

## CHAPTER 2

### LITERATURE REVIEW – TAXONOMIC STUDY

*Zingiberaceae* Lindl. is the family of aromatic rhizomatous herb. The true stem is poorly developed. The aerial stem is pseudo-stem formed by leaf-sheaths. Leaf blade is lanceolate or elliptic with entire margin, glabrous or pubescent, apex acute or acuminate. Inflorescence is produced on terminal of leafy shoot or on separate leafless shoot, arising directly from rhizome. Flower is epigynous, bisexual and zygomorphic. The one functional stamen is the median posterior of the inner whorl. The other two stamens of the inner whorl are sterile and connate to each other forming the labellum. The lateral stamens of the outer whorl are sterile and petaloid or inconspicuous. The anterior stamen of the outer whorl is totally reduced. Style is placed between thecae. Stigma appears on top of anther. (Larsen *et al.*, 1998).

The new system proposed by Kress *et al.* (2002) based on molecular phylogenetic analysis of nuclear ribosomal DNA (ITS) and chloroplast DNA (*matK*) is composed of four subfamilies and six tribes which are Alpinioideae (Alpinieae & Reidelieae), Siphonochiloideae (Siphonochileae), Tamijioideae (Tamijieae) and Zingiberoideae (Globbeae & Zingibereae). The morphological characteristic of each subfamily and tribe is summarized in table 1. The genus *Curcuma* has been placed under tribe *Zingibereae*.

Burt and Smith (1972b) proposed to conserve *Curcuma* Roxb. against *Curcuma* L. and to selected *C. angustifolia* Roxb. As the type species instead of *C. longa* L. with the reason that the original description of *Curcuma* L. was written for *Musa cliffortiana* L. in 1736 which was changed to *Curcuma rotunda* L. in 1753 in 'Species Plantarum'. The genus description was not modified when *Curcuma longa* L. was added. This made the conflict between genus description and type species. The Committee of Spermatophyte turned down this proposal on the ground that *Curcuma longa* L. should be retained as the type species of the genus *Curcuma* L. since it has been well-known and widely accepted. Later, Burt (1981) proposed to conserve *Curcuma* Roxb. against *Curcuma* L. The Committee of Spermatophyte (1984)

rejected this proposal with the consideration that the conserved name should be dated from 1753 and be attributed to Linnaeus.

### **Previous taxonomic studies**

The study of the genus *Curcuma* in neighboring countries was carried out long time ago. Baker (1890) reported 30 species in India. Among them, 14 species belong to section *Exantha*, 10 in section *Mesantha* and 5 species in section *Hitcheniopsis*, respectively. Gagnepain (1908) recorded 17 species from Indo-china. Ridley (1924) and Holttum (1950) recognized nine species for the Malay Peninsula four of which were cultivated species. Backer and Bakhuizen (1968) reported 16 species from Java. They divided them into three groups. The first group has one species, *C. aurantiaca* van Zijp. It distinguished by absent of anther spur. The second group is *C. zedoaria* (Christm.) Rosc. This group is characterized by having lateral inflorescence and anther spur. This group comprises seven species. The last is *C. viridiflora* Val. group which produce terminal inflorescence and calcarate anther. This group comprises eight species. In China, Wu & Larsen (2000) recognized 12 species, six are endemic and one is introduced, i.e. *C. longa* L.

Several species of *Curcuma* were described from South and Southeast Asia in the recent years, for example, *C. rhabdota* P. Sirirugsa & M.F. Newman (2000), *C. bicolor* Mood & K. Larsen, *C. glans* K. Larsen & Mood and *C. rhomba* Mood & K. Larsen (2001), *C. rubrobracteata* Skornick., M. Sabu & Prasanthk. (2003a), *C. codonantha* Skornick., M. Sabu & Prasanthk. (2003b) and *C. mutabilis* Skornick., M. Sabu & Prasanthk. (2004).

In Thailand, the first record is *C. aromatica* Salisb. from Koh Chang, Trat Province by Schumann (1902). After that, many species were documented in various publications. For example, Phengklai (1988) found *C. aeruginosa* Roxb. and *C. parviflora* Wall. in bog area in Chiang Mai. The preliminary studies by Larsen (1996) and Sirirugsa (1996a) reported 36 species in Thailand.

**Table 1** Characteristics of subfamilies and tribes of new system (modified from Kress *et al.*, 2002).

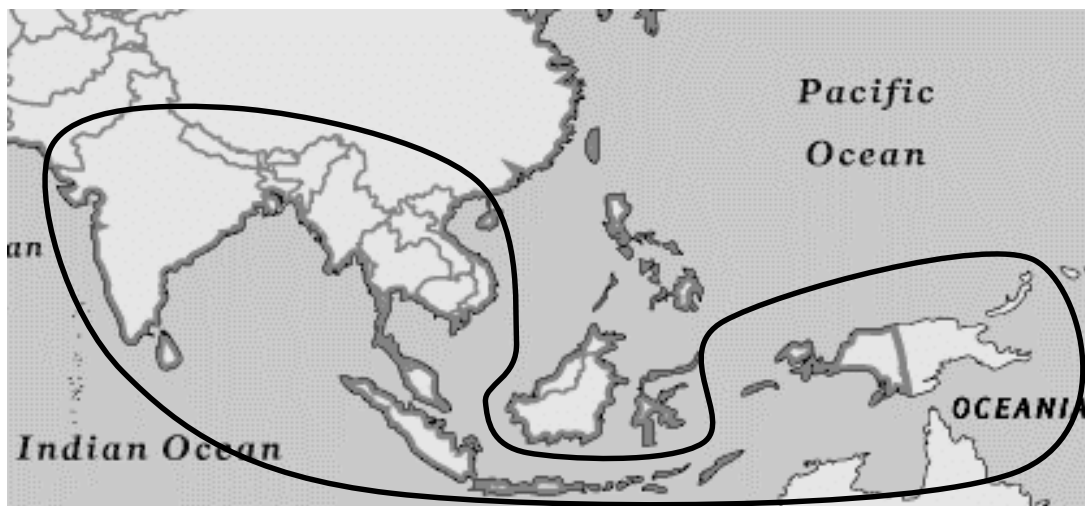
Characters	Siphonochiloidae	Tamijioideae	Alpinioidae		Zingiberoidae	
	Siphonochieae	Tamijieae	Riedelieae	Alpinieae	Zingibereae	Globbeae
1 Seasonality	dormancy	evergreen	evergreen	evergreen	dormancy	dormancy
2 Rhizome	fleshy	fibrous	fibrous	fibrous	fibrous	fleshy
3 Plane of distichy of leaves	perpendicular to rhizome	perpendicular to rhizome	perpendicular to rhizome	perpendicular to rhizome	parallel to rhizome	parallel to rhizome
4 Extrafloral nectarines	absent	absent	present on leaf blade	absent	absent	absent
5 Lateral staminodes	petaloid, fused to labellum	petaloid, fused to labellum	small or absent, never petaloid	small or absent, never petaloid	petaloid, free from or fused to labellum	petaloid, free from labellum or fused to filament
6 Labellum	not connate to filament	not connate to filament	not connate to filament	not connate to filament	not connate to filament	connate to filament in slender tube
7 Filament	short	short	medium	medium, sometimes arching	short to long	short to long, sometimes arching
8 Anther crest	petaloid	petaloid	petaloid or absent	petaloid or absent	absent, petaloid or well-developed and wrap around style	spurred or absent
9 Ovary	3-locular, (sometimes incomplete so)	1-locular	1 or 3-locular	3-locular	3-locular, (sometimes incomplete so)	1-locular
10 Placentation	axile	parietal	axile or parietal	axile or free central	axile, basal or free columnar	parietal
11 Capsule	fleshy	unknown	siliqua-like, open by longitudinal slits	indehiscent or fleshy	fleshy and dehiscent	globose and dehiscent

### **Infra-generic classification**

The intra-generic classification of the genus *Curcuma* has done by many taxonomists based on different criteria. Baker (1893) divided this genus into three sections, i.e. *Exantha*, *Mesantha* and *Hitcheniopsis* based on position of inflorescence, flowering period and bract character. *Exantha* has lateral inflorescences which is produced in summer and appear before leaves. *Mesantha* has terminal inflorescence, produced in rainy season and bracts not recurved. *Hitcheniopsis* has terminal inflorescence and flower in rainy season as well but its bract curved outwards. Schumann (1904) used bract characteristic and anther spurs to divide this genus into two subgenera, *Eucurcuma* and *Hitcheniopsis*. *Eucurcuma* has more or less straight bracts and calcarate while *Hitcheniopsis* has recurved bracts and ecalcarate. He also subdivided subgenus *Eucurcuma* into two sections, *Exantha* and *Mesantha* based on position of inflorescence. Valeton (1918) studied and divided this genus in Java and Malaya into two subgenera, *Eucurcuma* and *Paracurcuma* based on ligule and leaf characters. *Eucurcuma* has cuneate leaf-base and indistinct ligule. *Paracurcuma* has rounded to cordate leaf-base and auriculate ligule. Recently, Velayudhan *et al.* (1996) followed Valeton's system in dividing *Curcuma* into two subgenera, *Eucurcuma* and *Paracurcuma*. Furthermore, she divided *Eucurcuma* into three sections, i.e. *Nontuberosa*, *Stolonifera* and *Tuberosa* based on the underground part.

### **Biogeography:**

The genus *Curcuma*, with approximately 80 species (Larsen, 2005), distributes almost throughout tropical Asia from western India to South Asia, southern China, Southeast Asia, New Guinea, northern Australia and South Pacific Islands (figure 1). The westernmost record of *Curcuma* is in Kerala, western India. The easternmost and southernmost records are in the South Pacific Island. The northernmost record of wild species is in Yunnan, southern China.



**Figure 1** Distribution of the genus *Curcuma* L.

### **Morphological and anatomical characters**

The genus *Curcuma* is very variable in morphological characters. The anatomy of this genus has been rarely studied.

#### 1. Underground parts

There are two types of underground part. Primary tuber and branched rhizome (palmate rhizome) (Holttum, 1950). The colour of rhizome is important to distinguish species of *Curcuma* (Sirirugsa, 1996a). Some species have unique rhizome colour, for example, *C. aeruginosa* - bluish green, *C. aromatica* - bright yellow, *C. caesia* - grayish blue and *C. longa* - orange yellow. Storage food, in form of starchy granules, was reported in *C. longa* and *C. zedoaria* (Leonel *et al.*, 2003).

#### 2. Leaves

Leaf-sheath is green or reddish brown. Ligule is membranous or auriculate, truncate or bi-lobed, pilose or glabrous. Petiole is grooved, green or reddish brown, almost glabrous. The length of petiole is variable within the same plant. The outer leaves have the shorter petiole and become longer inwards. Leaf-shape varies from narrowly lanceolate to broadly ovate or elliptic, with or without reddish brown patch along midrib. Leaves of most species are glabrous but some species have densely hairy on lower surface. Leaf-base is almost cuneate but broad cuneate to rounded or slightly cordate in some species. Leaf-apex is acute or acuminate.

### 3. Inflorescence

Inflorescence is produced terminally on leafy shoot or on lateral separate shoot. Bracts are many and connate by side to the adjacent ones forming a pouch bearing flowers in cincinnus. Bracts are elliptic or ovate, glabrous or pilose. Colour of bracts is variable from green, white, pink, orange or red sometimes with stripes of different colour. Bract apex is mostly acute or rounded, sometimes acuminate or shallowly emarginate. The upper most bracts, coma, are usually sterile and differ in shape and colour from the flower bearing bracts but absent in some species. The colour of coma bracts varies from white to pink or dark red. Bracteole is ovate in shape and white or hyaline but absent in some species.

### 4. Flowers

Calyx is tubular, glabrous or pubescent, apex usually split into three unequally lobes. Corolla is funnel-shaped. Corolla tube is glabrous or pubescent, sometimes with hairy ring inside. Apex divided into three lobes. Dorsal lobe is usually larger and hooded or with cucullate apex. Lateral ones are shallowly concave. Staminodes vary from oblong to broadly elliptic or obovate with acute to rounded apex, sometimes covered by glandular hairs. Labellum is usually 3-lobed; the middle one is emarginate sometimes crenate or deeply bifid. Colour of staminodes and labellum are variable from white to yellow or dark blue. Stamen is glabrous or pubescent. Anther is spurred at base and crested at apex but absent in some species. Anther spurs are either short filament, sharply acute and downward-pointed or slender conical and forward-pointed. Ovary is barrel-shaped or subglobose. Stylodes or epigynous glands are short or long cylindrical or absent. Stigma is ciliate, funnel-shaped or depressed.

### 5. Fruits and seeds

Fruit of *Curcuma* is rarely documented. It is fleshy and dehiscent. Seeds are arillate. Seed coat can be divided into three layers: endotesta, mesotesta and exotesta. Exotesta of *C. kwangsiensis* is a single layer epidermis and endotesta is parenchymatous type. These characters are the same as in *Hedychium villosum* and *Roscoea purpurata* (Liao & Wu, 2000).

## Chromosomes

Chromosome numbers of *Curcuma* have been studied extensively. They were summarized in table 2. Somatic chromosome numbers of this genus vary from 20 in *C. harmandii* to 92 in *C. angustifolia*. Variation also occurs within species as in *C. angustifolia* (46, 84 and 92) and *C. parviflora* (24, 28, 30, 32, 34, 36 and 56). Basic chromosome number of *Curcuma* is 21 (Chen, 1989). Some species are triploidy with  $2n = 63$  and  $n$  number varies from 28-35. *C. angustifolia* is reported as tetraploidy,  $2n=84$  (Sirisawad, 2003). Some species have  $n$  number less than 21.

Sirisawad *et al.* (2003) studied chromosome numbers of *Curcuma* and divided this genus into five groups based on chromosome number and described common morphological characters of each group.

**Group 1** with  $2n=2x=42$  included *Curcuma* taxa having long, cylindrical inflorescences, large leaves and pseudostem. The member of this group is *C. aurantiaca*, *C. petiolata* and *C. roscoeana*.

**Group 2**  $2n=3x=63$  comprise of early flowering taxa that have the first short inflorescences arising from their dormant rootstock or 'stubbed rhizome'. Their coma bracts are normally spreading and rhizome are big and branching. This group is composed of *C. aeruginosa*, *C. elata*, *C. rubescens*, *C. xanthorrhiza* and *C. zedoaria*.

**Group 3**, with  $2n=4x=48$ , is another early flowering group with very short peduncles and no branching rhizome. This group has *C. angustifolia*.

**Group 4**,  $2n=24$  or  $32$ , comprise of plant which has long and erect peduncles, short spike and narrow or linear leaves. This group comprises of *C. alismatifolia* and *C. parviflora*.

**Group 5** exhibited various numbers; i.e.  $2n=20, 24, 28, 34, 36$  and  $56$ , included *Curcuma* taxa having undeveloped rhizomes, white staminodes and anther without spur. This group is composed of *C. harmandii*, *C. parviflora* and *C. rhabdota*.

**Table 2** Chromosome numbers of *Curcuma* species.

<b>Taxon</b>	<b>2n</b>	<b>n</b>	<b>Reference</b>
<i>C. aeruginosa</i>	63	28-35	Sirisawad <i>et al.</i> (2003)
<i>C. aff. oligantha (singularis)</i>	42		Eksomtramage <i>et al.</i> (2002)
<i>C. aff. oligantha (singularis)</i>	40		Saensuk and Chantaranothai (2002)
<i>C. alismatifolia</i>	32	16	Sirisawad <i>et al.</i> (2003)
<i>C. alismatifolia</i>	32		Saensuk <i>et al.</i> (1998)
<i>C. alismatifolia</i>	32		Saensuk and Chantaranothai (2002)
<i>C. angustifolia</i>	84		Saensuk <i>et al.</i> (1998)
<i>C. attenuate (angustifolia)</i>	84	42	Sirisawad <i>et al.</i> (2003)
<i>C. aurantiaca</i>	42	21	Sirisawad <i>et al.</i> (2003)
<i>C. elata</i>	63	28-35	Sirisawad <i>et al.</i> (2003)
<i>C. gracillima</i>	32	16	Sirisawad <i>et al.</i> (2003)
<i>C. gracillima</i>	24		Saensuk <i>et al.</i> (1998)
<i>C. gracillima</i>	24		Saensuk and Chantaranothai (2002)
<i>C. harmandii</i>	20		Eksomtramage <i>et al.</i> (1996)
<i>C. harmandii</i>	20	10	Sirisawad <i>et al.</i> (2003)
<i>C. longa</i>	63		de Guzman and Siemonsma (1999)
<i>C. parviflora</i>	30		Saensuk <i>et al.</i> (1998)
<i>C. parviflora</i>	32		Weerapakdee & Krasaechai (1997)
<i>C. parviflora</i>	30		Saensuk and Chantaranothai (2002)
<i>C. parviflora</i> var 1	32	16	Sirisawad <i>et al.</i> (2003)
<i>C. parviflora</i> var 2	24, 28, 34, 36, 56	12, 14, 17, 18, 28	Sirisawad <i>et al.</i> (2003)
<i>C. petiolata</i> var 1	42	21	Sirisawad <i>et al.</i> (2003)
<i>C. petiolata</i> var 2	42	21	Sirisawad <i>et al.</i> (2003)
<i>C. rhabdota</i>	24		Eksomtramage <i>et al.</i> (2002)
<i>C. rhabdota</i>	24	12	Sirisawad <i>et al.</i> (2003)
<i>C. roscoeana</i>	42		Eksomtramage <i>et al.</i> (1996)
<i>C. roscoeana</i>	42	21	Sirisawad <i>et al.</i> (2003)
<i>C. rubescens</i>	63	28-35	Sirisawad <i>et al.</i> (2003)
<i>C. sessilis (angustifolia)</i>	46, 92		Saensuk and Chantaranothai (2002)
<i>C. xanthorrhiza</i>	63	28-35	Sirisawad <i>et al.</i> (2003)
<i>C. zedoaria</i>	63	28-35	Sirisawad <i>et al.</i> (2003)

\* Epithet in blanket is corrected after re-identification.



### **Palynology**

Pollen of *Curcuma* is inaperturate, psilate, ellipsoid to subsphaeroid in shape and 52-75 x 102-110  $\mu\text{m}$  in size. Exine is very thin, 1.0  $\mu\text{m}$  thick, and not resistant to acetolysis (Chen, 1989). Medine is hyaline and opaque, 5  $\mu\text{m}$  thick (Nayar, 1996). The pollen contains starch and oil as storage food (Wang *et al.*, 2004).

### **Ethnology & medicinal usages:**

The most well-known species is turmeric (*C. longa*). It is used as spice, dye and medicinal plant. Some of *Curcuma* are also used as medicinal plant, for example, *C. comosa* Roxb., *C. zanthorrhiza* Roxb. and *C. zedoaria* (Christm.) Rosc. *C. angustifolia* Roxb. and *C. leucorrhiza* Roxb. are important starch plants in India and Bangladesh (Roxb, 1810). *C. aromtica*, *C. montana*, *C. zanthorrhiza* and *C. zedoaria* are also sources of nonseed carbohydrate (Oyen and Nguyen, 1999). Young inflorescence of *C. angustifolia* Roxb. and *C. singularis* Gagnep. are used as vegetable plants in Thailand as well as rhizome of *C. manga* Val. Some other species become important ornamental plants, for example, *C. alismatifolia* Gagnep., *C. parviflora* Wall., *C. roscoeana* Wall. and *C. sparganifolia* Gagnep.