Diversity and uses of Zingiberaceae in Nam Nao National Park, Chaiyaphum and Phetchabun provinces, Thailand, with a new record for Thailand

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ARTICLE INFO
Article history:
Received 15 February 2016
Accepted 25 August 2016
Available online 4 January 2017

Keywords:
Diversity
Nam Nao National Park
Traditional uses
Zingiberaceae

ABSTRACT
Three tribes, 12 genera and 38 species of the ginger family (Zingiberaceae) along five routes in Nam Nao National Park were surveyed between January 2012 and December 2013 to determine their diversity, ecological data, phenology, uses and conservation status. The highest diversity was found in the tribe Zingibereae (6 genera and 21 species), of which the genera Curcuma and Zingiber comprised the highest number species (eight species each). A species key was constructed based on morphology. The ginger family was found in four forest-types—deciduous dipterocarp forest, mixed deciduous forest, dry evergreen forest and pine forest. The most flowering bloom of the ginger family in Nam Nao National Park was during March to August and the most fruiting bloom was during June to September. The popular uses of Zingiberaceae were as a food, spice, in medicine, as ornamentation and in rituals. Eight species have been evaluated as of least concern and are presented in the IUCN Red List, while two rare species were reported in Thailand Red Data: Plants, while six rare Zingiberaceae species were identified based on the evaluation criteria of Saensouk (2011). Four species were endemic to Thailand. Moreover, Etlingera yunnanensis (T. L. Wu & S. J. Chen) R. M. Smith was a new record for Thailand.

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Introduction
Species in the ginger family (Zingiberaceae) are well known in everyday life. Many species are used as spices, in food, cosmetics and dyes, and as ornamental plants. The Zingiberaceae family consists of herbaceous perennial plants that grow well in humid tropical and subtropical areas. The family is centrally distributed in Southeast Asia, from 0 to 2000 m above sea level. The dominant characteristic of the ginger family is the presence of essential oils in all parts of the plant, especially in the rhizomes and leaves. The family Zingiberaceae contains approximately 50 genera and 1500 species world wide. In Thailand, the Zingiberaceae contains approximately 30 genera and 300 species (Larsen and Larsen, 2006). Several Thai genera of the Zingiberaceae have been studied, namely Kaempferia (Sirirugsa, 1992), Zingiber (Triboun, 2006), Amomum (Kaewsri, 2006), Curcuma (Maknoi, 2006), Alpinia (Saensouk, 2006) and Cornukaempferia (Saensouk, 2008). In Thailand, a number of localities have been studied focusing on the Zingiberaceae, such as in Phu Phan National Park, Sakon Nakhon province (Saensouk and Chantaranothai, 2003), Thong Pha Phum Forest, Kanchanaburi province (Suvandech and Sookchaloem, 2007), Phu Phra Bat Historical Park, Udon Thani province (Saensouk et al., 2014) and Phu Laen Kha National Park, Chaiyaphum province (Khamtang et al., 2014). Nam Nao National Park is located in Lom Sak district, Nam Nao district, Phetchabun province and Chaiyaphum province acts as a boundary between northeastern and northern Thailand. The National Park area is approximately 966 km², contains generally high mountains (about 700 m above sea level) and many forest types, streams and a variety of plants (http://www.dnp.go.th). However, there are no published reports of studies in the National Park on the ginger family. Therefore, this research aimed to study the diversity, conservation
status and uses of the Zingiberaceae in Nam Nao National Park and to construct an identification key.

Materials and methods

Study site

Ginger specimens were collected from Nam Nao National Park, in Chaiyaphum and Phetchabun provinces, monthly during the two-year study from January 2012 to December 2013, along five separate routes (Fig. 1).

Route 1 consisted of a nature trail (approximately 5.8 km) behind the headquarters of the park comprising forest types such as dry evergreen forest, mixed deciduous forest and pine forest.

Route 2 (Suan Son Ban Park) was approximately 5 km long comprising three forest types—deciduous dipterocarp forest, mixed deciduous forest and pine forest.

Route 3 went along the road to Suan Son Phu Kum Kao (approximately 14 km) comprising three forest types—deciduous dipterocarp forest, mixed deciduous forest and pine forest.

Route 4 (length approximately 700 m) at the Heaw Sai waterfalls comprised two forest types—deciduous dipterocarp forest and mixed deciduous forest.

Route 5 was along the roadside of highway No. 12 (approximately 30 km) and comprised three forest types—deciduous dipterocarp forest, mixed deciduous forest and pine forest.

Morphology and taxonomy

The dried plant specimens from many herbaria, including the Herbarium of the Department of National Parks, Wildlife and Plant Conservation (BKF), Bangkok Herbarium (BK), Chiang Mai University Herbarium (CMU), Queen Sirikit Botanical Gardens Herbarium (QBG), Prince of Songkla University Herbarium (PSU) and Khon Kaen University Herbarium (KKU) were checked for basic information such as correct species identification, ecological data, phenological data and notes on the dominant characters.

Important characteristics, such as the color of all the organs, ecological information and distribution data, were recorded. Specimens were collected as 3–5 pieces per specimen and then dried in an oven at 60 °C until completely dried. Flowers or other organs of some species were preserved in 70% alcohol. The specimens were collected and deposited as reference specimens in the Mahasarakham University Herbarium, Thailand. The morphology of the specimens was studied using a stereo microscope and the roots, rhizomes, pseudostems, leaves, inflorescence, flowers, fruit and seeds were described to verify taxonomy. Identification was based on morphological data and on references on the flora of Indo-China, British India, China and the Malay Peninsula monocotyledons and from scientific publications. A key to tribes, genera and species was constructed based on morphology. Utilization data of the Zingiberaceae was obtained through interviewing local villagers who were living in the Nam Nao National Park.

Conservation status evaluation

The conservation status of plants was based on the evaluation criteria of the IUCN Red List (IUCN Red List of Threatened Species, 2014), the Thailand Red Data: Plants (Santisuk et al., 2006) and the evaluation criteria of Saensouk (2011).

Results

Diversity of Zingiberaceae in Nam Nao National Park

Three tribes, 12 genera and 38 species of Zingiberaceae were collected from the five routes in Nam Nao National Park (Table 1 and Fig. 2). The tribe Alpinieae was comprised of four genera and 10 species—Alpinia (4 species), Amomum (4 species), Elettariopsis (1 species) and Etlingera (1 species). The tribe Zingibereae, with the highest diversity of Zingiberaceae species had 6 genera and 23 species—Boesenbergia (3 species), Cornuacempferia (2 species), Curcuma (8 species), Kaempferia (2 species), Stahlianthus (1 species) and Zingiber (7 species). The tribe Globbeae was represented by two genera and five species—Gagnepainia (2 species) and Globba (3 species) (Fig. 2).
Table 1
Diversity, ecological data, phenological data, uses and conservation status of Zingiberaceae in Nam Nao National Park.

<table>
<thead>
<tr>
<th>Species (Collection number)</th>
<th>Vernacular name</th>
<th>Ecological data</th>
<th>Species status</th>
<th>Route</th>
<th>Phenology</th>
<th>Fruiting</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Tribe Alpinieae</strong></td>
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</tr>
<tr>
<td><em>Alpinia blepharocalyx</em> K. Schum. (Saensouk 600; MSU)*</td>
<td>Kha Kom</td>
<td>Dry evergreen forest</td>
<td>***</td>
<td>1</td>
<td>Mar–Apr</td>
<td>Jun–Jul</td>
<td>Young inflorescence as food</td>
</tr>
<tr>
<td><em>A. conchigera</em> Griff. (Saensouk 601; MSU)*</td>
<td>Kha Ling</td>
<td>Dry evergreen forest</td>
<td>1.2</td>
<td>Jun–Jul</td>
<td>Jul–Sep</td>
<td>Young pseudostem, young inflorescence, rhizome as food; rhizome as spice</td>
<td></td>
</tr>
<tr>
<td><strong>2. Tribe Globbeae</strong></td>
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<tr>
<td><em>Amomum koenigii</em> J.F. Gmel. (Saensouk 604; MSU)</td>
<td>Reo Poung A-Ngoo</td>
<td>Dry evergreen forest</td>
<td>*</td>
<td>1</td>
<td>Mar–Apr</td>
<td>Jun–Jul</td>
<td>Fruit as a medicinal plant</td>
</tr>
<tr>
<td><em>A. schmidtii</em> (K. Schum.) Gagnep. (Saensouk 605; MSU)*</td>
<td>Wan Sane Sao Long</td>
<td>Mixed deciduous forest + dry evergreen forest</td>
<td>*</td>
<td>1</td>
<td>Mar–Apr</td>
<td>Jun–Jul</td>
<td>All parts as powerful magic plant</td>
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<tr>
<td><strong>3. Tribe Zingibereae</strong></td>
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<tr>
<td><em>Boesenhergia collinsi</em></td>
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</tr>
<tr>
<td><em>B. maxwellii</em> J. Mood., L.M. Prince &amp; Triboun (Saensouk 615; MSU)*</td>
<td>Krajiew Daeng</td>
<td>Deciduous dipterocarp forest</td>
<td>**</td>
<td>2.5</td>
<td>Mar–Apr</td>
<td>Jun–Jul</td>
<td>Young inflorescence as food; rhizome as food; rhizome as spice</td>
</tr>
<tr>
<td><em>B. rotunda</em> (L.) Mansf. (Saensouk 616; MSU)*</td>
<td>Kha Jiew Kao</td>
<td>Deciduous dipterocarp forest</td>
<td>2.3</td>
<td>Jun–Jul</td>
<td>Jul–Sep</td>
<td>Young pseudostem, young inflorescence, rhizome as food; rhizome as spice</td>
<td></td>
</tr>
<tr>
<td><em>B. caerulea</em> var. <em>caerulea</em> (Wall. ex Baker) T.J. Wu &amp; S.J. Chen (Saensouk 606; MSU)*</td>
<td>Krajiew Lek</td>
<td>Deciduous dipterocarp forest</td>
<td>2.5</td>
<td>Jun–Jul</td>
<td>Jul–Sep</td>
<td>Young pseudostem, young inflorescence, rhizome as food; rhizome as spice</td>
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<tr>
<td><em>B. barbatum</em> var. <em>barbatum</em> (Wall. ex Baker) T.J. Wu &amp; S.J. Chen (Saensouk 607; MSU)*</td>
<td>Kha Mii Pha</td>
<td>Deciduous dipterocarp forest</td>
<td>2.3</td>
<td>Jun–Jul</td>
<td>Apr–Jun</td>
<td>Young inflorescence as food</td>
<td></td>
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<th>Phenology</th>
<th>Fruiting</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. thoreliei Gagnep. (Saensouk 627; MSU)</td>
<td>Krajew Bu</td>
<td>Deciduous dipterocarp forest + pine forest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ornamental plant</td>
</tr>
<tr>
<td>Kaempferia rotunda L. (Saensouk 627; MSU)</td>
<td>Wan How Non</td>
<td>Mixed deciduous forest</td>
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<td></td>
<td>Ornamental plant; rhizomes as medicinal plant</td>
</tr>
<tr>
<td>K. albomaculata (Saensouk 628; MSU)</td>
<td>Proa Pha</td>
<td>Mixed deciduous forest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ornamental plant; young leaves as a food</td>
</tr>
<tr>
<td>Stahlianthus involucratus (King ex Baker) Craib</td>
<td>Wan Pet Noi</td>
<td>Deciduous dipterocarp forest</td>
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<td></td>
<td></td>
<td></td>
<td>Ornamental plant; young leaves as a food</td>
</tr>
<tr>
<td>Zingiber chrysostachys R &amp; L. (Saensouk 630; MSU)</td>
<td>Khing Pha</td>
<td>Deciduous dipterocarp forest + pine forest</td>
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<td></td>
<td></td>
<td></td>
<td>Ornamental plant; young leaves as a food</td>
</tr>
<tr>
<td>Z. mekongense Gagnep. (Saensouk 631; MSU)</td>
<td>Khing Pha</td>
<td>Deciduous dipterocarp forest + pine forest</td>
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<td></td>
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<td>Ornamental plant; young leaves as a food</td>
</tr>
<tr>
<td>Z. montanum (J. König) Link ex A. Dietr. (Saensouk 632; MSU)</td>
<td>Plai</td>
<td>Deciduous dipterocarp forest + pine forest</td>
<td></td>
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<td></td>
<td></td>
<td>Ornamental plant; young leaves as a food</td>
</tr>
<tr>
<td>Z. pyroglassum Triboun &amp; K. Larsen (Saensouk 633; MSU)</td>
<td>Khing Pha</td>
<td>Deciduous dipterocarp forest + pine forest</td>
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<td></td>
<td></td>
<td></td>
<td>Ornamental plant; young leaves as a food</td>
</tr>
<tr>
<td>Z. rubens Rottl. (Saensouk 634; MSU)</td>
<td>Khing Pha</td>
<td>Deciduous dipterocarp forest + pine forest</td>
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<td></td>
<td>Ornamental plant; young leaves as a food</td>
</tr>
<tr>
<td>Z. zerumbet (L.) Smith (Saensouk 64; MSU)</td>
<td>E-Tua</td>
<td>Mixed deciduous forest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ornamental plant; young leaves as a food</td>
</tr>
</tbody>
</table>

1 MSU = Mahasarakham University Herbarium; 1* = least concern species, IUCN. 1** = Thailand Red Data: Plants. 1*** = Saensouk (2011). 1**** = new record for Thailand. 1***** = endemic to Thailand.
The ginger family in the Nam Nao National Park presented the highest flowering bloom during March to August and the highest fruiting bloom during June to September (Table 1).

### Flowering periods

Twelve species bloomed in the hot season (March—early May)—*A. blepharocalyx, A. malaccensis, A. koenigii, A. schmidtii, A. cf. comosa, and E. yunnanensis*. Three species were reported in mixed deciduous forest and dry evergreen forest. A total of 14 ginger species were found, including eight species found only in deciduous dipterocarp forest and eight species found only in mixed deciduous forest. The ginger family in the Nam Nao National Park presented the highest flowering bloom during March to August and the highest fruiting bloom during June to September (Table 1).

### Habitat

The habitats of the specimens are described in Table 1. Three species (C. alismatifolia, *C. thorelii* and *S. involucratus*) were found only in deciduous dipterocarp forest. Only *A. galanga* was found in both deciduous dipterocarp and mixed deciduous forest types. Mixed deciduous forest contained 14 ginger species (Table 1). The ginger family in the Nam Nao National Park presented the highest flowering bloom during March to August and the highest fruiting bloom during June to September (Table 1).

### Flowering periods

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Uses of Zingiberaceae in Nam Nao National Park

The Zingiberaceae in Nam Nao National Park were popular as food, as spices, in medicines and rituals and for ornamentation.


Fruiting periods

All species fruited in the rainy season.
Some species were used as spices—A. conchigera, A. galanga, C. longa and B. rotunda.

Nine species were identified for medicinal use—A. cf. villosum var. xanthioides, A. uliginosum, A. koenigii, C. aurantiiflora, C. longipetiolata, C. longa, C. cf. comosa, K. rotunda and S. involucratus. Only A. schmidtii was used in rituals.

Twelve species were used as ornamental plants—G. godefroyi, G. thoreliana, C. albiflora var. albiflora, G. laeta, G. cf. sherwoodiana, C. aurantiiflora, C. longipetiolata, C. alismatifolia, C. gracillima, C. parviflora, C. thorelii, K. rotunda and K. albomaculata.

Conservation status of Zingiberaceae in Nam Nao National Park

The conservation status of plants, based on the evaluation of the IUCN Red List (http://www.iucnredlist.org/search), indicated there were 7 species of least concern and presented in the IUCN Red List—A. koenigii, A. schmidtii, A. uliginosum, A. cf. villosum var. xanthioides, B. rotunda, C. alismatifolia and G. albiflora var. albiflora while two rare species—E. triloba and C. aurantiiflora—were reported in the Thailand Red Data: Plants (Santisuk et al., 2006). There were 6 rare Zingiberaceae species based on the evaluation criteria of Saensouk (2011)—A. blepharocalyx, C. aurantiiflora, C. longipetiolata, C. gracillima, G. godefroyi and G. thoreliana. Four species (C. aurantiiflora, C. longipetiolata, K. albomaculata and Z. sadakornii) were endemic to Thailand. E. yunnanensis (T. L. Wu & S. J. Chen) R. M. Smith, previously known from China (Yunnan), was a new record for Thailand.

New record for Thailand

Terrestrial herb 2.5–3 m (shoot 3.5 m when flattened). Leafy shoots loose clump, (2–5 shoots but mainly 4), 13–25 cm apart.
Rhizome 1.5 cm diameter; scales to 4.5 cm, reddish when young. Leafy shoot with 17–27 leaves. Base of leafy shoot reddish. Sheath green, tinged purple in upper part. Ligule 12–15 mm. Petiole to 5 mm. Lamina to 54 × 13 cm, narrowly ovate, dull green, slightly plicate, pubescent below, young leaf tinged purple beneath; base rounded; apex asymmetrical. The cut base smells of aniseed, like *Etlingera foetens*. Old inflorescence 14–18 cm. Inflorescence are head borne on surface of ground. Peduncle embedded in ground, short; bracts red, ovate, 2.5–3 × 2–3 cm; bracteoles tubular, circa 2.7 cm × 7 mm. Flowers numerous, six opening together in a circle, red. Calyx 3.5–4 cm, apex 3-toothed. Corolla shorter than calyx. Labellum exerted from corolla, purple at center, yellow at margin, free part 2.5–3 cm, apex 2-cleft. Free part of filament circa 5 mm; anther 6–8 mm. Ovary circa 5 mm, pubescent. Style flat. Infructescence 8 × 11 cm with 28 fruits, capsule turbinate, 3.5 × 3.5 cm, 2.5–3 cm, densely pubescent. Bracts persistent purple (Fig. 2).

**Discussion**

Three tribes, 12 genera and 38 species of the ginger family (Zingiberaceae) from five routes in Nam Nao National Park were studied for their diversity, ecological status, phenological data, uses and species status. Routes 1, 3 and 2 had the highest species diversity, respectively. The tribe Zingibereae had the highest diversity of species with 6 genera and 21 reported species. The tribe Alpinieae was composed of 4 genera and 10 species. The tribe Globoseae was the smallest tribe with 2 genera and 5 species. Many characteristics of the Zingiberaceae were usable for identification, such as rhizomes, pseudostem, inflorescence and the structure of flowers and were used to develop keys to the species, genera and tribe. Species of the Zingiberaceae were found in four forest-types—deciduous dipterocarp forest, mixed deciduous forest, dry evergreen forest and pine forest. The ginger family in the Nam Nao National Park mostly presented flowering bloom during March to August and most fruiting bloom was during June to September. The Zingiberaceae in Nam Nao National Park are popular for traditional uses as food, spices and medicines and in rituals and for ornamentation. Eight rare species were evaluated as being of least concern based on the IUCN Red List (http://www.iucnredlist.org/search), while two rare species were reported in the Thailand Red Data: Plants (Santisuk et al., 2006). Moreover, six rare Zingiberaceae species were based on the evaluation criteria of Saensouk (2011). Four species—*C. aurantiiflora*, *C. longipetioloata*, *K. albomaclata* and *Z. sadakornii*—were endemic to Thailand. *E. yunnanensis*
(T. L. Wu & S. J. Chen) R. M. Smith was a new record for Thailand. Several Zingiberaceae species may be used as ornamentals because of their aesthetic value (Fig. 2 and Table 1).

Acknowledgements

This research was financially supported by Mahasarakham University, Thailand. The authors thank staff at the Nam Nao National Park, the Applied Taxonomic Research Center, Research Center for Mekong Regional Tourism (ReCMerT) Khon Kaen University, and the Walai Rukhavej Botanical Research Institute, Mahasarakham University for allowing use of their facilities during the study. We are deeply indebted Dr. A.D. Poulsen for determining the correct species names. Warm thanks are also recorded to the curators and staff of the herbaria visited (BK, BKF, KKU and QSBG) as well as thanks to Dr. Jolyon Dodgson for language editing and suggestions to improve an earlier version of the manuscript.

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