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Geographic Distributions and Ecology of Ornamental *Curcuma* (Zingiberaceae) in Northeastern Thailand

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Abstract: The genus *Curcuma* is a very important economic plant. Members of this genus were used as food, medicine and ornament plants. The objectives of this study were to examine the geographic distributions and ecological conditions in the natural habitats of *Curcuma* in Northeastern Thailand. Species diversity was examined using the line transect method. Ecological conditions of the species were examined using a sampling plot of 20×20 m. A total of five species were found including *Curcuma angustifolia* Roxb., *C. alismatifolia* Gagnep., *C. gracillima* Gagnep., *C. parviflora* Wall. and *C. rhabdota*. These species were in an altitudinal range between 290 m and 831 m above sea level. Four species (*C. angustifolia*, *C. alismatifolia*, *C. gracillima* and *C. rhabdota*) were distributed in open gaps in dry dipterocarp forest. One species, *C. parviflora* was found in the contact zone between dry dipterocarp and bamboo (*Gigantochloa* sp.) forest. *C. rhabdota* was found only in a habitat with high humidity and shading along the Thailand-Lao PDR border. Significant ecological conditions of the natural habitats of these *Curcuma* species were identified. Altitude is the most important factor when determining the geographic distributions of these *Curcuma* species in Northeastern Thailand.

Key words: *Curcuma*, ecology, zingiberaceae, Thailand, geographic distribution

INTRODUCTION

The genus *Curcuma* L. belongs to the family Zingiberaceae (Ridley, 1924). Members of this genus are found in South and Southeast Asia. Some species are also found in China, Australia and the South Pacific (Apavatjrut *et al*., 1999; Leong-Skornickova *et al*., 2008). The genus *Curcuma* is geographically wide spread in all regions of Thailand, but it is mostly found in the North and Northeastern regions. The number of species of *Curcuma* reported in Thailand varies between 50 and 100 species (Smith, 1981; Larsen *et al*., 1998; Sirirugsa, 1996).

Many species of *Curcuma* have been used as food, medicine and decorative plants (Schumann, 1904; Leong-Skornickova *et al*., 2008). Some species have beautiful colors and compound spikes with prominent bracts. The inflorescence has different colors, sizes and shapes. The general colors are yellow, orange, red, pink and white. *Curcuma* species grown for trading have been gathered and developed from wild species and cross breed to respond to the market that demands different plants, beautiful flowers and longer life. In addition to its beauty, these plants also contains essential oils that are used as a traditional medicine to cure skin disease, rashes, sores and sprains; it also reduces wound inflammation, eliminates gas in intestines and treats dyspepsia (Purseglove, 1974; Heywood, 1985; Majeed *et al*., 1995; Apavatjrut *et al*., 1999; Mahadtanapuk *et al*., 2006). The rhizome can be used as cloth dye, food dye, a food ingredient and as a spice to give a hot taste (Bhowmik *et al*., 2009).

According to Thai export statistics, ornamental *Curcuma* (e.g. *C. alismatifolia*) was ranked seconded to orchids (Del Pilar Paz *et al*., 2007). As a result, several species of *Curcuma* have been collected from their natural habitat and then used for variety improvement (e.g., *C. gracilima* Gagnep. (*C. thorelii* synonym), *C. parviflora* Wall., *C. roscoeana* Wall. and *C. harmandii* Gagnep.). Due to the high demand for *Curcuma* spp. it is important to consider the maintenance of the species in their natural habitats and for future research and development use. The objective of this study was to determine the geographic distributions and ecological conditions of the microhabitats of ornamental *Curcuma*

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species in Northeastern Thailand. The results of this study will be useful for conservation and selective breeding of these important plants.

MATERIALS AND METHODS

Study area: The study areas were selected in four National Parks (NP) in the Northeastern region of Thailand where *C. alismatifolia* and other ornamental *Curcuma* species are found, including, (1) Phu Phan NP, Sakon Nakhon Province, (2) Kaeng Tana NP, Ubon Ratchathani Province, (3) Sai Thong NP and (4) Pa Hin Ngam NP, Chaiyaphum Province (Fig. 1).

Phu Phan NP has a total area of 664.71 km^2. The topography of this site is composed of high mountains, sloping land with small steep mountains spreading in clusters. There are three types of forest: dry dipterocarp forest covered about 41.58% dry evergreen forest covered about 22.16% and mixed deciduous forest covered about 17.49% of the total area (Bunnag *et al*., 1999).

Kaeng Tana NP has a total area of 80 km^2. General topography is plateau and low mountains, while the Mun and Khong rivers passed through. The average elevation was 200 m above sea level. The forest types found in this area are dry evergreen forest covering approximately 8.35% and dry dipterocarp forest covering approximately 84% of the total area (BDP, 2004).

Sai Thong NP has a total area of 319 km^2. The typography is a mixture of high and low mountains that are at altitudes from 300 m to 1,000 m above sea level. The forest types are classified into three categories i.e., dry evergreen forest, dry dipterocarp forest and mixed deciduous forest (BDP, 2004).

Pa Hin Ngam NP has a total area of 99.9 km^2. The topography includes a mountain range consisting of several mountains with altitudes ranging between 200 m and 800 m above sea level. The forest types are dry dipterocarp forest and mixed deciduous forest (Sudee, 1994).

Sample collection and identification: Samples were collected from four national parks in Northeastern Thailand (Table 1, Fig. 1) using line transect and sampling plot methods during June to October 2011. Species were identified using the keys and descriptions of *Curcuma* from Wu and Larsen (2000) and Maknoi (2006). Geographic positions of the species were recorded using a GRAMIN GPS 60 model (Table 1). Environmental conditions at the sampling location were measured from a sampling plot (20×20 m^2). Soil density (kg m^{-3}) was measured by Eijkel kamp P.O. Agrisearch equipment box 6987 ZG and was pH measured by Soil pH Moisture Tester.

Data analysis: One-way analysis of variance (One-way ANOVA) was used to test the differentiation of the soil density, pH and altitude between species. Principal Components Analysis (PCA) was used to group the habitats of *Curcuma* species according to similarities in environmental conditions.

RESULTS AND DISCUSSION

Species diversity and geographic distributions: Five species (*C. angustifolia* Roxb., *C. alismatifolia* Gagnep., *C. gracillima* Gagnep., *C. parviflora* Wall. and C rhabdota (Sirirugsa and M. Newman, 2000) of the ornamental *Curcuma* were found in the four

Table 1: Study areas in four national parks in Northeastern Thailand and list of species based on the line transect method

			Location	
Study sites (Code)	Species list	Altitude (m)		
Kaeng Tana National Park, Ubon Ratchathani Province (KT)	*C. angustifolia*	158	N 15° 17.847′	E 105° 29.176′
	C. gracillima	137	N 15° 17.769′	E 105° 29.240′
	C. rhabdota	121	N 15° 17.804′	E 105° 29.095′
Pa Hin Ngam National Park, Chaiyaphum Province (PH)	*C. angustifolia*	792	N 15° 38.660′	E 101° 23.167′
	C. alismatifolia	814	N 15° 39.096′	E 101° 23.287′
	C. gracillima	801	N 15° 39.076′	E 101° 23.346′
Si Thong National Park, Chaiyaphum Province (ST)	*C. angustifolia*	821	N 15° 53.506′	E 101° 27.502′
	C. alismatifolia	831	N 15° 53.319′	E 101° 27.291′
	C. gracillima	804	N 15° 52.934′	E 101° 27.298′
	C. parviflora			
Phu Phan National Park, Sakon Nakhon Province (PP)	*C. angustifolia*	302	N 17° 03.587′	E 103° 58.252′
	C. alismatifolia	290	N 17° 03.420′	E 103° 58.002′
	C. gracillima	289	N 17° 03.343′	E 103° 57.961′
	C. parviflora			

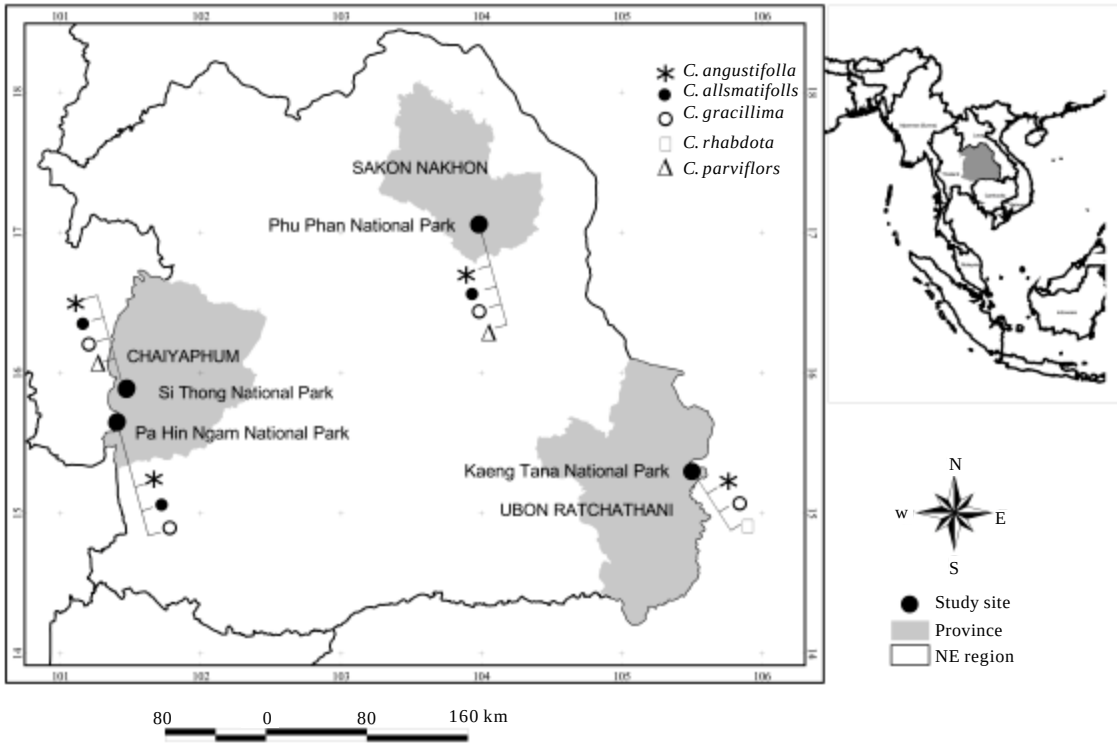

Fig. 1: Approximate locations of the study areas in four national parks in Northeastern Thailand and (inset) map of Thailand showing the area of the Northeastern Region (shaded)

Fig. 2(a-h): Ornamental *Curcuma* species found in this study (a and b) *Curcuma alismatifolia* (c and d), *Curcuma parviflora* (e and f), *Curcuma gracillima*, (g), *Curcuma angustifolia* (h), *Curcuma rhabdota*

National Parks in Northeastern Thailand (Table 2, Fig. 1-2). Four species were found in Sai Thong NP and Phu Phan NP, including *C. angustifolia*, *C. alismatifolia*, *C. gracillima* and *C. parviflora*. Three species

Table 2: Ecological conditions in sampling plot (20×20 m) and list of species of *Curcuma* found in sampling plot in four national parks in Northeastern Thailand

Study area	Plot No.	Species list	Altitude (m)	Soil pH	Soil density (kg m^{-3})
KT	I	*C. angustifolia*	158	6.84	483.4
	II	*C. angustifolia* *C. gracillima*	137	6.81	516.0
	III	*C. angustifolia* *C. rhabdota*	121	6.62	428.0
PH	I	*C. alismatifolia* *C. angustifolia*	792	6.80	420.0
	II	*C. gracillima*	814	6.63	456.0
	III	*C. alismatifolia* *C. gracillima*	801	6.74	452.0
ST	I	*C. gracillima*	821	6.74	455.0
	II	*C. alismatifolia* *C. gracillima*	831	6.75	418.0
	III	*C. alismatifolia*	804	6.78	443.5
PP	I	*C. alismatifolia*	302	6.31	418.0
	II	*C. alismatifolia* *C. angustifolia*	290	6.28	424.0
	III	*C. parviflora*	289	6.45	480.0

Table 3: Statistical analysis of soil densities, pHs, and altitudes of five species of *Curcuma*

	Parameters								
	Soil density (kg m^{-3})			pH			Altitude (m)		
Species	Min	Max.	Mean (±SE)	Min.	Max.	Mean (±SE)	Min.	Max.	Mean (±SE)
C. angustifolia	360.00	660.00	473±9.05^{b}	6.00	7.00	6.73±0.26^{b}	121.00	290.00	145±4.50^{ab}
C. rhabdota	360.00	500.00	428±8.99^{a}	6.00	6.90	6.61±0.54^{b}	121.00	121.00	121±0.00^{a}
C. alismatifolia	360.00	600.00	429±3.76^{ab}	6.28	6.90	6.64±0.21^{b}	290.00	831.00	678±2.14^{c}
C. gracillima	380.00	660.00	459±3.59^{ab}	6.20	7.00	6.73±0.12^{b}	137.00	831.00	680±2.73^{c}
C. parviflora	460.00	460.00	460±0.00^{ab}	6.45	6.45	6.45±0.00^{a}	289.00	289.00	289±0.00^{b}
Min.		360.00			6.00			121.00	
Max.		660.00			7.00			831.00	
Mean (±SE)		4.49±3.42			6.68±0.01			5.22	
F-test		7.792			5.720			99.457	
p-value		<0.001			<0.001			<0.001	

Means separation within columns by Duncan's multiple rang test, Values in columns follow by the same letter are not statistically different

(*C. angustifolia*, *C. gracillima* and *C. rhabdota*) were found in Kaeng Tana NP and three species (*C. angustifolia*, *C. alismatifolia* and *C. gracillima*) were found in Pa Hin Ngam NP (Table 2).

A previous study reported 13 species of *Curcuma* in Northeastern Thailand (Maknoi, 2006). The species that were not found in the present study included *C. amada* Roxb., *C. harmandii* Gagnep., *C. petiolata* Roxb., *C. pierreana* Gagnep., *C. singularis* Gagnep., *C. sparganiifolia* Gagnep., *C. stenochila* Gagnep. and *C. ubonratchathani* (Maknoi, 2006). As different species flower at different times (Apavatjrut *et al*., 1999) and the flower is very important for species recognition in the *Curcuma* it could be possible that these species were not flowering during our sampling period, thus we were not able to collect them.

Two species were geographically widespread and covered almost all areas in Northeastern Thailand, they were *C. alismatifolia* and *C. gracillima*. *C. altismatifolia* was found in three national parks, namely Pa Hin Ngam NP, Sai Thong NP and Phu Phan NP. *Curcuma gracillima* was found in three national parks (Kaeng Tana NP, Pa Hin Ngam NP and Sai Thong NP). Our results are consistent with previous reports related to the geographic distributions of these species (Paisooksantivatana *et al*., 2001, 2002; Saensouk, 2000; Saensouk and Chantaranothai, 2003). The geographically widespread nature of these species was consist with the wide range of ecological conditions that are suitable as habitats (Table 3) as species that can exploit a wide range of ecological niches will be distributed in a wider range of geographic areas.

Two species were geographically restricted to only one area. *C. parviflora* was found only in Phu Phan NP and *C. rhabdota* was found only in Kaeng Tana NP. First description of *C. rhabdota* reported that the samples were collected from the Lao PDR but the exact location was not identified (Sirirugsa and Newman, 2000). Our results revealed that this species is also found in Thailand in Ubon Ratchathani Province, which is located along the Thailand-Lao PDR border.

Ecological conditions of the habitats: *C. angustifolia* was found in habitats with the highest soil density

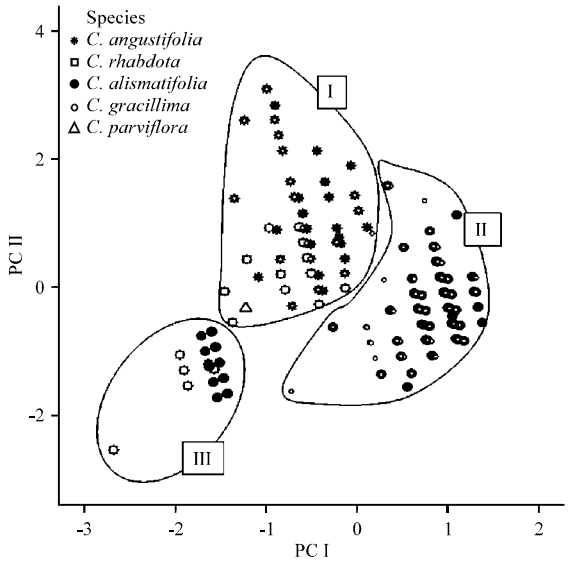

Fig. 3: Plot of the two principal components scores (PC I and PC II) derived from principal components analysis of the three environmental conditions of the 12 sampling plots for *Curcuma* species from four national parks in Northeastern Thailand

(473±9.05 kg m^{-3}) and pH (6.73±0.26). *C. rhabdota* was found in the habitat with the lowest soil density (428±8.99 kg m^{-3}) and *C. parviflora* found at the lowest pH (6.45±0.00) (Table 3). The *Curcuma* species that were found at low altitude (<300 m above sea level) were *C. angustifolia*, *C. parviflora* and *C. rhabdota*. *C. angustifolia* was found in an altitude range between 121 and 290 m above sea level.

C. parviflora and *C. rhabdota* were geographically restricted to Phu Phan NP at an altitude of 289 m above sea level and Kaeng Tana NP at an altitude of 121 m above sea level, respectively. *C. alismatiolia* and *C. gracillima* were found at a wide range of altitudes from 137 to 831 m above sea level (Table 2).

Comparisons of the ecological conditions between habitats revealed significant differences among the *Curcuma* species found in this study (Table 3). *C. rhabdota* was found in a habitat with significantly lower soil density than the other species. *C. parviflora* was found in a habitat with significantly lower pH than other species. *C. alismatifolia* and *C. gracillima* were found in habitats that were at significantly higher altitudes than *C. angustifolia*, *C. rhabdota* and *C. parviflora*.

At the wider ecological scale (i.e., forest types) four species (*C. angustifolia, C. parviflora, C. alismatifolia* and *C. gracillima*) were found in dry dipterocarp forest and grass fields along the edges of the dry dipterocarp forest. One species, *C. rhabdota* was found in a habitat composed of sedimentary clay that originated from the Mun River and had high moisture content. This specialized habitat requirement explains the narrow geographic distribution of this species.

Principal components analysis of the environmental conditions in the habitats revealed two Principal Components (PC) with eigenvalues higher than 1.0. The two PCS together accounted for 81.9% of the total variance. PC-1 accounted for 41.5% of the variation among species. Sampling plots with higher PC-1 scores have higher altitudes. PC-2 accounted for 39.4% of the variation in environmental variables. Sampling plots with higher PC-2 were high soil density and pH. Taken together, a plot of these two axes revealed three groups (group I, II and III) for the habitats of *Curcuma* species (Fig. 3). The sampling site for *C. parviflora* and almost all sampling sites for *C. angustifolia* fell into group I which is characterized by high altitude with moderate soil density and pH. Most sampling sites for *C. rhabdota* also fall in this group. Sampling sites for *C. alismatifolia* and *C. gracillima* belonged to group II which was characterized by high soil density and pH with moderate altitude. Some sampling site for *C. alismatifolia* belonged to group III which was characterized by low altitude, soil density and pH. These results suggest that *C. angustifolia, C. parviflora* and *C. rhabdota* are found mainly in higher altitude areas compare to *C. alismatifolia* and *C. glacillima* which are found mainly in lower altitude areas.

In conclusion, we found that *Curcuma* species in Northeastern Thailand largely overlap geographically but were also ecologically distinct. Our result indicates that altitude, pH and soil density are important ecological conditions habitats that determine the geographic distributions of *Curcuma* species.

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