CHAPTER 2

LITERATURE REVIEW

TOPOGRAPHY AND CLIMATE OF THAILAND

Topography

Thailand (formerly known as Siam) is located in the centre of mainland Southeast Asia between 5˚27´-20˚17´ north latitude and 97˚21´-105˚37´ east longitudes. The total area of Thailand is 513,115 sq km. The country shares its borders with four neighboring countries: on the north by Shan State, Myanmar (Burma) and northern Laos; on the northeast and the east by Laos and Cambodia (Kampuchea), respectively; on the west by Myanmar; and on the south by Malaysia. Its long coastlines are flanked by the Gulf of Thailand on the southeast and eastern sides of the peninsula and on the western side of the peninsula by the Andaman Sea (Figure 1).

Figure 1. Map of Thailand and neighboring countries (source: NYSTROM, 2008).

Thailand is divided into four natural regions: the North; the Central or the Chao Phraya river basin; the Northeast or the Khorat Plateau; and the South or the Southern Peninsula (Figure 2).

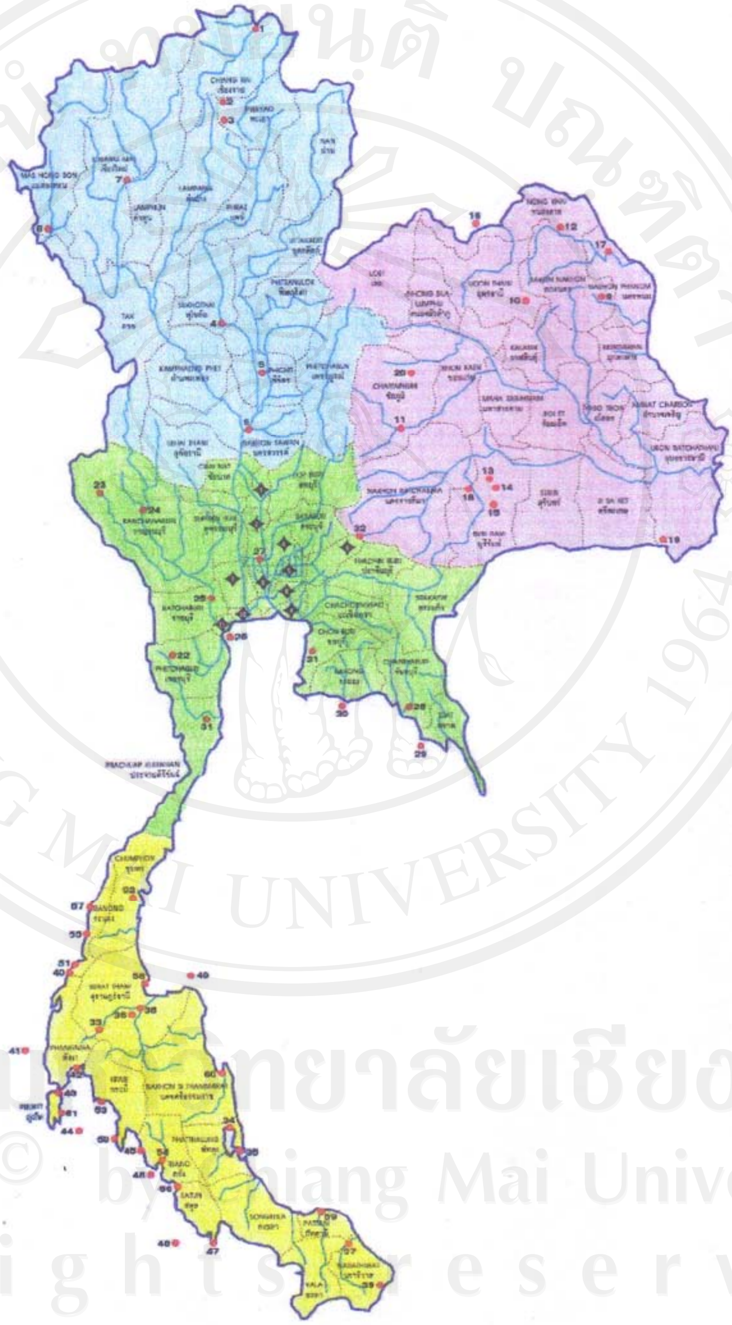

Figure 2. Map of Thailand and wetlands in Thailand divided into four natural regions of Thailand: Blue= North, Pink = Northeast, Green=Central, Yellow = Peninsular (Source: Office of Environmental Policy and Planning, 2002).

Northern Thailand is a region of roughly parallel mountain ranges between which the Nan, Yom, Wang, Ping, and other rivers flow southward to join and create the Chao Phraya river basin in the central valley. In the northernmost tip, drainage is northward to the Mekong river; on the western side, drainage runs westward to the Salaween river in Myanmar. Most people of Northern Thailand live in small intermountain plains and basins that generally widen into the major river valleys. Along the Myanmar border from Northern Thailand to Peninsular Thailand is a sparsely inhabited strip of rugged mountains, deep canyons, and restricted valleys. One of the few natural gaps through this wild mountain country is Three Pagodas pass along the Thailand-Myanmar boundary, used by the Japanese during World War II for their "death railway" (now dismantled) between Thailand and Myanmar.

The heartland of the nation is the central valley, fronting the Gulf of Thailand and enclosed on three sides by hills and mountains. This valley, the alluvial plain of the Chao Phraya river and its many tributaries and distributaries, is 365 km from north to south and has width of 160–240 km. On this plain, and most especially on its flat delta land bordering the Gulf, Thailand's main agricultural wealth and population centers are found. The small southeastern coastal region faces the Gulf of Thailand and is separated from the central valley and Cambodia by hills and mountains that rise in places to over 1,500 m. This is a well-watered area, and the vegetation is, for the most part, lush and tropical. Most of the people live along the narrow coastal plain and the restricted river valleys that drain southward to the Gulf.

The Northeast, much of it often called the Khorat, is a low, undulating plateau roughly at 120–210 m above sea level in the north and west, gradually declining to about 60 m in the southeast. Hill and mountain ranges and scarps separate the northeast from the central valley on the west and from Cambodia on the south; its northern and much of its eastern boundaries are influenced by the Mekong river. Most of the northeast is drained by the Mun River and its major tributary, the Chi, which flow eastward into the Mekong. The northeast, in the rain shadow of the Indochinese Cordillera, suffers from shortage of water and from mostly thin and poor soils (Advameg Inc., 2007).

Peninsular Thailand extends almost 750 km from the central valley in the north beginning at Chum Phon province to the boundary of Malaysia in the south at Narathiwat province and is anywhere from 16-220 km wide between the Gulf of

Thailand on the east and the Andaman Sea (Indian Ocean) and Myanmar on the west. At the Isthmus of Kra, the Peninsula itself is only 64 km wide. A series of north–south oriented, roughly parallel, ridges divide the peninsula into distinct western and eastern coast sections. The west coastal plain is narrow and the coast itself is much indented and often very swampy. The east coastal plain is much wider, up to 32 km in sections, and the coast is smooth, with long beach stretches and few bays. Well-watered (especially the west coast), hot, and densely forested, the peninsula, unlike most of Thailand, lies within the humid tropical forest zone (The office of the permanent Secretary of Defence, 2004; Boonchai, 2007).

Climate

Thailand has a tropical climate, determined primarily by its location in tropical latitudes, and generally by a monsoonal or seasonal reversal of the prevailing winds, blowing south-westerly from November to January and north-easterly from May to October (Sternstein, 1976; Donner, 1978).

Thailand has the following climates: savanna for the areas above Peninsular Thailand, excluding the eastern section of the southeast coast; tropical rainforest for the lower east coast of the peninsula; tropical monsoon climate for the rest of the peninsula and also the eastern section of the southeast coast. In addition, humid subtropical climate occurs in the far north-eastern part of the continental highlands.

Thailand's monsoonal climate has three distinct seasons; the hot season from approximately March to May, a rainy season from approximately May to the end of October, and a sometimes less distinct cool season from approximately November through February.

For most of Thailand, the temperature rarely falls below 13°C (55°F) or rises above 37°C (98°F), and in most places averaging between 24°C and 32°C (75°F and 89°F). Temperatures in Thailand show slight variations with the seasons. In the lower elevations, the minimum temperature occurs during the cool season, the mean monthly temperatures during January range from 26°C to 28°C (78°F to 82°F) for most of the country. In the hot season, during April, the temperature ranges from 28°C to 32°C (82°F to 89°F). Southern Thailand shows even less variation, the mean monthly temperatures remaining between 26°C (78°F) and 30°C (86°F) throughout the year. Temperature in the highlands of the north and northeast are lower due to the altitude.

The rainy season is more extended along the southeastern coast of Peninsular Thailand where average annual rainfall commonly exceeds 2,000 mm and reaches up to 4,000 mm in some areas. The majority of Thailand experiences average annual rainfalls between 1,100 mm and 1,500 mm, with the lowest rainfall commonly recorded in the western continental highland rain shadow where average annual rainfall is less than 1,100 mm. Rainfall is influenced by monsoons, cyclones, and convection from all directions except the protected northwest monsoon (Falvey, 2000). However, its temporal and spatial distribution is highly uneven. In temporal terms, some 85% of the rainfall comes in the rainy season from May to October. In the south of the country, over 50% of the annual rainfall may come between October and January. In spatial terms, the level of rainfall tends to increase from northern to southern regions, with the average annual rainfall around 1,250 mm in the north, 1,417 mm in northeast, 1,239 mm in the central region, 1,742–2,719 mm in Peninsular Thailand (from the east to the west) (Ghassemi *et al*., 1995).

Because of the unique geographical position, Thailand does not posses strong endemic floristic elements since the majority of plant species in the country are closely related to the species in neighboring countries. Thus, the flora of Thailand is mainly influenced by three major floristic elements: Indo-Burmese element (E Himalayan element) from NE India, Nepal, Bhutan, Shikkim, Bangladesh and Myanmar; Indo-Chinese element from S China, Laos, Vietnam and Cambodia; and Malaysian element from Malaysia and Indonesia (Figure 3).

Figure 3. Floristic regions and provinces of Thailand.
(Source: Flora of Thailand 7(3), 2001).

***N* (NORTHERN)** 1 Mae Hong Son 2 Chiang Mai 3 Chiang Rai 4 Phayao 5 Nan 6 Lamphun 7 Lampang 8 Phrae 9 Uttaradit 10 Tak 11 Sukhothai 12 Phitsanulok 13 Kamphag Phet 14 Phichit 15 Nakhon Sawan. ***NE* (NORTH-EASTERN)** 16 Phetchabun 17 Loei 18 Nong Bua Lum Phu 19 Udon Thani 20 Nong Khai 21 Sakon Nakhon 22 Nonkhon Phanom 23 Mukdahan 24 Kalasin 25 Maha Sarakham 26 Khon Kaen. ***E* (EASTERN)** 27 Chaiyaphum 28 Nakhon Ratchasima 29 Buri Ram 30 Surin 31 Roi Et 32 Yasothon 33 Amnat Charoen 34 Si Sa Ket 35 Ubon Ratchathani. ***SW* (SOUTH-WESTERN)** 36 Uthai Thani 37 Kanchanaburi 38 Ratchaburi 39 Phetchaburi 40 Prachuap Khiri Khan. ***C* (CENTRAL)** 41 Chai Nat 42 Sing Buri 43 Lop Buri 44 Suphan Buri 45 Ang Thong 46 Phra Nakhon Si Ayutthaya 47 Saraburi 48 Nakhon Pathom 49 Pathum Thani 50 Nakhon Nayok 51 Nonthaburi 52 Krung Thep Maha Nakhon (Bangkok) 53 Samut Prakan 54 Samut Songkhram 55 Samut Sakhon. ***SE* (SOUTH-EASTERN)** 56 Sa Kaeo 57 Prachin Buri 58 Chachoengsao 59 Chon Buri 60 Rayong 61 Chanthaburi 62 Trat. ***PEN* (PENINSULAR)** 63 Chumphon 64 Ranong 65 Surat Thani 66 Phangnga 67 Phuket 68 Krabi 69 Nakhon Si Thammarat 70 Phatthalung 71 Trang 72 Satun 73 Songkhla 74 Pattani 75 Yala 76 Narathiwat.

WETLANDS IN THAILAND

Wetland ecosystems occupy about 6% of the world's land surface. The difficulty in defining a wetland arises partly because of its highly dynamic character, and partly because of difficulties in defining their boundaries (Mitsch and Gosselink, 1993 cited in Turner *et al.*, 2000). The official definition proposed by the Ramsar Convention (1971) was: wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters." In addition, the Ramsar Convention (Article 2.1) states that wetlands: "…may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands" (UNESCO 1994).

Wetlands make up one of the ecological systems on earth, supporting an immense variety of plants and animals, and yielding great wealth for mankind through fisheries, timbers and other plant resources, and their roles in the storage and release of water.

Wetlands can be found all over the world, from the polar regions to the tropics. In many regions, wetlands are deteriorating rapidly. People around the world rely on wetlands for their spiritual, cultural as well as economic well-being. That is why we need to safeguard the existence of wetlands worldwide.

Wetlands provide services of great value to society; they control floods, protect coastal zones and they host a great diversity of species. The cultural and economic importance of wetlands to indigenous communities is beyond words.

There are several ways to categorize wetlands. Wetlands have been classified based on their sources of water, nutrients and ecological character. According to Kirsten (2002) and Bishnu (2003) wetlands are classified as follows:

Marine wetlands: coastal areas, lagoons, coral reefs and rocky shores. Coasts mean areas between land and open sea that are not influenced by rivers, e.g., shorelines, beaches, mangroves and coral reefs.

Estuarine wetlands: where rivers meet the sea and water changes from fresh to salt as it meets the sea, e.g., deltas, tidal marshes, mudflats and salt marches.

Lacustrine wetlands: areas of permanent or semi-permanent water with little flow, e.g., lakes, ponds.

Palustrine wetlands or marshes/swamps: areas where water is more or less permanently at the surface and/or causing saturation of the soil, e.g., fen, peatlands, bogs. Marshes are also called slow water dams. They are like huge sponges absorbing water during the wet season and releasing it slowly during the dry season.

Riverine wetlands: areas along rivers and streams

Floodplains: areas next to the permanent course of a river that extends to the edge of the valley, e.g., ox-bow lakes and river-islands.

Artificial wetlands: fish ponds, canals, irrigated lands, rice paddies, salt pans and reservoirs.

The Ramsar Convention adopted the Ramsar Classification of Wetland Types at the Conference of the Parties in 1990. It divides wetlands into three main categories; Marine/Coastal wetlands, Inland wetlands and Human-made wetlands as a broad framework to aid rapid identification of wetland habitats (Kabii, 1998).

Thailand has long recognized the value and importance of wetlands due to the close association between the Thai way of life and wetlands since ancient times. Wetlands in Thailand cover an area of 36,616 square kilometers or approximately 7.5% of the total area of the country (Office of Environmental Policy and Planning. 1999). Freshwater wetlands, including canals, streams, rivers, waterfalls, marshes, ponds, water reservoirs, dams, lakes, inundated grasslands, peat swamp forests, and inundated agricultural lands account for 45% of all wetlands in the country. Coastal wetlands consisting of estuaries, sandy beaches, mudflats, mangrove forests, coral reefs and sea-grass beds cover 55%. The two most important wetlands in Thailand are the Gulf of Thailand and the lower central plain. For freshwater lakes, the important sites include Bung Boraphet, Nong Han, Bung Lahan, Thale Noi and Khao Sam Roi Yot (Office of Environmental Policy and Planning, 2002).

AQUATIC PLANTS

Aquatic plants, also called hydrophytic plants or hydrophytes, are plants normally found growing in water at or above the surface of the soil. Aquatic plants can only grow in water or permanently saturated soil.

Aquatic plants are classified by their growth habit as floating plants, submersed plants, emergent plants, and marginal plants (Dallas and Charles, 2005) (Figure 4).

Floating Plants: Some plants are free-floating while others, rooted in the bottom, have floating leaves that rise or fall with the water level (water lily, *Nymphaea* spp.). Many floating plants grow rapidly and are among the most troublesome aquatic weeds. Duckweeds (*Lemna* spp.) and watermeal (*Wolffia* spp.) are true floating plants of this group whose roots feed from water rather than soil.

Submersed Plants: These are true seed plants with roots, stems, and leaves. Rooted on the bottom, these plants grow chiefly below the surface, although their flowers and seeds and a few leaves may extend above it. A depth of 3–4 meters (10–12 feet) in clear water is the limit for most submersed plants. Important submersed plants include: *Potamogeton* spp., *Blyxa* spp., *Hydrilla* spp., coontail (*Ceratophyllum* spp.), naiads (*Najas* spp.), *Barclaya* spp. and bladderwort (*Utricularia* spp.).

Emergent Plants: These are rooted in the bottom and produce most of their leaves and flowers at or above the surface. Leaf shape, size, and point of attachment are variable within this group. Leaves of emergent plants do not rise and fall with the water level as do those of attached floating plants. Important emergent plants include: watershield (*Brasenia* spp.), arrowhead (*Sagittaria* spp.), water primrose (*Ludwigia* spp.), lotus (*Nelumbo* spp.) and water-willow (*Justicia* spp.).

Marginal Plants: These are emergent plants that grow on saturated soil beyond the water's edge. These plants vary in size, shape, and habitat. They may be found growing in moist soils along shorelines into water up to 60 centimeters (2 feet) in depth. Important marginal weeds are: cattails (*Typha* spp.), smartweeds (*Polygonum* spp.), *Monochoria* spp., *Canna* spp., *Sagittaria* spp. and *Limnocharis* spp.

Aquatic plants are unique in their habitats, but are not separately classified by botanists from other plants on earth. Terrestrial and aquatic plants share the same structures, forms and functions. The differences between aquatic and terrestrial plants are in of the adaptations made by some species to allow their growth in water (Nash, 1994).

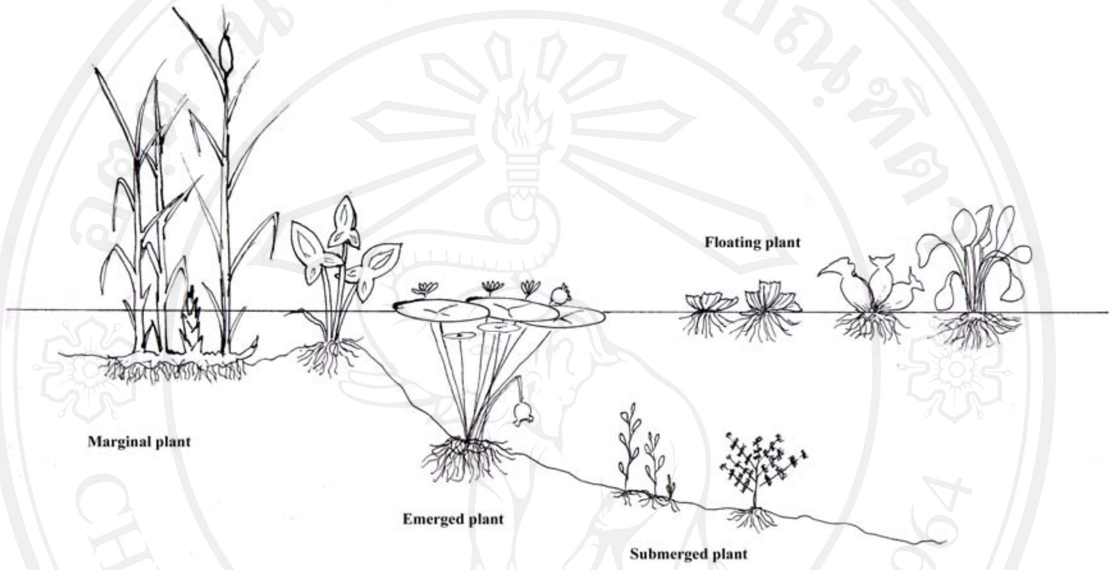

Figure 4. Types of aquatic plants.

THE LOTUS AND THE WATER LILIES

The words describing water lilies and lotuses have been used interchangeably. This is still the case in many foreign languages, where the words "water lily" and "lotus" can mean either *Nymphaea* or *Nelumbo*, or both. The most common confusions are the "Blue Lotus" from ancient Egypt that refers to the blue water lily, *Nymphaea caerulea*; the " Egyptian Lotus" that is *Nymphaea lotus*, a white night bloomer; and the subgenus of *Nymphaea* called *Lotos*. The precise use of the name "lotus" for aquatic plants relates to the *Nelumbo* family, which includes two species and many hundreds of cultivars. In Thailand, all lotus and water lilies are well circumscribed in the name "Bua."

The lotus is an aquatic emergent angiosperm, belonging to Nelumbonaceae (Lotus family), and the genus *Nelumbo*. The water lilies are in the family Nymphaeaceae. Once, both were included in the same family, but they differ by the following points (Figure 5):

- Most leaves of the lotus are large and stand above the surface of the water, but those of water-lilies are small and float on it.
- Lotus has many tepals, which are arranged spirally and drop after blooming where as the tepals in water-lilies are persistent.
- The carpels of lotus are separate and sunken in hollows on the upper surface of the receptacle, but in water lilies the carpels are not embedded in the receptacle.
- Some flowers of the water-lilies are blue whereas this color is never found in the lotus.
- The leaves of lotus reject water but water lily leaves do not.

Figure 5. Lotus and water lilies

A. Lotus.

B. Water lilies.

RELATIONSHIP BETWEEN THE LOTUS AND THE WATER LILIES

Nelumbo has large showy flowers and peltate leaves. Due to an overwhelming resemblance to some of the other genera of water lilies it was indeed placed in Nymphaeaceae in several classifications until quite recently (e.g., Lawrence 1968; Hutchinson, 1973; Heywood, 1993). But we now know that the striking similarities between *Nelumbo* and Nymphaeaceae are due to convergent evolution.

The phylogenetic position of Nymphaeaceae is as one of the two basal-most lineages of extant angiosperms and that position is strongly supported by nearly all molecular analyses. *Nelumbo* does not have the same *rbcL* gene sequence in the chloroplast as the genera in Nymphaeaceae (Les *et al*., 1991; Qui *et al*., 1993) and there is a compelling support for the recognition of three distinct 'water lily' lineages: Nymphaeales, Nelumbonales, and Ceratophyllales. Additionally, there are many other features, such as possession of gallic and ellagic acids and benzylisochinolines (Goleniewska-Furmanowa, 1970; Gibbs, 1974), lacking perisperm and its tricolpate pollen (Ito, 1987) floral anatomy/morphology (Moseley and Uhl, 1985) justifying that *Nelumbo* is now excluded from Nymphaeales (Figure 6).

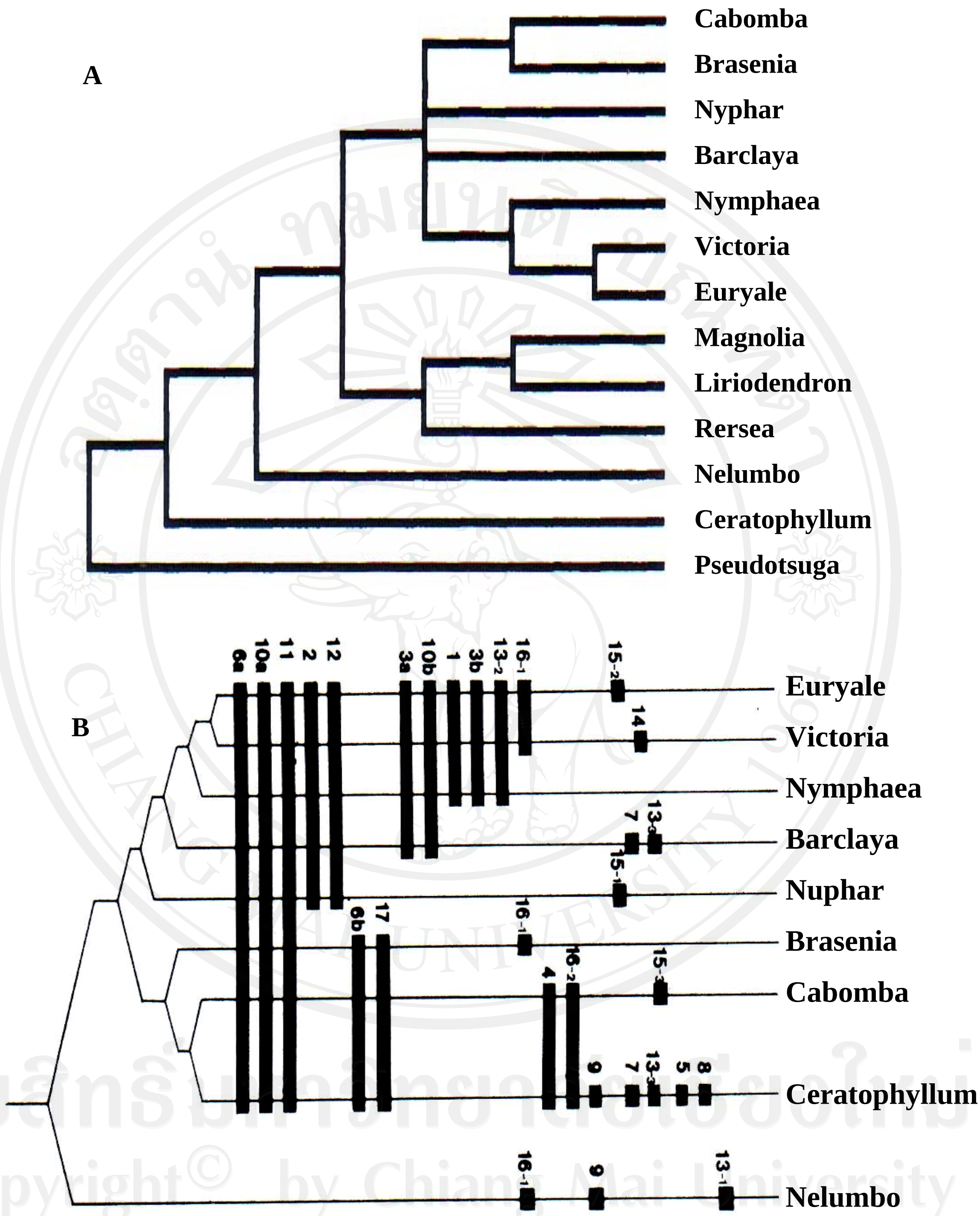

Figure 6. Cladograms of the Nymphaeales and allied groups.

A. Strict consensus tree of four equally shortest trees found by parsimony analysis of *rbcL* data in 'water lily' genera and woody Magnoliidae rooted using a gymnosperm (*Pseudotsuga*) as an outgroup (Les *et al*., 1991).

B. Cladogram constructed by Ito (1987) using 17 characters of gross morphology, anatomy, and palynology. The numbers correspond to those 17 characters.

Circumscription of water lilies and Nymphaeaceae

Water lilies belong in the order Nymphaeales, which in their broadest circumscription (Cronquist, 1981) include ten genera *(Barclaya, Brasenia, Cabomba, Ceratophyllum, Euryale, Nelumbo, Nuphar, Nymphaea, Ondinaea, Victoria)* variously placed in different combinations in a number of more or less inclusive families. At one extreme, all except *Ceratophyllum* are assigned to Nymphaeaceae (Melchior 1964 in suborder Nymphaeineae under Ranunculales corresponding to the older Ranales) and in the other extreme they are divided among seven families (for a discussion see Les, 1988; Les *et al*., 1991; Williamson and Moseley, 1989). *Ceratophyllum* has inconspicuous flowers and is very unlike the other genera and has been associated with the water lilies only because of its aquatic habit. Based on cladistic and molecular work, *Ceratohyllum* is now excluded from Nymphaeales and placed as a sister group to the angiosperms (Chase *et al*., 1993), a sister group to the monocots (Qui *et al*., 1993; Graham and Olmstead, 2000) or as a sister group to the eudicots (Soltis *et al*., 2000).

On one hand, the removal of *Ceratophyllum* and *Nelumbo* (see above, Relationship of the lotus to water lilies) from the Nymphaeales is widely accepted (Les and Schneider, 1995) and on the other hand there are now much evidence pointing to that the remaining genera form a monophyletic group (Les *et al*., 1999). That monophyletic group is variously classified as order Nymphaeales with only a single family Nymphaeaceae s.l. (as in Judd *et al*., 2002) or with two families, Cabombaceae including *Cabomba* and *Brasenia* and Nymphaeaceae s. str. with *Nuphar, Barclaya, Ondinea, Nymphaea, Euryale*, and *Victoria* (Les *et al*., 1999; Stevens, 2001).

The position of *Nymphaea* and *Barclaya* within Nymphaeaceae s. str.

The phylogeny of Nymphaeaceae was studied using a combination of 68 non-molecular characters and molecular data derived from *rbcL*, matK and 18S rDNA sequences by Les *et al*. (1999). Of the six genera in Nymphaeaceae s. str. *Victoria* and *Euryale* together form a clade in the most derived position strongly supported by both molecular and morphological shared derived features such as their acauleate and short-lived habit with peltate, floating leaves and no submersed leaves. *Nymphaea* has traditionally been associated with *Victoria* and *Euryale* (Conard, 1905) and the phylogenetic analysis also places *Nymphaea* in a clade with those two genera although the association is not as strongly supported as the *Victoria+Euryale* clade; no obvious morphological characters support the association but the organization of the gynoecial vascular strands in the three genera share derived features (Weidlich, 1980).

The next branch of the cladogram was made up of *Ondinea* which, however, share many derived features with *Nymphaea* in floral structure (Hartog, 1970; Williamson and Moseley, 1989) and vegetative morphology (Williamson *et al*., 1989) and which in some molecular analysis form a clade with *Nymphaea*.

The genus *Barclaya,* which has often been seen as different enough to form its own family (Les, 1988), formed the next branch. *Barclaya* and the higher branches share several derived morphological features such as perigyneous/epigyneous flowers with a continuous stigmatic surface and underwater fruit maturation, staminodes, zonasulcate pollen and an inner satellite peduncle bundle.

Finally the basal branch of the tree presented by Les *et al.* (1999) includes the genus *Nuphar*. In summary the two Nymphaeaceae genera represented in Thailand, *Nymphaea* and *Barclaya*, are placed as the second and fourth most basal branches in the Nymphaeaceae s. str. cladogram and their biogeography and evolution in the Thai flora should thus be interpreted independently.

TAXONOMIC LITERATURE

1. Classification of the Families Nelumbonaceae and Nymphaeaceae

Nelumbonaceae and Nymphaeaceae were traditionally classified in the order Nymphaeales (Cronquist, 1981; Cronquist, 1988; Heywood, 1993; Williamson and Schneider, 1993). They were merged into one family, Nymphaeaceae by Hutchinson (1960), Lawrence (1968) and Heywood (1993). Several studies however, show that Nelumbonaceae is not closely related to the Nymphaeaceae and Cabombaceae (Thorne, 1974, 1992; Williamson and Schneider, 1993; Mabberley, 1997). Li (1955) and Cronquist (1988) reviewed the classification and included further five families in Nymphaeales (Nelumbonaceae, Nymphaeaceae, Barclayaceae, Cabombaceae and Ceratophyllaceae). A recent classification by Takhtajan (1997) treats Nymphaeaceae and Barclayaceae in Subclass Nymphaeidae, Superorder Nymphaeanae and order Nymphaeales whereas Nelumbonaceae is treated in Subclass Nelumbonidae, Superorder Nelumbonanae and order Nelumbonales. As can be noticed the classification of these plants has been considerably confused. For the purpose of this study the system of Mabberley (1997) is followed and *Barclaya* is treated as a member of Nymphaeaceae.

Understanding phylogenetic relationships within the angiosperms, use of cladistic methodology, and the incorporation of morphological, anatomical, embryological, palynological, karyological, chemical and molecular data has been particularly useful in assessing angiosperm relationships. As a consequence Nymphaeaceae (including Barclayaceae and Cabombaceae) are now treated in the order Nymphaeales under the non-monocot paleoherbs group (the primitive extant angiosperm) and Nelumbonaceae are treated in the order Proteales of the eudicots group or tricolpates (Judd *et al*., 2002; Simpson, 2006) (Figure 7).

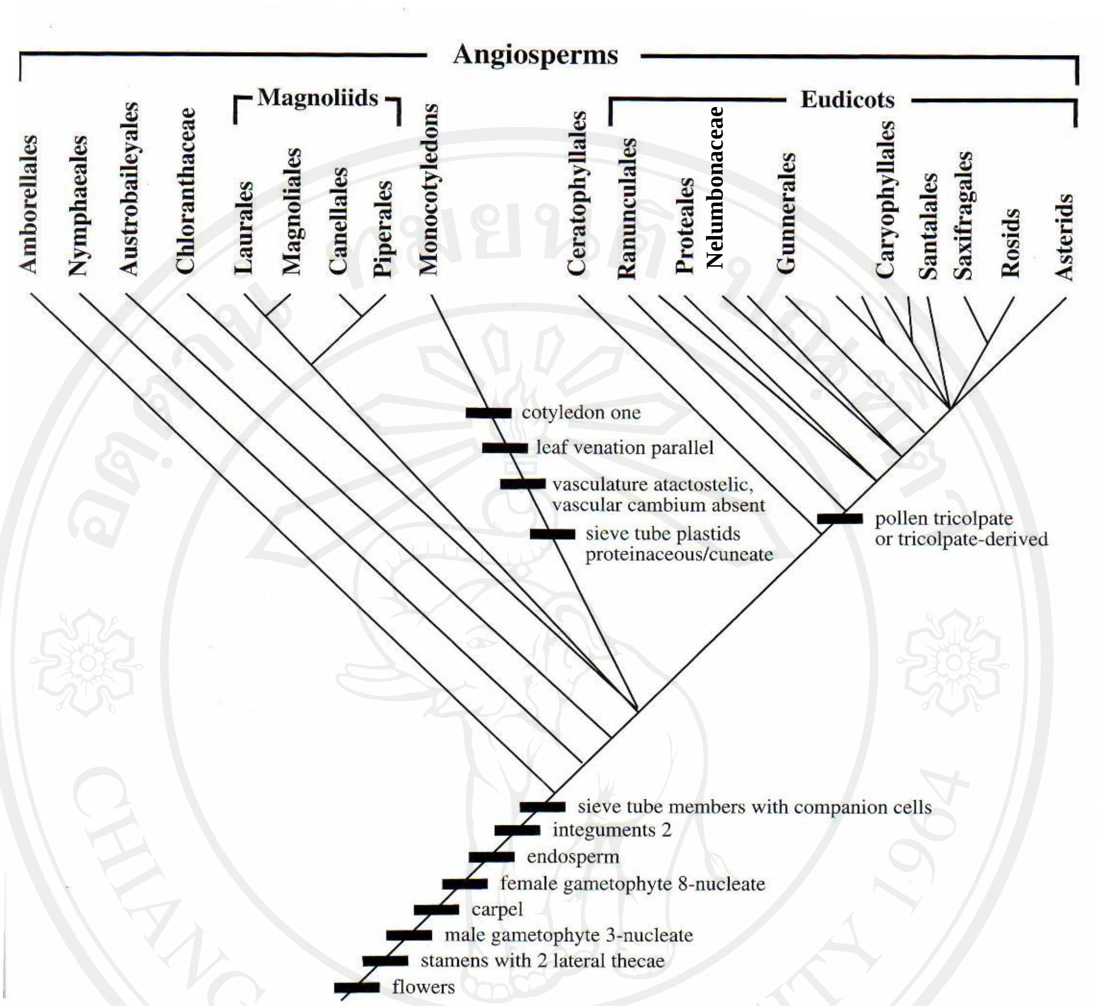

Figure 7. Cladogram showing the relationships of the major groups of angiosperms (modified from Simpson, 2006).

Nelumbonaceae consists of the single genus *Nelumbo* with two species. *Nelumbo nucifera* is native to southern Russia, Asia, India and Australia, and to Thailand. *Nelumbo lutea* is native to eastern North America.

Nymphaeaceae consists of six genera and approximately 75 species (Mabberley, 1997). The family is almost cosmopolitan, distributed in fresh water habitats. The genus *Victoria*, with two species, occurs in tropical South America, the single species of *Euryale* is distributed from northern India to China and Japan, *Ondinea* is endemic to north western Australia, *Nymphaea* with 50 species at tropical and temperate latitudes and in all continents, *Barclaya* with four species, is native to tropical southeastern Asia to New Guinea and *Nuphar* with ca. 20 species, occurs in North America, Europe and eastern Asia (Schneider and Williamson, 1993). In

Thailand, native populations of *Nymphaea* and *Barclaya* have been observed and some of the other genera are exotic and cultivars.

The genus *Nymphaea*, as established by Linnaeus (1753), includes species that are now referred to the genera *Nuphar* Smith and *Nelumbo* Adanson. Subsequent confusion arose with the maintaining of the name *Nymphaea* by Salisbury (1806) for yellow water lilies [*Nuphar*] and the establishment of a new name, *Castalia*, for the white water lilies [*Nymphaea*]. This action preceded a similar segregation of these genera by Smith (1809), who applied *Nuphar* to the yellow water lilies and retained *Nymphaea* in its current circumscription.

Conard (1905) divided *Nymphaea* into two groups, and five subgenera. Group Apocarpiae includes the subgenera *Anecphya* and *Brachyceras,* while group Syncarpiae consists of the subgenera *Hydrocallis*, *Lotos* and *Castalia*. Group Apocarpiae consists of *Nymphaea gigantea* and other tropical day-blooming water lilies. Conard placed the hardy water lilies of subgenus *Castalia* in group Syncarpiae with the night-blooming tropical (*Hydrocallis* and *Lotos*) because his studies show a closer botanical relationship between hardy water lilies and night-blooming tropical ones than with day-blooming tropical species.

Williamson and Schneider (1993) reported that *Nymphaea* was cosmopolitan, composed of approximately 50 species, and they classified it into five subgenera in the following key:

1. Carpel fusion incomplete 2.
1. Carpel fusion complete 3.
2. Carpellary appendages absent or inconspicuous
subg. *Anecphya* Caspary
2. Carpellary appendages slightly developed, triangular-tapered
subg. *Brachyceras* Caspary
3. Anthesis diurnal
subg. *Nymphaea* Planchon [=subg. *Castalia* (Salisb.) DC.]
3 Anthesis nocturnal 4.
4. Carpellary appendages well developed, usually clavate
subg. *Hydrocallis* (Planchon) Conard
4. Carpellary appendages well developed, linear
subg. *Lotos* DC.

Wiersema (1982) found *Nymphaea lotus* for the first time in the western Hemisphere. A recently discovered population in Florida is discussed and additional records in Louisiana, Guyana, Panama, Venezuela, Colombia, and Brazil are presented.

Mitra and Subramanyan (1982) studied several populations of *Nymphaea rubra* in the Howrah, Hooghly, and 24 Parganas districts in West Bengal and Barisal district in Bangladesh. They showed that this species, which is claimed to be a native of Bengal, never sets fruit in nature, but plants propagate mainly through stolons and vegetative buds and, in exceptional cases, by proliferation of flowers.

2. Anatomical studies of the Families Nelumbonaceae and Nymphaeaceae

Nelumbonaceae:

Gupta, *et al.* (1968) reported the fewer stomata develop on the lower surface of leaves of *Nelumbo nucifera* during aerial growth. The stomata become obliterated by the readjustment of neighboring epidermal cells. During initial stages of degeneration the guard cells show irregularly thickened walls, disinterated nuclei and highly vacuolated cytoplasm. The stomata on leaves, perianth lobes, stamens, receptacles and carpels are haplocheilic in development and anonocytic at maturity.

Kosakai *et al.* (1970) examination of the primary xylem of roots of *Nelumbo* revealed the presence of vessel elements with intra-face, transversely-rowed to obliquely-rowed bordered pitted side walls and end wall with scalariform perforations.

Esau and Kosakai (1975) reported that the laticifer of *Nelumbo nucifera* occur in ground tissue and more prominently in the vascular bundles, in which spatially associated with both xylem and phloem. The laticifera are long thin-walled cells, many show single perforation in the end walls.

Esau (1975) found that *Nelumbo nucifera* has a relatively strongly developed phloem tissue. The vascular system consists of discrete collateral bundles in which no cambium develops and the phloem and xylem are separated by a narrow layer of parenchyma cells. The phloem consists of sieve elements, companion cells, and phloem parenchyma cells. The sieve elements have transverse end walls with simple sieve plates. The cells attain considerable width in the late phloem (metaphloem). The companion cells are in vertical strands. In the early phloem (protophloem) of large bundles the sieve tubes and companion cells are eventually obliterated. The parenchyma cells also form vertical strands that may contain tannin cells. Some parenchyma cell and companion cells are binucleate. The sieve elements show ultra structural features common for these cells in dicotyledons. At maturity, they lack nuclei, ribosome and tonoplasts, but retain a plasmalemma, mitochondria, and plastids. The latter are poorly differentiated and form starch. The endoplasmic reticulum is in part stacked, in part it forms a network next to the plasmalemma. The P-protein occurs in two forms. One consists of tubules not assembled in any specific type of array. The other, possibly composed of much extended tubules, is assembled in crystalline aggregates that are retained in mature cells. The sieve plate pores are lined with callose and plasmalemma. The lateral walls are relatively thin and the nacreous layer varies in degree of distinctness.

Ito (1986) studied the floral anatomy of *Nelumbo nucifera* and reported that vascular bundles in the peduncle have large tracheids. The receptacle morphology of the central vascular bundles changes to typical collateral bundles which have xylem with many slender tracheids. The floral vasculature in the receptacle consists of two systems, central and cortical systems. The main vascular system of the perianth was supplied by a single trace from the central vascular system. Traces to stamens are supplied from the cortical vascular system. Single cortical usually strand supplies several stamens by the division of these strands.

Schneider and Carlquist (1996) studied the vessels in roots and rhizomes of *Nelumbo nucifera*. Vessels are characteristic of root metaxylem. Pores in primary walls of pits of end walls of these vessels are various in size, but feature incomplete lysis of pit membranes, often with residual webs or threads of primary wall material. Vessels in metaxylem of rhizomes; pores in these vessels are smaller and more confined than in those of roots. They conclude that organographic distribution of vessels in *Nelumbo* follows the patterns seen in monocotyledons, which like Nymphaeaceae and other aquatics, have sympodial architecture.

Nymphaeaceae:

Weidlich (1976) studied anatomy and arganinzation of the stem vascular system in representative taxa of *Nymphaea* (subgenera *Anecphya, Lotos,Brachyceras*, *Castalia,* and *Hydrocallis*). The stem vascular system consists of a series of concerntric axial stem bundles from which traces to lateral organs depart. Xylem elements consist of tracheids with spirally or weakly reticulated secondary wall thickenings. The phloem is made up of companion cells and short sieve tube members with simple sieve plates that are nearly transverse. The node each leaf is supplied with two lateral leaf traces and a median leaf trace. A root trace is also present and supplies a series of adventitious roots borne on the leaf base. Flower and vegetative buds occupy leaf sites in the genetic spiral and in the parastichies seen on the stem exterior. Each flower or vegetative bud is related to a leaf through specific spatial and vascular association. The related leaf is separated from the related flower by three members of the genetic spiral and occupies an adjacent orthostichy. Vascular tissue for the related flower arises from the inner surfaces of the four stem bundles supplying leaf traces to the related leaf and extends through the pith to the flower or vegetative bud via a peduncle fusion bundle.

Weidlich (1980) reported organization of the stem vascular system was analyzed in *Victoria* species and *Euryale ferox*. The stem vascular system consists of a number of concentrically-organized continuing axial stem bundles. At the node each leaf is supplied with a root trace, two lateral leaf traces, and a median leaf trace. A peduncle fusion bundle is also present at each node. The peduncle fusion bundle supplies vascular tissue to the median leaf trace and to the peduncle trace. Flowers are nonmedian axillary but have specific vascular, spatial, and developmental relationships to leaves in a manner that resembles the genus *Nymphaea*. On the basis of the analysis of the stem vascular system, *Victoria* and *Euryale* are more similar to each other than to *Nymphaea*.

Schneider *et al* (1995) found vessels in roots of *Nuphar, Nymphaea* and *Ondinea* and determines presence of perforations in end walls of tracheary elements. *Nuphar* has occasional small perforations and *Nymphaea* has a scattering of small perforations, but no perforations were observed in *Ondinea*. In *Nuphar* and *Nymphaea*, metaxylem elements have helical-reticulate wall thickenings, but end walls of tracheary elements have at least some scalariform pitting; in *Ondinea*, end walls are identical to side walls. In all three genera, striations (thickenenings) in primary walls of tracheary elements are common, as in *Euryale* and *Victoria*

Schneider and Carlquist (1995) found vessels in roots and stems of *Barclaya rotundifolia* and revealed perforations on tracheary elements of roots, but not on those of stems. End walls of vessels are identical with lateral walls except for the presence of perforations.

Carpenter (2005) studied stomata architecture and evolution in basal angiosperms. Stomata architecture of Nymphaeaceae: four *Nuphar*, six *Nymphaea*, two *Victoria*, and one *Euryale*; Cabombaceae: one *Brasenia*, has a continuum ranging from those lacking subsidiaries (anomocytic), to those with weakly specialized rings of cells (weakly stephanocytic and weakly actinocytic), to more strongly specialized rings of cells (stephanocytic and actinocytic), to complexes with incomplete rings of cells (incomplete stephanocytics), as well intermediates between actinocytic and stephanocytic (the actino-stephanocytic type).

3. Palynology of the Families Nelumbonaceae and Nymphaeaceae

Mitranant (1984) studied the genus *Nelumbo* Adanson in Thailand. Its morphology, anatomy, growth, number of chromosomes and pollen morphology revealed that there are altogether six varieties. Their external and internal structures are also similar. The pollen morphology is prolate-spheroidal and basically tricolpate but rarely pericolpate.

Williamson and Schneider (1993) studied the floral morphology of the genus *Barclaya*. Floral structure reveals vasculature and developmental support for the theory that the hypogynous appendages are sepals. The pollen is zonasulculate, the floral ontogeny is similar to that previously described for epigynous members of the Nymphaeaceae and anatomical and morphological similarities with other Nymphaeaceae. The cleistogamous and chasmogamous flowers are self-pollinated, the latter perhaps facilitated by flies in emergent flowers.

Kreunen and Osborn (1999) studied pollen and anther development in *Nelumbo lutea*. The exine development occurs during the free spore stage with the deposition of a tectate-columellate ectexine, a lamellate endexine, and unusual granular layer below and intermixed with the endexine lamellae. A two-layered intine forms rapidly during the earliest mature pollen stage. Major events of anther development include the degradation of a secretory-type tapetum during the free spore stage and the rapid formation of U-shaped endothecial thickenings and diaperturate grains also develop. The mature pollen grains are tricolpa (Figure 8).

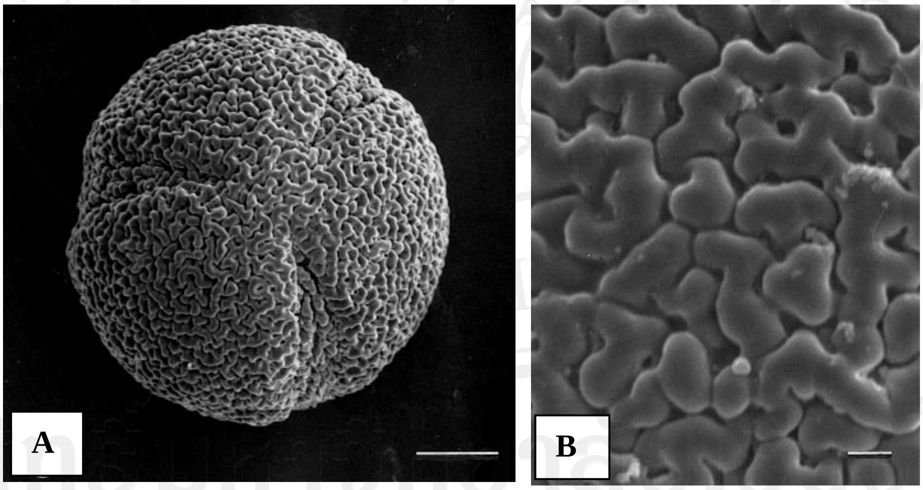

Figure 8. Mature pollen grain stage of *Nelumbo nucifera* Gaertn.
(Source: Kreunen and Osborn, 1999)
A. Polar view of a triaperturate pollen grain. Portions of the three apertures are visible. Bar = 10 mm.
B. Detail of the nonapertural pollen surface. Note that the tectum forms a densely reticulate ornament. Bar = 1 mm.

Perveen (1990) studied pollen morphology of 16 species from Karachi in Pakistan and Sukkaewmanee (2001) studied pollen morphology of plants at Thale Noi, Changwat Phatthalung found that pollen grains of *Nymphaea lotus* [=*N. rubra*] (Figure 9A), *N. stellata* [=*N. nouchali*] are monads, bilateral symmetry, heteropolar, prolate-spheroidal or subprolate, heteropolar, monocolpate (Figure 9B). Exine surface in *N. lotus* [=*N. rubra*] is psilate-rugulate and regulate in *N. nouchali*. Pollen grains of *Nelumbo nucifera* is mononad, radial symmetry, isopolar, prolate-spheroidal or subprolate, tricolpate, with regulate exine surface.

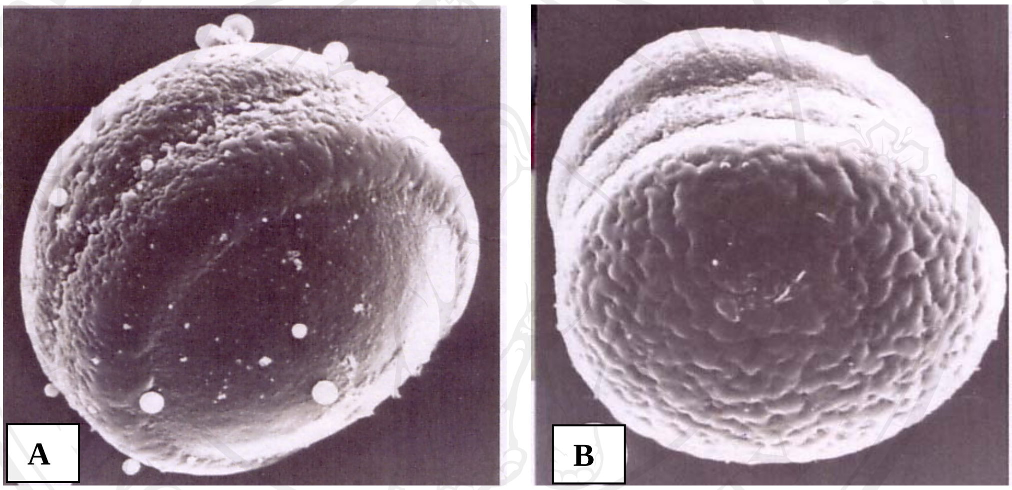

Figure 9. Mature pollen grain stage of *Nymphaea*. (Source: Perveen, 1990)
A. *Nymphaea rubra* Roxb. ex Andr.; B *Nymphaea nouchali* Burm. f.

4. Taxonomic studies on Nelumbonaceae and Nymphaeaceae

The taxonomic study of the families Nelumbonaceae and Nymphaeaceae in neighboring countries was carried out.

Ridley (1967) recognized six species and three genera in family Nymphaeaceae for the Malay Peninsula; 1. *Nymphaea* with two species, *N. stellata* [= *N. nouchali*] and *N. lotus* 2. *Barclaya* with three species, *B. motleyi, B. kunstleri* and *B. longifolia* and 3. *Nelumbium* [=*Nelumbo*] with one species *Nelumbium speciosum* [=*Nelumbo nucifera*].

Humbert and Gagnepain (1950) recorded three species in family Nymphaeaceae from Indo-china, *Nymphaea lotus, Nymphaea tetragona* and *Nymphaea stellata* [=*N. nouchali*].

Royan (1962) reported three genera of family Nymphaeaceae in New Guinea: 1. *Nelumbo* with one species, *Nelumbo nucifera* 2. *Nymphaea* with six species, *N. pubescens, N. nouchali, N. gigantean, N. macrosperma, N. dictyophlebia and N. violacea* and 3. *Barclaya* with one species and two forms, *B. motleli* forma *motleyi* and *B. motleli* forma *membranacea*.

Backer and Bakhuizen (1963) reported *Nelumbo nucifera*, *Nymphaea pubescens* and *Nymphaea nouchali* in family Nymphaeaceae from Java and also included five cultivated species, *Victoria amazonica, Nymphaea gigantea* var. *violacea*, *Nymphaea nouchali*, *Nymphaea capensis* var. *zanzibariensis* and *Nuphar japonicum*.

Khan (1987) recognized eight species in five genera belonging to family Nymphaeaceae for the Bangladesh: 1. *Euryal*e with one species, *E. ferox* 2. *Nelumbo* with one species, *Nelumbo nucifera* 3. *Nuphar* with one species, *Nuphar luteum* 4. *Nymphaea* with four species, *N. amazonum, N. capensis, N. nouchali* [=*N. rubra*], *N. stellata* [= *N. nouchali*] and 5. *Victori*a with one species, *V. amazonica.*

Mitra (1990) reported the plant surveyed in India, and enumerated one species in family Barclayaceae, *Barclaya longifolia*; one species in family Nelumbonaceae, *Nelumbo nucifera*; seven species and two genera in family Nymphaeaceae: 1. *Euryale* with one species, *E. ferox,* 2. *Nymphaea* with six species, *N. alba, N. candida, N. nouchali, N. pubescens, N. rubra* and *N. tetragona*. Six cultivated species were also reported, among them, four species belong to genus *Nymphaea*, *N. caerulea, N. micrantha, N. alba* x *N. mexicana = N. marliacea* and *N. alba* var. *rubra*, two species in genus *Victoria*, *V. amazonica* and *V. cruziana*, respectively.

Qaiser (1993) enumerated six species and two genera in family Nymphaeaceae in Pakistan: 1. *Euryale* with one species, *E. ferox* 2. *Nymphaea* with five species, *N. alba, N. candida N. nouchali, N. pubescens,* and *N. tatragona*.

Dassanayake (1996) reported one species in Nelumbonaceae, *Nelumbo nucifera* and two species belong to one genus, *Nymphaea* in Nymphaeaceae, *N. nouchali* and *N. pubescens* found in Sri Lanka.

In China, Wu *et al.* (2001) recognized *Nelumbo nucifera* in family Nelumbonaceae and family Nymphaeaceae consisted of nine species in three genera, *Nuphar pumila* subsp. *pumila, Nuphar. pumila* subsp. *sinensis, Nuphar lutea, Nymphaea alba, Nymphaea candida, Nymphaea tetragona, Nymphaea lotus, Nymphaea nouchali and Euryale ferox.*

5. The taxonomic studies on Nelumbonaceae and Nymphaeaceae in Thailand

The Nelumbonaceae and Nymphaeaceae have been little studied taxonomically in Thailand although they are quite common. The Thai species of *Nymphaea* belong to subgenus *Nymphaea* (equal to subg. *Castalis*) and to subgenus *Lotos*. The genus *Barclaya* has been neglected in the scientific literatures owing to its remote distribution in Southeast Asia and poor representation in herbaria (Schneider and Carlquist, 1995). One of its conspicuous characters is that it has completely inferior ovaries. At present about four species are known from tropical evergreen rain forests in Indo-Malaysia, Thailand and Burma. Three species grow in small, clear, slow-moving streams, while, *B. rotundifolia* grows in marshy areas and produce aerial leaves. Some of them flower when exposed (Cronquist, 1988; Takhtajan, 1997).

Ridley (1911) studied the lower Siam, and showed a boundary line between the Siamese and Malay floras. The report indicated that Nymphaeaceae was represented with two genera and two species: *Barclaya longifolia* and *Nymphaea stellata* var. *parviflora* [=*Nymphaea nouchali* Burm. f.].

Schmidt (1916) studied the Nymphaeaceae in Koh Chang (The Gulf of Siam) and mentioned that two genera and two species occurred there: *Nymphaea stellata* Willd. [=*Nymphaea nouchali* Burm.f] and *Nelumbo nucifera* Gaertn.

Craib (1931) enumerated the plants known from Siam at that time and listed the Nymphaeaceae with three genera; *Nymphaea* with three species, *Nymphaea cyanea* Roxb., *Nymphaea lotus* Linn. var. *pubescens* Hook f. et Th. [=*Nymphaea pubescens* Willd] and *Nymphaea stellata* Willd. [=*Nymphaea nouchali* Burm. f.]; *Barclaya* with two species, *Barclaya Kunstleri* Ridl. and *Barclaya longifolia* Wall; and *Nelumbo* with *Nelumbo nucifera* Gaertn..

Suvatabandhu (1957, 1958) in his study of the Thai flora included four genera of Nymphaeaceae: *Nelumbo, Nymphaea, Barclaya* and *Victoria*, but reported that the *Victoria* was an exotic species from South America; in which five *Nymphaea* taxa (*N. lotus* , *N. lotus* var. *pubescens* [=*Nymphaea pubescens* Willd], *N. capensis* var. *zanzibariensis* , *N. stellata* [=*Nymphaea nouchali* Burm. f.], *N. cyanea*), and three *Barclaya* species (*B. motleyi, B. longifolia, B. kunthleri*), one species of *Nelumbo* (*Nelumbo nucifera*).and one species of *Victoria* (*V. amazonica*) included with description, common Thai names and their occurrence in Thailand.

Hoitong (1976) studied some species of Nymphaeaceae in Thailand that were described as aquatic herbs, growing in stagnant or slowly flowing water. The external structures of the flowers, leaves and fruits vary from species to species, whereas internal structures were similar. The number and distribution of air canals in the petiole and peduncle were used to classify them into five species of *Nelumbo* and *Nymphaea*. The chromosome numbers of somatic cells were different at the species level and similar at variety level; i.e., three varieties of *Nelumbo nucifera* had 2n=16 and *Victoria amazonica* had 2n=20 being diploids whereas the species of *Nymphaea* are diploid (*Nymphaea capensis* var. *zanzibariensis*, 2n=28), tetraploid (three varieties of *Nymphaea lotus* var. *pubescens,* 4n=56) and hexaploid (*Nymphaea nouchali*, 6n=84). The chromosome structures are different at species level but more or less similar at variety level.

A comparison of Thai Nelumbonaceae and Nymphaeaceae species mentioned in different literature sources is presented in Table 1.

Table 1. Comparison of Thai Nelumbonaceae and Nymphaeaceae species mentioned in different literature sources.

Species	Ridley 1911	Schmidt 1916	Craib 1931	Suvatabandhu 1957, 1958	Suvatti 1978	Wasuwat 1994	Sriphen 2000	Smitinand 2001
B. longifolia	×		×	×	×		×	×
B. kunstleri			×	×	×		×	
B. motleyi				×	×		×	
N. stellata var parviflora [=N. nouchali]	×							
N. stellata [=N. nouchali]		×	×	×		×	×	×
N. cyanea			×	×	×	×	×	×
N. lotus var. *pubescens[=N. pubescens]*			×	×	×			×
N. lotus				×	×	×	×	
N. rubra						×		
N. rubra var. *rosea[=N. rubra]*						×		
N.capensis var. *zanzibariensis* [cultivated]				×	×	×		×
N. maxicana					×			×
N. versicolor[=N. nouchali]					×cf			
N. ' Lin Jong'						×		
N. Jongkolnee[cultivated]						×		
Victoria amazonica [cultivated]				×	×	×	×	
Nelumbo nucifera		×	×	×	×	×	×	×
Total (species) 17	2	2	5	10	11	10	8	7

ETHNOBOTANY LITERATURE

The study of the uses of Nelumbonaceae and Nymphaeaceae

The uses of Nelumbonaceae

Nelumbo nucifera is a high-quality starch crop, and its rhizomes and nuts are eaten in Malaysia, Singapore, Thailand and China. Several of its parts, including the stamens, are used in Chinese medicine and the Cambodians make a tea of its stamens. The embryo – taken as tea – is used by Chinese, Malaysian and Thai to reduce high fever. The stamens are astringent and diuretic and also used in cosmetics. In India they are employed as an astringent and cooling medicine. In Indo-China the stamens are used for flavouring tea, the leaves may be used for wrapping parcels. In Thailand cigarettes are wrapped in its rose-red petal. The cooked rhizomes are also eaten as vegetable in India and China; sometimes the young fruits are eaten as a salad, and the juice is used in treating gonorrhoea but apparently with no real effect (Burkill, 1966; Keng, 1974).

In Indonesia, the fruit are eaten raw or cooked as delicacy. Young rhizomes, especially the stolon and also young leaves are cooked, stewed or roasted. Even the young petioles, after the rough outer layer has been scraped off can be eaten after cooking. The old leaves are very useful for wrapping material, especially for fresh fish, meat and vegetables which are sold on the market in some regions of Indonesia (Ochse, 1931).

The uses of Nymphaeaceae

The ancient Egyptians cultivated and used *Nymphaea* flowers in religious ceremonies, and in Thailand it has been observed that local people cook and eat the peduncle of *Nymphaea pubescens*. In India and also in the Philippines, the seeds of *Nymphaea lotus* are eaten; they are pounded and made into a kind of bread. The roots and seed of *Nymphaea stellata* [=*N. nouchali* Burm. f.] are famine food in India, Africa, and its young flowers are eaten in Thailand, and the juice of the leaves is applied to the skin for fever in Cambodia. Several species of *Nymphaea, Nelumbo,* and *Barclaya* are grown as ornamental plants in gardens, and frequently cultivated as a decorative aquarium plant (Burkill, 1966; Keng, 1974).

Kumar and Solanki (2002) observed that *Nymphaea alba* was eaten by the Capped Langur (*Trachypithecus pileatus*) in Pakhui Wildlife Sanctuary, Arunachal Pradesh, India and found that plants were a rich source of protein, minerals, energy and contained low fiber because it contain crude protein 23%, ether extract (crude fat) 3%, crude fiber 7%, ash (total minerals) 10% and nitrogen free extract 58%; organic matter 90%.

Pharmacological uses

Mukherjee *et al.* (1996, 1997) reported that methanol extract of *Nelumbo nucifera* rhizome produced significant dose dependent lowering of normal body temperature and yeast provoked elevation of body temperature in rats and significant anti-inflammatory activity in both the models of inflammation in rat.

Bunyaprapath (1998) reported that *Nelumbo nucifera* rhizomes were used for enhancing body energy, relieving high internal body temperatures and thirst, treating fevers and sore throats, and as anti-inflammants. It is also mentioned in ancient Thai pharmacopoeias that *N. nucifera* embryos can be used to nourish the heart, to treat hematemesis, to prevent ejaculation while sleeping, and to quench thirst. Finally the same study reported stamens of *Nelumbo nucifera* were used as a cardiac tonic, neurotic supplement, nourishment, and restorative. This was already known in the ancient pharmacopoeia in which it was suggested that they should be mixed with stamens from several other plants such as *Mammea siamensis* T. Anderson (Clusiaceae), *Mesua ferrea* L. (Iron Wood, Clusiaceae), *Mimusops elengi* L. (Bullet Wood, Sapotaceae), *Jasminum sambac* Ait. (Oleaceae), *Cananga odorata* Hook.f. & Thomson (Annonaceae), *Michelia champaca* L. (Magnoliaceae), *Melodorum fruticosum* Lour. (Annonaceae), and *Pandanus odoratissimus* L.f. (Pandanaceae).

Fossen *et al.* (1999) isolated seven flavonols from blue flowers of the African water lily *Nymphaea caerulea* (=*Nymphaea capensis*). This included novel 3-(2''-aceturjamnosides) of myricetin and quercetin (2 and 6), the rare kaempferol 3-(2''-acetylrhamnoside) and quercetin 3-(3''-acetylrhamnoside), and the 3-rhamnosides of kaempferol, quercetin.

Jittiporn (2002) reported the crude extract from *Nelumbo nucifera* embryo had an effect on the cardiovascular system in rats. The function was possible due to β1 adrenergic receptors, which produce vasodilation, transient hypotension, and a positive chronotropic effect. In high oral doses, long-term administration of embryo extract increased peripheral blood flow.

Suntronjaruennon (2003) reported that in traditional Thai medicine, pods of *Nelumbo nucifera* were used to flush the remaining placenta, to treat a crippled uterus, as an astringent, and to treat diarrhea.

Bhandarkar and Khan (2004) reported that flower extract of *Nymphaea stellata* Willd. was effective in treating liver disorders against carbon tetrachloride-induced hepatic damage in albino rats.

Trongtorsak *et al.* (2005) demonstrated that crude leaf extracts of *Nelumbo nucifera* had positive isotropic and chronotropic effects in rats, and accelerated cardiac electricity through the β1-adrenergic receptors.

Dhanabal *et al.* (2007) reported that ethanolic extract of leaves of *Nymphaea stellata* [=*N. nouchali* Burm. f.] given to diabetic rats in doses of 100 and 200 mg/kg/day for seven days reduced significantly by 32% and 43% the plasma glucose level increased by intraperitoneal injection of 120 mg/day alloxan and the treatment significantly affected the plasma level of cholesterol and triglyceride.