The Genus *Curcuma* L. (Zingiberaceae): Distribution and Classification with Reference to Species Diversity in Thailand

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Abstract

The genus *Curcuma* L. is one of the largest genera in the Zingiberaceae, with about 80 species, and distributed throughout tropical Asia from India to South China, Southeast Asia, Papua New Guinea and Northern Australia. In Thailand, thirty-eight species have been found. Taxonomic knowledge of this genus is necessary for citing correctly the species used commercially as spices, ornamentals and medicines. Formerly, *Curcuma* was a member of the tribe Hedychieae. According to the new classification of the Zingiberaceae proposed by Kress *et al*. (2000), this genus belongs to the tribe Zingibereae. This paper presents an overview of the genus *Curcuma* and its species diversity in Thailand. The infrageneric classification of the genus based on morphology and molecular evidences with reference to species diversity in Thailand is discussed. The representative taxa, their distribution and uses are provided.

Introduction

Curcuma is one of the largest genera in the Zingiberaceae which comprises approximately 80 species (Larsen, 2005). It is widely distributed in the tropics of Asia from India to South China, Southeast Asia, Papua New Guinea and Northern Australia (Fig. 1). In Thailand they are normally found in the teak, pine or dipterocarp forests at the altitude 500-900 m. Some species, such as *C. alismatifolia* Gagnep., grows well in the open areas. The most common species, *C. parviflora* Wall., grows in wide range of altitudes from 100 – 1300 m on limestone hills. Generally, most *Curcuma* grows well in loose and sandy soil in shaded areas.

Figure 1. Distribution of the genus *Curcuma*

Morphological Characters of *Curcuma*

The habit of *Curcuma* is a rhizomatous herbaceous plant, comprising of underground parts, leafy shoot and leaf blades (Fig. 2).

Underground parts. At the base of the aerial shoot, the stem consists of erect ovoid or globose structure (primary rhizome), bearing few to many horizontally branches, and roots. However, branched rhizomes are rarely produced in some species. The roots often produce ellipsoid tubers. Inner part of rhizomes varies in various colours, i.e., white, cream, yellow, orange, blue and bluish-green. Some species have a unique colour of rhizomes which are useful for identification, such as the bluish-green rhizome in *C. aeruginosa Roxb*.

Leafy shoots. These are 1-2 m high, forming a pseudostem by the leaf-sheaths and surrounded by the leafless sheaths at the base. Leaf blades are usually large, lanceolate or elliptic, rarely linear with or without the purple stripe along either side of the midrib.

Inflorescence. This occurs either terminally on the leaf-shoot, with the peduncle enclosed by the leaf sheaths, or on the separate shoot with the peduncle enclosed by the bladeless sheaths. The inflorescence can be cylindric, conic or ovoid in shape.

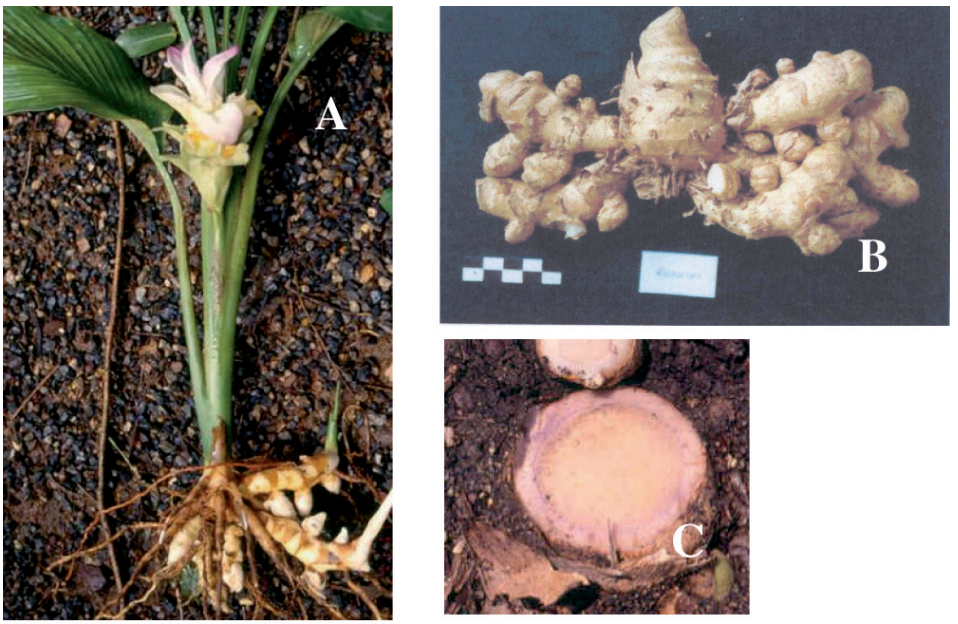


Figure 2. *Curcuma*. A. Habit; B. Primary rhizome with branches; C. Rhizome of *C. caesia.*

Bracts. Bracts are usually large and joined to each other forming pouches at the base, the free ends of the bracts are normally wide spread, each subtending a cincinnus of 2-10 flowers. In many species the uppermost bracts, which are called "coma", are longer than the rest and differently coloured. They are usually sterile.

Flowers. Flowers are enclosed by bracteoles, comprising of the following floral parts: **Calyx** is tubular, unequally toothed, deeply divided along one side. **Corolla-tube** is more or less funnel shaped; **corolla-lobes** are unequal, the dorsal slightly larger than the lateral ones, and its apex is hooded. **Staminodes** are petaloid, elliptic, oblong or linear. **Labellum** has a thickened middle part and thinner lateral lobes which overlap the staminodes. **Stamen** has a short and broad filament, and a constricted apex. **Anther** is versatile, with or without spurs, and the anther-crest is usually small. **Spurs** vary in several shapes and sizes, and they are important characters for infra-generic classification. **Ovary** is glabrous or pubescent, and 3-lobed. **Stylodes** can be present. **Capsule** is ellipsoid, and **seeds** are arillate.

Flower forms (Fig. 3). The different arrangement of staminodes and corolla-lobes made up the 2-formed flowers, i.e., *closed form*: the staminodes are wrapped by the dorsal corolla-lobe; and the *open form*: the staminodes are free from the dorsal corolla-lobe.

Figure 3. *Curcuma* flowers, showing the closed form (left) and open form (right).

Distinguished Characters

It is easy to distinguish *Curcuma* from other genera of Zingiberaceae by the following characters: the joining bracts to form pouches; flowers borne in cincinni, subtended by bracteoles and bracts; and the sterile and differently coloured coma bracts.

Classification of Zingiberaceae

Zingiberaceae (Burtt & Smith, 1972)		**Zingiberaceae** (Kress *et al.,* 2002)		
Tribe	Genus	Subfamily	Tribe	Genus
Hedychieae	***Curcuma***	Siphonochiloideae	Siphonochileae	
Zingibereae		Tamijioideae	Tamijieae	
Alpinieae		Alpinioideae	Alpinieae	
Globbeae			Riedelieae	
		Zingiberoideae	**Zingibereae**	***Curcuma***
			Globbeae	

According to the system of Burtt & Smith in 1972, which was accepted for many years, the family Zingiberaceae was classified into 4 tribes and *Curcuma* was placed in the tribe **Hedychieae.** In the year 2002 a new system was proposed by Kress *et al.* Zingiberaceae was classified into 4 subfamilies and 6 tribes (as shown above), and *Curcuma* has been placed in the tribe **Zingibereae**.

The genus *Curcuma* shows great morphological variations, the overlapping similarities among them made confusion in the identification of species. Several systems of the infra-generic classification of *Curcuma*

have been developed. Some of them are shown below.

Infra-generic classification of *Curcuma*

Baker (1892)	**Schumann (1904)**	**Valeton (1918)**
	Subgenus	Subgenus
	Eucurcuma	***Eucurcuma***
Section	Section	Section
Exantha	***Exantha***	***Exantha***
Section	Section	Section
Mesantha	***Mesantha***	***Mesantha***
	Subgenus	Subgenus
Section ***Hitcheniopsis***	***Hitcheniopsis***	***Paracurcuma***

Baker (1890) divided *Curcuma* into three sections: Section *Exantha* (the spikes separate from the shoot), Section *Mesantha* (the spikes borne on the shoot either with or without leaves), and Section *Hitcheniopsis* (characterized by autumnal spikes from the centre of the tuft of leaves; bracts are very obtuse, adnate at the sides and spreading at the tip).

Schumann (1904) divided the genus into subgenus *Eucurcuma* and raised the taxonomic rank of *Hitcheniopsis* Baker to subgenus. Subgenus *Eucurcuma* is again divided into section *Exantha* and section *Mesentha*.

Valeton (1918) divided the genus into subgenus *Eucurcuma* and *Paracurcuma* and divided the subgenus *Eucurcuma* into section *Exantha* and *Mesantha*. Subgenus *Paracurcuma* was characterized by bracts connected at least partly beyond the middle and often very numerous. Spike is cylindrical, with comparatively short coma bracts. Anther spurs are very short (not a quarter of the anther) or none.

However, more information for resolving the problems of identification of this genus is still required.

Taxonomic Treatments

The previous taxonomic works on *Curcuma* from whole range of the distribution of the genus are shown below. From these records and also from recent collections from Thailand it can therefore be estimated , that there are over 90 species of *Curcuma* in the world.

Baker (1890) recorded 29 species from India (10 species are not found in Thailand).

Holttum (1950) reported 9 species from Malay Peninsula (1 species is not found in Thailand.

Backer & Bakhuizen Van Den Brink (1963) reported 18 species from Java (11 species are not found in Thailand).

Sabu and Mangaly (1996) presented 18 species from South India (8 species are added to the Baker's list, and these are not found in Thailand).

Wu and Larsen (2000) published 12 species from China (6 species are not found in Thailand).

Newman *et al.* (2004) reported 20 species from Malesia (16 species are not found in Thailand).

Curcuma Species in Thailand

In Thailand, 38 species of *Curcuma* are now recognized. Among them, six species are undescribed (no. 33-38), three species are new records for Thailand (11, 21, 25*)*, three known species are endemic to Thailand (7,10 and 12) and eight species are cultivated for food and spices (1, 3, 5, 9, 17, 18, 30, and 31).

1. *C. aeruginosa* Roxb.
2. *C. alismatifolia* Gagnep.
3. *C. amada* Roxb.
4. *C. angustifolia* Roxb.
5. *C. aromatica* Salisb.
6. *C. aurantiaca* Zijp
7. *C. bicolor* Mood & K. Larsen
8. *C. cochinchinensis* Gagnep.
9. *C. comosa* Roxb.
10. *C. ecomata* Craib
11. *C. flaviflora* S.Q. Tong
12. *C. glans* K. Larsen & Mood
13. *C. gracillima* Gagnep.
14. *C. harmandii* Gagnep.
15. *C. latifolia* Roscoe
16. *C. leucorhiza* Roxb.
17. *C. longa* L.
18. *C. mangga* Valeton & Zijp
19. *C. parviflora* Wall.
20. *C. petiolata* Roxb.
21. *C. pierreana* Gagnep.
22. *C. rhabdota* Sirirugsa & M.F. Newman
23. *C. roscoeana* Wall.
24. *C. rubescens* Roxb.
25. *C. rubrobracteata* Skornick., M. Sabu & Prasanthk.
26. *C. singularis* Gagnep.
27. *C. sparganiifolia* Gagnep.
28. *C. stenochila* Gagnep.
29. *C. viridiflora* Roxb.
30. *C. zanthorhiza* Roxb.
31. *C. zedoaria* (Christm.) Roscoe
32. *C. larsenii* Maknoi & Jenjitt.
33. *C. sirirugsae* (in prep.)
34. C. sp.
35. C. sp.
36. C. sp.
37. C. sp.
38. C. sp.

Infra-generic Classification of *Curcuma* in Thailand

Based on morphological characters, 38 species of *Curcuma* in Thailand can be divided into 5 groups. Anther types of *Curcuma* are the important distinctive characters for the classification into groups (Fig. 4).

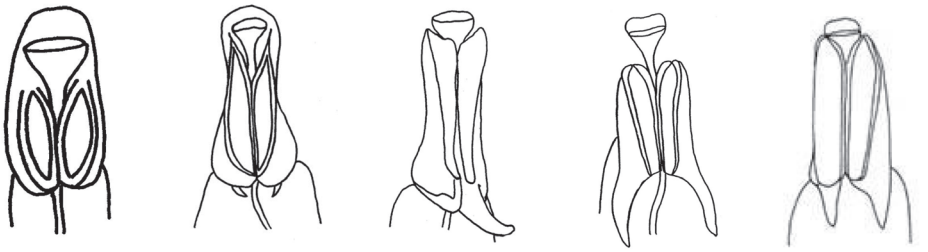


Figure 4. Anther types: A. "Alismatifolia" type; B. "Cochinchinensis" type; C. "Ecomata" type; D. "Longa" type; E. "Petiolata" type.

Five Groups of *Curcuma* in Thailand

The distinguished characters, representative species, with short information and illustrations of the five groups of *Curcuma* in Thailand are presented below (Fig. 5).

1. "Alismatifolia" group
Distinguished characters are:
- Anther spurs absent;
- Stylodes absent.

Eight species are in this group: *C. alismatifolia*, *C. gracillima*, *C. harmandii*, *C. parviflora, C. rhabdota, C. sparganiifolia* and two new species.

C. alismatifolia Gagnep.
This species is native to Thailand in the northeast and distributed to Laos and Cambodia. It is commonly found in open areas in the pine or deciduous forests at altitude 1300 m above sea level. *C. alismatifolia* has become an important economic plant for the aesthetics of its inflorescences. It is easily identified by the long, slender and stiff peduncle, the large and bright pink coma bracts. The newly improved cultivars of this species, such as the white-bract form, have also appeared in the markets for more than ten years (Wanakrairote in 1996).

C. parviflora Wall.
This species was originally found in Myanmar and distributed throughout tropical Asia. It grows in wide range of altitudes from 300 to over 1000 m above sea level. It is also commercially popular for cut flowers or as potted plants. The plant is small, about 30 cm tall. Its inflorescence is attractive with the white coma bracts.

C. rhabdota Sirirugsa & M. F. Newman
This species was described in 2000 after it has become popular as ornamental plant. It is widely spread both in Thailand and other countries. It was first known from a selling at Chong Mek market at the Laos-Thai border in Ubon Ratchathani province, and was collected from Laos as told by the seller. This plant was brought to grow in the Royal Botanic Garden Edinburgh, from which it was taken as the type specimen. However, it has been found later that this species commonly grows in Ubon Ratchathani Province of Thailand.

C. harmandii Gagnep.
This species is native to Cambodia and distributed to eastern, southeastern and central Thailand. The uniqueness of its bracts with dark green, lanceolate and reflexed apex is attractive and easily recognized for this species.

C. sparganiifolia Gagnep.
This is a native of Indochina and is distributed to northeastern, eastern and southeastern Thailand. It is a small plant; its leafy shoot is about 15-20(-30) cm tall. This species can be distinguished by its spike with slender peduncle, pinkish-purple and suborbicular bracts.

2. "Cochinchinensis" group

Distinguished characters are:
- Anther spurs filamentous;
- Stylodes shortly cylindrical.

Two species are in this group: *C. cochinchinensis* and *C. pierreana*

C. pierreana Gagnep.
The species is native to Cambodia. In Thailand, it is found only in the northeast. Its sessile inflorescence, white staminodes with large purple blotches apices are distinctive characters for this species.

3. "Ecomata" group

Distinguished characters are:
- Anther spurs broad and blunt;
- Stylodes long and slender.

Seven species are in this group: *C. bicolor, C. ecomata, C. flaviflora, C. glans, C. singularis, C. stenochila,* and one new species)

C. bicolor Mood & K.Larsen
This species is endemic to Thailand, which was described in 2001. The plant is 40-60 cm tall. It can be distinguished from other species in the "**Ecomata**" group by its yellow staminodes with red blotches at the bases.

C. ecomata Craib
This is also endemic to Thailand. It is easily recognized by its purple labellum with the dark yellow midband.

C. flaviflora S.Q. Tong
This is a Yunnan plant and distributed to northern Thailand. It grows at high altitude from 1200-1400 m above sea level. This species can be distinguished by its bright yellow flowers.

C. glans K.Larsen & Mood
This is another endemic species of Thailand that was recently described in 2001. Its yellow staminodes with red apices covering with densely glandular hairs are the important distinctive characters of this species.

It is noted that the above four species of "**Ecomata**" group are uncommon in Thailand.

4. **"Longa" group**
Distinguished characters are:
- Anther spurs acicular, inwardly curved;
- Stylodes cylindrical;
- Bract apex acute.

Thirteen species are in this group: *C. aeruginosa, C. amada, C. angustifolia, C. aromatica, C. comosa, C. latifolia, C. leucorrhiza, C. longa, C. mangga, C. rubescens, C. viridiflora, C. zanthorrhiza, and C. zedoaria*.

C. aeruginosa Roxb**.**
This is a native of Myanmar and distributed to India, Indochina, Malaysia, Indonesia and Ceylon. In Thailand, it is commonly found in the dipterocarp forests and is also cultivated. It is distinguished from other species by its bluish-green rhizome and red corolla-lobes. The rhizome is medicinally used throughout its range of distribution.

C. comosa Roxb.
The original country of this species is Myanmar, but is distributed to India, and is cultivated in Malaysia. In Thailand, it is rarely found in the deciduous

and bamboo forests. It is commonly cultivated for medicinal purpose. This species can be identified by its sessile inflorescence, white bracts tinted with pink and white coma bracts with pink apex throughout dorsal midband.

C. longa L.
This species is well known as the "commercial turmeric". It is widely cultivated in Asia. Turmeric is an important spice, which is used in the preparation of curries in many Asian countries. It is also used in many other ways, such as the source of yellow dye, cosmetic and medicines. Its coma bracts are mostly white but vary to pale yellow or white with pink apices.

C. mangga Valeton & Zijp
This species is cultivated throughout Thailand. It is also commonly cultivated in Malay Peninsula and Java. Coma bracts are pink or white, with a largely pink blotch at the centre. This species is easily recognized by its white rhizome that is pale yellow inside and the smell of mango. It is extensively used as vegetable.

C. rubescens Roxb.
It is native to India, distributed to Myanmar, and uncommonly cultivated in Thailand. Its red petioles and leaf-sheaths are good distinguishing characters for this species.

C. zanthorrhiza Roxb.
This species was described by Roxburgh from a plant said to have been introduced to Calcutta from Amboina, Moluccas (Holttum, 1950). It is widely cultivated throughout SE Asia. Its rhizome is large, dark yellow or yellowish-orange inside. It is used extensively in traditional medicine particularly in Malaysia and Indonesia.

C. zedoaria (Christm.) Roscoe
A native species of India, it is cultivated throughout Southeast Asia. The plant is about a meter tall, the primary rhizome is ovoid, and the inside of the tuber is pale sulphur yellow. It is widely used as medicine in India and Malaysia. The leaves are also used for flavouring fish and other foods in Java.

5. " Petiolata" group

Distinguished characters are:
- Anther spurs shortly acicular, straight;
- Stylodes cylindrical;
- Bract apex truncate or rounded.

Eight species are in this group: *C. aurantiaca, C. petiolata, C. roscoeana, C. rubrobracteata* and four new species.

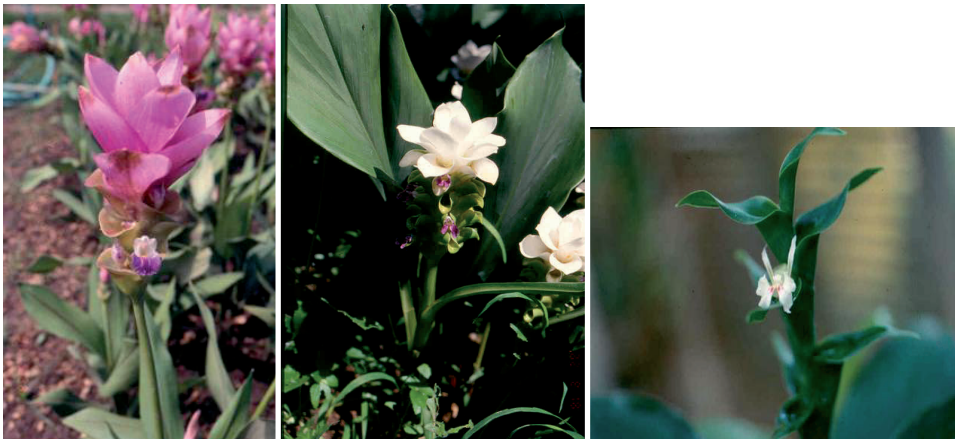
C. aurantiaca Zijp
This is a native of Ceylon and is also present in Java and Malaysia. In Thailand, it commonly grows in the clearing of evergreen forests and rubber plantations in the south. This species can be recognized by its brownish-green flower bracts, purplish-pink coma bracts, and anther without spurs. It is also a well-known ornamental plant.

C. petiolata Roxb.
This species is distributed in India, Myanmar, Laos, Java and Thailand. It can be identified by its large leaves with cordate base, pink coma bracts, and white flower with yellow midband on the labellum. Its inflorescence may be the largest of the genus. It is highly popular as an ornamental plant. The variegated form of this species is called in Thai "Bua Chun". Its flower bracts are greenish with pink apices and its inflorescence is narrower. Note: the hybrids between *C. aurantiaca* and *C. petiolata* have produced attractive plants.

C. roscoeana Wall.
It is a native of Myanmar. In Thailand, it commonly grows in deciduous forests and has been well known as an ornamental plant for a long time. This species is easily identified by its orange flower bracts and anthers without spurs.

C. rubrobracteata Skornick., M. Sabu & Prasanthk.
This species is distributed in India and Myanmar. In Thailand, it is commonly found in deciduous and dry evergreen forests. The species was described in 2003, and is one of the new records for Thailand in 2005.

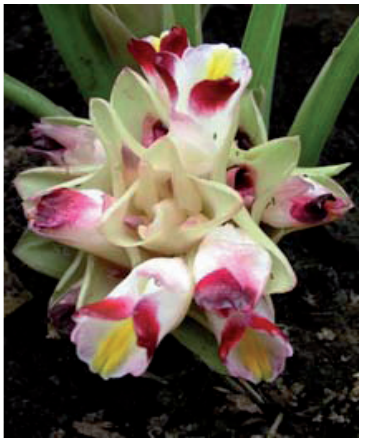
Figure 5. A gallery of representative species of *Curcuma* in Thailand.



C. alismatifolia *C. parviflora* *C. harmandii*

C . sparganiifolia

C. rhabdota



C. pierreana

C. ecomata

C. flaviflora

C. glans

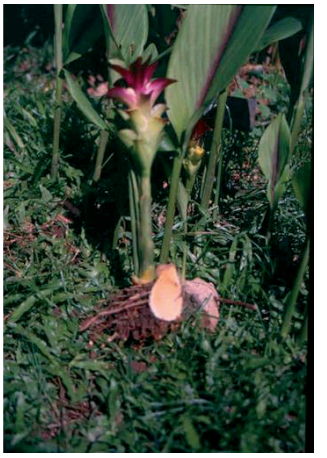
C. aeruginosa

C. comosa

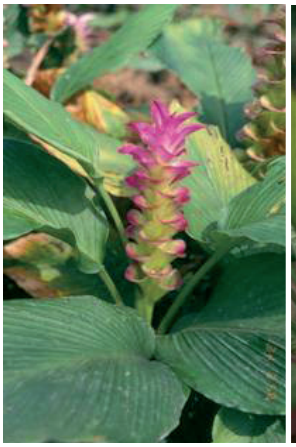
C. longa

C. rubescens

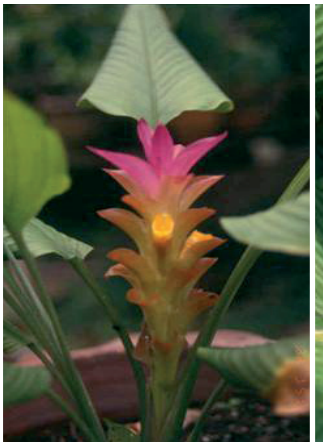
C. zanthorhiza



C. zedoaria

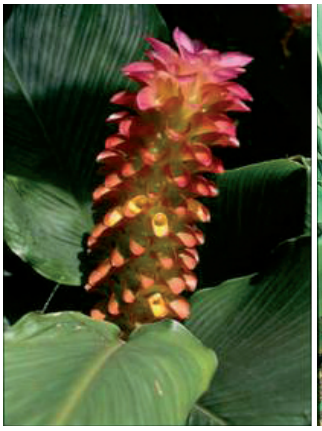


C. petiolata
(variegated form)



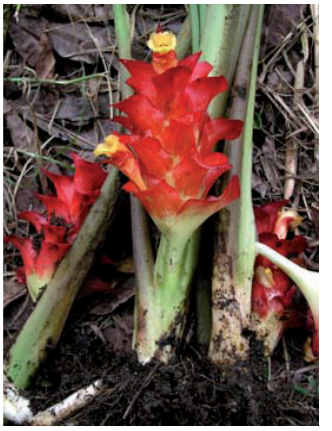
C. aurantiaca

C. petiolata



C. aurantiaca x petiolata

C. roscoeana



C. rubrobracteata

A Summary of Distribution of *Curcuma* in Thailand

"Alismatifolia" group has its centre of distribution in the northeastern and eastern regions of the country.

"Cochinchinensis" group consists of only 2 species: one (*C. cochinchinensis*) occurs in the north and southwest, another one (*C. pierreana*) has its limited distribution in the eastern region.

"Ecomata" group has all its species occurring in the northern region; however, two of them, *C. singularis* and *C. stenochila*, are also distributed in the northeastern, eastern and southeastern parts of the country.

"Longa" group has most of its member species cultivated. In Thailand, few of them grow wild in the north.

"Petiolata" group has most species distributed from the north to the peninsula along the western ranges (Fig. 6).

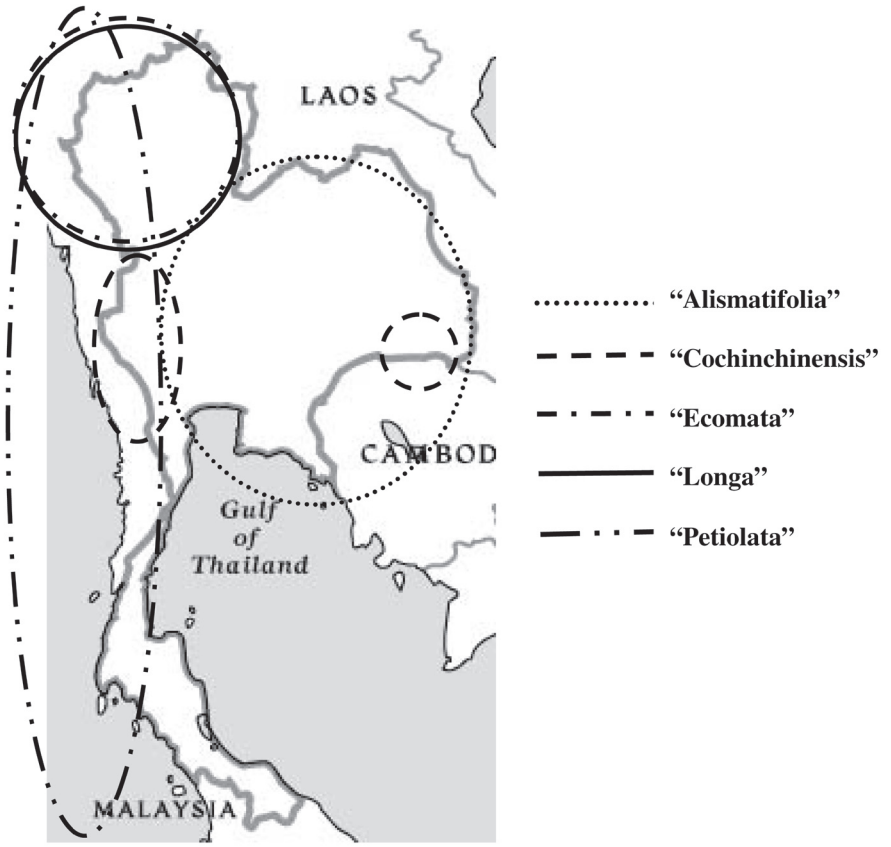


Figure 6. Distribution of *Curcuma* in Thailand

Phylogenetic Relationship of *Curcuma* Species in Thailand

The strict concensus of three most parsimonious cladograms, which resulted from ITS sequence analysis (Fig. 7) reveals that three groups ("Alismatifolia", "Cochinchinensis" and "Ecomata") are clearly separated from each other and from the "Longa" group. The relationship of "Petiolata" group is unclear. The study shows that except for "Petiolata" group, the remaining four groups proposed by the morphological classification are supported by molecular evidence. It also suggests that the new classification of the genus *Curcuma* should be considered.

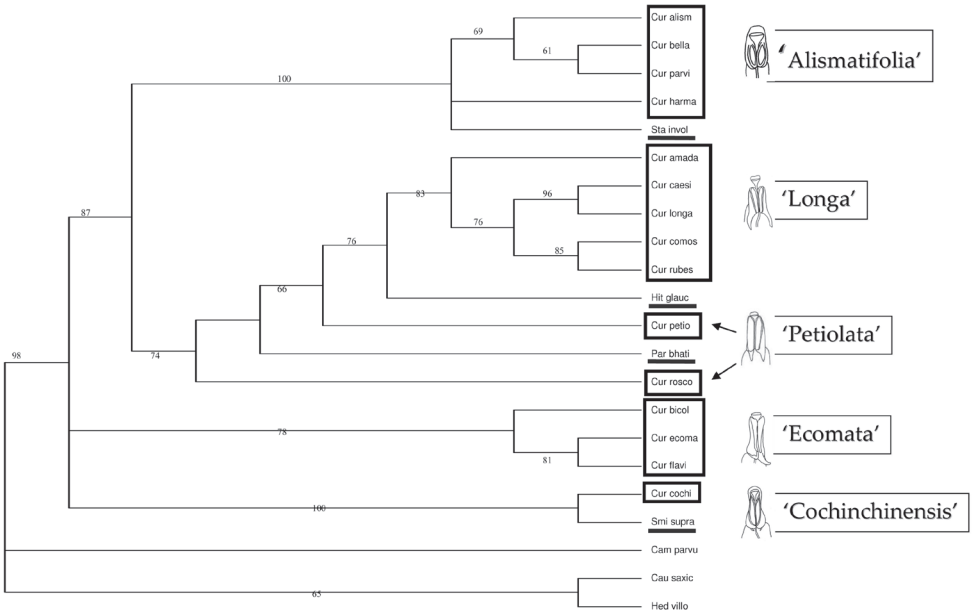


Figure 7. Cladogram showing the relationships of some *Curcuma* species (Maknoi, 2005)

Conclusion

Some suggestions for further studies on the genus *Curcuma* are:

1. Though several classification systems of *Curcuma*, as well as one from this paper, have been proposed, it seems that the taxonomic problems of this genus still exist. Further studies for more information, particularly the phylogenetic relationships of species, are needed and required to support the taxonomy of the grouping of this genus.

2. Regarding the diversity of the genus, it is believed that more undescribed species of *Curcuma* can still be found in natural forests of tropical Asia. Therefore, more explorations for new taxa are suggested.

3. *Curcuma* is a genus very useful to man. Many species are used as medicines, ornamental plants, dyes, cosmetics, foods and spices. It is reported that less than 50 % of the species are used by man. The rest, more than 50 % of *Curcuma* species have not been known of their uses. Therefore, more studies on the biological activities and pharmacological actions of *Curcuma* are needed in order to explore and search for their potential uses. Species with high potential use in decoration are also suggested to be commercially developed.

However, on account of conservation, over exploitation or over collection of plants from the wild may cause the genetic erosion. The awareness and warning of over using some species should be heeded.

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