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Diversity and cytological studies of the Genus *Amomum* Roxb. former *Elettariopsis* Baker (Zingiberaceae) in Thailand

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Abstract. *Saensouk P, Saensouk S. 2021. Diversity and cytological studies on the genus* Amomum *Roxb. former* Elettariopsis *Baker (Zingiberaceae) in Thailand. Biodiversitas 22: 3209-3218.* A comprehensive diversity and cytological studies of the genus *Amomum* Roxb. in Thailand have not been reported. This work aims to study the diversity and cytological including chromosome numbers and karyotypes of the genus *Amomum* Roxb. former *Elettariopsis* Bakerin Thailand. Ten species of *Amomum* were recognized from Thailand. Nomenclatures, vernacular names, distribution, ecology, and traditional utilization are provided. Only *Amomum wandokthong* is widely cultivated in all parts in Thailand. Four living species, i.e. *Amomum curtisii*, *A. monophyllum*, *A. trilobum*, and *A. wandokthong* have been collected from field trips. Therefore, the somatic chromosome numbers from four species of this genus were studied from root tips. The somatic chromosome numbers of each species in this study were counted from 20 cells. The karyotype formulas were derived from measurements of the metaphase chromosomes in photomicrographs. The chromosome numbers of four species were found to be 2n = 48. Karyotypes of four species were reported to be *Amomum curtisii* (32m + 8sm + 8st), *A. monophyllum* (26m + 12sm + 10st), *A. trilobum* (18m + 24sm + 6st), and *A. wandokthong* (28m + 16sm + 4st with five visible satellites chromosomes). The chromosome numbers of *A. monophyllum* and *A. wandokthong* were reported for the first time. The karyotypes of four species were studied for the first time.

Keywords: *Amomum*, cytogenetic, *Elettariopsis*, plant diversity, Thailand

INTRODUCTION

Zingiberaceae or the ginger family is aromatic perennial herbs with creeping horizontal or tuberous rhizomes. It consists of about 57 genera and a total of about 1,600 known species in the world (http://www.ipni.org and http://apps.kew.org/wcsp/) and distributed throughout tropical Africa, Asia, and the Americas, with Southeast Asia as the center of diversity for this family (Kress et al. 2007; Leong-Škorničková et al. 2019). Zingiberaceae in Thailand is found as more than 26 genera and over 300 species, and the numbers will most certainly rise (Boer et al. 2018).

The genus *Amomum* is established by Roxburgh (1820). It is flowering plants in the tribe Alpinieae, subfamily Alpinioideae, family Zingiberaceae with consists of approximately 69 species, of which almost 30 were previously in *Elettariopsis*Baker.*Amomum*is small to large-sized herbs, clump-forming to loosely clump-forming, or creeping. This genus can be distinguished from other closely related genera by the following combination of characters: labellum white with a yellow patch in the center and usually with red markings, or yellow with or without red markings; lateral staminodes small or absent; anthers with a well-developed fan-shaped and more or less obscurely trilobed crest or with an extended, longer than wide and often bluntly rectangular crest (in most species previously classified as *Elettariopsis*) (Ye et al. 2021). It includes several species of cardamom that are remarkable for their pungency and aromatic. A few years ago, former the small genus *Elettariopsis* is established by Baker (1892). It has now been subsumed into the genus *Amomum* based on molecular data in a multi-marker phylogenetic framework using *matK* and nrITS including multiple accessions of the species (Boer et al. 2018). Therefore, the genus *Elettariopsis* is a synonym of the genus *Amomum* which is accepted genus and species (Kress et al. 2007; Boer et al. 2018).

The center of diversity of the genus *Amomum* is distributed mainly in Southeast Asia. In Thailand, few botanists, i.e. Picheansoonthon and Yupparach (2007), Saensouk and Saensouk (2014), and Saensouk et al. (2016), studied *Amomum* including previously in genus *Elettariopsis*. Most of them are traditionally used as local food (including ingredients), medicinal, ornamentals, and in rituals Saensouk et al. (2016).

The chromosome number of *Amomum* former *Elettariopsis* were studied by few workers i.e. Kam (1982) (four species) and Beltran and Kam (1984) (three species) reported to be $n = 24$ while Eksomtramage et al. (2001) and Saenprom et al. (2018) reported being $2n = 48$. The karyotype of this genus was studied only in *E. biphylla*by Saenprom et al. (2018). This work aims to study the diversity and some cytological including chromosome numbers and karyotypes of the genus *Amomum* in Thailand.

MATERIALS AND METHODS

Plant materials

Some plant materials were collected from field trips in Thailand between 2018 and 2020 (Table 1). Some voucher specimens were deposited at the Mahasarakham University Herbarium, Thailand. Four living species, i.e. *Amomum curtisii*, *A. monophyllum*, *A. trilobum* and *A. wandokthong* were grown at Mahasarakham Plant Nursery, the Center of Excellence for Silk Innovation, Division of Research Facilitation and Dissemination, Mahasakham University for karyological studies.

Plant diversity study

Plant diversity, vernacular names, distribution data, and ecological data were taken from the field, herbarium specimens, and available literature. The morphological characters, such as leaf, leaf-sheath, inflorescence, bract, bracteole, flower, calyx, corolla lobe, labellum, lateral staminode, stamen, stigma, ovary were studied under stereo microscopy. The specimens in this study were compared with herbarium specimens which kept aboard herbaria (AAU, BK, BKF, E, K, P, KKU, and QBG), available taxonomic literature, i.e. Picheansoonthon and Yupparach (2007), Saensouk and Saensouk (2014) and Saensouk et al. (2016) or digital images available online and all the published studies of species of *Amomum* (Table 1). The distribution data and ecological data were taken from the field, herbarium specimens, and available taxonomic literature.

Traditional utilization study

Traditional utilization data was taken from interviews with local people near the site locality of each species, herbarium specimens, and available taxonomic literature.

Karyology study

Chromosome numbers were studied from root tips of four species. Root tips were collected in the morning after sunrise. The root tips of all specimens were pretreated with paradichlorobenzene (PDB) at 4°C for 6 h, fixed in ethanol–acetic acid (3:1, v:v) at room temperature for 30 min and stored at 4°C or used immediately. Samples were washed in distilled water, hydrolyzed in 1M HCl for 5 min at 60°C and washed again in distilled water, then they were stained and squashed in 2% aceto-orcein, and then they were observed under a microscope (Zeiss Axiostar Plus) (Saenprom et al. 2018). The somatic chromosome numbers of each species in this study are counted from 20 cells. The karyotype formulas were derived from measurements of the metaphase chromosomes in photomicrographs. The nomenclature used for the description of the chromosome morphology is that proposed by Levan et al. (1964).

RESULTS AND DISCUSSION

Diversity of the genus *Amomum* former *Elettariopsis* from Thailand

Amomum Roxb. is accepted genus, and its native range is Tropical and Subtropical Asia to N. Queensland(Ye et al. 2021). Recently, ten species of the genus *Amomum* former *Elettariopsis* in Thailand (Table 1), namely *Amomum biphyllum* (Saensouk & P. Saensouk) Skornick. & Hlavatá, *A. chayanianum* (Yupparach) Skornick. & Hlavatá, *A.curtisii* (Baker) Skornick. & Hlavatá, *A. elan* (C.K. Lim) Skornick. & Hlavatá, *A. exertum* (Scort.)Skornick. & Hlavatá, *A. monophyllum* Gagnep., *A. slahmong* (C.K. Lim) Skornick. & Hlavatá, *A. smithiae* (Y.K. Kam) Skornick. & Hlavatá, *A. trilobum* Gagnep. and *A. wandokthong* (Picheans. & Yupparach) Skornick. & Hlavatá were reported.

Table 1 The genus *Amomum* former *Elettariopsis* in Thailand

Species	Site localities	References
Amomum biphyllum (Saensouk & P.Saensouk) Skornick. & Hlavatá	North-Eastern: Bueng Kan province (PhuWua Wildlife Sanctuary).	Saensouk and Saensouk (2014)
A. chayanianum (Yupparach) Skornick. &Hlavatá	Khao Sapan Hin Range of AmphoreKlung, Chantaburi province	Picheansoonthon and Yupparach (2007)
A. curtisii (Baker) Skornick. & Hlavatá	Peninsular Thailand: Nakhon Si Thammarat (KhaoLuang), Phattalung province	Picheansoonthon and Yupparach (2007)
A. elan (C.K.Lim) Skornick. & Hlavatá	Peninsular Thailand: Yala (Hala Forest)	Picheansoonthon and Yupparach (2007)
Amomum exertum (Scort.) Skornick. & Hlavatá	Peninsular Thailand: Yala (PhuKhao Thong, Bala Forest)	Picheansoonthon and Yupparach (2007)
A. monophyllum Gagnep.	North-eastern Thailand: BuengKan, Nakhon Phanom	Picheansoonthon and Yupparach (2007)
A. slahmong (C.K.Lim) Skornick. &Hlavatá	Peninsular Thailand: Yala (Phu Khao Thong, Bala Forest)	Picheansoonthon and Yupparach (2007)
A. smithiae (Y.K.Kam) Skornick. &Hlavatá	Peninsular Thailand:SongKla (Than Pliu Waterfall), Satun (Thaleban National Park)	Picheansoonthon and Yupparach (2007)
A. trilobum Gagnep.	North-eastern Thailand: KhonKaen, Sakon Nakhon (Phu Phan)	Picheansoonthon and Yupparach (2007), Saensouk et al. (2016)
A. wandokthong (Picheans. &Yupparach) Skornick. & Hlavatá	All parts in Thaiand	Picheansoonthon and Yupparach (2007)

Morphological characters of *Amomum* former *Elettariopsis* from Thailand

Morphological characters were described base on living specimens, herbarium specimens and available literature as follows: perennial herbs, up to 150 cm tall. Rhizomes creeping, slender, bearing pseudostems at intervals. Leaves 1–8; ligule entire or 2-lobed; petiole erect, long; leaf blade ovate, lanceolate, elliptic, or oblong. Inflorescences arising from the base of pseudostems, with flowers spaced along rachis or sometimes in an erect, dense head; rachis prostrate or erect, simple or branched; bracts 1- or 2-flowered; bracteoles open, not tubular. Flowers white or pinkish; calyx white or pinkish, tubular, apex 2- or 3-toothed; corolla tube longer than calyx, slender; lobes 3, ovate-oblong or elliptic; lateral staminodes absent or very short; filament short and broad; connective appendage ± quadrate, lateral lobes not spreading; ovary 3-loculed; ovules numerous per locule. Stigma obconical, ciliate; styloides 2, slender. Fruits capsule, globose, glabrous. Seeds numerous, elliptic-globose, 4-5 mm, covered entirely with gelatinous aril.

Key to species

The key to species of *Amomum* former *Elettariopsis* from Thailand is constructed base on the morphology from living specimens, herbarium specimens, and available literature as follows:

1.a. Scape with flowers in a dense head ……. 2
1.b. Scape with flowers spaced along a decurrent rachis ..…….. 7

2.a. Leaves prominently veined ……..… *A. slahmong*
2.b. Leaves not prominently veined ..……...….. 3

3.a. Anther crest with a small tooth-like lobe at the base on each side ……...……...….. 4
3.b. Anther crest without a small tooth-like lobe at the base 5

4.a. Ligule glabrous …….……. *A. trilobum*
4.b. Ligule puberulo ……..... *A. wandokthong*

5.a. Leaf base attenuate ……..…….....…… *A. elan*
5.b. Leaf base obliquely acute ……..……..…… 6

6.a. Leaf apex acuminate to shortly caudate, leaf 2-4 ……..…… ……..……..... *A. chayaniana*
6.b. Leaf apex mucronate, leaf one .....….. *A. monophyllum*

7.a.Leaf shape lanceolate; leaves 8 ……. *A. smithiae*
7.b.Leaf shape elliptic; leaves 2-3-5 ……..…… 8

8.a. Leaves 2 ……..……..……..…… *A. biphyllum*
8.b. Leaves 3-5 ……. 9

9.a. Leaf blade 15-20 × 40-68 cm; leaves 3 ……..... *A. exsertrum*
9.b. Leaf blade 5-12 × 8–25 cm; leaves 5 ……..….. *A. curtisii*

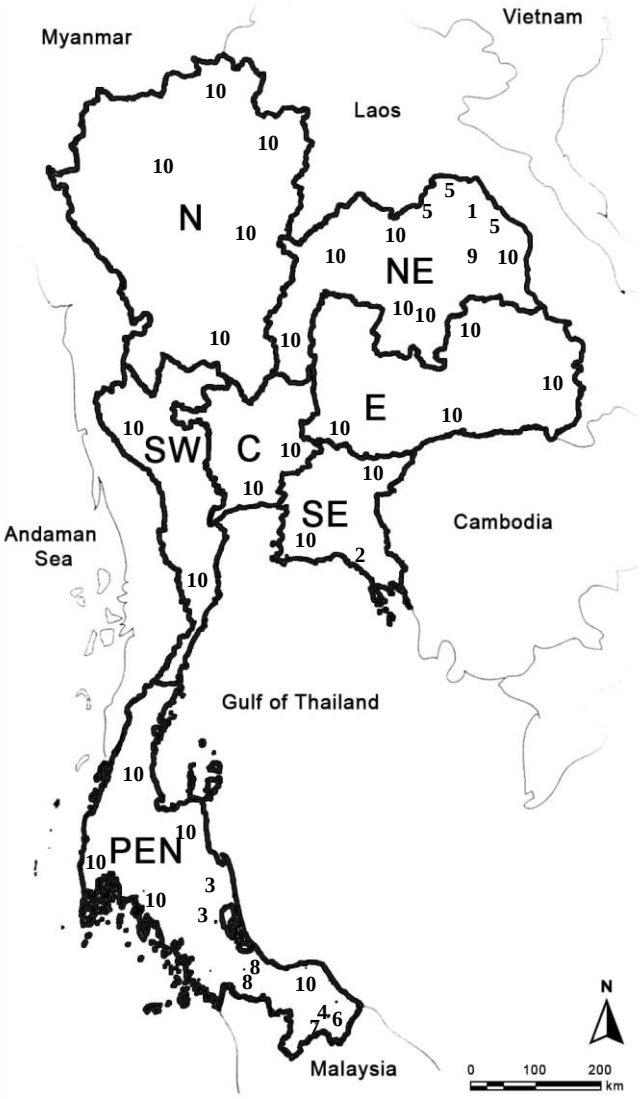

Figure 1. Map of Thailand with neighbor countries showing the distribution of ten species of *Amomum* former *Elettariopsis* from Thailand. 1. *Amomum biphyllum*, 2. *A. chayanianum*, 3. *A. curtisii*, 4. *A. elan*, 5. *A. monophyllum*, 6. *A. exertum*, 7. *A. slahmong*, 8. *A. smithiae*, 9. *A. trilobum*, and 10. *A. wandokthong* (Phytogeographical areas of Thailand as used in the Flora of Thailand project. Provincial borders are indicated. N: Northern, NE: North-eastern, E: Eastern, SW: South-western, C: Central, SE: South-eastern, PEN: Peninsular)

Amomum biphyllum (Saensouk & P. Saensouk) Skornick. & Hlavatá

Synonym: *Elettariopsis biphylla* Saensouk & P. Saensouk

Vernacular names. Khing-Nok-Kho (Thailand)

Distribution. It is endemic to Thailand, only known from BuengKan Province Bung Khla District, (PhuWua Wildlife Sanctuary) (Figure 1).

Ecology. This species grows in the shade of mixed deciduous to dry evergreen forest at an elevation of c. 140 m asl.

Note. The species has two distinctive leaves and dark red veins in parts of the labellum. The morphological characters of *A. biphyllum* are similar to those of *A. monophyllum*, but it differs in its two leaves, dark red veins in parts of the labellum and length of petioles, the pseudostem and the apex of the anther crest.

Traditional utilization. Even though this species has only recently been discovered, its fresh young leaves are eaten as a vegetable in Northeastern Thai cuisine.

Amomum chayanianum (Yupparach) Skornick. & Hlavatá

Synonym: *Elettariopsis chayaniana* Yupparach

Vernacular names. Wan Kambang (Chantaburi province).

Distribution. It is found in Khao Sapan Hin Range of Amphore Klung, Chantaburi province, Thailand (Figure 1).

Ecology. It grows under the shade of dried evergreen forest at the altitude of 140-500 m asl.

Note. It closely related to a group of *A. elan*, *A. slahmong*, and *A. trilobum* based on a clustered-head inflorescence, while others species in Thailand are with an elongated shape. Unique bilobed anther-crest (linear with a bilobed apex) and fruits (ovate with seven longitudinal ridges) are dominant characteristics of *A. chayaniana*. Moreover, the distinctive smell and aroma in leaves of this species differ from other species in this genus. Leaves of *A. elan* give a geranium sweet smell, while *A. slahmong* yields a distinctive “stinging bug” odor. However, *A. trilobrum* releases weakly smell. Therefore, *A. chayaniana* gives a distinctive smell different from those three species.

Traditional utilization. The local villagers in Chantaburi province, Thailand used this species as a medicinal plant and eaten young leaves as a fresh vegetable.

Amomum curtisii (Baker) Skornick. & Hlavatá

Synonym: *Elettariopsis curtisii* Baker, *Cyphostigma curtisii* (Baker) K. Schum., and *C. serpentinum* (Baker) K. Schum.

Vernacular names. Wan (Nakhon Si Thammarat, Phattalung province).

Distribution. It is discovered in Peninsular Thailand: Nakhon Si Thammarat (Khao Luang), Phattalung provinces and Peninsular Malaysia (Figure 1).

Ecology. It grows under the shade of evergreen forest at an altitude of about 1,000 m asl.

Traditional utilization. The local villagers in Nakhon Si Thammarat, Phattalung provinces, Thailand used this species as medicinal plant and eaten as a fresh vegetable.

Amomum elan (C.K.Lim) Skornick. & Hlavatá

Synonym: *Elettariopsis elan* Lim

Vernacular names. Pud (Southern Thailand).

Distribution. It is reported in Peninsular Thailand: Yala (Hala Forest) and Peninsular Malaysia (Figure 1).

Ecology. It grows under the shade of evergreen forest at an altitude of about 300 m asl.

Traditional utilization. The local villagers in the southern part of Thailand used this species as a medicinal plant and eaten young leaves as a fresh vegetable.

Amomum exertum (Scort.) Skornick.&Hlavatá

Synonym: *Elettariopsis exserta* Baker

Vernacular names. Pud (Southern Thailand).

Distribution. It is found in Peninsular Thailand: Yala (Phu Khao Thong, Bala Forest) and Peninsular Malaysia (Figure 1).

Ecology. It grows under the shade of evergreen forest at an altitude of about 300 m asl.

Note. The plant is often two or three leaves, and may form pseudostems, and is usually not as tall in disturbed forests where the juveniles are re-emerging, thus similar in size to *A. curtisii*. Apart from the dull finish, the leaves are strongly plicate, whereas they are smooth and not prominently veins in *A. curtisii*; both are coriaceous. In keeping with the scale of a plant, the inflorescence is often longly "exserted" out of leaf litter; the flowers are quite similar to others in the genus.

Traditional utilization. The local villagers in the southern part of Thailand recognized for uses this species as a medicinal plant and eaten young leaves as a fresh vegetable.

Amomum monophyllum Gagnep.

Synonym: *Elettariopsis monophylla* (Gagnep.) Loes.

Vernacular names. Pud Bai Diew.

Distribution. It is distributed in North-eastern Thailand: Bueng Kan, Nakhon Phanom and Nong Khai provinces; South China (Yunan and Hainan Provinces); Peninsular Malaysia; Laos (Luang Prabang, Vientiane and Savannakhet Provinces) (Figure 1).

Ecology. This species grows under the shade of mixed deciduous forests to dry evergreen forests, at the altitude of c. 140 m asl.

Note. Large population of this species was recently discovered in the protected area of the forest in Bueng Kan, Nakhon Phanom and Nong Khai provinces of Thailand, only less than 30 km away from the Mekhong River.

Traditional utilization. The local people in Nakhon Phanom province, the northeastern part of Thailand used this species as a medicinal plant and eaten young leaves as a fresh vegetable.

Amomum slahmong (C.K. Lim) Skornick. & Hlavatá

Synonym*: Elettariopsis slahmong* Lim

Vernacular names. Pud (Southern Thailand).

Distribution. It is distributed in Peninsular Thailand: Yala (Phu Khao Thong, Bala Forest) and Peninsular Malaysia (Figure 1).

Ecology. This species grows under the shade of evergreen forest, at the altitude of c. 600 m asl.

Note. The epithet recognizes the Teminar name (meaning smelly leaves).

Traditional utilization. The local people in the southern part of Thailand used this species as a medicinal plant and eaten young leaves as a fresh vegetable.

Amomum smithiae (Y.K. Kam) Skornick. & Hlavatá

Synonym*: Elettariopsis smithiae* Y.K. Kam

Vernacular names. Pud (Southern Thailand).

Distribution. It is found in Peninsular Thailand: Song Kla (Than Pliu Waterfall), Satun (Thaleban National Park) and Peninsular Malaysia (Figure 1).

Ecology. This species grows under the shade of evergreen forest, at the altitude of c. 700 m asl.

Note. Named after R.M. Smith of Edinburgh, Scotland, UK.

Traditional utilization. The local people in the southern part of Thailand used this species as medicinal plant and eaten young leaves as a fresh vegetable.

Amomum trilobum Gagnep.

Synonym: *Elettariopsis triloba* (Gagnep.) Loes.

Vernacular names. Pud-Noo (Northeastern Thailand).

Distribution. It is found in North-eastern Thailand: Sakon Nakhon (Phu Phan National Park) and Peninsular Malaysia (Figure 1).

Ecology. This species grows under the shade of mix-deciduous to dry evergreen forests, at the altitude of c. 400 m asl.

Traditional utilization. The villagers in the northeastern part of Thailand have eaten the young rhizome and young fruit of this plant as fresh vegetable.

Amomum wandokthong (Picheans. & Yupparach) Skornick. & Hlavatá

Synonym: *Elettariopsis wandokthong* Picheans. & Yupparach

Vernacular names. Wan Dok Thong or Wan Maha Saneh.

Distribution. This species is widely cultivated in Thailand.

Ecology. This species grows under the shade of dry deciduous forest, at the altitude of 62-240 m asl.

Note. Named after Thai local name.

Traditional utilization. It is ritual plant. This species is believed to process a magical power, and therefore, it is used as a good-luck charm. The Thai names imply magical seductive power. The plants are grown in pots, and put in front of shops believing that they will help to attract customers, especially when the plant is in bloom (usually as early as January to early May). The rhizomes of this species are also used as one of the ingredients for making "magical herbal charming oil" or "magical charming lip balm", believing that after applying it to one's body (oil) or lips (lip balm), it will help to attract the targeted opposite sex, particularly women. Moreover, this species is used for ornamental plants.

Members of the genus *Amomum* previously *Elettariopsis* from Thailand can be divided into two groups, i.e. the group with a clustered-head inflorescence, and the group with an elongated shape which corresponds to Picheansoonthon and Yupparach (2007), Saensouk and Saensouk (2014), and Saensouk et al. (2016). This species, together with *A. elan*, *A. slahmong*, and *A. trilobum* belongs to the first group. Among these 3 species, *A. wandokthong* is morphologically closest to *A. trilobum*, particularly the anther crest. The connective appendages of both species are similar in the presence of the small (c. 1 mm long) tooth-like lobes at the base on each side. This result found ten species of the genus *Amomum* former *Elettariopsis* in Thailand which differs from previously reported by Picheansoonthon and Yupparach (2007) and Saensouk et al. (2016). The traditional uses are found to be local food (including ingredients), medicinal, ornamentals and rituals which consistent with the report of Saensouk et al. (2016). *Amomum curtisii*, *A. monophyllum*, *A. trilobum* and *A. wandokthong* were reported as rare plants followed Picheansoonthon and Yupparach (2007) and Saensouk et al. (2016). Moreover, most species of this study are distributed in the southern part of Thailand except *A. wandokthong* is wildly cultivated in all parts of Thailand which correspond to Picheansoonthon and Yupparach (2007), Saensouk and Saensouk (2014).

Cytological study of four species in genus *Amomum* former *Elettariopsis* from Thailand

The somatic chromosome numbers, karyotype formula, and chromosome structures with satellite positions from four species of genus *Amomum* from Thailand, namely *Amomum curtisii*, *A. monophyllum*, *A. trilobum*, and *A. wandokthong* obtained in this current study are presented in Table 2, Figures 2-3.

Amomum curtisii.

The number of somatic chromosomes of *A. curtisii* was found to be $2n = 48$ (Figure 2.A). The shortest chromosome length was $0.55 \pm 0.01\mu$m, the longest chromosome length was $2.44 \pm 0.11\ \mu$m and the total chromosome length of the individual chromosomes ranged between 1.99 ± 0.03 to $4.47 \pm 0.24\ \mu$m. According to the centromeric index (CI), chromosome ranged from 0.53 to 0.74, and the relative lengths (RL%) ranged from 2.70 to 6.09. The karyological information of *A. curtisii* has 16 metacentric pairs, four submetacentric pairs, and four subtelocentric pairs of chromosomes and the karyotype formula was determined to be 32m + 8sm + 8st, which was observed as asymmetrical karyotypes (Table 3, Figure 3.A). The results correspond with the gametic number ($n = 24$), which is reported for *Elettariopsis* by Beltran and Kam (1984). Moreover, Chen and Huang (1996) concluded that the basic number of *Elettariopsis* was $x = 12$. The karyotype of this species was studied for the first time.

Amomum monophyllum

The number of somatic chromosomes of *A. monophyllum* was found to be $2n = 48$ (Figure 2.B). The shortest chromosome length was $0.50 \pm 0.05\ \mu$m, the longest chromosome length was $2.49 \pm 0.14\ \mu$m and the total chromosome length of the individual chromosomes ranged between 1.33 ± 0.08 to $3.73 \pm 0.23\mu$m. According to the centromeric index (CI), chromosomes ranged from 0.50 to 0.77, and the relative lengths (RL%) ranged from 2.17 to 6.09. The karyological information of *A. monophyllum* has 13 metacentric pairs, six submetacentric pairs, and five subtelocentric pairs of chromosomes and the karyotype formula was determined to be 26m + 12sm + 10st, which was observed as asymmetrical karyotypes (Table 4, Figure 3.B). This is the first report of the karyotype for this species.

Amomum trilobum

The number of somatic chromosomes for*A. trilobum* was $2n = 48$ (Figure 2.C). The shortest chromosome length was $1.32 \pm 0.07\ \mu$m, the longest chromosome length was $5.80 \pm 0.17\mu$m and the total chromosome length of the individual chromosomes ranged between 3.78 ± 0.10 to $8.30 \pm 0.27\ \mu$m. According to the centromeric index (CI), chromosomes ranged from 0.50 to 0.74, and the relative lengths (RL%) ranged from 3.15 to 6.91. The karyological information of *A. trilobum* has nine metacentric pairs, 12 submetacentric pairs, and three subtelocentric pairs of chromosomes and the karyotype formula was determined to be 18m + 24sm + 6st, which was observed as asymmetrical karyotypes (Table 5, Figure 3.C). The results

correspond with the gametic number (n = 24), which was reported for *Elettariopsis* (Beltran and Kam 1984), and this chromosome number agrees with a previous count by Eksomtramage et al. (2001) who reported 2n = 48. Moreover, Chen and Huang (1996) concluded that the basic number of *Elettariopsis* was x = 12. The karyotype of this species was studied for the first time.

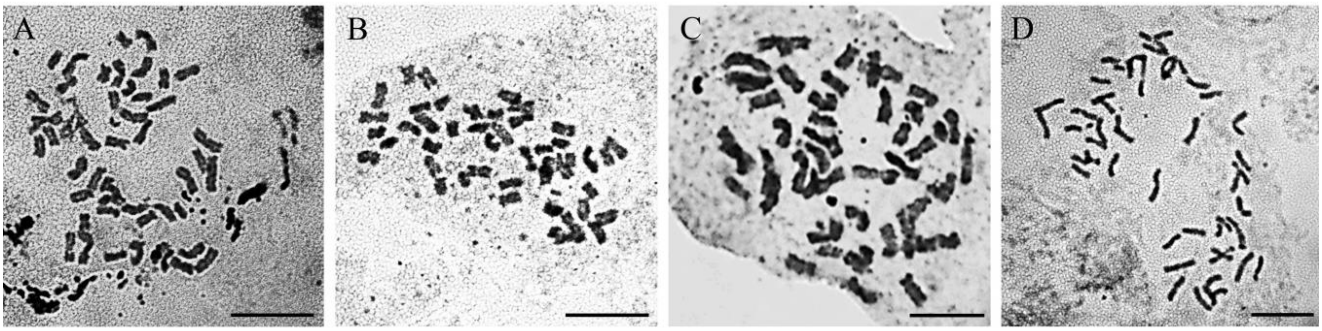

Figure 2. Microphotographs of somatic metaphase plate. A. *Amomum curtisii*, (B. *A. monophyllum*, (C. *A. trilobum*, and (D. *A. wandokthong*. Scale bars = 10 μm.

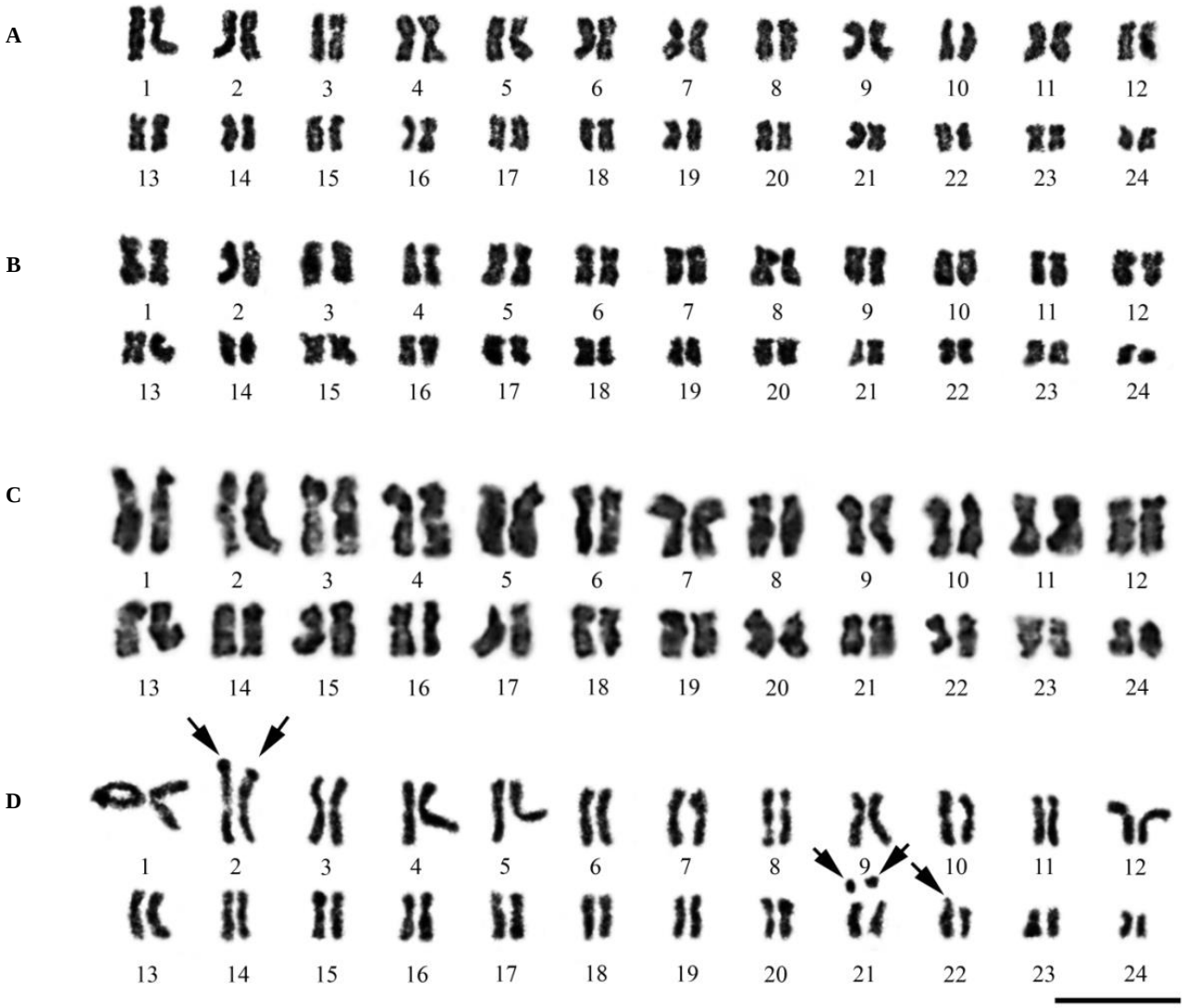

Figure 3. Karyotypes by conventional staining. A. *Amomum curtisii*, B. *A. monophyllum*, C. *A. trilobum*, and D. *A. wandokthong*. Arrows in B and E indicate satellites. Scale bar = 10 μm

Amomum wandokthong

The number of somatic chromosomes of *A. wandokthong* was 2*n* = 48 (Figure 2.D). The shortest chromosome length was 1.28 ± 0.05 μm, the longest chromosome length was 4.25 ± 0.09 μm and the total chromosome length of the individual chromosomes ranged between 2.80 ± 0.10 to 8.01 ± 0.28 μm. According to the centromeric index (CI), chromosomes ranged from 0.50 to 0.76, and the relative lengths (RL%) ranged from 2.15 to 6.14. The karyological information of *A. wandokthong* has 14 metacentric pairs, eight submetacentric pairs, two subtelocentric pairs, and five visible satellite chromosomes. The environmental factors are affected to be satellite chromosomes of this plant. The karyotype formula was determined as 28m + 16sm + 4st, which was observed as asymmetrical karyotypes (Table 6, Figure 3.D). This is the first report of the chromosome number and karyotype for this species.

Table 2. Summary of previous reports of somatic chromosome numbers studied in former genus *Elettariopsis*

Species	2*n*	n	Karyotype formula	Location	References
E. biphylla (Synonym of *A. biphyllum*)	48	-	18m+26sm+4st	Thailand	Saenprom et al. (2018)
E. burtiana (Synonym of *A. billburttii*)	-	24	-	Malaysia	Kam (1982)
E. curtisii	-	24	-	Malaysia	Kam (1982)
(Synonym of *A. curtisii*)	-	24	-	Malaysia	Beltran and Kam (1984)
	48	-	32m+8sm+8st	Thailand	Present study*
E. monophylla (Synonym of *A. monophyllum*)	48	-	26m+12sm+10st	Thailand	Present study*
E. smithiae	-	24	-	Malaysia	Kam (1982)
(Synonym of *A. smithiae*)	-	24	-	Malaysia	Beltran and Kam (1984)
E. triloba	-	24	-	Malaysia	Beltran and Kam (1984)
(Synonym of *A. trilobum*)	48	-	-	Thailand	Eksomtramage et al. (2001)
	48	-	18m+24sm+6st	Thailand	Present study*
E. trilobum	-	24	-	Malaysia	Kam (1982)
(Synonym of *A. trilobum*)	-	24	-	Malaysia	Beltran and Kam (1984)
E. wandokthong (Synonym of *A. wandokthong*)	48	-	28m+16sm+4st (five visible satellites)	Thailand	Present study*,**

Note: *: First report, **: Shows satellites

Table 3. Chromosome characters of *Amomum curtisii*

Chromosome pair	Ls±SD (μm)	Ll±SD (μm)	LT±SD (μm)	RL (%)	CI	Chromosome Shape
1	2.11±0.08	2.36±0.16	4.47±0.24	6.09	0.53	Metacentric
2	1.75±0.08	2.38±0.02	4.13±0.20	5.63	0.58	Metacentric
3	1.32±0.06	2.44±0.11	3.75±0.17	5.11	0.65	Submetacentric
4	1.66±0.06	2.18±0.11	3.84±0.16	5.23	0.57	Metacentric
5	1.49±0.04	2.13±0.10	3.62±0.13	4.93	0.59	Metacentric
6	1.45±0.04	1.97±0.08	3.42±0.11	4.66	0.58	Metacentric
7	1.45±0.04	1.91±0.07	3.36±0.10	4.58	0.57	Metacentric
8	1.40±0.00	1.95±0.08	3.35±0.07	4.56	0.58	Metacentric
9	1.41±0.00	1.87±0.07	3.28±0.07	4.47	0.57	Metacentric
10	0.85±0.02	2.42±0.05	3.27±0.06	4.45	0.74	Subtelocentric
11	1.32±0.02	1.88±0.05	3.20±0.06	4.36	0.59	Metacentric
12	1.15±0.00	1.99±0.09	3.13±0.09	4.27	0.63	Submetacentric
13	1.32±0.00	1.80±0.09	3.13±0.09	4.26	0.58	Metacentric
14	1.10±0.00	1.96±0.03	3.07±0.03	4.18	0.64	Submetacentric
15	0.82±0.08	2.20±0.05	3.02±0.12	4.11	0.73	Subtelocentric
16	1.15±0.06	1.55±0.05	2.70±0.11	3.68	0.57	Metacentric
17	0.88±0.00	1.77±0.01	2.65±0.01	3.61	0.67	Submetacentric
18	0.66±0.00	1.98±0.02	2.64±0.02	3.60	0.75	Subtelocentric
19	1.02±0.04	1.35±0.06	2.37±0.09	3.23	0.57	Metacentric
20	0.98±0.00	1.32±0.00	2.30±0.00	3.13	0.57	Metacentric
21	0.99±0.02	1.28±0.03	2.27±0.05	3.10	0.56	Metacentric
22	0.98±0.01	1.25±0.02	2.24±0.03	3.05	0.56	Metacentric
23	0.90±0.01	1.32±0.03	2.22±0.04	3.02	0.59	Metacentric
24	0.55±0.01	1.44±0.02	1.99±0.03	2.70	0.72	Subtelocentric

Note: Ls: mean length of short arm chromosome, L1: long arm chromosome, LT: total arm chromosome, RL: relative length, CI: centromeric index, and SD: standard deviation (SD)

Table 4. Chromosome characters of *Amomum monophyllum*

Chromosome pair	Ls±SD (*μ*m)	Ll±SD (*μ*m)	LT±SD (*μ*m)	RL (%)	CI	Chromosome shape
1	1.54±0.09	2.20±0.13	3.73±0.23	6.09	0.59	Metacentric
2	1.01±0.07	2.49±0.14	3.50±0.22	5.70	0.71	Subtelocentric
3	1.00±0.08	2.49±0.11	3.49±0.20	5.69	0.71	Subtelocentric
4	1.29±0.08	2.20±0.13	3.49±0.22	5.69	0.63	Submetacentric
5	1.74±0.10	1.74±0.11	3.47±0.22	5.66	0.50	Metacentric
6	1.59±0.09	1.76±0.11	3.35±0.21	5.46	0.52	Metacentric
7	1.29±0.09	2.00±0.09	3.29±0.19	5.36	0.61	Submetacentric
8	1.32±0.08	1.87±0.12	3.18±0.21	5.19	0.59	Metacentric
9	1.32±0.08	1.76±0.11	3.08±0.19	5.01	0.57	Metacentric
10	0.65±0.04	2.20±0.13	2.85±0.18	4.65	0.77	Subtelocentric
11	1.09±0.06	1.76±0.11	2.85±0.18	4.65	0.62	Submetacentric
12	1.11±.060	1.52±0.09	2.64±0.17	4.30	0.58	Metacentric
13	1.00±0.06	1.59±0.11	2.59±0.19	4.22	0.61	Submetacentric
14	0.71±0.05	1.69±0.11	2.40±0.17	3.91	0.71	Subtelocentric
15	0.98±0.06	1.00±0.06	1.98±0.13	3.23	0.50	Metacentric
16	0.87±0.05	1.11±0.08	1.98±0.14	3.22	0.56	Metacentric
17	0.78±0.06	1.06±0.09	1.84±0.16	3.00	0.58	Metacentric
18	0.78±0.06	1.02±0.08	1.80±0.15	2.94	0.57	Metacentric
19	0.50±0.05	1.30±0.09	1.80±0.15	2.94	0.72	Subtelocentric
20	0.58±0.05	1.12±0.08	1.70±0.14	2.77	0.66	Submetacentric
21	0.56±0.04	1.12±0.08	1.68±0.13	2.74	0.67	Submetacentric
22	0.70±0.05	0.96±0.07	1.66±0.13	2.71	0.58	Metacentric
23	0.69±0.04	0.97±0.07	1.66±0.12	2.70	0.59	Metacentric
24	0.54±0.03	0.79±0.05	1.33±0.08	2.17	0.59	Metacentric

Note: Ls: mean length of short arm chromosome, L1: long arm chromosome, LT: total arm chromosome, RL: relative length, CI: centromeric index, and SD: standard deviation (SD)

Table 5. Chromosome characters of *Amomum trilobum*

Chromosome pair	Ls±SD (*μ*m)	Ll±SD (*μ*m)	LT±SD (*μ*m)	RL (%)	CI	Chromosome shape
1	2.50±0.09	5.80±0.17	8.30±0.27	6.91	0.70	Subtelocentric
2	2.70±0.08	4.86±0.17	7.56±0.26	6.29	0.64	Submetacentric
3	2.85±0.09	4.52±0.13	7.38±0.23	5.48	0.61	Submetacentric
4	2.88±0.09	4.48±0.14	7.36±0.25	5.27	0.61	Submetacentric
5	1.78±0.10	4.01±0.14	5.79±0.25	4.82	0.69	Submetacentric
6	1.81±0.09	3.62±0.13	5.43±0.23	4.52	0.67	Submetacentric
7	2.20±0.10	3.20±0.11	5.40±0.22	4.49	0.59	Metacentric
8	1.35±0.08	3.83±0.14	5.18±0.22	4.31	0.74	Subtelocentric
9	2.27±0.09	2.81±0.12	5.07±0.22	4.22	0.55	Metacentric
10	2.19±0.05	2.80±0.14	4.99±0.20	4.16	0.56	Metacentric
11	2.22±0.08	2.71±0.12	4.93±0.21	4.10	0.55	Metacentric
12	1.32±0.07	3.48±0.11	4.79±0.19	3.99	0.73	Subtelocentric
13	1.79±0.07	2.99±0.12	4.78±0.21	3.98	0.63	Submetacentric
14	1.74±0.06	2.84±0.12	4.57±0.19	3.81	0.62	Submetacentric
15	1.49±0.07	2.90±0.08	4.39±0.16	3.65	0.66	Submetacentric
16	1.96±0.06	2.20±0.09	4.15±0.16	3.46	0.53	Metacentric
17	1.32±0.07	2.79±0.11	4.11±0.18	3.42	0.68	Submetacentric
18	1.57±0.06	2.53±0.09	4.11±0.17	3.42	0.62	Submetacentric
19	1.45±0.06	2.60±0.09	4.05±0.16	3.37	0.64	Submetacentric
20	1.82±0.06	2.20±0.09	4.03±0.16	3.35	0.55	Metacentric
21	1.50±0.04	2.50±0.09	4.00±0.14	3.33	0.63	Submetacentric
22	1.85±0.06	2.08±0.08	3.93±0.15	3.27	0.53	Metacentric
23	1.90±0.05	2.00±0.08	3.90±0.13	3.24	0.51	Metacentric
24	1.90±0.03	1.88±0.06	3.78±0.10	3.15	0.50	Metacentric

Note: Ls: mean length of short arm chromosome, L1: long arm chromosome, LT: total arm chromosome, RL: relative length, CI: centromeric index, and SD: standard deviation (SD)

Table 6. Chromosome characters of *Amomum wandokthong*

Chromosome pair	Ls±SD (*μ*m)	Ll±SD (*μ*m)	LT±SD (*μ*m)	RL (%)	CI	Chromosome Shape
1	4.00±0.12	4.01±0.15	8.01±0.28	6.14	0.50	Metacentric
2*	3.82±0.10	4.04±0.16	7.86±0.27	6.02	0.51	Metacentric
3	3.50±0.10	3.87±0.13	7.37±0.25	5.65	0.53	Metacentric
4	3.18±0.10	3.72±0.15	6.90±0.26	5.29	0.54	Metacentric
5	2.98±0.12	3.87±0.13	6.85±0.26	5.25	0.57	Metacentric
6	2.81±0.10	3.00±0.12	5.81±0.23	4.45	0.52	Metacentric
7	2.90±0.10	2.91±0.11	5.81±0.23	4.45	0.50	Metacentric
8	2.20±0.09	3.53±0.14	5.73±0.23	4.38	0.62	Submetacentric
9	2.28±0.09	3.42±0.13	5.70±0.22	4.36	0.60	Submetacentric
10	2.72±0.06	2.96±0.14	5.68±0.21	4.35	0.52	Metacentric
11	1.48±0.07	4.14±0.13	5.62±0.21	4.30	0.76	Subtelocentric
12	2.52±0.08	2.99±0.11	5.51±0.20	4.22	0.54	Metacentric
13	2.10±0.08	3.40±0.13	5.50±0.22	4.21	0.62	Submetacentric
14	2.06±0.07	3.40±0.13	5.45±0.20	4.18	0.62	Submetacentric
15	1.20±0.07	4.25±0.09	5.45±0.17	4.18	0.73	Subtelocentric
16	2.44±0.07	3.00±0.10	5.44±0.18	4.16	0.55	Metacentric
17	1.94±0.07	3.37±0.11	5.31±0.20	4.06	0.63	Submetacentric
18	1.98±0.07	3.20±0.10	5.18±0.18	3.96	0.62	Submetacentric
19	1.68±0.06	3.16±0.11	4.84±0.18	3.70	0.65	Submetacentric
20	1.91±0.06	1.99±0.09	3.90±0.16	2.99	0.51	Metacentric
21*	1.37±0.05	2.42±0.09	3.79±0.15	2.90	0.64	Submetacentric
22	1.35±0.06	1.75±0.08	3.11±0.15	2.38	0.56	Metacentric
23	1.28±0.05	1.70±0.07	2.98±0.13	2.28	0.57	Metacentric
24	1.39±0.04	1.41±0.05	2.80±0.10	2.15	0.50	Metacentric

Note: *: satellite chromosome, Ls: mean length of short arm chromosome, L1: long arm chromosome, LT: total arm chromosome, RL: relative length, CI: centromeric index, and SD: standard deviation (SD)

In conclusion, ten species of *Amomum* former *Elettariopsis* were recognized in Thailand, namely *A. biphyllum*, *A. curtisii*, *A. chayaniana*, *A. elan*, *A. exserta*, *A. monophyllum*, *A. slahmong*, *A. smithiae*, *A. trilobum*, and *A. wandokthong*. The chromosome number of four species in the *Amomum* from Thailand is 2n = 48. The karyotypes of *A. curtisii* is 32m + 8sm + 8st, *A. monophylla* is 26m + 12sm + 10st, *A. triloba* is 18m + 24sm + 6st, and *A. wandokthong* is 28m + 16sm + 4st with five visible satellite chromosomes. The chromosome structures of all species were found to be asymmetrical.

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