathiphyllum* was also studied and new species were found in Malaysia, such as *S. lanceifolium* (Schott *et al.*, 1831). One species in the *Homalonema*, *H. cordata*, was discoveried by Schott *et al.,* (1831). Subsequently, *Cyptosperma lasioides* was found by Griffith (1851). One of the first aroid botanist, Schott found *Bucephalandra motleyana* in Borneo (Schott, 1858). *Apoballis* has been certified a new species, namely *A. neglecta* (Schott, 1858). At the end of 1800s, *Podolasia stipitata* was included in aroid family (Joseph *et al.*, 1897).

In west Malaysia, early studies were made by Burkill (1923) and Rendle (1924-1925). Hetterscheid reported thirty-three new species of the *Amorphophallus.* Kato *et al.*, (2000) also found *Homalomena propinqua*, *Philodendron lacerum* and *Scindapsus aureus* in Peninsular Malaysia.

On the other hand, in East Malaysia, sixteen new *Amorphophallus* were identified by Hetterscheid and Van Der Ham (2001). In Malaysia, *Typhonium flagelliforme* commonly known as the 'rodent tuber' by Choo *et al.,* (2001) and an indigenous plant is found by Lai *et al.,* (2010) has been reported to have medicinal properties. Steenis *et al.,* (2006) worked on the flora in Malaysia and further carried out the intensive studies on Java. Boyce and Wong (2008) have identified a new species in the *Bakoa* (*Bakoa lucens*) in Boneo. Another new species was discovered by Boyce which belongs to *Schottarum*, *S. sakieense* (Boyce & Wong, 2008). In addition, Wong and Boyce (2010) also found the new species *Hestia longifolia*.

A total of 21 *Colocasiomyia* species are reported from Sabah and neighboring areas, including 17 undescribed species based on samples collected from inflorescences of Araceae species (Toda & Lakim, 2011). In addition, two new species of the *Schismatoglottis* and *Calyptrata* were described in Malaysia by Yeng (2012). *Alocasia macrorrhizos* was discovered in Sabah, Malaysia by Takano *et*

al.,(2012). According to Stanly *et al.,* (2012), *Homalomena pineodora* is found to have impressive foliage characteristics and is a evergreen species throughout the year.

2.3.3 Distribution in Vietnam

There were limited scientists working on Araceae in Vietnam. The earliest studies on aroid has been conducted by Ho (1960). Recently, more scientists have started to work in aroid group (Nguyen, 1994; Thin, 1997). They had done good reports on Vietnamese aroids. The recent checklist of aroids in Vietnam was compiled by Matthews (2012a). Matthews found 135 species belonging to 25 genera in Vietnam. The species distribute through out the country and occur in different habitats at elevation between 0 and 3000 metters altitude (Matthews, 2012a).

Two new species such as *Amorphophallus scaber* and *A. pusillus* from Vietnam were recorded in 1994 (Hetterscheid & Serebryanyi, 1994). Serebryanyi (1995) described *Pseudodracontium macrophyllum*in Vietnam. Four new species *P. fallar,P. kuznetsovii, P. lanceolum,* and *P.latifolium* are also discovered in Vietnam and Thailand by Serebryanyi (1995).

Arisaema claviforme, a new species, belonging to section *Anomala* was described, illustrated and compared with related taxa at Hon Ba Nature Reserve, Khanh Ha province in southern Vietnam (Tan *et al.*, 1997). Since 1994, according to Professor Pham Hoang Ho and some other authors, 108 new species of aroid were recorded in Indochina. Since then, after 15 years, more new species from Indochina have been discovered, described and published (Le *et al.*, 1999). According to Boyce (2000), 14 species are newly described. Among them, three species were validated for the first time such as *Amydrium* (Hesse *et al.*, 2001). Thirty-three new species of the *Amorphophallus* are described from South East China, Vietnam, Myanmar,

Thailand, Malaysia and Indonesia (Van der Ham *et al.*, 2005). According to Darling (2007), the phylogeny of Araceae and the restricted host records suggest a co-evolutionary arms race and parallel phylogenesis. *Spathiphyllum patinii* was also found in Vietnam (Ha *et al.*, 2008). In Vietnam, the domestic species of such as the *Anthurium, Phylodendron, Zantedeschia, Homalomena*, are rarely exploited for their ornamental value (Nguyen & Croat, 2010). Currently, the majority of aroid ornamental species in Vietnam are imported from Thailand and China. Some aroids ornamentals are thought to have originated in South America or of unknown origin. According to Tran (2010), the commercial species found in natural areas are being seriously threatened because of over-exploitation. Some new species, such as *Typhonium vermiforme* were collected from Quang Binh Province (Nguyen & Croat, 2010). In addition, species of *Typhonium*, *Amorphophallus*, and *Arisaema* were commonly observed. Out of these, 12 species of *Typhonium* (Nguyen & Croat, 2010), 10 new species of *Amorphophallus* (Gong & Li, 2012)and *A. candidissimus* (Gong & Li, 2012) were reported in Vietnam. In addition, a species regarded as an endemic to southern Thailand, namely *Arisaema simaicum* was published as a new record from Vietnam by Bruggeman *et al.,* (2013) and 4 other *Arisaema* were studied. More species had been added to the distribution list of Indochina and Vietnam such as in *Arisaema* with 11 species (Bruggeman *et al.*, 2013)

2.4. Ethnobotany

Aroids are considered as an important food crop and had played an important role in tropical areas for centuries. The local inhabitants have used aroid since historical time in cooking, religious ceremony and medical purposes. Some species are rich in carbohydrate and have provided crucial food for millions of people in the world. The more than 800 species of Araceae have been found to have economic

value demonstrate the importance of Araceae to human societies. This is based on their value as food, ornamentals, medicine, and other ethnobotanic value.

2.4.1 Medicine

According to Chilpa and Estrada (1995), 800 antidotal plants are known in the world, including many of aroid species. Snake bites are serious problems in many parts of the world and can cause death. For example, in Pakistan, *Caladium* is known as an antidote for snake poisoning and used in traditional medicine for snake (Bin Asad *et al.*, 2011). Scorpion stings also cause extreme painful in some countries and some *Caladium* are also known to be effective to treat this pain. Nasim *et al.,* (2013) had done some excellent research in 35 medicinal plants from Araceae with anti-scorpion potential.

Another useful value of aroid species is identified from the chemical constituents of *Typhonium flagelliforme*, an indigenous plant of Malaysia that is often used as an essential ingredient of herbal remedies for alternative cancer therapies (Choo *et al.*, 2001). This plant has anti-proliferative properties towards human cancer cell lines and has been used to treat cancer (Lai *et al.*, 2010).

In Vietnamese traditional medicine, some species have been found to have curative values. Dan (2011) had done research on *Alocasia macrorhizos*. Local people use this species to treat gout, flu and beriberi. The local people soak *A. macrorhizos* in wine or boil with water and then drink this every day as a cure for various ailments. In traditional medicine, some folk used *Typhonium trilobatum* to cure asthma and vomiting. When bitten by bees and snakes, *T. trilobatum* tubes are utilized (Sinh, 2011). According to Sinh (2012), *Lasia spinosa* can cure hepatitis, malaria, rheumatism, backache, arthritis, orchitis and cough. This species can also be used as vegetables after being boiled. Based on Phuc (2013), *Acorus verus* is

popularly used for oriental medicine. This species is considereda good cure for haemorrhage, tinnitus and rheumatism. Another species that has medicinal values is *T. flagelliforne* but its usage as medicine is different from Malaysia. Its tuber can treat bronchitis, cough, scabies and insect bites (Ong, 2014). It is also used as fresh vegetables or as fermented vegetables. Besides, Ong (2014) mentioned *Pothos scandens* as a cure for arthritis and backache. Stems and leaves of this species are also used to treat snake bites, smallpox and asthma. One species used popularly in Vietnam for medicine is *Amorphophallus konjac*. The tuber is a useful medicine in treating flatulence, snake bites and malaria (Toan, 2014a). In addition, Toan (2014b) mentioned about the medicinal value of *Arisaema consanguinesum*. The stems, roots and tubers of *A. consanguinesum* are used in treatingsome diseases such as cough, dizziness, convulsions and tetanus.

2.4.2 Horticulture and ornamentals

It should be noted that, *Dieffenbachia*, *Aglaonema*, *Caladium*,*Nephthytis*, *Philodendron* and *Epipremnum* are popular in ornamental and interior decoration usages. Specially, *Philodendron*, an important genus growing in rainforest ecosystems is often used as an ornamental plant in home decoration (Henny *et al.*, 2004).

Anthurium and *Zantedeschia* are well known as flowering genera (Henny *et al.*, 2004). Some popular foliage plants are *Anthurium*, *Aglaonema*, *Caladium*, *Dieffenbachia*, *Philodendron*, *Zantedeschia,Epipremnum, Spathiphyllum* and *Syngonium* (Chen & Beeson, 2004; Nelson, 2008). In addition, Pemberton and Liu (2009) stated that aroids are an important source of commercial ornamental plants. Araceae has great potential for horticulture. For example, in Bolivia, Araceae has a particular local importance mainly as traditional medicines and well as having a great potential as ornamental plants. The family offers numerous uses as non-timber

ornamental plants (Acebey *et al.*, 2010). Another species of aroid, namely *Homalomena pineodora* is grown as an ornamental plant and popular throughout the world (Stanly *et al.*, 2012).

2.4.3 Food

It should be noted that an edible vegetable in many tropical and subtropical regions of the world and commonly known as "Imperial Taro" is *Colocasia antiquorum* var. *esculenta* (Kim *et al.*, 2010). Taro is characterized as an unconventional vegetable. Taro or scientific name *C. esculenta* is a tuberous plant which tuber is now the 14th most consumed food crop in the world (Nunes *et al.*, 2012). They stated that taro is planted in Brazil as a subsistence crop, but began to gain commercial importance in recent years, especially in the states of Espirito Santo, Minas Gerais and Rio de Janeiro.

According to Berlingeri and Crespo (2012), the number of crops to meet food requirements in a global perspective is relatively small (staple crops). The number of useful plants in local usage may increase as food demand grows and these becoming important underutilized crops. Local varieties and wild useful plants will become more important. For example, in addition to taro, *Xanthosoma roseum* (elephant ear or 'ape) has high food value (Vaneker, 2012). One species in the aroid group, *L. spinosa* is used as a vegetable after boiling in Vietnam (Sinh, 2012). Toan (2014a) mentioned that *Amorphophallus konjac* is often planted as food. Besides, its branches are used in cooking vinegar soup and fermented food.

2.4.4 Food for non-human species

Besides food for humans, Araceae is also used as parts of the diet for fish, turtles and large herbivores, such as manatees and buffalo, for example *Montrichardia*

linifera (Amarante *et al.*, 2011). About 10% of the world population use taro rhizome (*C. esculenta*) in feeding domestic animals (Zarate *et al.*, 2012). According to Toan (2014a), *Amorphophallus konjac* is often planted for feeding cattle. People take stems and leaves to feed pigs.

2.5 A typical example of Araceae species with widespread distribution

Another important example of aroid as food is the genus *Colocasia* (taro) within the subfamily Colocasiodeae and this includes *C. esculenta* and *C. antiquorum*, two common species found in agriculture (Pereira *et al.*, 2005). Extensive research on *Colocasia* has been conducted on its ecology and morphology. Because taro's leaf has large transpiring surfaces, it requires high moisture. Therefore, taro grows in very wet or flooded conditions with rainfall or irrigation from 1,500 mm to 2,000 mm. However, *Colocasia* can thrive in dry conditions with reduced growth. The average temperature for normal production is above 21^{o}C (Onwueme, 1999).

Taro is considered a lowland plant because it cannot thrive in freezing conditions. In high altitudes, taro distribution is relatively poor. Most aroid species prefer less intensive sunlight. This particular ecological characteristic enables Araceae to grow in shade conditions as interior decoration in household or to fit into unique intercropping systems. *Colocasia* is more adaptable than other genera in adapting to different environmental conditions. Taro species can tolerate heavy soils and can withstand flooding and water logging. This is because the transportation oxygen through spongy petioles from the leaves to roots enables the roots to thrive in flooded conditions. *Colocasia* is one genus in the aroid group that can survive in high salinity. This useful characteristic is utilized in reclamation of saline soils (Krikorian, 1984). Hence, *C. esculenta* and *C. antiquorum* can be possible choices in some difficult ecological adaptation where other species might fail.

The life circle of taro begins from root formation and root growth. Subsequently, the shoot grows rapidly. The new leaf unfurls from the center of the whorl of leaf three months from growth. Corm formation follows closely. After six months, the corm grows very rapidly. In tropical regions, the shoot decline in acceleration in dry season until it is totally dead. However, the corn can thrive through adverse season and sprout new plant in next season (Onwueme, 1999). Normally, it is not easy to find flower and seed in taro under natural conditions. In some natural instances, it can flower in early season. However, it should be noted that taro crop can complete their life in the field without flowering (Schultes, 1984).

Taro belongs to the herbaceous group with a height up to 1 – 2 meters. It has been suggested that the origin of taro come from China and Japan several centuriesago. After that, taro was introduced into West Indies and other part of the world (Purseglove, 1972). On the other hand, according to Purseglove (1972) *C. esculenta* and *C. antiquorum* originated in South Central Asia or possibility in India or the Peninsular Malaysia. Their wild forms were found in various regions of South East Asia. Then they spread eastward and westward. Onwueme (1999) suggested that over 2,000 years ago, *Colocasia* species were taken to east coast of Africa by voyagers. Nowadays, *Colocasia* is found in cultivation there with the greatest intensity. *Colocasia* contributes to the local diet in large quantity.