Agriculture and Natural Resources 52 (2018) 125–131

Contents lists available at ScienceDirect

Agriculture and Natural Resources

journal homepage: http://www.journals.elsevier.com/agriculture-and-natural-resources/

Original Article

Diversity and distribution of family Araceae in Doi Inthanon National Park, Chiang Mai province

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ARTICLE INFO

Article history:
Received 28 November 2016
Accepted 18 December 2017
Available online 17 July 2018

Keywords:
Altitudinal gradient
Araceae
Doi Inthanon National Park
Ecological niche
Species distribution

ABSTRACT

Species of the family Araceae are known for their ethnobotanical utilization; however their species diversity is less documented. This study aimed to clarify the relationships between species diversity of the Araceae and altitudinal gradients in the mountain ecosystems in Doi Inthanon National Park, Chiang Mai province, northern Thailand. In 2014, tree permanent plots (4 m × 4 m) including one strip plot (5 m × 500 m) were established every 300 m above mean sea level (amsl) in the range 300–2565 m amsl. All species of Araceae were investigated and environmental factors were also recorded. The results showed that 23 species were mostly found in the rainy season and identified into 11 genera: *Alocasia*, *Amorphophallus*, *Arisaema*, *Colocasia*, *Lasia*, *Pothos*, *Rhaphidophora*, *Remusatia*, *Sauromatum*, *Scindapsus*, and *Typhonium*. The top five dominant species were *Arisaema consanguineum*, *Amorphophallus fuscus*, *Remusatia hookeriana*, *Amorphophallus yunnanensis* and *Colocasia esculenta*. Low species diversity was found at the lowest and highest altitude. A generalized linear model was used to detect specific environmental factors; only five species were determined using soil pH, a percentage of sand, the quantity of organic matter, a percentage of clay, light intensity, elevation and a percentage of silt, respectively. The results indicated that high species diversity of the Araceae was supported by the wide range of ecological niches. However, anthropogenic factors formed the main threats to decreased biodiversity. Thus, to maintain high biodiversity, not only the niches but also the threats should be of concern.

Introduction

Mountain ecosystems provide important services to people and are the habitats of many organism species; however, they are fragile areas and vulnerable, facing many threats from natural disasters, deforestation, shifting agriculture, infrastructure development and climate change (European Environment Agency, 2010). The Convention on Biological Diversity adopted a program of work on mountain biodiversity by having a set of actions addressing characteristics and problems specific to mountain ecosystems for conserving and maintaining biodiversity, genetic diversity and goods and services (CBD Secretariat, 2010). The most important character of tropical mountain ecosystems is the altitudinal factor which could affect climatic factors, particularly temperature (Aigang et al., 2009). Many plant species at high altitude are capable of surviving as a result of a hardening process (Beniston, 2003). Many researchers have found significant differences regarding the distribution of species based on an altitudinal gradient (Lomolino, 2001; Tunjai et al., 2003; Lai et al., 2009; Kurmen, 2010; Zhang et al., 2013).

In Thailand, the Araceae or the Arum family or Aroids is represented in the database of the Royal Botanic Gardens, Kew (2015) by 28 genera and 190 species in 6 subfamilies of native Araceae. Twenty-six genera and 209 species are published in the Flora of Thailand, with more than 60 species found in northern Thailand (Boyce et al., 2012). Araceae abundance is dependent on available water and atmospheric humidity. In the humid tropics, the Araceae are most diverse and have many variety of life forms as hemi-epiphytes, epiphytes, geophytes, rheophytes, submerged or periodically submerged aquatics, helophytes and free floating aquatics, with flowering and fruiting varying by species and pollination and dispersal facilitated by wind, water, insects, animals and humans (Mayo et al., 1997). Many species of this family are utilized for cooking native dishes, medicinal use and as ornamental plants

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https://doi.org/10.1016/j.anres.2018.06.009

(Mayo et al., 1997; Sukumolnondha, 2005; Boyce, 2008). Such human-based activity is one of the factors threatening Araceae extinction, while habitat loss is another serious threat (CBD Secretariat, 2010).

Doi Inthanon in northern Thailand (Fig. 1) represents a unique habitat for species diversity and bioresources (Santisuk, 2007). Many studies have identified endemic species and vulnerable species existing at high altitude in this the most famous protected area in northern Thailand (Khamyong et al., 2003; Teejuntuk et al., 2003; Tunjai et al., 2003; Santisuk, 2007). The summit of Doi Inthanon is the highest point in Thailand, at an elevation of 2565 m above mean sea level (m amsl). The mountain ranges in this area are a part of the Himalayan range, humidity is very high in the rainy season and there is a high temperature variation ranging from below 0 °C up to 40 °C in the winter and the dry season, respectively (Department of National Parks, Wildlife and Plant Conservation, 2012). The relationships of temperature and soil properties change significantly with elevation and the lapse rate of the air temperature is 0.69 °C per 100 m amsl (Sahunalu, 2010). Many researchers have reported high species diversity (Sungpalee, 2002; Teejuntuk et al., 2003; Boonrodklab, 2007; Biological Diversity Division, 2009) however, there is less documented information regarding the Araceae.

This study aimed to clarify species diversity, and the importance of environmental factors regarding the Araceae distribution in Doi Inthanon National Park. The results should be useful in the development of a sustainable management plan.

Materials and methods

Data collection

The study was conducted in Doi Inthanon National Park, Chiang Mai province (18°24′N to18°40′N and 98°24′Eto 98°42′E) during January 2014–December 2014. The Araceae diversity and distribution were studied over seven zones, based on altitudinal gradients divided into intervals of 300 m amsl –2565 m amsl (Fig. 1). Species diversity of the Araceae was investigated using purposive permanent sampling plots where Araceae species existed and temporary strip plots. Three permanent plots (4 m × 4 m), resulting in 21 plots, including one temporary strip plot (5 m × 500 m) were established in every zone. Monitoring was undertaken monthly in the permanent plots and all Araceae species were identified and their growth measured and individual numbers were recorded.

The physical factors (elevation, soil properties and the slope of each plot) were determined and recorded. Soil samples (depth 0–20 cm) were collected from five positions in each permanent plot (in each of four corners and at the center of each plot). Soil samples were composited into one sample for analysis of soil properties, soil pH, soil texture (percentage of sand, silt and clay) and the amount of organic matter, which was carried out in soil laboratory of the Department of Soil Science, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand. In addition, the soil moisture content and light intensity were also recorded. The soil moisture content was measured using a 3-in-1 soil moisture meter (model pH 01; Shenzhen Huangshi Junwei Aluminum Kitchenware Co., Ltd., Shenzhen, Guang Dong, China) and light intensity was measured using a digital lux meter (Nicety model LM801; Starmeter Instruments Co., Ltd., Shenzhen, Guang Dong, China). The phenology of Araceae specimens was recorded, especially the morphology and period of flowering and fruiting of individual number in each species.

Data analysis

The importance value index (IVI%) was used to evaluate the dominant species in the area and was calculated as the sum of the relative density and relative frequency (Whittaker, 1975). A species with a higher IVI% value has greater dominance of the site (Parotta et al., 1997). In addition, species diversity of the Araceae in each zone was analyzed based on the Shannon-Wiener index (Shannon and Weaver, 1949).

To detect the determined physical environmental factors on Araceae distribution, a generalized linear model (GLM) was applied

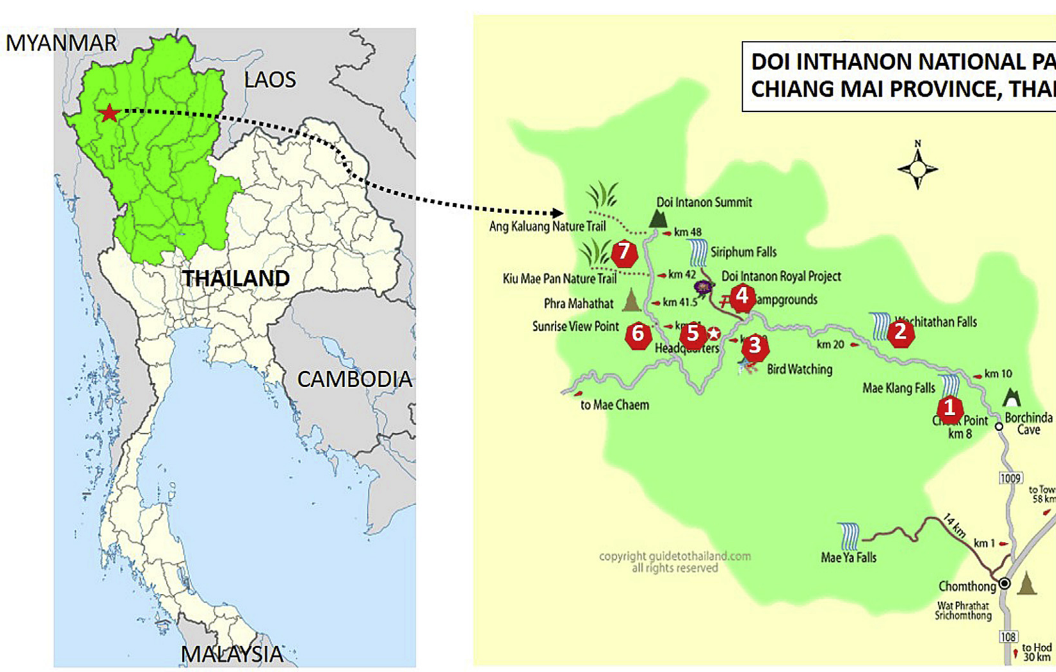

Fig. 1. Seven zones (1–7) in this study in Doi Inthanon National Park in Chiang Mai province, northern Thailand Wikimedia Commons (2016); Guide to Thailand.com (2017).

using stepwise regression analysis of Araceae species density using software the R version 3.1.3 software package (R Core Development Team., 2014). All Araceae species with sufficient density for statistical analyses (n ≥ 30 individuals) were used based on the seven altitudinal zones (each zone included three subplots, 4 × 4 m). The independent physical factors (altitudinal, light intensity, soil texture, soil pH and organic matter) were analyzed and the model with the lowest Akaike's information criterion (AIC) was selected for each species (Ing et al., 2012).

Results and discussion

Diversity of Araceae

In total, 23 species in 11 genera were identified (Table 1 and Fig. 2) and could be classified into two groups based on whether they were deciduous or evergreen (Mayo et al., 1997). There were 13 deciduous species having a dormancy stage in winter and summer: *Amorphophallus fuscus* Hett., *Amorphophallus macrorhizus* Craib, *Amorphophallus thaiensis* (S.Y.Hu) Hett., *Amorphophallus yunnanensis* Engl., *Arisaema consanguineum* Schott, *Arisaema yunnanense* var. *yunnanense* Buchet, *Colocasia fallax* Schott, *Remusatia hookeriana* Schott, *Remusatia* sp., *Sauromatum hirsutum* (S.Y.Hu) Cusimano & Hett., *Sauromatum horsfieldii* Miq., *Sauromatum* sp. and *Typhonium roxburghii* Schott.

The other 10 species were evergreens: *Alocasia acuminata* Schott, *Alocasia navicularis* (K.Koch & C.D.Bouché) K.Koch & C.D.Bouché., *Arisaema omkoiense* Gusman, *Colocasia esculenta* (L.) Schott, *Lasia spinosa* (L.) Thwaites, *Pothos scandens* L., *Rhaphidophora decursiva* (Roxb.) Schott, *Rhaphidophora megaphylla* H.Li., *Rhaphidophora peepla* (Roxb.) Schott and *Scindapsus officinalis* (Roxb.) Schott (Table 1 and Fig. 2). However, Boyce et al. (2012) reported in the Flora of Thailand that *Alocasia acuminata* and *Scindapsus officinalis* were evergreen, but in this study, these two species were dormant in the dry season. The latter seven species had lower growth in the dry season than in the rainy season; however, contrasting patterns were found, such as for *Arisaema omkoiense* where growth was influenced by threats from insects and rot diseases. High elevation had a direct effect on the distribution of epiphytic and/or lithophyte species and at 2101–2565 m asl; *Rhaphidophora* (an evergreen genus) could not be found.

The dominant species of the Araceae based on the IVI% in September 2014, the rainy season (Table 1) were *Arisaema consanguineum* (33.31%), *Amorphophallus fuscus* (29.87%), *Remusatia hookeriana* (20.68%), *Amorphophallus yunnanensis* (19.79%) and *Colocasia esculenta* (18.60%). These species were geophytic and deciduous with a dormancy period during the dry season, except for *Colocasia esculenta* which grew all year.

The other species were epiphytic, lithophytic or helophytic and were evergreen and less abundant. Two species of helophyte (*Colocasia esculenta* and *Lasia spinosa*) were distributed along a river margin at 300–600 m amsl. As either an epiphyte or geophyte in this study, *Remusatia hookeriana* was found at 1501–2565 m amsl, climbing on the trunk of *Betula alnoides* Ham. and in decaying leaves or sandy soil under the shade of trees. *Pothos scandens*, an epiphyte, grew from the soil and was on the trunk of *Castanopsis* sp. in the Fagaceae. Four species of epiphyte or lithophyte or both were recorded: *Rhaphidophora megaphylla* on *Xylia xylocarpa* (Roxb.) Taub, but *Scindapsus officinalis* was on *Dalbergia oliveri* Gamble ex Prain and on sandstone along a waterfall at 601–900 m amsl, *Rhaphidophora decursiva* was on a bamboo culm and on limestone along the cliff of the waterfall at 901–1200 m amsl, *Rhaphidophora peepla* was on sandstone and the trunk of *Castanopsis* sp. in the Fagaceae at 1501–1800 m amsl and on the trunk of *Betula alnoides* Ham. at 1801–2100 m amsl.

Some Araceae species (*Arisaema consanguineum*, *Pothos scandens*, *Rhaphidophora decursiva*, *Rhaphidophora megaphylla*, *Rhaphidophora peepla* and *Scindapsus officinalis*) are widely distributed ranged from the tropical eastern Himalaya (Assam) through northern Burma (Boyce, 2009), while 11 species (*Amorphophallus yunnanensis*, *Arisaema yunnanense*, *Colocasia esculenta*, *Lasia spinosa*, *Pothos scandens*, *Remusatia hookeriana*, *Rhaphidophora decursiva*, *Rhaphidophora megaphylla*, *Rhaphidophora peepla*, *Sauromatum hirsutum* and *Sauromatum horsfieldii*) are reported in the Flora of China (Li et al., 2010).

Table 1
Importance value index (IVI) of 23 species in Doi Inthanon National Park in September 2014.

Species	Elevation (m above mean sea level)	Life form	Habit	RD (%)	RF (%)	IVI (%)
1. *Alocasia acuminata*	601–1500	Geo	E	0.64	1.69	2.33
2. *Alocasia navicularis*	1201–1500	Geo	E	0.07	0.48	0.55
3. *Amorphophallus fuscus*	901–1500	Geo	D	16.58	13.29	29.87
4. *Amorphophallus macrorhizus*	300–1500	Geo	D	0.13	0.97	1.10
5. *Amorphophallus thaiensis*	601–1500	Geo	D	4.50	12.08	16.58
6. *Amorphophallus yunnanensis*	601–1500	Geo	D	8.68	11.11	19.79
7. *Arisaema consanguineum*	901–2565	Geo	D	17.85	15.46	33.31
8. *Arisaema omkoiense*	1501–1800	Geo	E	7.84	5.80	13.64
9. *Arisaema yunnannese* var. *yunnannese*	1501–1800	Geo	D	0.27	0.48	0.75
10. *Colocasia esculenta*	300–1500	Helo	E	7.01	11.59	18.60
11. *Colocasia fallax*	901–1200	Helo/Litho	D	9.20	0.97	10.17
12. *Lasia spinosa*	300–600	Helo	E	1.38	0.48	1.86
13. *Pothos scandens*	1501–1800	Epi	E	1.48	4.11	5.59
14. *Remusatia hookeriana*	1501–2565	Geo/Epi	D	13.68	7.00	20.68
15. *Remusatia* sp.	901–1200	Litho	D	0.38	0.24	0.62
16. *Rhaphidophora decursiva*	901–1200	Epi/Litho	E	1.04	0.48	1.52
17. *Rhaphidophora megaphylla*	601–900	Epi/Litho	E	2.05	2.17	4.22
18. *Rhaphidophora peepla*	1201–2100	Epi/Litho	E	3.68	7.73	11.41
19. *Sauromatum hirsutum*	901–1500	Geo	D	0.68	0.97	1.65
20. *Sauromatum horsfieldii*	1201–1500	Geo	D	0.39	1.21	1.60
21. *Sauromatum* sp.	1201–1500	Geo	D	0.34	0.48	0.82
22. *Scindapsus officinalis*	601–900	Epi/Litho	E	1.38	0.72	2.10
23. *Typhonium roxburghii*	300–600	Geo	D	0.75	0.48	1.23
		Total		100	100	200

(RD = relative density, RF = relative frequency, E = evergreen, D = deciduous, Geo = geophyte, Helo = helophyte, Epi = epiphyte, Litho = lithophyte).

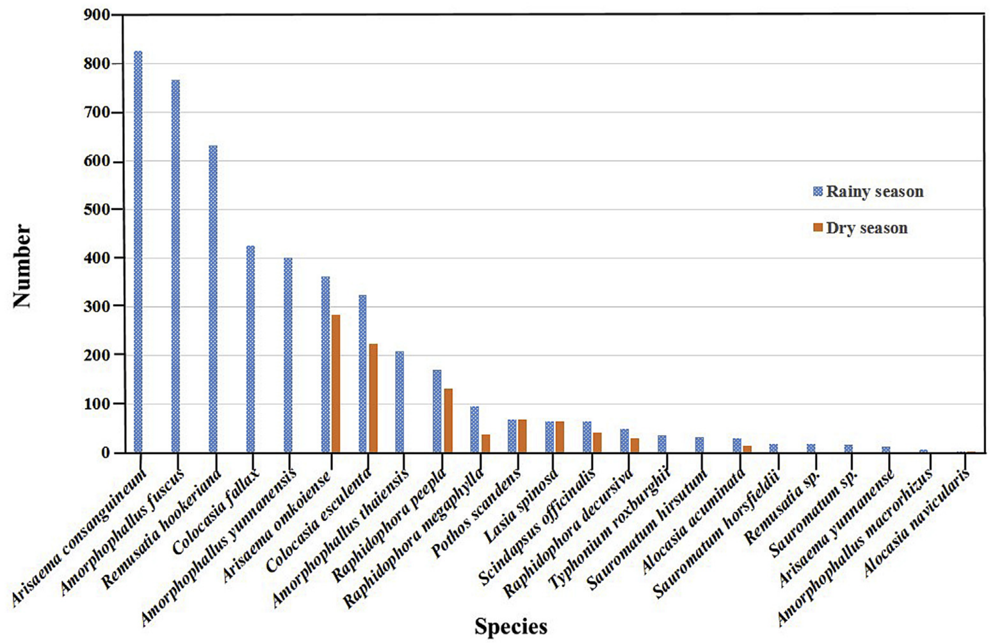

Fig. 2. Number of individuals by season for the 23 Araceae species.

Variation in species and individual numbers among seasons was detected ($p < 0.01$ and $p < 0.05$, respectively) with increases in the rainy season compared to the dry season (Fig. 3). The species diversity based on the Shannon-Wiener index was also significantly ($p < 0.01$) different between seasons with the growing season of most Araceae species being in the rainy season (from May to October), when a higher soil moisture content was detected than in the dry season (1.80–3.76% versus, 1.24–1.89%, respectively), and many species were dormant in the dry season (from December to April). In contrast, *Arisaema omkoiense* rapidly decreased in number in the rainy season due to disease damage.

The number of Araceae species tended to increase with elevation up to 1500 m amsl above which there was a decrease (Table 1 and Fig. 4). Some Araceae species were found at specific elevations, for example, only two species (*Lasia spinosa* and *Typhonium roxburghii*) were found along a stream at 300–600 m amsl. Similarly, only two species (*Arisaema consanguineum* and *Remusatia hookeriana*) were found in the highest elevation category (above 2100 m amsl). Other species could be found at intermediate elevations (601–2100 m amsl) indicating their distribution may have been dependent on different niches as for other plants (Teejuntuk et al., 2003).

Anthropogenic activity was the main threat to Araceae loss; for example as a result of non-timber forest product harvesting, trampling by tourists and weeding practices, especially along the nature trails. In addition, natural disturbance, drought, and forest fire also destroyed some Araceae species, especially in the dry season and also during flash flooding in the rainy season. Plant

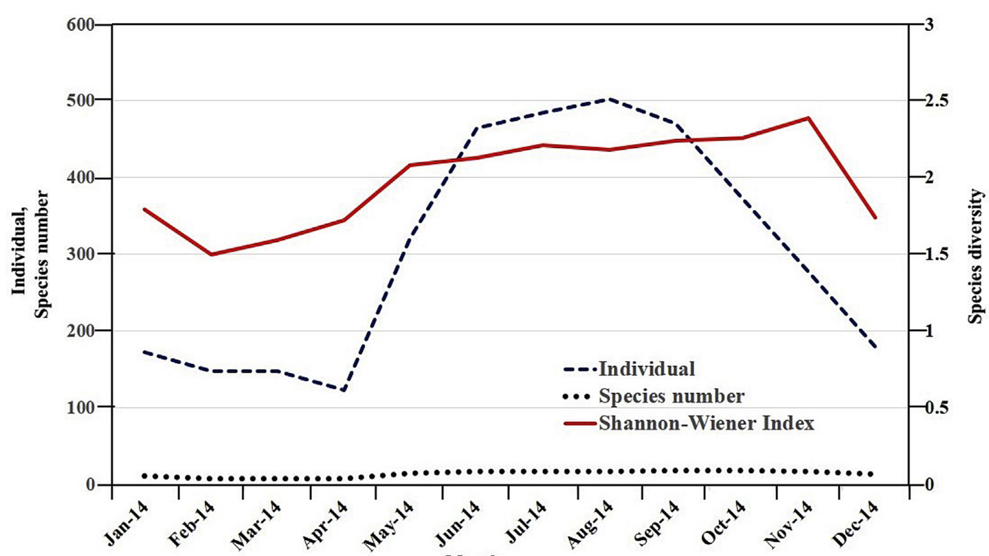

Fig. 3. Diversity of Araceae based on Shannon-Wiener Index at Doi Inthanon National Park January–December 2014.

Fig. 4. Araceae species abundance along the altitudinal gradient, 300 to 2565 m above mean sea level in Doi Inthanon National Park. Leaf shapes number 1–23 ascending order to 23 species in Table 1.

diseases and insects damaged aerial stems, underground stems, leaves, petioles, inflorescence, fruit, and seed (Padmavathi et al., 2013; Sungkajanttranon et al., 2013).

Physical factors determining Araceae distribution

The results of the GLM analysis showed that the distribution of Araceae species was determined by various physical factors (Table 2) and varied among species. However, the modeling was only successful for five Araceae species (Table 3). The physical factors of soil pH, a percentage of clay, light intensity and elevation were negatively correlated with Araceae distribution, only *Remusatia hookeriana* had a positive correlation. This species was mostly distributed at higher elevations (1501–2565 m amsl). In contrast, organic matter and percentage of sand were significantly positively correlated with species distribution, indicating soil properties were the most important factors in determining suitable sites for these Araceae species in Doi Inthanon National Park (Table 3).

Percentage of sand, silt, and clay, soil pH, organic matter (OM) were highly significantly different among the soil properties in the zones (Table 3). Soil pH can be classified into two groups (neutral and acid), where the soil pH tended to decrease with increased elevation. In contrast, OM tended to increase with elevation.

Soil properties, particularly soil texture and soil nutrient, have been reported as important factors and highly correlated with forest types (Sahunalu et al., 2001; Sungpalee, 2002; Santisuk, 2007; Marod and Kudintara, 2009; Marod et al., 2014). In addition, light intensity also differed by forest type (Thery, 2001) with high light intensity reported in deciduous forests compared with evergreen forests (Marod et al., 2004). This result supported the high species diversity of Araceae, as 15 species were found at 901–1500 m amsl, where the soil was sandy and had a high OM content (Table 2 and Fig. 4).

In Nepal, Peru and Iran, altitudinal gradients were reported to be an important factor determining the distribution of many plant families (Vetaas and Grytnes, 2002; Werff and Consiglio, 2004; Heydari and Mahdavi, 2009, respectively).

Various environmental factors in Doi Inthanon National Park provide good opportunities for Araceae diversity, with 23 identified species of Araceae and high species diversity compared to other sites. Fifteen species from 10 genera from Chaleamrattanakosin National Park (Sungkajanttranon et al., 2010) and 13 species from 8 genera from Saiyok National Park (Napiroon et al., 2013), Kanchanaburi province have been reported. In the Sului Mountain and Uluisimbone Forest, South-East Sulawesi, 24 species from 14 genera; were recorded (Nugroho and Santika, 2008). There was only one species in common with Doi Inthanon (*Typhonium roxberghii*). In Brazil, 18 genera were reported in a semi-arid region of Ceará (Andrade et al., 2013) and none of the species in the 28 taxa were found in Doi Inthanon. These results showed that reported

Table 2
Soil properties in each study zone.

Zone	Elevation (m above mean sea level)	Soil texture (%)			Soil pH	Organic Matter (g/kg)
		Sand	Silt	Clay		
1	300–600	90.6^{a}	3.5^{c}	5.9^{b}	6.6^{a}	13.9^{c}
2	601–900	66.8^{bc}	14.7^{a}	15.2^{ab}	6.5^{a}	90.7^{b}
3	901–1200	65.1^{bc}	14.0^{ab}	14.3^{ab}	5.7^{b}	157.7^{a}
4	1201–1500	67.6^{bc}	12.7^{ab}	13.1^{ab}	5.7^{b}	118.1^{ab}
5	1501–1800	70.^{bc}	10.4^{abc}	19.3^{a}	5.3^{b}	124.7^{ab}
6	1801–2100	74.7^{b}	9.1^{bc}	16.1^{ab}	5.6^{b}	141.8^{ab}
7	2101–2565	57.7^{c}	7.4^{bc}	11.6^{ab}	5.7^{b}	151.5^{ab}
	F-test	**	**	**	**	**
	Mean	70.4	10.2	13.6	5.9	114.0

Mean in the same column followed by a common lowercase superscript letter are not significantly different at $p < 0.01$ and the 0.05 level using Duncan's new multiple range test.
$^{*} = p < 0.05$, $^{**} = p < 0.01$.

Table 3
Results of GLM analysis of selected physical factors, elevation (Elev), light intensity (lux), soil pH, organic matter (OM), percentage of sand, silt and clay for Araceae species distribution in Doi Inthanon National Park. Only significant factors with lowest Akaike's information criterion are shown.

Species	Elev (m above sea level)	Light (lux)	Soil pH	OM (g/kg)	Sand (%)	Silt (%)	Clay (%)
1. *Amorphophallus fuscus*	−0.0056**	−0.0022***	−7.3129***	0.0502***	0.3286***		−1.0638***
2. *Amorphophallus yunnanensis*	−0.0058***		−2.0802**	0.0166*		0.1479**	−0.2327***
3. *Arisaema consanguineum*		−0.0013**	−1.8478*	0.0385***	0.2620***		−0.4833**
4. *Remusatia hookeriana*	0.0284***	−0.0067***			0.4617***		
5. *Rhaphidophora peepla*			−7.3442**		0.5498**	−0.4029**	

$^{*} = p < 0.05$, $^{**} = p < 0.01$, $^{***} = p < 0.001$.

research and the geography were very important and were correlated to the diversity, and distribution of Araceae species in each region. Species abundance, diversity and distribution were highly correlated with soil properties followed by altitudinal gradient and light intensity.

Although Araceae species are still widely distributed in Doi Inthanon National Park, they are threatened by anthropogenic factors, diseases and natural disasters that can destroy species diversity. Some species may be lost from habitats. High temperature and drought in summer could advance the timing for flowering and leaf production which in turn may affect plant distribution which may vary with ecological and evolutionary ecosystem productivity, species interaction, community structure phenomena and conservation of biodiversity (Bertin, 2008). Scaling between species is a response to recent climate changes and a shift in ecosystem productivity and the global carbon cycle (Cleland et al., 2007). Thus, sustainable management, particular watershed and forest management, in Doi Inthanon National Park is urgently required to conserve vegetation cover, species diversity, and productivity in this mountain ecosystem for mitigation and adaptation under global climate change.

Conflict of interest

None declared.

Acknowledgements

The authors thank the Center for Advanced Studies in Tropical Natural Resources under the Program of National Research Universities, Kasetsart University, Bangkok, Thailand for research funding and approval of the thesis proposal and also thank the research team from Doi Inthanon National Park and the Faculty of Forestry, the Faculty of Agriculture and the Faculty of Liberal Arts and Science, all from Kasetsart University. Finally, the ANRES reviewers provided valuable suggestions that contributed to the final research publication.

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