

Morphological Diversity and Distribution of *Etilingera littoralis* (König) Giseke (Zingiberaceae) in Southern Thailand

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Abstract

Etilingera littoralis is a common ground species in Zingiberaceae. It is widely distributed in Peninsular Thailand both in the Gulf of Thailand and the Andaman Sea coasts. The morphological characters of *E. littoralis* and two related species, *E. megalochilos* and *Etilingera* sp. are similar. Although *E. megalochilos* were not found in this study, its morphological characters from previous studies indicated that *E. littoralis* and *E. megalochilos* are different species. Interestingly, an unknown *Etilingera* sp. was found instead. The morphological character of *Etilingera* sp. is superficially similar to *E. littoralis*. The morphological characters of both *E. littoralis* and *Etilingera* sp. were studied using R statistic. The results showed that *E. littoralis* and *Etilingera* sp. can be clearly separated by reproductive parts (inflorescence color pattern, labellum length, labellum and stamen length ratio, and angle of anther). The morphological characters indicate that *E. littoralis* and *Etilingera* sp. can be classified as 2 different species.

Keywords: *Etilingera littoralis*, *Etilingera* sp., Zingiberaceae, southern Thailand, morphological diversity, distribution

Introduction

Etilingera littoralis (König) Giseke, a member of Zingiberaceae, is widely distributed in the Malay Peninsula, including southern Thailand. A specimen of *Etilingera littoralis* was collected by König in 1779 from Phuket Province, Thailand but lost at sea [1]. Later researchers used only its description as a basis for its morphological characters. To date, we know that *E. littoralis* is median red with a yellow lateral labellum. In 1986, RM Smith reviewed Bornean Zingiberaceae, including the *Etilingera* genus, using only morphological characters. At that point, from König's morphological description, *E. megalochilos* was placed synonymously with *E. littoralis*. She (Smith) mentioned that *E. littoralis* is commonly distributed in the Malay Peninsula and extends to southern Thailand [2] even though their flowers showed no yellow on the labellum, but bright red and bloom on the ground level.

In 2004 - 2005 and 2009 - 2010 new collections from Phuket Island were made by the authors of the present research, which corresponded to König's morphological description. It was found that the description of *E. littoralis* from Phuket Island, Thailand by König cannot be applied to species found in Borneo, because *E. littoralis* in southern Thailand are mainly yellow on the margin of each flower. On the other hand, species found in Borneo have a red flower and sometimes a yellowish color on the margin, a longer lip, a usually longer labellum, a narrower central lobe of the labellum, a shorter and narrower

filament, a shorter and narrower stamen, the labellum being 3 - 4 times as long as the stamen, and anther dehiscence in the upper half to two-thirds.

Two basic objectives are addressed in the present study: (1) to study morphological characters of *E. littoralis* populations between *E. littoralis* and *E. megalocheilos* on the east coast and the west coast in southern Thailand; and (2) to study distribution ranges of *E. littoralis* and *E. megalocheilos* in southern Thailand.

Materials and methods

Sampling taxon

Etilingera samples were collected from all provinces in southern Thailand (except 3 provinces in the lowest part of southern Thailand). All morphological characters of the samples collected from the field work were measured for both qualitative and quantitative characters (**Table 1**). Those morphological characters were converted to “0” and “1” and the data were grouped by Cluster Analysis using R program version 2.11.1 [3].

Table 1 Morphological characters of *Etilingera* sample collection in southern Thailand for R statistic analysis.

Morphological characters	0	1
1. Leaf forms	Simple	Compound
2. Leaf shape	Oblong	Lanceolate
3. Leaf length and width ratio	1 - 5 times	>5 times
4. Leaf base	Oblique	Rounded
5. Leaf margin	Entire	Not entire
6. Leaf apex	Acuminate	Acute
7. Leaf length	50 - 100 cm	>100 cm
8. Leaf width	1 - 10 cm	>10 cm
9. Leaf abaxial	Hairs	Glabrous
10. Leaf adaxial	Hairs	Glabrous
11. Number of leaves	1 - 20	>20
12. Leafy shoot height	1 - 5 m	5.1 - 10 m
13. Leafless	1 - 2 m	2.1 - 3 m
14. Leafy shoot	Hairs	Glabrous
15. Inflorescence color	Entire red labellum	Yellow edge labellum
16. Inflorescence length	1 - 10 cm	>10 cm
17. Total number of flowers	10 - 20	21 - 30
18. Number of flowers open at a time	1 - 10	>10
19. Bract length	1 - 5 cm	>5.0 cm
20. Bract width	1 - 3 cm	3.1 - 5 cm
21. Bract length and width ratio	1 - 3 times	>3 times
22. Bract tip	Acuminate	Acute
23. Flower length	1 - 10 cm	>10 cm
24. Dorsal corolla lobe	1 - 3 cm	3.1 - 5 cm
25. Labellum length	1 - 5 cm	5.1 - 10 cm
26. Labellum width (middle of the labellum)	0.1 - 1 cm	>1.0 cm
27. Labellum tip	Emarginated	Rounded
28. Corolla tube	1 - 5 cm	>5 cm
29. Stamen length	0 - 1.5 cm	>1.5 cm
30. Labellum and stamen length ratio	1 - 3 times	>3 times

Results

Distribution

Thirty *Etlingera* samples were collected from all but 3 provinces in southern Thailand, (Yala, Pattani and Narathiwat, in the lowest part of southern Thailand). (Table 2 and Figure 1). They are divided into *E. littoralis* (11 samples), *Etlingera* sp. (17 samples) and *E. araneosa* (2 samples).



Figure 1 *Etlingera* samples collected in this study. 1 - 11 *E. littoralis*, 12 - 28 *Etlingera* sp. and 29 - 30 *E. araneosa*.

Table 2 *Etilingera* samples collected from southern Thailand.

No.	Sample code	Species Name	Location (District, Province)	GPS locality	Ass. No.
1.	RN1_Etilingera	<i>Etilingera littoralis</i>	Kra Buri, Ranong	N 010° 30' 43.1", E 098° 53' 27.3"	WU11
2.	PNG1_Etilingera	<i>Etilingera littoralis</i>	Ta Kua Pa, Phang Nga	N 08° 49' 56.8", E 098° 26' 49.8"	WU36
3.	PNG2_Etilingera	<i>Etilingera littoralis</i>	Tai Muang, Phang Nga	N 08° 29' 49.4", E 098° 17' 0"	WU37
4.	KB1_Etilingera	<i>Etilingera littoralis</i>	Khlong Tom, Krabi	N07° 55' 27.2", E099° 15' 38.8"	WU29
5.	KB2_Etilingera	<i>Etilingera littoralis</i>	Khlong Tom, Krabi	N07° 55' 502.6", E099° 12' 22"	WU30
6.	NST2_Etilingera	<i>Etilingera littoralis</i>	Lan Saka, Nakhon Si Thammarat	N08° 22' 56.4", E099° 44' 12"	WU40
7.	NST6_Etilingera	<i>Etilingera littoralis</i>	Si Chon, Nakhon Si Thammarat	N09° 1' 18.9", E099° 46' 22.3"	WU68
8.	NST7_Etilingera	<i>Etilingera littoralis</i>	Tha Sala, Nakhon Si Thammarat	N07° 5' 6.6", E099° 47' 54.2"	WU87
9.	PK1_Etilingera	<i>Etilingera littoralis</i>	Tha Lang, Phuket	N08° 1' 51", E098° 22' 27.1"	WU31
10.	PK2_Etilingera	<i>Etilingera littoralis</i>	Tha Lang, Phuket	N08° 2' 37.3", E098° 16' 43.4"	WU34
11.	SRT1_Etilingera	<i>Etilingera littoralis</i>	Pa Nom, Surat Thani	N08° 54' 10.5", E098° 37' 19.1"	WU38
12.	SRT2_Etilingera	<i>Etilingera</i> sp.	Wipa Wadee, Surat Thani	N09° 9' 42.1", E098° 53' 5.9"	WU88
13.	TR1_Etilingera	<i>Etilingera</i> sp.	Yan Ta Koaw, Trang	N07° 24' 45.2", E099° 49' 20.7"	WU55
14.	TR3_Etilingera	<i>Etilingera</i> sp.	Yan Ta Koaw, Trang	N07° 26' 27.6", E099° 48' 56.3"	WU61
15.	NST1_Etilingera	<i>Etilingera</i> sp.	Lan Saka, Nakhon Si Thammarat	N08° 22' 56.2", E099° 44' 12"	WU39
16.	NST3_Etilingera	<i>Etilingera</i> sp.	Lan Saka, Nakhon Si Thammarat	N08° 22' 56.2", E099° 44' 12.1"	WU43
17.	NST4_Etilingera	<i>Etilingera</i> sp.	Si Chon, Nakhon Si Thammarat	N09° 5' 26.4", E099° 53' 50.8"	WU63
18.	NST5_Etilingera	<i>Etilingera</i> sp.	Sichon, Nakhon Si Thammarat	N09° 5' 19.7", E099° 53' 20.6"	WU66
19.	ST1_Etilingera	<i>Etilingera</i> sp.	Kuan Ka Lhung, Satun	N06° 54' 43.1", E0100° 7' 47.4"	WU70
20.	ST2_Etilingera	<i>Etilingera</i> sp.	Kaun Don, Satun	N06° 45' 28.9", E100° 9' 18.6"	WU75
21.	ST3_Etilingera	<i>Etilingera</i> sp.	Kuan Don, Satun	N06° 43' 39", E100° 9' 45.1"	WU76
22.	SKL1_Etilingera	<i>Etilingera</i> sp.	Boripat, Songkhla	N07° 0' 31.2", E100° 18' 45.4"	WU78
23.	SKL2_Etilingera	<i>Etilingera</i> sp.	Had Yai, Songkhla	N07° 0' 5.3", E100° 14' 5.9"	WU79
24.	SKL3_Etilingera	<i>Etilingera</i> sp.	Had Yai, Songkhla	N06° 59' 40.1", E0100° 8' 57"	WU80
25.	SKL4_Etilingera	<i>Etilingera</i> sp.	Natawee, Songkhla	N06° 35' 13.7", E100° 34' 33.7"	WU82
26.	SKL5_Etilingera	<i>Etilingera</i> sp.	Natawee, Songkhla	N06° 36' 1.3", E100° 35' 15.9"	WU85
27.	PTL1_Etilingera	<i>Etilingera</i> sp.	Si Banphot, Phatthalung	N07° 40' 38.2", E098° 53' 27.3"	WU46
28.	PTL2_Etilingera	<i>Etilingera</i> sp.	Si Banphot, Phatthalung	N07° 42' 20.3", E099° 48' 51.6"	WU50
29.	CP1_Etilingera	<i>Etilingera araneosa</i>	Muang, Chumporn	N010° 43' 26.3", E099° 7' 23.6"	WU09
30.	SRT3_Etilingera	<i>Etilingera araneosa</i>	Khoa Sok, Surat Thani	N08° 53' 53.7", E098° 44' 29.1"	WU90

The distribution map shows that *Etilingera* species are widely dispersed in southern Thailand, both in the Gulf of Thailand and Andaman Sea sides (Figure 2). The collected data showed that the habitats of *E. littoralis* and *Etilingera* sp. overlap in the middle part of southern Thailand. *Etilingera littoralis* is mostly distributed in the upper part of southern Thailand: Krabi, Phuket, Nakhon Si Thammarat, Phang Nga, Ranong, and Surat Thani provinces. While *Etilingera* sp. is generally distributed in the lower part of southern Thailand: Trang, Phattalung, Satun, Songkhla, Surat Thani, and Nakhon Si Thammarat provinces. However, both species were found in Surat Thani and Nakhon Si Thammarat provinces. *E. araneosa* were found only in Chumporn and Surat Thani provinces.

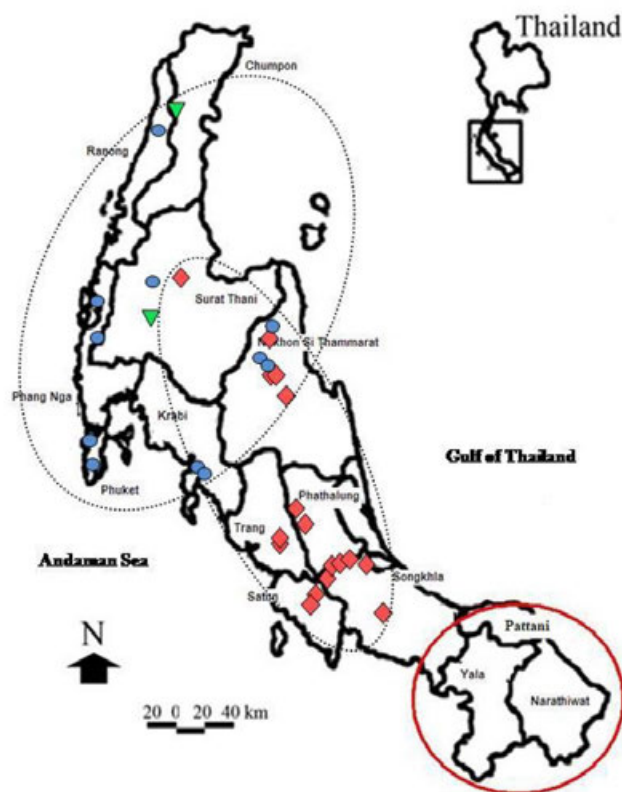


Figure 2 Geographical distributions of all *Etilingera* samples collected from all provinces in southern Thailand, except for the three provinces in the lowest part. ● *E. littoralis*, ◆ *Etilingera* sp., ▼ *E. araneosa*.

Morphological studies

Inflorescences and Infructescences

There are three *Etilingera* inflorescence forms. In the *Etilingera littoralis* form, inflorescences are embedded in the soil. The flowers have a median red with yellow lateral labellum. The labellum length has a mean of 4.92 cm, shorter than the other forms. The middle of the labellum has a mean width 1.7 cm, and is broadest below the middle. The stamen is 1.5 - 2.0 by 0.7 - 1.1 cm. The anther is 1.0 - 1.2 by 0.5 - 0.6 cm. It is quite erect with filaments, or sometimes the anther shows an angle depression (10° - 15°), broadest at the apex, and emarginated at 0.1 - 0.2 cm, the thecae dehiscing in the upper 1/2 - 2/3.

Infructescences are embedded in the soil; they are brown, deeply ridged and densely pubescent (**Figure 3**).

The inflorescence form of *Etilingera* sp. is divided into 2 forms; a median red with yellow lateral labellum and an entirely red labellum. Inflorescences are also embedded in the soil. The labellum length has a mean of 6.8 cm; the middle of the labellum is quite narrow at 0.8 - 1.0 cm, a broader apex of 1.0 - 1.7 cm, emarginated and broadest below the middle at 1.9 - 2.5 cm. The stamen is 0.5 - 1 by 0.4 - 0.6 cm, emarginated, and narrower than the stamen of *E. littoralis*. The anther is 1.0 - 1.2 by 0.3 - 0.5 cm. It is much angled at *ca.* 40° - 65° with filament, emarginated, with thecae dehiscing in the upper 1/2 - 2/3. Infructescence is very similar to *E. littoralis*; embedded in the soil, brown, deeply ridged and densely pubescent (**Figure 4 and 5**).



Figure 3 *Etilingera littoralis*; (a) a whole inflorescence, (b) dissected parts of the inflorescence, (c) fruits and (d) stamen and stigma.



Figure 4 *Etilingera* sp. (yellow lateral labellum); (a) a whole inflorescence, (b) dissected parts of the inflorescence, (c) fruits and (d) stamen and stigma.

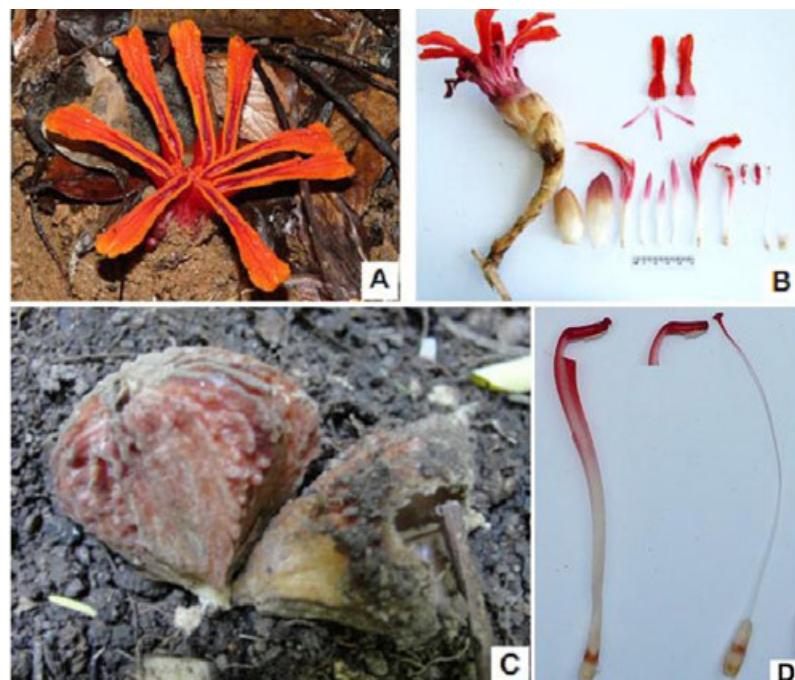


Figure 5 *Etilingera* sp. (entirely red labellum); (a) a whole inflorescence, (b) dissected parts of the inflorescence, (c) fruits and (d) stamen and stigma.

Cluster analysis of morphological characters

In this study, R statistic v.2.11.1 [3] was used for cluster analysis of the *Etilingera* samples. All of the morphological characters of the samples, both qualitative and quantitative characters, were considered and measured respectively. Those characters were converted to symbols (“0” and “1”) for analysis by R program.

The morphological character analysis was studied in 3 patterns (only vegetative character, only reproductive character, and reproductive and vegetative characters together) (Figures 6 - 8 respectively). The results showed that the morphological character of the only reproductive part, and the reproductive and vegetative together parts, and analyses separated the collected samples into 2 groups; *E. littoralis* and *Etilingera* sp., with R value from ANOSIM statistic analysis = 0.55 and 0.79 respectively (Figure 8 and 9).

The morphological character from the only vegetative part cannot be grouped to *E. littoralis* or *Etilingera* sp. There are 4 groups in which they were mixed between *E. littoralis* and *Etilingera* sp. (Figure 6).

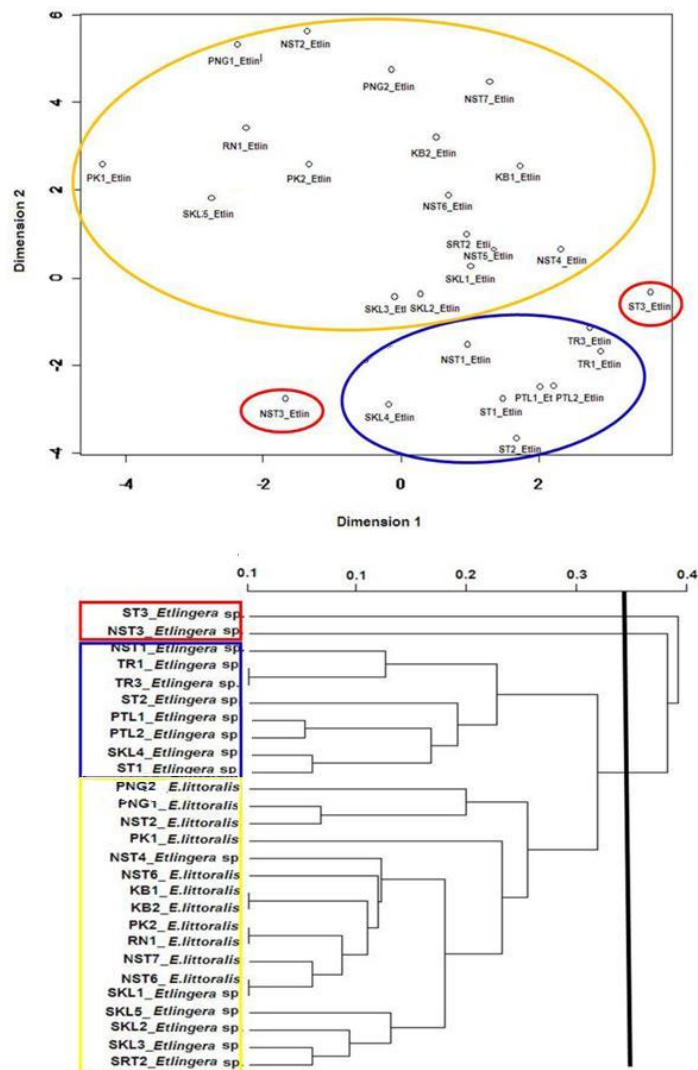


Figure 6 A cluster analysis pattern of vegetative characters. The samples are not clearly separated into *E. littoralis* or *Etilingera* sp. groups.

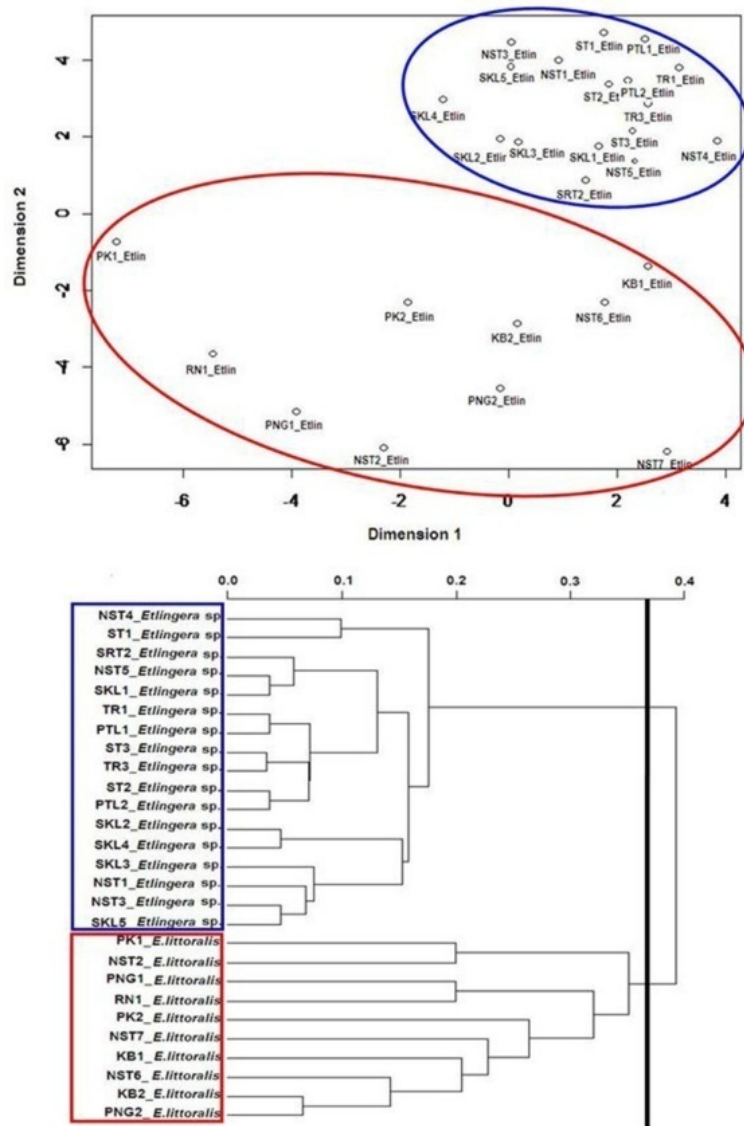


Figure 7 A cluster analysis pattern of only reproductive characters. The samples were separated into 2 groups by R statistic, R value = 0.79.

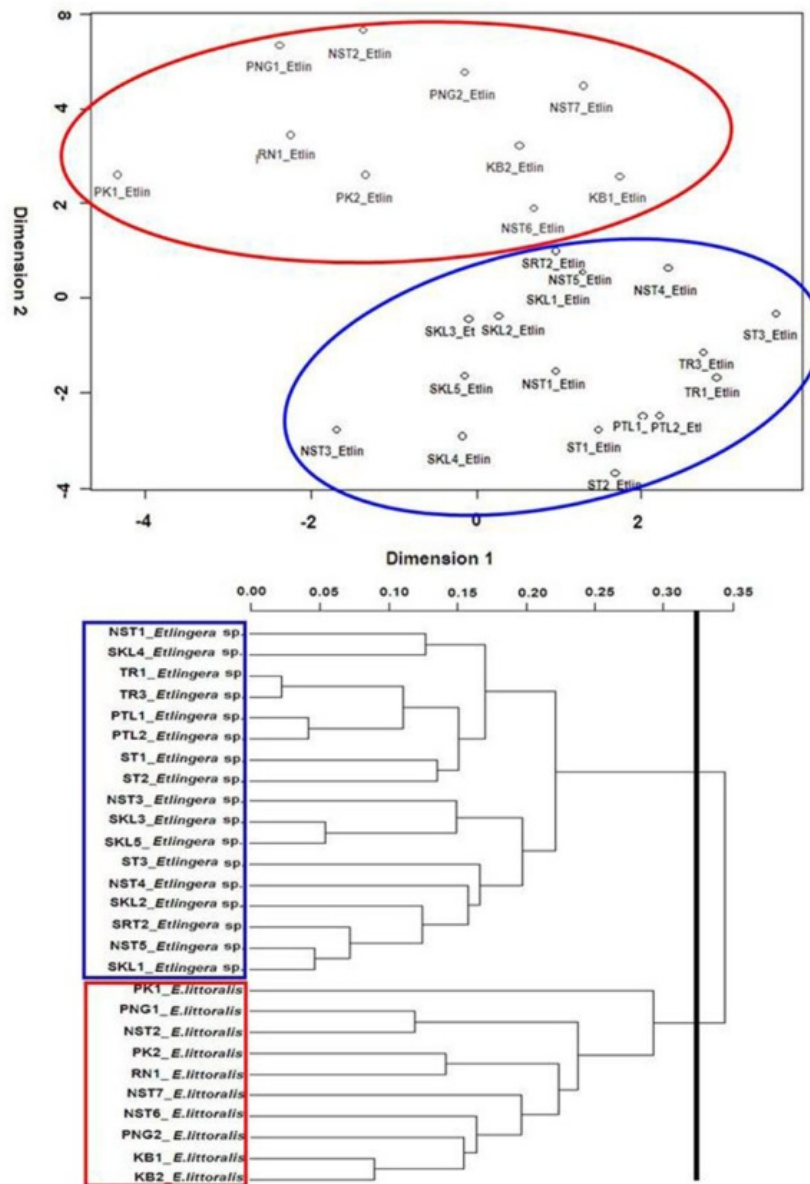


Figure 8 A cluster analysis pattern of reproductive and vegetative characters. The samples were separated into 2 groups by R statistic, R value = 0.55.



Figure 9 The infructescence and inflorescences of *E. littoralis* (a) and *E. megalocheilos* (b).

Discussion

In this study of *E. littoralis* (König) Giseke and *E. megalocheilos* (Griff.), A.D. Poulsen has confirmed that they actually are different, even though *E. megalocheilos* has not yet been found in southern Thailand. However, there is one collection in Peninsular Malaysia where photographs of both inflorescences and fruits were taken (Forest Research Institute Malaysia (FRIM)). Comparison between the two species showed that the inflorescences of *E. littoralis* and *E. megalocheilos* are quite analogous, except the fruits are rather different, *E. littoralis* fruits are deeply ridged, but the fruit of *E. megalocheilos* are smooth (**Figure 9**).

Interestingly, *Etilingera* sp. is another species which was collected from southern Thailand. *Etilingera* sp. cannot be identified with either *E. littoralis* or *E. megalocheilos*, even though the external morphology, including their infructescences and fruits, look very alike to *E. littoralis* (**Figure 10**); however other morphological characters are quite different, particularly reproductive characters, such as inflorescence color pattern, labellum length, labellum and stamen length ratio, and angle of anther.



Figure 10 The infructescence and inflorescences of *Etilingera* sp. (a) and *E.littoralis* (b).

Morphology between *E. littoralis* and *Etilingera* sp.

External morphology

The external morphologies of *Etilingera* sp. and *E. littoralis* samples, which were collected from southern Thailand, are very similar in terms of vegetative parts, e.g. leaf (green blade color), leaf margin (most often ciliate to pubescent), leaf shoot height (up to 8 - 10 m, the sheath is often striate or variously reticulate) etc. Consideration of floral morphology, on the other hand, shows a superficial similarity. The inflorescence of *E. littoralis* is short and compact. Each flower shows bright red and yellow labellum [4]. The floral morphology of *Etilingera* sp. varies. There are 2 different inflorescence color forms, absolute red and median red with yellow edge labellum (**Figure 11**).

Considering the fifteen characters of the reproductive parts, the cluster analysis showed that *E. littoralis* and *Etilingera* sp. were separated into 2 groups; *E. littoralis* and *Etilingera* sp. Morphologically, *E. littoralis* is distinguished from the related species, *Etilingera* sp., by many floral characters, such as inflorescence pattern color, labellum length, labellum and anther length ratio, and the angle of anther.



Figure 11 Inflorescence of *E. littoralis* (a), *Etilingera* sp. (entirely red) (b), and *Etilingera* sp. (median red with yellow edged labellum) (c)

Species distribution and their ecology

Etilingera samples collected from southern Thailand can grow in different areas. They grow along logging roads, river banks, and damp and humid shady places [5] (**Figure 12**). They are less frequently found in secondary forests, along jungle trails, and lowlands to the highest elevations in secondary and primary forests. Some species can be fully exposed to the sun [4]. *E. littoralis* is mostly found in the upper part of southern Thailand, while *Etilingera* sp. is mostly found in the lower part. There are only 2 provinces, Surat Thani and Nakhon Si Thammarat, where both plant species were found concurrently. The lower part of southern Thailand has better environmental conditions - such as temperature, humidity, rainfall, etc. - than the upper part of southern Thailand. It is favorable for *Etilingera* sp. but not *E. littoralis*. However, *Etilingera* sp. may be widely distributed in the Malay Peninsula, and just extends slightly into southern Thailand.

In addition, some species of the flora of Thailand has encouraged collaboration with Flora Malesiana because of the considerable overlap in the floras (65 % of Thai species are also found in Malaysia) [6]. Peninsular Thailand includes an important biogeographic transition between Thai seasonal dry evergreen forest and the extremely diverse mixed dipterocarp forest characteristic of much of western Malaysia [7]. This transition has never been quantitatively described but it is clear that the Isthmus of Kra, the northern limit for Flora Malesiana accounts, is much further north than the edge of this forest type. However, there are areas in the southern Thai provinces right on the Malaysian border, so one would expect many more of the Malaysian elements to be found here if they were better collected. This would have benefits: firstly, that taxa found there could be incorporated into the ongoing flora of Thailand, and secondly, that biogeographic studies would have a more accurate pool of data to use in describing this transition zone [8].



Figure 12 *Etilingera* samples were found in different habitats in southern Thailand.

In addition, *E. araneosa*, which were used as an outgroup, were found in 2 provinces, Chumpon and Surat Thani. *E. araneosa* was first described in Myanmar and is commonly found along border areas in northern Thailand. In addition, in this study, *E. araneosa* were also found in southern Thailand, in the Chumporn and Suratthani provinces.

Conclusions

The results indicate that *E. littoralis* is widely distributed in southern Thailand, both in the Gulf of Thailand and Andaman Sea coasts; particularly, the upper part of southern Thailand. Normally, *E. littoralis* can grow in different habitats, from lowland to high elevation. They grow along logging roads, river banks, damp and humid shady places. They are also frequently found in secondary forests, areas along jungle trails and in secondary and primary forests. Some species can be fully exposed to the sun.

Morphologically, the inflorescence of *E. littoralis* is short and compact. Each flower shows bright red and yellow labellum. The labellum length has a mean of 4.92 cm, broadest below the middle. The stamen (length by width) is 1.5 - 2.0 by 0.7 - 1.1 cm. The anther (length x width) is 1.0 - 1.2 by 0.5 - 0.6 cm, quite erect with filament or a little angled *ca.* 10° - 15°, broadest at the apex, emarginated at 0.1 - 0.2 cm, thecae dehiscent in the upper 1/2 - 2/3. The fruit is rounded and hardly ridged.

E. megalocheilos was not found in the study. This species is widely distributed in Borneo and the Malay Peninsula. Its characters are different from *E. littoralis*, i.e. a longer lip, a longer corolla tube, a longer labellum, a narrower central lobe of the labellum, and a shorter and narrower stamen [9]. Consequently, *E. megalocheilos* cannot be synonymous to *E. littoralis*.

Morphological characters and ecological habitats of *Etilingera* sp. very similar to *E. littoralis* were found. It is mainly distributed in the lower part of southern Thailand. Morphological characters showed that *Etilingera* sp. is not *E. megalocheilos*. *Etilingera* sp. is also not *E. littoralis*, even though their morphological characters, both vegetative and reproductive parts, are very similar. Cluster analysis using R statistic program showed that *Etilingera* sp. was clearly separate from *E. littoralis*.

There are 2 flower forms of *Etilingera* sp., a median red with yellow lateral labellum and an entirely red labellum. Inflorescences are also embedded in the soil. The labellum is more elongated than that of *E. littoralis*. The Labellum length of the *E. littoralis* is 1 - 5 cm, but the Labellum length of the *Etilingera* sp. is 5.1 - 10 cm. The middle of the labellum is quite narrow, broader at the apex, emarginated and broadest below the middle. The stamen is emarginated and narrower than the stamen of *E. littoralis*. The anther is highly angled at *ca.* 40 - 65 degrees with filament, emarginate, with thecae dehiscing in the upper 1/2 - 2/3. The labellum and anther length ratio of the *Etilingera* sp. is about 3 time of the *E. littoralis*. Inflorescence and fruits are very similar to *E. littoralis*, embedded in the soil. The fruit is brown, deeply ridged and densely pubescent. In summary, some clear external morphological characters can be used to identify *Etilingera* sp., *E. megalocheilos* and *E. littoralis*.

Acknowledgements

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