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Diversity in Cultivated and Wild *Nephelium* species in South-East Asia

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The diversity of *Nephelium* species in the home gardens, orchards and forests from 12 selected sites in Malaysia, Thailand and Indonesia were studied. A total of 20 *Nephelium* species including four unidentified species were recorded in the three countries. The highest number of species was recorded in Malaysia (12 including one unidentified species), followed by Thailand and Indonesia each with six species, with two unidentified species in Thailand and three unidentified species in Indonesia. Most of the *Nephelium* species were found in the forest: Malaysia (seven), Thailand (four) and Indonesia (five). Using the four cell analysis, Shannon Diversity Index was highest at Sijunjung (*H'*=1.386) followed by Sibuti, Serian and Papar each with *H'*= 1.099; and followed by Nakhon Sithamarat and Sisaket, *H'*=0.693. Although Sibuti and Papar had three species each but the Shannon Diversity Index was higher in Sibuti (*H'*=0.558) compared to Papar (*H'*=0.400) due to the uneven number of the trees for the species. In Sisaket and Nakhon Sithamarat, Shannon Diversity Index showed highest *H'*=0.693. Lambir Forest Reserve showed the highest number of species (seven), followed by Sijunjung (five) and Kota Belud (three). Similarly, Shannon Diversity Index was highest at Lambir Fores Reserve *H'*=1.946, followed by Sijunjung (Sumatera) *H'*=1.609 and Kota Belud *H'*=1.099. The commercial species, *N. lappaceum* is widely cultivated in all the three countries. *N. ramboutan-ake* and *N. maingayi* can be considered as rare while the other species are threatened. In order to capture enough genetic variability for conservation it requires to select many home gardens and large areas of forest reserves. It is recommended to intensify the survey of the cultivated and wild *Nephelium* species in other areas in order to obtain comprehensive data pertaining to species diversity and distribution. The genetic materials of the wild *Nephelium* species also need to be collected and planted in the field genebank at various government institutions for *ex situ* conservation.

Key Words: ***Nephelium ramboutan-ake, N. maingayi, N. cuspidatum* var. *robustum*, Species richness, Shannon diversity index**

Introduction

The genus *Nephelium* (Sapindaceae) consists of 22 species, with 20 species occurring in Malaysia (Yap, 1989; Leenhouts, 1986), six in Thailand (Van Welzen, 1999) and 16 in Kalimantan, Indonesia (Siebert, 1991). The genus is distributed in South East Asia from Yunnan and Assam to Hainan, Peninsular Malaysia, Sumatra, Jawa, Borneo, the Phillippines, Sulawesi and Maluku

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(Yap, 1989; Leenhouts, 1986). Among these species only *N. lappaceum* locally known as 'rambutan' in Malaysia and Indonesia, or 'Ngo' or 'Phruan' in Thailand is commonly and widely cultivated in the home gardens and orchards in the three countries. Another species which can be considered rare, *N. ramboutan-ake* locally known as pulasan (Malaysia) and kapulasan (Indonesia) is rarely cultivated and the fruits are sold in the local markets. Many other species are very rare and wild and mostly can be found in the forest. The fruits of some of the wild species such as *N. cuspidatum* var. *robustum, N. cuspidatum* var. *eriopetalum, N. maingayi, N. hypoleucum* and *N. unicatum* are edible and normally they are harvested from the forest and sold in the local markets by the farmers.

Diverse fruit tree species including *N. lappaceum* are cultivated in home gardens and orchards in Malaysia (Salma *et al*., 2006; Raziah *et al*., 2006). Similarly, Tahan Uji (2007), reported that many of the fruit species were cultivated in the home gardens in Indonesia, while Siregar (2006) stated that many *Nephelium* species were found cultivated and also in the wild in Kalimantan (Indonesia). Likewise in Thailand, of the five *Nephelium* species found in the wild, the fruits of *N. hypoleucum* are normally harvested by the locals and sold in the local markets.

N. lappaceum exhibits a wide range of genetic variation within the species. The seedling progeny of *N. lappaceum* is heterogenous and shows a great variability in fruit characters such as fruit size, shape and colour, sarcotesta taste, thickness, juiciness, flavour and adherence to the seed (Salma, 1986). Clonal selection of *N. lappaceum* was carried out in Malaysia, Indonesia and Thailand. Malaysia has a great diversity of *N. lappaceum* clones and till to date more than 200 *N. lappaceum* clones were registered by the Department of Agriculture (DOA, 1995), and the recommended clones include R 160, R 161, R 162, 'anak sekolah' and 'jarum mas'. In Thailand the common *N. lappaceum* clones include 'Rongrian', 'Seechompoo',and 'Bangyeekkhan', while in Indonesia the main commercial cultivars are 'Lebakbulus', 'Binjai' and 'Simacan' (Lye *et al*., 1987).

However, the diversity present in most of the *Nephelium* species has been not fully exploited. These species are rapidly declining and in danger of being lost forever due to development, land conversion, planting of modern and superior crop varieties and more profitable crops. Further, the potential value of many of these fruit species which are well adopted to currtent climate and local conditions is enormous and can provide the local communities with food security and as a source of nutrition (Amin *et al*., 2004; Emmy Hainida, *et al*., 2007; Mohd Shukri *et al*., 2008).

Currently, a very few accessions of *Nephelium* species were collected for conservation. There were four *Nephelium* species *viz*. *N. ramboutan-ake, N. cuspidatum* var. *robustum, N. maingayi* and *N. milliferum* conserved at MARDI field genebank in Serdang, Malaysia. In Indonesia the collection of wild *Nephelium* is scattered at several institutions. Indonesian Tropical Fruit Research Institute (ITFRI) has *N. mutabile* (kapulasan) collection planted in Subang Experimental Farm, West Java. While *N. maingayi* (ridan) collection is at Balai Benih Induk (BBI) Padang Marpoyan, Riau Province, *N. jugladifolium* (rambutan hutan) planted in Bogor Botanical Garden and *N. cuspidatum* (sibau) at Assessment Institute for Agricultural Technology (AIAT) of South Kalimatan. In Thailand, *Nephelium.* sp. var. *paunmuang*, *N. hypoleucum* var. *kholan,* were planted at Chanthaburi Horticultural Research Center, Chanthaburi province whereas *Nephelium.* sp. var. *ngo bant* and *N. ramboutan-ake* var. *pakonsan luklek* were conserved at Trang Horticultural Research Center, Trang province.

The current knowledge on the variation and diversity of *Nephelium* species is lacking and thus the objective of the present study is to assess the inter and intra-specific diversity of the species from the genus *Nephelium* in the home gardens, orchards and forests in the selected sites from the three countries using rapid participatory methods and structured survey as well as to determine the common, rare and threatened species (*i.e*. common and rare in term of use and threatened not in cultivation particularly as a species is rarely or seldom used) so as to identify the type of interventions for conservation of these fruit species *ex situ* or on farm.

Materials and Methods

Study Sites

A total of 12 provinces or states were selected based on the richness of the target species in the areas. In Malaysia six districts that had high richness of the target species in the areas were obtained from the results of site selection analysis. These sites were Yan (Kedah) and Bukit Gantang (Perak) in Peninsular Malaysia; Serian and Sibuti in Sarawak; and Papar and Kota Belud in Sabah. Similar selection analysis was carried out in Thailand and Indonesia, and provinces with high target species

Table 1. Study sites from the three countries

Country	State/ Province	District	Habitat
Malaysia	Kedah	Yan	HG, ORC
	Perak	Bukit Gantang	HG, ORC, FOR
	Sabah	Papar	HG, ORC
		Kota Belud	HG, ORC, FOR
	Sarawak	Serian	HG, ORC
		Sibuti	HG, ORC, FOR
Thailand	Chiang Mai		HG, ORC
	Si Sa Ket		HG, ORC
	Chanthaburi	Klong Narai, Muang, Trok Nong, Klung	HG, ORC, FOR
	Trang	Nong Bua, Rasda	HG, ORC, FOR
	Nakhon Si Thammarat	Kiriwong, Lanska	HG, ORC, FOR
Indonesia	West Sumatra	Sijunjung	HG, FOR

HG – Home garden; ORC – Orchard; FOR – Forest

were selected (Table 1). Five provinces were selected in Thailand and these were Chiang Mai, Si Sa Ket, Chanthaburi, Trang and Nakhon Sri Thammarat while in Indonesia Sijunjung in West Sumatra was chosen.

Two types of surveys were carried out at these sites to gather *Nephelium* species and their varietal richness at household or community level in the home gardens, orchards as well as forest. Fruit species studied were all the *Nephelium* species including their landraces, varieties and clones.

Four Cell Analysis

Four Cell Analysis (FCA) is a participatory approach where it involved the participation of the farmers at the sites in the three countries. This method is a rapid assessment technique to determine the diversity and distribution of the fruit species in the home gardens or orchards (de Boef and Thijssen, 2007). It involved a focus group discussion among the farmers, men and women, from various villages. The farmers were requested to distinguish the fruit species available in their villages into four categories and place them in the appropriate quadrants. The tree species or varieties are categorized into many or a few fruit trees when grown in many or in a few households; or a few few trees in many or a few households.

Structured Survey

A systematic survey of the fruit trees in the home gardens and orchards was carried out in Malaysia and Thailand only while the survey in the forest was carried out in all the three countries. In Malaysia, 240 home gardens including orchards in the six districts while in Thailand 200 home gardens were surveyed. Initially the farmer was requested to draw the layout of the fruit tree species or varieties available in his home gardens and orchards on a paper and followed up by field walk to verify the species. Among other parameters recorded include home garden size, species name, local name, number of trees per species, age of fruit tree, yield, fruit taste, marketing and pest and disease. Besides, information on the source of fruit trees and those species that have commercial value from farmer's perspective were also recorded.

In Thailand, the wild species in the forest were surveyed in the sampling plots constructed. Three sampling plots of 20×20 m area at the edge of Kaolung Park covering 9,000 ha in Nakhom Sri Thammarat Province, ten plots of 40×40 m area at Khao Bantat wild life sanctuary covering 127,752 ha in Trang Province and six sampling plots of 40×40 m at Plew waterfall National Park covering11,250 ha at Chantaburi were made. *Nephelium* species encountered in these plots were recorded. In Malaysia wild *Nephelium* species at Bukit Bintang Hijau near Bukit Gantang were surveyed along transcects that covered an area of 10 ha. While at Kota Belud the *Nephelium* species were surveyed along 30 transects of 1000 m length and 10 m width at Crocker range. At Lambir Forest reserve in Sarawak a 52 ha plot was made and *Nephelium* species in the plot were scored. While in Sumatra, data on the *Nephelium* species in the nearby forest near Sijunjung were recorded.

Results and Discussion

Diversity and Richness of Nephelium Species

A total of twenty *Nephelium* species including four unidentified species were recorded in the three countries (Table 2). The highest number of species was recorded in

Table 2. Summary of *Nephelium* species identified from four cell analysis, genetic diversity analysis and forest survey

No.	Species	FCA			GDA			FOREST		
		Mal	Thai	Ind	Mal	Thai	Ind	Mal	Thai	Ind
1	*Nephelium aculeatum*							+		
2	*N. costatum*							+		
3	*N. cuspidatum*							+		
4	*N. cuspidatum* var. *robustum*	+			+					
5	*N. daedaleum*							+		
6	*N. hypoleucum*		+			+			+	
7	*N. lappaceum*	+	+	+	+	+		+		+
8	*N. maingayi*	+		+				+		+
9	*N. melliferum*								+	
10	*N. ramboutan-ake*	+			+			+		
11	*N. subfalcatum*							+		
12	*N. uncinatum*							+		
13	*N. xanthoides*							+		
14	*N. xerospermoides*			+						+
15	*Nephelium* sp.1 (Bantut)	+								
16	*Nephelium* sp.2 (Oge)			+						
17	*Nephelium* sp.3								+	
18	*Nephelium* sp.4								+	
19	*Nephelium* sp.5									+
20	*Nephelium* sp.6									+

Mal = Malaysia, Thai = Thailand, Ind = India, + = present

Malaysia (12 including one unidentified species), followed by Thailand and Indonesia each with six species, with two unidentified species in Thailand and three unidentified species in Indonesia. Most of the *Nephelium* species were found in forests, Malaysia (seven), Thailand (four) and Indonesia (five).

Participatory Identification and Diversity of Nepehelium Species

Based on the Four Cell Analysis, six identified *Nephelium* species and two unknown *Nephelium* species locally known as 'Bantut' in Sibuti (Malaysia) and 'Oge' in Sijunjung (Sumatera) were reported (Table 2). Sijunjung in Indonesia was reported to have the highest species richness (S=4) *i.e. N. lappaceum, N. maingayi, N. xerospermoides* and one unidentified species (Oge), followed by Sibuti, Serian and Papar in Malaysia where S=3, and Nakhon Sithammarat and Sisaket in Thailand with each S=2, (*N. lappaceum* and *N. hypoleucum*) (Tables 2 and 3). Like-wise, Shannon Diversity Index was highest at Sijunjung (*H'*=1.386) followed by Sibuti, Serian and Papar each with *H'*= 1.099; and followed by Nakhon Sithamarat and Sisaket, *H'*=0.693 (Table 3). However, by comparing all the study sites among the three countries, Malaysia recorded the highest number of *Nephelium* species with a total of five *i.e. N. lappaceum, N. ramboutan-ake, N. cuspidatum* var. *robustum, N. maingayi* and one unidentified species (Bantut). The high number of *Nephelium* species could be due to the fact that Malay Peninsular being the centre of origin of the genus *Nephelium* (Van Welzen (1999). The commercial fruit of *N. lappaceum* is common and found to be cultivated in the three countries.

Diversity of Nephelium Species in Home Gardens and Orchards

The genetic diversity analysis from the baseline data (Syauqi, 2015) showed that only four *Nephelium* species were recorded in the home gardens and orchards in Malaysia and Thailand. The number of species found during the survey was less compared to the information given by the farmers during the focussed group discussion. This situation happened because during the FCA, the farmer will narrate the list of species that appears to his mind but in reality during the actual survey the species are not encountered due to several reasons, either the plant has been cut down, died or probably growing in other areas not included in the surveyed area. The commercial species, *N. lappaceum* is widely cultivated in all the sites except in Sisaket (Thailand) only one tree was recorded. Chantaburi in Thailand showed the highest number of trees *i.e.*750 planted followed by Bukit

Table 3. Shannon diversity index, evenness and species richness of *Nephelium* species based on four cell analysis

Country	Site	Shannon diversity index (H')	Evenness (E)	Species richness (S)
Thailand	Chanthaburi	0.000	0	1
	Chiangmai	-	-	0
	Nakhon Sithammarat	0.693	1	2
	Sisaket	0.693	1	2
	Trang	0.000	0	1
Malaysia	B. Gantang	0.000	0	1
	K. Belud	0.000	0	1
	Papar	1.099	1	3
	Serian	1.099	1	3
	Sibuti	1.099	1	3
	Yan	0.000	0	1
Indonesia	Sijunjung	1.386	1	4

Table 4. Number of trees in each *Nephelium* species in eleven locations

Country	Site	*Nephelium cuspidatum* var. *robustum*	*Nephelium lappaceum*	*Nephelium ramboutan-ake*	*Nephelium hypoleucum*
Thailand	Chanthaburi	0	750	0	0
	Chiang Mai	0	0	0	0
	Nakhon Si Thammarat	0	520	0	5
	Sisaket	0	1	0	1
	Trang	0	354	0	0
Malaysia	B.Gantang	0	728	9	0
	K.Belud	0	230	0	0
	Papar	19	334	25	0
	Serian	0	224	0	0
	Sibuti	2	503	150	0
	Yan	0	321	2	0

Gantang in Malaysia (728 trees) (Table 4). *N. ramboutan-ake* which is a close relative of *N. lappaceum* was only recorded at Sibuti, Papar, Bukit Gantang and Yan in Malaysia. Although *N. ramboutan-ake* was not found in the surveyed home gardens and orchards in Kota Belud and Serian, but it was found to be grown in other areas in these two districts. However, there was no record of *N. ramboutan-ake* in the surveyed sites in Thailand. Therefore *N. ramboutan-ake* can be considered as a rare species. The wild species, *N.cuspidatum* var. *robustum* was only located at two sites *i.e.* Papar (19 trees) and Sibuti (two trees). This species normally occurs as a single individual formerly grown by the older generation or left uncut during land clearing for developing an orchard or building houses. While *N. hypoleucum* was only recorded from Nakhon Sithammarat (five trees) and Sisaket (one tree). This species was reported to be cultivated in Thailand (Tindall, 1994).

Sibuti and Papar possessed three species each but Shannon Diversity Index is higher in Sibuti (H'=0.558) compared to Papar (H'=0.400) due to the uneven number of the trees for the species (Table 5). The same situation is shown in Sisaket and Nakhon Sithamarat where Shannon diversity index showed highest H'=0.693 due to the same number of trees for both species. There was no rambutan trees growing in Chiang Mai.

Comparison of the various communities at the different sites showed that the Malay community in Yan and Bukit Gantang (Malaysia) has maximum number of *N. lappaceum* trees in their home gardens and orchards (Table 6). Normally the farmers in Malaysia planted the recommended clones given by the Department of Agriculture (R 156, 'lekang nyiur' or 'anak sekolah') or they bought the seedlings from the private nurseries. Similarly in Thailand the commercial cultivars of *N. lappaceum* planted are Ngo Rongrian, Ngo Si Chompu or Ngo Ban. The Kadazan Dusun and Kedayan in Papar and Sibuti simultaneously still maintained the wild *N. cuspidatum* var. *robustum* in their orchards for their own consumption.

Diversity of Wild Nephelium Species in Selected Forests

Many *Nephelium* species were found in the forest as

Table 5. Shannon diversity index, evenness and species richness of *Nephelium* species based baseline data

Country	Site	Shannon diversity index (H')	Evenness (E)	Species richness (S)
Thailand	Chanthaburi	0	0	1
	Chiang Mai	-	-	0
	Nakhon Si Thammarat	0.054	0.078	2
	Sisaket	0.693	1.000	2
	Trang	0.000	0.000	1
Malaysia	B. Gantang	0.066	0.095	2
	K. Belud	0.000	0.000	1
	Papar	0.439	0.400	3
	Serian	0.000	0.000	1
	Sibuti	0.558	0.508	3
	Yan	0.038	0.054	2

Table 6. *Nephelium* species and number of trees owned by the different communities

Site	Community	*Nephelium cuspidatum* var. *robustum*	*Nephelium lappaceum*	*Nephelium ramboutan-ake*	*Nephelium hypoleucum*	Grand Total
Chanthaburi	Trok Nong		750			750
Chiang-Mai	Banmaeya		0			0
	Banmae-onai		0			0
Kota Belud	Bajau		230			230
Nakhon Si Thammarat	Kiriwong		520		5	525
Papar	Kadazan Dusun	19	334	25		378
Serian	Bidayuh		224			224
Sibuti	Kedayan	2	503	150		655
Sisaket	Nongsingyai		1		1	2
Trang	Banchongphli		61			61
	Banlongnam		117			117
	Bannakhao		72			72
	Bannamtok		52			52
	Banthamphraphut		74			74
Yan / Bukit Gantang	Malay		1049	11		1060

recorded during the survey made. The density of trees for each *Nephelium* species varies greatly from 1-20 trees per species. A total of 13 identified and four unidentified species were recorded in three countries with Malaysia showing the highest number of species (10) followed by Indonesia (six) and Thailand (four) (Table 2). Lambir Forest Reserve showed the highest number of species (seven), followed by Sijunjung (five) and Kota Belud (three) (Table 7). Similarly, Shannon Diversity Index was highest at Lambir Forest Reserve *H'*=1.946, followed by Sijunjung (Sumatra) *H'*=1.609 and Kota Belud *H'*=1.099. The high number of species found at Lambir Forest Reserve was probably due to the larger area surveyed compared to the other sites. In Thailand, two species were found in Trang and another two unidentified species were found in Nakhon Sithammarat. In Thailand, the fruits of *N. hypoloceum* eventhough of inferior quality were normally harvested and sold in local markets. However at Sijunjung, Sumatera, of the five species recorded, only three species were identified (Table 1). In general, the wild *Nephelium* species produce sarcotesta which is thin, sour and adhered to the seed. However, through selection and domestication or participatory breeding the fruit quality can be improved.

Conclusion and Recommendations

Based on the number of trees per species and their occurence at the studied sites, *N. ramboutan-ake* and *N. maingayi* can be considered as rare while the other species are threatened besides *N. lappaceum* which is

Table 7. Shannon diversity index, evenness and species richness of *Nephelium* species in selected forests

Country	Site	Shannon diversity index	Evenness	Species richness
Malaysia	Bukit Gantang	0.000	0	1
	Kota Belud	1.099	1	3
	Lambir FR	1.946	1	7
Thailand	Nakhon Si Thammarat	0.693	1	2
	Trang	0.693	1	2
Indonesia	Sijunjung	1.609	1	5

common to all the three countries. Home gardens and forest reserves have the potential for maintaining and conserving *Nephelium* species. Since the occurence of the number of trees for each species either in the home garden or forest is small at each site, therefore, in order to capture enough genetic variability for conservation it requires to select many home gardens and large areas of forest reserves. Besides, it is recommended to intensify the survey of the cultivated and wild *Nephelium* species in other areas in the country in order to obtain comprehensive data pertaining to species diversity and distribution. In addition, the genetic material of the wild *Nephelium* species also need to be collected and planted in the field genebank at various governmental institutions as *ex situ* conservation. Besides exploration on the value addition of the *Nephelium* species in the home gardens and linking them with market should be an important strategy for *in situ* conservation. Research programmes on selection and breeding for crop improvement of the wild *Nephelium* species should be enhanced.

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