An Ethnobotanical Study on Folk Taxonomy and Uses of *Mangifera* Trees Grown in Southeast Asia

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CONTENTS

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Chapter 1

Introduction

Large wild mango trees often stand in the midst of paddy fields in Northeast Thailand. A landscape of sparsely populated trees in crop fields is typical of rural areas in Northeast Thailand (Takaya and Tomosugi, 1972). The wild trees appear to be remnants of the original vegetation of mixed dry deciduous forests comprising dipterocarp trees, e.g., *Dipterocarpus tuberculatus*, *Shorea obtuse*, *Terminalia tomentosa*, and *Diospyros rhodocalyx*, dating from before the agricultural transformation (Watanabe *et al*., 1990). Wild mango trees also tend to remain in crop fields. Wild mango trees are characterized by their towering height, straight trunk, and dark-green canopy. In careful searches of wild mango trees, I can find them not only in crop fields but also on roadsides and in the vicinity of settlements. An abundance of fruits grow on branches and fall from the trees in mid-April following *Songkran* (Thai New Year), after which the rainy season commences. These fruits are much smaller than the common mango. Many of the trees are called “forest mango” or “wild mango” in Thai, but some trees are called other names. How many kinds of these wild mangoes exist? Although the fruits are utilized locally, indigenous knowledge on the uses of the plant is not common outside the region. The present study entails an investigation on how these wild

mango trees are utilized by the local people.

Genus *Mangifera* L.

The genus *Mangifera* is one of the 73 genera belonging to the family Anacardiaceae, and it has been reported to consist of either 40 species (Chayamarit, 2010; Gruezo, 1992) or 69 species (Kostermans and Bompard, 1993). At least 26 species have edible fruits (Gruezo, 1992).

Origin Based on morphological, biogeographical, and fossil evidence, *Mangifera* species are thought to have originated in Southeast Asia, from Myanmar to Vietnam or the Malay Peninsula (Mukherjee, 1953).

Distribution The natural range of *Mangifera* species is restricted to tropical Asia, and the wild species occur in India, Sri Lanka, Bangladesh, Myanmar, Thailand, Cambodia, Vietnam, Laos, south China, Malaysia, Singapore, Indonesia, Brunei, the Philippines, Papua New Guinea, the Solomon Islands, and the Caroline Islands (Bompard and Schnell, 1997). They are found abundantly in India, China, Indochina, and Malesia, and 17 species have been reported from Thailand (Chayamarit, 2010). Some species, especially *M. indica* L., occur outside their natural range due to their introduction by humans into regions such as the U.S., Africa, Australia, and China for their economic importance (Mukherjee, 1953).

Morphology *Mangifera* species are large trees, 30–40 m in height, with some exceeding 50 m in height that consist of a clear straight trunk and usually form a dense and rounded canopy. Bark and other parts of the tree contain irritating sap. Leaves are scattered, simple, entire, and glabrous. Inflorescences are paniculate and glabrous or pubescent. Flowers are glomerulate and male or bisexual, and the plants are andromonoecious. There are four or five petals, often with ridges on the inner surface. The number of stamens is either 10 (–12), 4, 5, or 1, and the remainder are staminodial or lacking. Fertile stamens are usually 1 or 5. Drupes

exist in a variety of shapes. Immature fruits have white latex, and the mesocarp is often thick and fleshy. The endocarp is often fibrous or woody. Most species are evergreens, although a few are deciduous (Kostermans and Bompard, 1993). Wild *Mangifera* species flower and fruit irregularly.

Ecology and habitat The majority of wild *Mangifera* species occur individually scattered in tropical lowland rainforests on well-drained soils (Bompard and Schnell, 1997). The species is distributed mostly below 300 m but can occur up to *c*. 1000 m above sea level. Some species are also found in periodically inundated areas, swamp forest, or sub-montane forests above 1000 m (Bompard and Schnell, 1997). Other species have adapted to seasonally dry climates in deciduous forests.

Difficulties in surveying *Mangifera* species *Mangifera* trees occur not as populations but as single individuals and are scattered widely over extensive areas. Their flowering and fruiting seasons are short, occur irregularly, and are even skipped occasionally. They are towering trees with often inaccessible canopies. For these reasons, it is difficult to obtain or observe their flowers and fruits, and specimens of *Mangifera* species are consequently poorly represented among herbarium collections (Bompard, 1995). The flowers and fruits of a few species are still unknown, although species identification is difficult from leaves alone because of intraspecific variation in vegetative characteristics. Therefore, the necessary knowledge regarding species identification is not entirely complete. Moreover, some of the original species descriptions were based on poorly classified specimens, and frequent misidentification based on these specimens has resulted in much confusion. Thus, there is a strong need to continue collecting flowers and fruits of *Mangifera* species.

***Mangifera* species in Insular Southeast Asia** Kostermans and Bompard (1993) contributed significantly to revision of the classification system used for *Mangifera* species and increased botanical and horticultural knowledge on this

genus. They conducted intensive field explorations and recorded abundant data through direct observations. Their work was conducted mainly in Kalimantan and West Malaysia. Information regarding *Mangifera* species on Mainland of Southeast Asia is still insufficient.

Mainland of Southeast Asia has experienced great economic development in recent years. Deforestation and expansion of crop lands are under way today in vast areas. This has caused a decline in the natural vegetation, and consequently populations of *Mangifera* species, similar to many other tropical fruit trees, are decreasing. Therefore, recording the current utilization of *Mangifera* species in Mainland Southeast Asia is a matter of urgency.

Potential of wild mangoes as edible fruits

Domestication of *M. indica* *M. indica* is now under cultivation as the common mango in all tropical regions across the globe. DeCandolle (1884) estimated that mango cultivation began at least 4000 years ago in India, and this estimate has been accepted presently (Mukherjee, 1997). The common mango was cultivated within India for a long time. The global spread of the common mango outside the original centers of domestication, e.g., to Africa and Latin America, probably occurred after the European voyages of discovery and colonization during the 15th and 16th centuries (Mukherjee, 1997). During the early stages of domestication, the fruits were probably small with thin flesh, and then selection of superior seedlings over many hundreds of years would have resulted in larger fruits with thicker flesh (Mukherjee, 1997). Wild *M. indica* trees are still being recorded in locations such as Chittagong Hill tract in Bangladesh (Bompard and Schnell, 1997).

Domestication of fruit trees progresses gradually and slowly (Ladizinsky, 1998). The most dramatic change that occurs in domesticated fruit trees is loss of seeds. Seedless fruit yields relatively more edible flesh, which leads to an increase in convenience and in the economic value of the fruit, although domesticated plants are unable to reproduce without human intervention and to grow independently in the wild. Seedless fruit trees are considered the final stage

of domestication. Bananas and breadfruits are examples of this stage of domestication, although bananas are not woody plants, and their fruits serve as a staple food. Other changes in fruit trees under domestication include the development of hermaphroditism as grape, elimination of bitterness as almond, self-compatibility as peach, and lower resin content as mango (Spiegel-Roy, 1986). These changes do not interfere with reproduction and can be considered intermediate stages in the evolutionary process of domestication.

Potential availability of *Mangifera* species other than *M. indica* In the case of the common mango, larger fruits with thicker flesh have been developed as a result of selection of superior seedlings over hundreds of years (Mukherjee, 1997; Speigel-Roy, 1986). However, the present situation in which *M. indica* is cultivated worldwide to a greater extent than any other congener of the genus *Mangifera* might simply be a coincidental result. Other *Mangifera* species also produce relatively larger and more palatable fruits, even though they are wild or semi-cultivated. However, edible non-indica mangoes are utilized locally, and their existence and usefulness are not known outside of their local regions. If domestication of the common mango had developed under different cultural, social, ecological, or geographical conditions, other congeners might have plausibly dominated as globally known fruit trees today, although “if” does not exist in history.

The genus *Mangifera* includes species adapted to various ecological environments. Non-indica mangoes have potential value as edible fruits, breeding materials for selection and hybridization, a source of rootstocks, and a source of stress-resistant strains.

People and mangoes

The study of how plants are distinguished by local people leads to increased understanding of the relationships between people and plants. Fruit trees usually provide edible food in nature. Some fruits may be edible without strong human intervention, and some plants may reproduce independently even if

they are regularly utilized by humans. Focusing on wild fruit trees utilized by people enables us to observe a range of people-plant relationships, including wild gathering, semi-cultivation, and cultivation. Relationships between people and fruit trees are initiated when people collect the fruits from the wild. Observing the long and complicated processes connecting ‘wild’ and ‘domesticated’ fruit trees would help us trace the origin of fruit trees, although it is difficult to determine when ‘domestication’ began.

The present study also plays a role in keeping live records via field surveys. Records regarding ordinary people’s lives tend to be minor compared with historical records. The output of the present study can serve as a record of the daily lives of the local people. Cultures, societies, and ways of living are not static. Therefore, recording the current ways of plant use will have significance not only in an academic sense but also as a tool for future generations to trace the past lives of the local people.

The objective of this study

In this study, the current uses of *Mangifera* species in Southeast Asia, especially in Thailand, were recorded, thereby relaying relevant information on the local people for future generations. Folk taxonomies which may be based on not only species but also intraspecific variation were investigated. Direct observations and interviews regarding fruit morphology and qualities were conducted to understand the criteria used in folk taxonomies. First, extensive surveys were conducted on Mainland Southeast Asia (Chapter 2). Subsequently, *M. pentandra* trees growing in Northeast Thailand were investigated and their local names and uses recorded (Chapter 4). Some *M. pentandra* trees in this region were found to have superior fruits; therefore, a discussion on the initiation of domestication of this species is also provided. The research area was extended to North (Chapter 5) and South Thailand (Chapter 6), where ecological conditions differ, to understand the utilization of the genus *Mangifera* in the entire country. Field surveys were also conducted in the surrounding regions, i.e., north and central Laos and northeast Vietnam (Chapter 2) and Java (Chapter 6) to compare

and understand the characteristics of *Mangifera* utilization in each region. Local names were recorded in each region and were linked to botanical species. However, two different descriptions on the number of fertile stamens were found for *M. caloneura* Kurz. Therefore, taxonomic developments were reviewed to reveal how inconsistencies have arisen and to determine which descriptions I should use (Chapter 3). In addition, people-plant relationships involving *Mangifera* species were compared among regions (Chapters 5 and 6).

Chapter 2

An Extensive Field Survey on *Mangifera* Species in Mainland Southeast Asia

Introduction

In this chapter, an extensive field survey for *Mangifera* species in Mainland Southeast Asia is conducted. There is a linguistic and ethnological similarity between Thailand and Laos: the term *ma muang*, for example, indicating mango in Thailand, sounds similar to the term *mak muang* in Laos. In both countries Tai language families settle. Tai language families have also settled in northwest Vietnam, where the mango is called *mak muang* or *mai muong*. Among the countries of Mainland Southeast Asia where *Mangifera* species diversified, a continuum over four regions containing Northeast Thailand, central and north Laos and northwest Vietnam was examined to facilitate comparison of the study areas using Tai as a common language.

No comprehensive study of the local names and uses of wild mangoes in Mainland Southeast Asia has been previously reported, although some studies have explored the genetic resources of wild mangoes in Mainland Southeast Asia. For example, Eiadthong *et al.* (1999b) investigated *Mangifera* species in Thailand, confirmed the existence of 13 species, and recorded their morphological and ecological characteristics to examine the genetic relationship among the species.

Kostermans and Bompard (1993) conducted an intensive investigation in the Kalimantan and Malay Peninsula to collect the information on local names and uses of wild mangoes and to revise the botanical taxonomy of the genus *Mangifera*.

The objective of this chapter is not a botanical or molecular taxonomy but is to understand indigenous knowledge and folk taxonomy of wild mangoes in Thailand, Laos and Vietnam. Wild *Mangifera* trees were explored and classified them according to their morphological characteristics, and their local names, uses and growing environments were recorded.

Materials and Methods

Research Sites

The elevation, topography, natural vegetation and ethnic groups of the interviewees in each study area are shown in Table 2-1, and the study locations are shown in Fig. 2-1. Topography ranged widely, from undulating and flat in Northeast Thailand[1], to flat and hilly in central Laos and to mountainous in north Laos and northwest Vietnam. The natural vegetation was dry dipterocarp forest on plain in Northeast Thailand and central Laos, and mixed deciduous forest in mountainous regions in Laos and northwest Vietnam.

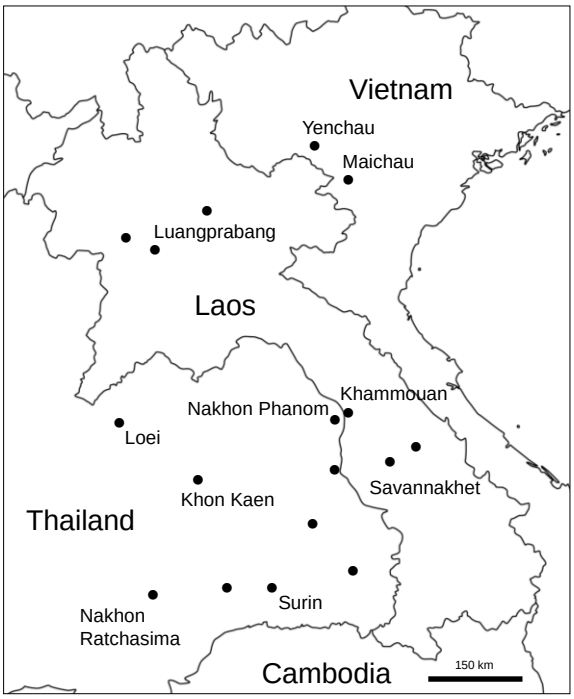

Fig. 2-1. Research sites over Thailand, Laos, and Vietnam.

In Northeast Thailand, the original dry dipterocarp forest has mostly been reclaimed as paddy fields. At present, the dry dipterocarp forest remains only as sparse groves covering small hilltops or scattered on gently

[1] Thailand is administratively divided into six regions: Northeast Thailand (Isan), North Thailand, West Thailand, Central Thailand, East Thailand, and South Thailand.

undulating plains. The majority of the people there is mainly the immigrants from Laos. In this chapter, Northeast Thailand is divided into central, east and south regions, represented by the provinces of Khon Kaen, Nakhon Phanom and Surin, respectively. Interviewees were sometimes Khmer in the south part but Lao in the other parts. The languages used for the interviews were Thai and Lao.

In Laos, research was conducted in both central and north parts of the country. In the central region, the provinces of Savannakhet and Khammouan, located across the Mekong from Northeast Thailand were examined. In Savannakhet Province, the research was conducted in the Phalanxay and Vilabouly Districts. In Phalanxay, reclamation of the original dry dipterocarp forest has spread, and landuse has mostly changed to paddy fields as in Northeast Thailand. Forests are thus limited. Vilabouly has more mountainous topography and is still mostly covered with mixed deciduous forest. Paddy fields are commonly constructed along the long and narrow lowlands between the mountains, where most of the villages are also scattered. In the surrounding forests, villagers are engaged in shifting cultivation and gather forest products. The landscape in

Table 2-1. Elevation, topography, natural vegetation and ethnic groups of interviewees of the research sites.

Research site	District	Elevation (m asl)	Topography	Natural vegetation	Ethnic groups of informants*
Northeast Thailand		120–280	Undulating plain	Dry dipterocarp forest	Lao, Phutai and Khmer
Central Laos	Phalanxay Tha Khek	140–180	Undulating plain	Dry dipterocarp forest	Lao
	Vilabouly	180–230	Hilly	Mixed deciduous forest	Lao, Phutai and Cali
North Laos	Xieng Ngeun Chom Phet Pak Xeng	290–1220	Mountainous	Mixed deciduous forest	Lao and Khmu
Northwest Vietnam	Maichau	170	Valley	Mixed deciduous forest	Tai
	Yenchau	300	Valley	Mixed deciduous forest	Tai

*: Lao, Phutai and Tai belong to Tai language family, and Khmu and Cali belong to Austroasiatic language family (Chazee, 1999). Khmer belongs to Austroasiatic language family.

Tha Khek District, the study site in Khammouan Province is similar to that of the undulating plains in Savannakhet and Northeast Thailand. The plain of Lao and the more mountainous Phutai and Cali areas were examined. In all three areas, interviews were conducted in the Lao language.

In north Laos, research was conducted in Xieng Ngeun, Chom Phet and Pak Xeng Districts in the mountainous province of Luangprabang. Paddy rice and field crop cultivation are major livelihood activities in Xieng Ngeun and Chom Phet Districts. In mountainous Pak Xeng, shifting cultivation is practiced. Mixed deciduous forests remain in north Laos. Here, interviews of Khmu and Lao people were conducted in the Lao language.

In northwest Vietnam, Maichau District in Hoa Binh Province and Yenchau District in Son La Province were focused. Both districts are mountainous areas and border Laos. The original vegetation was mixed deciduous forest, although little remains. Large areas of the mountain slopes have been deforested and reclaimed. Paddy rice and field crop cultivation are practiced on the limited narrow flat plains in the valley. Villages lie along the road that runs through this valley. Tai residents account for 60% and 80% of Maichau and Yenchau population, respectively. The interviews were conducted in Lao and Vietnamese.

Methods

Field surveys were conducted in November 2008, December 2009 and June 2010. The surveys were conducted in two ways to gain insight into local knowledge of wild *Mangifera* species. One was visiting villages and asking the villagers whether they knew wild mangoes. If mangoes were present, the villagers were asked to take to the habitat, where information through direct observation and interviews were collected. Another way was by exploring the area myself. When wild *Mangifera* trees were found, the owners of the trees or any neighboring villagers were interviewed. Through these interviews, information was collected about the local names of wild mangoes, their meanings, uses, parts used and impressions of fruit taste. One exception was that information on uses was not collected in Vietnam because of lack of interview permission. Throughout

this chapter, local names were recorded using Roman characters as they were pronounced by interviewees. Thus the spellings of the names listed here were different from the original spellings, though Vietnamese uses Roman characters.

The height of the *Mangifera* tree was measured by triangulation, and the diameter at breast height was calculated from the length of the circumference directly measured with a tape. Tree shape, roughness, trunk bark color and leaf morphology were recorded. The length and width of the fully expanded leaves were also measured using more than five leaves, and the means and standard deviations of the length, width and width-to-length ratio were calculated. ANOVA and Tukey's test were used to determine the statistical significance.

Trees were classified based on the morphological characteristics of leaf and tree shape. Botanical species were identified based on the whole shape and details of the trees, using dry samples and photographs. Reproductive organs, such as flowers, could rarely be observed. Wild *Mangifera* species usually flower during December to February though they do not flower regularly.

Some species, which were recognized as wild mango by local people but were not *Mangifera* species, were excluded from this survey. In some other cases, *Mangifera* species recognized as wild mango were included although some *M. indica* trees may have been included. Thus, in the present survey, some *M. indica* trees might be referred to as "wild mangoes."

Results and Discussion

Morphological Classification

The morphological characteristics of "wild mangoes" such as trunk straightness, crown shape and density, bark roughness and leaf shape and size varied widely (Plate 2-1). Local people distinguished "wild mangoes" in each area. The criteria for distinguishing wild mangoes were related chiefly to leaf and tree shape morphological characteristics. On the basis of these characteristics, a total of 260 "wild mangoes" were observed and classified into four groups, namely A (143 trees), B (39 trees), C (10 trees) and D (60 trees) (Table 2-2), except for eight trees which remained non-classified because of their intermediate

morphological characteristics. Type A trees had stiff, broad and oblong leaves with the highest width/length ratio. Type B leaves were thin, linear-oblong like a bamboo leaf and shortest in length. Type C leaves were oblong and longest among the categories. Type D leaves were oblong-lanceolate with a normal shape and similar in size to those of *M. indica*.

The form of type A trees varied widely. Some trees had a straight trunk with many branches from the base, a sparse and longitudinally long globose crown and deeply fissured bark vertically. Others had a straight trunk with few branches at the base, a rather dense globose crown and thin fissures densely covering the bark. Trees were up to 24 m tall and 130 cm in diameter, but usually much smaller (15 m tall and 70 to 80 cm in diameter) (Table 2-3). B type trees had a straight trunk in half of the tree's height that branched off and spread to sparse crowns. Bark was rather smooth or slightly fissured. Most of the large trees taller than 20 m were classified into type A or B, and all the trees over 30 m belonged to type B. Type C trees had a smooth and pale brown bark with whitish patches. These trees

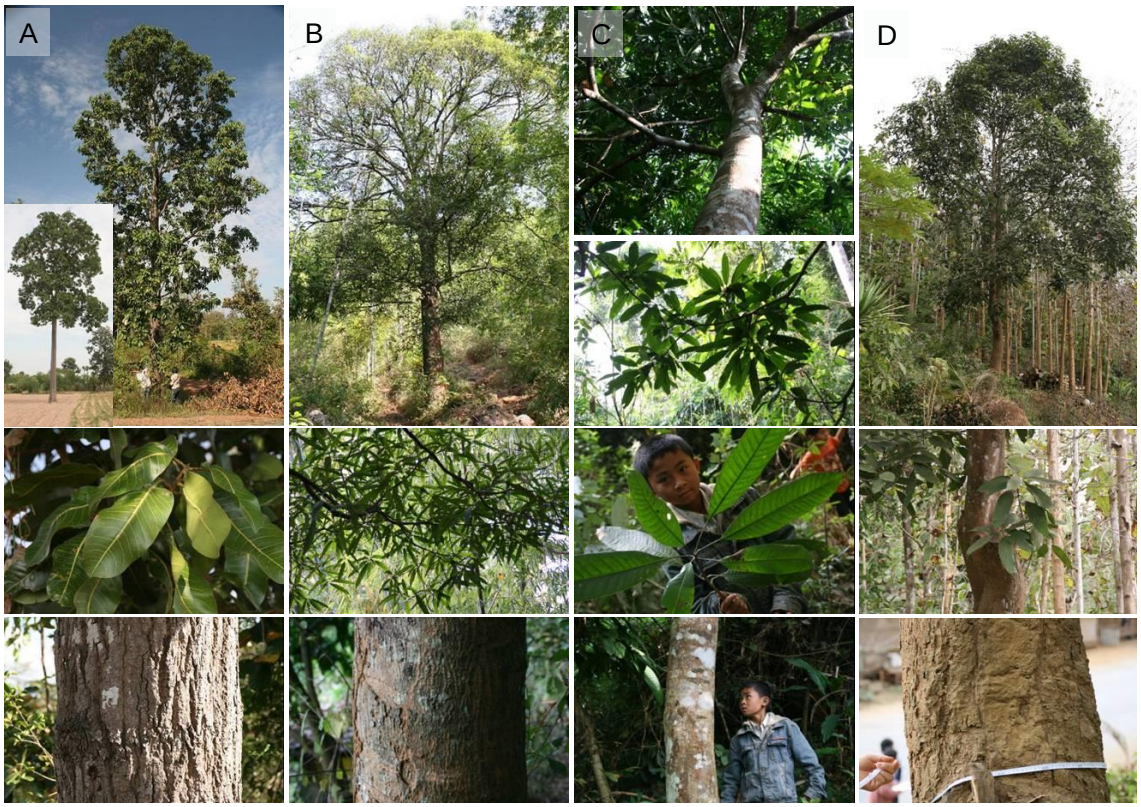

Plate 2-1. Typical tree shape, leaf morphology, and roughness of bark of wild *Mangifera* trees in Northeast Thailand, central and north Laos and northwest Vietnam. They were classified into four groups of A, B, C and D.

Table 2-2. Leaf morphology of wild *Mangifera* trees in Northeast Thailand, central and north Laos and northwest Vietnam.

Type	Number of trees	Leaf morphology (average ± standard deviation)			Discription of leaf morphology
		Length (cm)	Width (cm)	Width/length ratio	
A	143	22.6 b ± 8.2	7.8 a ± 2.0	0.36 a ± 0.07	Thick, stiffy, chartaceous, widest, oblong to elliptic with blunt apex
B	39	22.7 b ± 16.3	3.7 b ± 0.9	0.20 c ± 0.04	Thin, coriaceous, shortest, linear-oblong, similar to bamboo leaf
C	10	30.7 a ± 3.9	6.9 a ± 1.6	0.22 c ± 0.03	Soft, coriaceous, longest, oblong or elliptic-oblong
D	60	24.2 ab ± 3.4	7.4 a ± 1.8	0.30 b ± 0.05	Coriaceous, lanceolate to oblong-lanceolate, similar to *M. indica*

Same letters are not significantly different at P<0.05 by the Tukey's test.

Table 2-3. The number of trees and frequency distribution of dimensions and morphology of trunk and crown of wild *Mangifera* trees in Northeast Thailand, central and north Laos and northwest Vietnam.

Tree dimensions	Type of wild mango trees							
	A		B		C		D	
	No. trees	Frequency	No. trees	Frequency	No. trees	Frequency	No. trees	Frequency
Height (m)								
less than 5	0	0 %	1	3 %	2	25 %	2	2 %
5-10	35	25 %	2	6 %	2	25 %	36	36 %
10-15	65	47 %	16	44 %	3	38 %	49	49 %
15-20	34	24 %	12	33 %	1	13 %	11	11 %
20-25	5	4 %	2	6 %	0	0 %	2	2 %
25 and over	0	0 %	3	8 %	0	0 %	0	0 %
Diameter* (cm)								
less than 30	5	4 %	2	5 %	3	38 %	6	15 %
30-60	42	31 %	6	16 %	2	25 %	18	39 %
60-90	70	52 %	14	38 %	3	38 %	13	28 %
90-120	15	11 %	9	27 %	0	0 %	7	15 %
120-150	2	1 %	4	8 %	0	0 %	1	2 %
150 and over	0	0 %	2	5 %	0	0 %	0	0 %
Description:								
Shape of crown	Not dense and cylindrical, or dense and vertically-long globose		Not dense and dome-shaped		Not dense, not massive and dome-shaped		Dense and dome-shaped	
Color of bark	Black to grey to brown		Dark brown to pale brown		Pale brown and white in patches		Dark brown to pale brown	
Texture of bark	Deeply or shallowly fissured		Smooth or fissured shallowly		Smooth		Smooth or cracked irregularly	

*: Diameter at breast height (DBH).

were about 10 m tall and 40 cm in diameter, with a rather slender trunk. The total shape of the trees was difficult to observe because the trees appeared only in thick forests. The crowns of type D trees were usually dense and rounded, while the other types had sparse crowns. Tree height usually ranged between 10 to 15 m. This type included some individuals that resembled and possibly were *M. indica*.

One species was likely identified: *M. caloneura* Kurz[2] corresponded to all of the type A trees as well as two type D trees and two non-classified trees. In spite of not being classified into type A, based on the leaf morphology and tree shape, the flowers of four individuals were observed and identified as *M. caloneura*. In addition, it was considered that *M. linearifolia* and *M. dognaiensis* could be included in B type, *M. oblongifolia*, *M. cochinchinensis* and *M. indica* in type C, and *M. laurina*, *M. sylvatica* and *M. indica* in type D. Further identification requires floral and fruit analysis.

Distribution

The distributions differed among the morphology types (Fig. 2-2). Plates 2-2 to 2-5 show the tree shape and leaf morphology of typical examples in each study area. Type A trees were distributed throughout Northeast Thailand. The trees did not grow on lowland but were instead found on small hilltops scattered over a gently undulated plain, indicating their intolerance to flooding. The distribution range of type A trees also included the plain

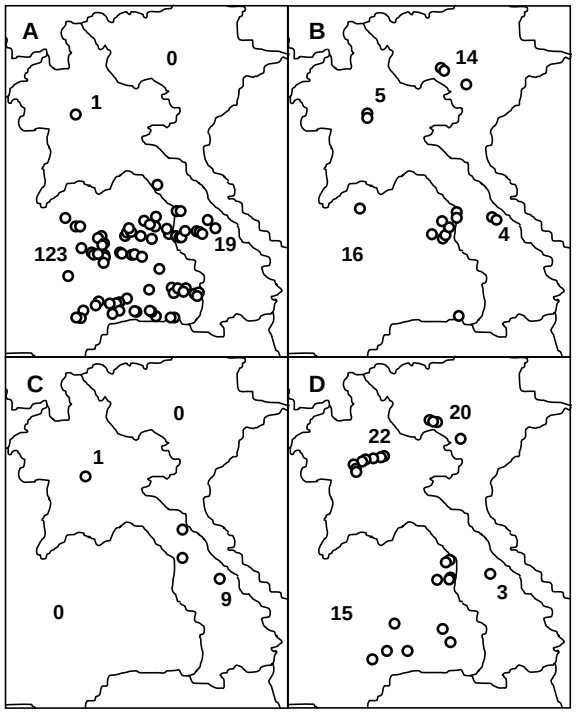

Fig. 2-2. Locations of the observed wild *Mangifera* of type A, B, C and D. The numbers in the map indicate the number of observations in each area of Northeast Thailand, central Laos, north Laos and northwest Vietnam.

[2] This species is *M. pentandra* Hook. f., although the species was misidentified as *M. caloneura* Kurz in this chapter. The confusion can be traced back to two different descriptions of *M. caloneura*. See Chapter 3 for details.

of central Laos, on the other side of the Mekong from Northeast Thailand. *M. caloneura* has been reported to be distributed from south Myanmar to Vietnam (Kostermans and Bompard, 1993), which includes the type A distribution.

Type B trees were found regionally in Thailand and Laos. Their distribution was very limited in the study area to the east part of Northeast Thailand and mountainous areas in north and central Laos. Both Maichau and Yenchau Districts in the mountainous areas of Vietnam had type B trees. Thus, type B is considered to be distributed in highland areas. This type may include *M. linearifolia* and *M. dognaiensis*. It has been reported that *M. linearifolia* is endemic to Thailand and that *M. dognaiensis* grows in sub-montane, wetland and evergreen forests in south Vietnam (Kostermans and Bompard, 1993). If the type

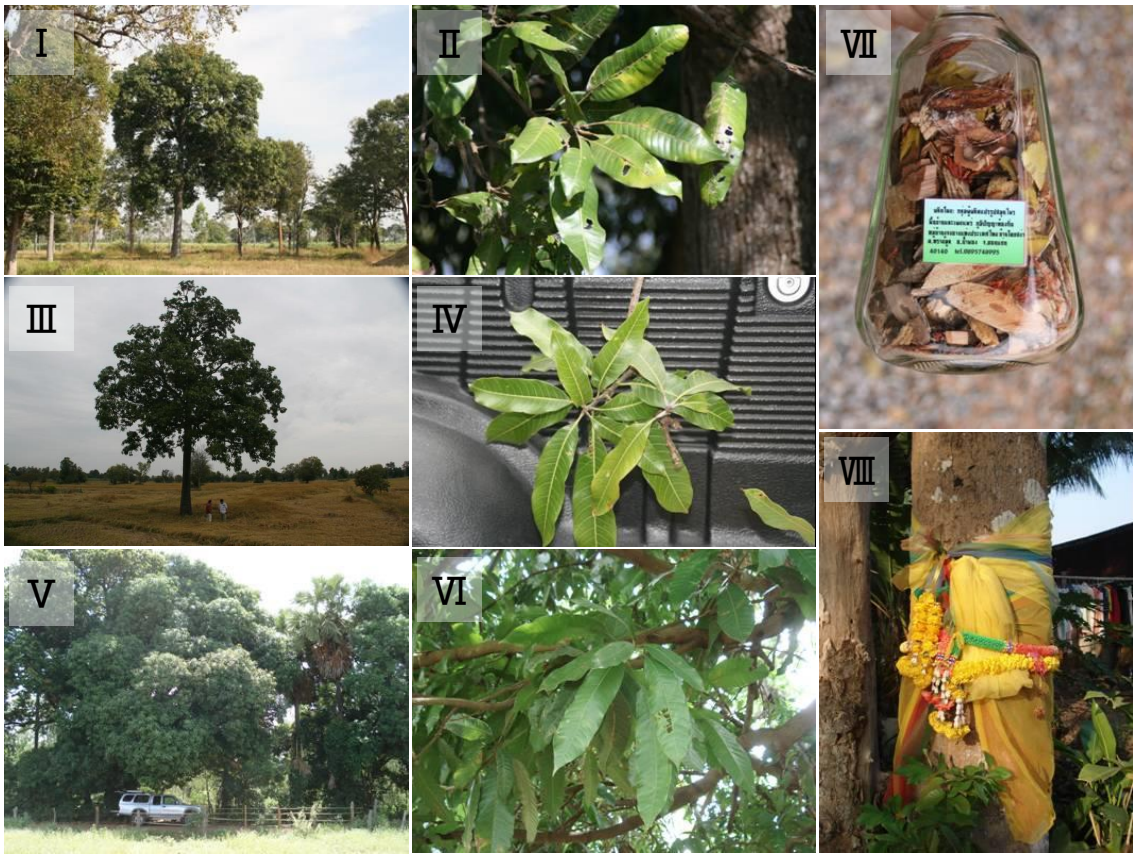

Plate 2-2. Left two rows show tree shape and leaf morphology of wild *Mangifera* trees in Northeast Thailand: *muang paa* (I and II), type A *muang kalon* (III and IV) and type D *muang kalon* (V and VI). Right row show uses of wild *Mangifera* trees in Northeast Thailand: bark of wild *Mangifera* and other species were sold in a bottle as a traditional vitalizer in Khon Kaen (VII). A wild *Mangifera* tree in Mukdahan were decorated for religious purpose: the spirit of animism, called *phii*, was believed to dwell within the tree (VIII).

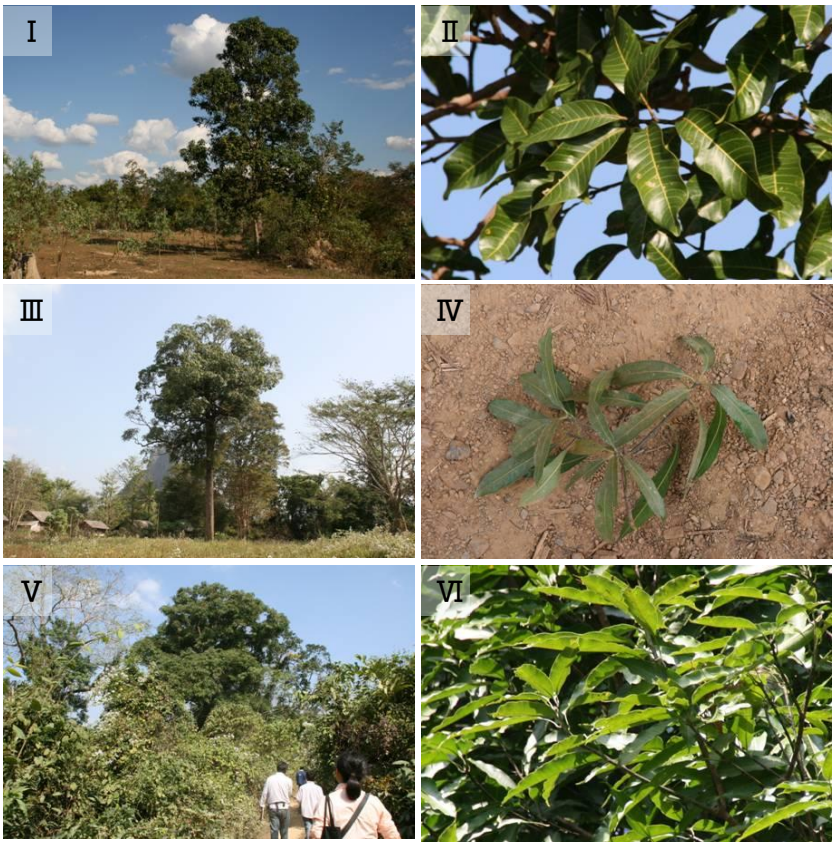

Plate 2-3. Tree shape and leaf morphology of wild *Mangifera* trees in central Laos: *muang khan* (I and II), *muang khai* (III and IV) and *muang kasoo* (V and VI).

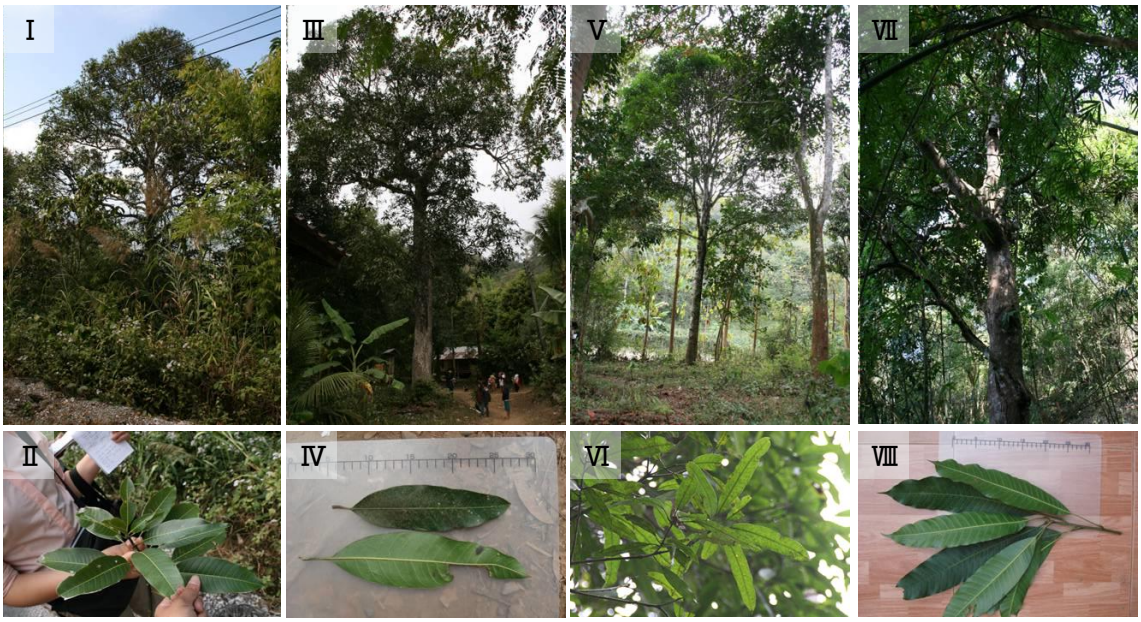

Plate 2-4. Tree shape and leaf morphology of wild *Mangifera* trees in north Laos: *muang khai* (I and II), *muang kasoo* (III and IV), *muang kaeo noi* (V and VI) and *muang khai nguu* (VII and VIII).

B trees in Laos and northwest Vietnam are identified as *M. linearifolia* or *M. dognaiensis*, the distributions may expand farther east or north, respectively.

Type C trees were found only in Laotian forests. Several trees sometimes occurred together with many seedlings under the canopy. *M. cochinchinensis*, which might be included in type C, reportedly occurs in Laos (Newman *et al.*, 2007), which would agree with my observation.

Type D trees were found throughout the study areas. *M. laurina* and *M. sylvatica*, which were included in this type, have been reported in deciduous forests from Thailand to Vietnam (Kostermans and Bompard, 1993: Eiadthong *et al.*, 1999b), in agreement with my findings. The type D category also likely included cultivated species such as *M. indica*, which is not a component species of the natural vegetation. It is possible that the so-called local varieties that have been cultivated extensively and utilized locally may be considered as "wild mangoes" compared to some recently introduced improved varieties.

Local Names

All the local names, categorized based on the area and morphological classification, are listed in Table 2-4. When a tree had two names in different languages, both names were noted using parentheses, e.g., *muang khiu* (=*soai hoi*, in Vietnamese). Some nouns in Lao are prefixed by "ki" or "ka," causing *muang sii* to be called *muang kisii*, and *muang soo* to be called *muang kasoo*. The names with these prefixes are adopted throughout this study.

Differences among the local names well reflected differences among morphology types. Therefore, this classification reflected the local people's recognition. A total of 50 local names were recorded, including 17 in Thailand, 20 in Laos and 20 in Vietnam. Four names were common in plural countries: *muang khai* (egg mango), *muang kaeo* (glass mango), *muang khan* (itchy mango) and *muang kisii* (resin mango). Among these, *muang khai* was used in central and north Laos and in the east part of Northeast Thailand, but the morphological types varied among regions. *Muang khai* referred to type B in central Laos, type D in north Laos and types B and D in Northeast Thailand. Only *muang kaeo* was

Table 2-4. Local names of wild *Mangifera* in Northeast Thailand, central and north Laos and northwest Vietnam according to the morphologies.

Area		A		B		C		D		Non-classified	
		Local name	Number of interview	Local name	Number of interview	Local name	Number of interview	Local name	Number of interview	Local name	Number of interview
Thailand	Central part of N.E.Thailand	*muang paa*	11					*muang noi*	1		
		muang kalon	1								
	South part of N.E.Thailand	*muang paa* (=*swai prii* (K))	19	*muang khai khin ka*	1			*muang kalon*	3	*muang kalon* (=*swai kro* (K))	1
								muang noi	1		
		muang kisii	2								
		muang som	1								
		muang chii	1								
	East part of N.E.Thailand	*muang paa*	6	*muang khai*	6			*muang khai*	3	*muang kaeo*	1
		muang khan	1	*muang khi muu*	1			*muang paa*	1	*muang paa*	1
		muang kisii	1					*muang khai khi muu*	1		
		muang kao kwaang	1					*muang man*	1		
		muang khai	1								
Laos	Central Laos	*muang khan*	8	*muang khai*	3	*muang kaeo*	1	*muang kaeo*	1	*muang kisii*	1
		muang kisii	1	*muang paan*	1	*muang khai*	1	*muang kasoo*	1		
		muang khiu	1	*muang horm*	1	*muang paa*	1				
		muang toon	1			*muang paa lung noi*	1				
		muang men wan	1			*muang paa lung nyai*	1				
		muang ngaa saang	1								
		juprong	1								
	North Laos	*muang hiit*	1	*maung kaeo noi*	4	*muang khai nguu*	1	*muang khai*	10	*muang kasoo*	1
				muang kaeo	1			*muang kasoo*	6	*muang teet saang*	1
								muang kaeo	2		
								muang kham	2		
								muang kong	1		

Table 2-4. Continued.

Area		A		B		C		D		Non-classified	
		Local name	Number of interview	Local name	Number of interview	Local name	Number of interview	Local name	Number of interview	Local name	Number of interview
Northwest Vietnam	Maichau district			*moi*	3			*muom*(V)	1	*moi*	1
				(=*muom chon*(V))				*muom zai*(V)	1		
				(=*muom*(V))				*keo*	1		
	Yenchau district			*mak chai*	4			*muang khiu* (=*soai hoi*(V))	4		
								muang mon (=*soai chon*(V))	3		
								muang som (=*muom*(V))	1		
								muong (=*muom*(V))	1		
								muang hii (=*soai mut*(V))	1		
								muang kaeo (=*soai zung*(V))	1		
								hoa dain	1		

Meaning of local names are (from type A to D); *muang paa*: wild mango; *swai prii*: wild mango; *muang som*: sour mango; *muang khan*: itchy mango; *muang kao kwaang*: nine deer mango; *muang khai*: egg mango; *muang kisii*: resin mango; *muang khiu*: acrid mango; *muang men wan*: fly mango; *muang ngaa saang*: elephant hoon mango; *muang khai khin ka*: lizard egg mango; *muang khi muu*: pig excrement mango; *muang horm*: fragrant mango; *muang kaeo noi*: small glass mango; *muang kaeo*: glass mango; *muom chon*: round muom; *muang paa lung noi*: smaller wild mango; *muang paa lung nyai*: bigger wild mango; *muang khai nguu*: snake egg mango: *muang noi*: small mango; *muang khai khi muu*: pig excrement egg mango; *muang man*: potato mango or oily mango; *muang kham*: golden mango; *muom dai*: long muom; *soai hoi*: fragrant mango; *soai chon*: round mango; *soai mut*: suck mango; *soai zung*: wild mango. Meanings of other words are unknown.

(K)= in Khmer, (V)= in Vietnamese.

recorded across all three countries. *Muang khan* and *muang kisii* were known as Isan (Northeast Thailand) dialect in Thailand.

In Northeast Thailand, *muang paa* (Plates 2-2I, 2-2II) was the most common name (Table 2-4). All except for two individuals of *muang paa* belonged to type A. *Muang paa* trees were often observed in crop fields, usually alone, although sometimes many trees were scattered over the fields.

In central Laos, the most common names were *muang khan* and *muang khai*. *Muang khan* (Plates 2-3I, 2-3II) belonged to type A and *muang khai* (Plates 2-3III, 2-3IV) to type B. A clear morphological difference existed between the two. *Muang khan* was the same species as *muang paa* in Northeast Thailand and their growing environments were very similar. Although *muang khai* was known in both flat and hilly areas of central Laos, the trees were found only in hilly areas. *Muang khai* was considered to produce more palatable fruits than *muang khan*. *Muang kasoo* (Plates 2-3V, 2-3VI), which belonged to type D, was also well-known, but only a single tree was detected. The same type A *muang khan* (itchy mango) trees in central Laos were called by the generic name *muang paa* (wild mango) in Northeast Thailand. Wild *Mangifera* species have likely long

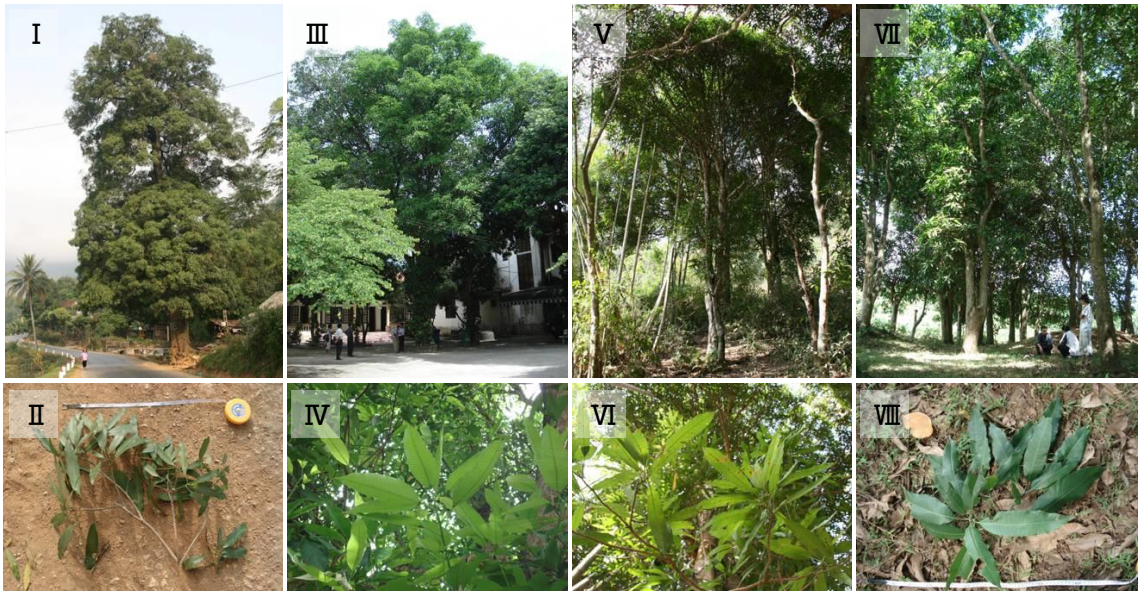

Plate 2-5. Tree shape and leaf morphology of wild *Mangifera* trees in Maichau and Yenchau, northwest Vietnam: *moi* in Maichau (I and II), *muom* in Maichau (III and IV), *mak chai* in Yenchau (V and VI) and *muang khiu* in Yenchau (VII and VIII).

been called by a generic name in the area of pre-Angkor, Northeast Thailand and Cambodia. The term *swai prii* (wild mango in Khmer; i.e., *M. caloneura*) has been found in pre-Angkorian Khmer inscriptions dating back from the sixth to eighth century A.D. (Pou and Martin, 1981).

Well-known names in north Laos were *muang khai*, *muang kasoo* and *muang kaeo noi* (Table 2-4). Among these, *muang khai* (Plates 2-4I, 2-4II) and *muang kasoo* (Plates 2-4III, 2-4IV) were classified into type D. *Muang kaeo noi* (Plates 2-4V, 2-4VI) was assigned to type B. One type C tree was also observed in north Laos and called *muang khai nguu* (snake egg mango) (Plates 2-4VII, 2-4VIII).

In northwest Vietnam, all the *Mangifera* species were classified into type B or D (Table 2-4). In Maichau, *moi* (Plates 2-5I, 2-5II) belonged to type B. Others such as *muom* (Plates 2-5III, 2-5IV) and *keo* were type D. In Yenchau, *mak chai* (Plates 2-5V, 2-5VI) was type B, while others such as *muang khiu* (Plates 2-5VII, 2-5VIII) and *muang mon* were all type D. In northwest Vietnam, trees of type B were given one name in each district, whereas type D trees were given several names. The villagers seemed to distinguish trees by different names even within the same species, paying attention to the wide variation within the type D trees.

Drift in Recognition

Most of the type A trees in Northeast Thailand were called *muang paa* generically, while some trees were called *muang kalon* specifically as an exception. Trees with the name *muang kalon* have been identified as *M. caloneura* (Gardner *et al.*, 2000; Tomita, 1997; Suvatti, 1978). The Latin term "*caloneura*" means "obvious nerves," although it sounds similar to *kalon*. The name *muang kalon* was widely known in Northeast Thailand, while *muang kalon* trees were seldom observed. I found five *muang kalon* trees, which were classified into one type A tree, three type D trees, and one non-classified tree. The type A tree (Plates 2-2III, 2-2IV) was found in a paddy field in Khon Kaen in Northeast Thailand. Its leaves were much thicker than those of *M. indica*, but rather thin and slender

compared to the other type A leaves. The bark was gray. The type D *muang kalon* trees (Plates 2-2V, 2-2VI) were found near houses or in crop fields. The morphological characteristics of type D *muang kalon* differed from those of type A; the leaves were softer and slimmer and the bark color was lighter brown.

The type A *muang kalon* was likely the same species as *muang paa*. The leaves of the two mangoes might vary, but local people were not conscious of these differences. They were conscious of the taste of *muang kalon*, which was highly rated, and it was often said that "*muang kalon* tastes better than *muang paa*" (Khon Kaen). It is suspected that people may come across some trees or races producing tastier fruit and call these *muang kalon* to distinguish them from other *muang paa*. Similar cases in which superior races have been found within wild *Mangifera* species are not rare. Variations with sweeter and less fibrous flesh of *M. odorata* and *M. foetida* have been identified in Malaysia, and a form of *M. caesia* from Bali and Borneo had green skinned fruit with milky white, soft flesh and a sweet taste quite different from the fruit of common forms of *M. caesia* (Bompard, 1993).

However, some type D trees were also referred to as *muang kalon* in this survey, indicating that what was called "*muang kalon*" could have been changing. The number of trees called *muang kalon* would have decreased, and these trees are now rarely seen due to deforestation and commercialization of agriculture. Modern *M. indica* varieties have spread and become more common to local people; consequently these trees have possibly replaced the wild mangoes. As new varieties of *M. indica* have become available with infrastructure improvements brought by rapid economic growth, the recognition of "wild edible mango" may have been drifting from *M. caloneura* to the older local *M. indica* varieties. The major changes in *M. indica* under domestication have included fruit enlargement and resin reduction (Spiegel-Roi, 1986). Among the *M. indica* varieties that were introduced long ago and localized to the region, some varieties produce smaller fruits containing much resin. Such mango trees may have been included in *muang kalon*.

Uses

Both mature green and fully ripe fruits were used as food in Northeast Thailand. People ate mature green fruits, usually with seasonings such as *phrik klua* (dry chili and salt), *jeo* (meat or fish ground with dry chili and some condiments), *namplaa waan* (sauce made from fish or shrimp) and *paadaek* (fermented fish). Ripe fruits were also eaten with sweetened sticky rice. Green fruits were added to *somtam* (salad of julienned green papaya with chili pepper, garlic, calamondin etc.) instead of green papaya. In a good crop year, fruits were processed into pickles or *kuan* (stiff mango paste-like toffee) and preserved. In Laos, leaves as well as wild *Mangifera* fruits were used as food. Both mature green and ripe fruits were eaten fresh. Mature green fruits were usually eaten with *paadaek* or salt and were also added to *laap* (minced meat stirred with herbs and roasted rice and then flavored with fish sauce, garlic, calamondin etc.) or *tammakhung* (Lao name for *somtam*). Leaves were boiled to eat, and *muang kasoo* leaves were often said to have the best taste. In Yenchau District of northwest Vietnam, local mangoes were prepared for food in various ways: Tai people were reported to prepare about 20 dishes using the fruits and leaves (Hue *et al.*, 2004).

The palatability of each wild mango to local people differed. People estimated the fruit taste based on its sweetness, sourness, redolence, acridity and irritativeness. *Muang kalon* was considered to be particularly “delicious.” *Muang khai* was considered to be favorable overall, although the evaluations varied for sweetness and irritativeness. *Muang kaeo* was considered to be “sweet.” Fruits from type A trees were often reported as “itchy,” and thus had to be washed in water before being eaten (Table 2-5). Despite the irritativeness, the redolence of these fruits was not disagreeable.

Wild *Mangifera* was also used as medicines and dyes. Its bark was sold as a traditional revitalizer (Plate 2-2VII) in Khon Kaen in Northeast Thailand. Other medicinal applications included using the peel of *muang kalon* to treat a cold, the bark of *muang paa* for stomachache and the root to treat wounds. Other known uses were as follows: the bark of *muang kasoo* as revitalizer (central Laos), the leaf of *muang kaeo* to treat sore throat and the bark of *muang kasoo* and *muang*

Table 2-5. Local uses of wild *Mangifera* trees in Northeast Thailand and central and north Laos[1].

Country	Local name	How to prepare for food	Count	Other use	Part used	Count
Thailand	*muang chii*	Fruit washed in water before eaten	1			
	muang kaeo	Unripen fruit eaten raw	1			
	muang kalon	Fruit cooked into *kuan*[2]	2	Medicine	Peel	1
		Fruit pickled	1	Rootstock	Trunk	1
		Fruit eaten with sticky rice	1			
		Fruit eaten with flavoring[3]	1			
	muang khai	Fruit eaten raw	4	Ornament	Trunk	1
		Fruit eaten with flavoring	3			
		Fruit eaten with sticky rice	1			
	muang khai khi muu	Fruit eaten raw	1			
		Fruit eaten with flavoring	1			
	muang khan	Fruit eaten raw	2			
		Fruit eaten with flavoring	1			
	muang kisii	Fruit eaten raw	1			
	muang noi	Fruit cooked into *kuan*	2			
		Fruit eaten raw	1			
		Fruit added to *somtam*[4]	1			
		Fruit eaten with sticky rice	1			
	muang paa	Fruit eaten raw	20	Firewood	Branch	2
		Fruit eaten with flavoring	13	Medicine	Bark	1
		Fruit washed in water before eaten	4	Medicine	Root	1
		Fruit pickled	2	Medicine	Peel	1
		Fruit eaten with sticky rice	1	Dye	Peel	1
				Ornament	Trunk	1
	soai prei	Fruit eaten raw	3	Medicine	Peel	1
		Fruit washed in water before eaten	1			
		Fruit eaten with flavoring	1			
Laos	*muang hiit*	Ripen fruit eaten raw	1			
	muang kaeo	Ripen fruit eaten raw	2	Medicine	Leaf	1
	muang kaeo noi	Leaf boiled	3	Medicine	Bark	1
		Fruit eaten raw	2			
	muang kasoo	Leaf boiled	5	Medicine	Bark	3
		Fruit eaten raw	4	Medicine	Bark	1
		Fruit eaten with flavoring	2	Dye	Bark	1
		Leaf added to *laap*[5]	1			
		Leaf added to *tammakhung*[4]	1			
	muang khai	Fruit eaten raw	3			
		Fruit eaten with flavoring	1			
	muang khan	Fruit eaten raw	2			

[1] Exclusion of building materials.

[2] Preserved mango like toffy or jam.

[3] Such as *phrik klua* (dry chili and salt), *namplaa waan* (sauce made from fish or shrimp), *paadaek* (fermented fish), *jeo* (meat or fish ground together with dry chili and some condiments) and salt.

[4] Salad of julienned green papaya with chili pepper, garlic, calamondin and so on; *Somtam* in Thai and *tammakhung* in Lao.

[5] Minced meat stirred with herbs and roasted rice and then flavored with fish sauce, garlic, calamondin and so on.

kaeo noi as a medicine for stomachache (north Laos). Libman *et al.* (2006) surveyed commonly used medicinal plants in Laos and reported that "*muang so*" (=*muang kasoo*) bark was used as medicine for diarrhea. The bark of wild *Mangifera*, but only *muang kasoo*, was also used as a light brown dye in central Laos. In Thailand, the peel of *muang paa* fruit was applied to dye fish nets.

Wild *Mangifera* trees were additionally utilized for building furniture or as firewood. Any *Mangifera* species could be used for these purposes except for *M. indica*. Wood of *M. indica* cannot be used as building material or firewood, but it can be used for carving because of its softness. Such uses include digging out *M. indica* to create a vessel or canoe (Mbuya *et al.*, 1994). In contrast, wild *Mangifera* wood is hard and useful as a building material, as mentioned by one female interviewee who noted that "the heartwood of *muang paa* is blackish and hard enough for floorboard in the kitchen" (Khon Kaen). Some tree trunks in Northeast Thailand were decorated for religious purposes (Plate 2-2VIII). This kind of ornamentation could be applied to any large tree not only of *Mangifera*. The spirit of animism, called "*phii*," was believed to dwell within huge trees, and believers could pray for their wishes facing the trees.

Many of the above uses were also common to cultivated *Mangifera* species in the same region. The varied culinary uses appeared to follow the wide uses of *M. indica*. The bark of *M. indica* has been used as medicine in India since ancient times, as well as a dye source (Morton, 1987). In Laos, *M. indica* and *muang kasoo* had many uses in common, such as use of the fruit and leaves for food and the bark for medicine and dye. The uses of wild *Mangifera* trees were limited except for *muang kasoo*, suggesting that Lao villagers have recognized *muang kasoo* as similar to *M. indica*.

Growing Environment

The growing environment of wild *Mangifera* trees differed among the regions. Plate 2-6 shows representative examples. Wild *Mangifera* trees were frequently observed on undulating plains in Northeast Thailand and central Laos in paddy fields (Plate 2-6I), in crop fields (Plate 2-6II) and dry dipterocarp forests

(Plate 2-6III). Most trees were huge, suggesting that they represented primary forest. Huge trees in Northeast Thailand and Laos also remained around temple premises (Plate 2-6IV) and schools (Plate 2-6V), where the component species of the original vegetation have been preserved since before construction.

The landscape of the trees growing in agricultural fields seemed as if the trees would interfere with agricultural practices. However, Kosaka *et al.* (2006) surveyed the remnant trees in the paddy fields in central Laos and reported that the trees had various uses, i.e., timber, oleoresin from *Dipterocarpus* spp. for fuel in traditional torches, resin from *Shorea* spp. for waterproof coating as well as edible fruits and leaves and pleasant shade for farmers. Many of the interviewees also stated that they kept wild *Mangifera* trees to utilize the fruit and timber, implying that wild *Mangifera* trees have been retained because of their usefulness, in the same way as dipterocarp trees. A female interviewee explained that "wild mango trees were left to be utilized at the time when the cultivated mango varieties were not available yet" (Surin). This indicates that wild *Mangifera* had been recognized enough to be conserved. Dry dipterocarp forests have mostly been cut to make way for rainfed paddy fields since the 18th century in Northeast Thailand (Fukui, 1993). Trees growing in crop fields probably represent the original vegetation, considering that the area would have originally been covered with forest. These remnant trees may soon decrease in number. This situation may inspire some local people to protect them. For example, a wild *Mangifera* tree was preserved in a crop field "in order to show the kids" (Khon Kaen) on the outskirts of Khon Kaen, a rapidly urbanized central city of Northeast Thailand.

Wild *Mangifera* trees were often found in the mixed deciduous forest in mountainous areas of Laos, where shifting cultivation was practiced (Plates 2-6VI, 2-6VII). Trees were seldom observed around villages, although the villagers knew where and what kinds of wild *Mangifera* trees were growing in the forest. It was common for the villagers to know the locations of certain forest trees, even some that took hours to reach on foot. The villagers had no intention of protecting the wild *Mangifera* trees in the forest or of transplanting seedlings from the forest into their garden or crop fields. A male interviewee said, "I cut down wild mango

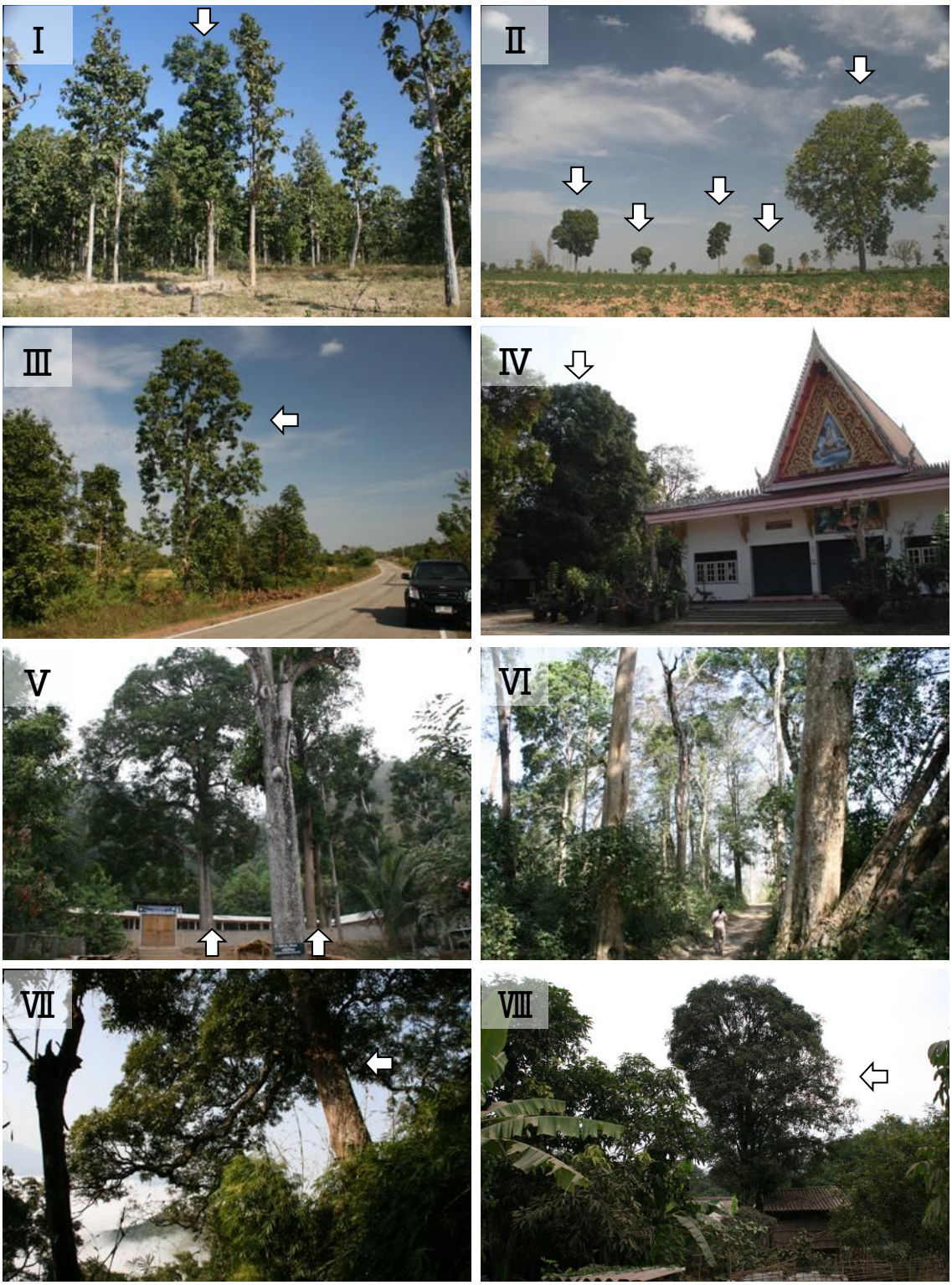

Plate 2-6. Growing environments of wild *Mangifera* trees observed: I. in paddy field (Phalanxay), II. in cassava field (Buriram), III. in dry dipterocarp forest (Loei), IV. in temple (Mukdahan), V. in front of school (Chom Phet), VI. in mixed deciduous forest (Vilabouly), VII. on a steep slope of mountain (Pak Xeng) and VIII. aside house (Yenchau).

trees when I slash and burn the forest land for cultivation, and later flush will sprout. If the trees are not cut down, however, they will be burned and die down" (Vilabouly). As of 2005, 69.9% of Laos was estimated to still be covered with forest, a figure much larger than the forest cover values of 28.4% in Thailand and 39.7% in Vietnam (FAO, 2006). Local people may appreciate the value of decreasing wild plant resources differently depending on how much the forest remains. In flat areas of Northeast Thailand and central Laos, people would leave useful species in their fields to provide forest products for daily use when they had reclaimed the forest. On the other hand, in the mountainous area in Laos, people may not want to grow or transplant useful species in their fields and gardens because they can still obtain forest resources directly from the rich forest surrounding their villages.

Research in Yunnan Province, China, found that wild fruit trees had been transplanted from the forest into homegardens in villages and were grown for daily consumption (Fu *et al*., 2003: Jin *et al*., 1999). In Yenchau, northwest Vietnam, many wild *Mangifera* trees were observed in the village (Plate 2-6VIII), the clumps around the village and crop fields. Many had been planted by the villagers. Shifting cultivation was once practiced in this region, although it has since been replaced by permanent field cultivation. From the village, natural forest could not be seen on the mountain slopes, which were covered with permanent crop fields. An interviewee reported that "wild *Mangifera* trees were cut down but were transplanted into the village as well as other useful plants" in Yenchau, while in Maichau "wild *Mangifera* trees had been conserved as they were, without cutting in the case of slash and burn." These cases may represent a last chance to conserve vanishing plant resources.

Identification of *M. caloneura* Kurz is found to be misidentification of *M. pentandra* Hook. f. after the research in this chapter. In the next Chapter 3, inconsistencies of species description of *M. caloneura* are clarified. In addition, highly rated *kalon* mango in Northeast Thailand is focused especially for its fruit traits in Chapter 4.

SUMMARY Wild *Mangifera* species were explored broadly in Mainland Southeast Asia. A total of 260 wild *Mangifera* trees were observed and classified into four groups based on morphological characteristics of leaves and tree shape. Broad-leaf type was distributed in flatland of Thailand and Laos and called *muang paa* or *muang khan*, respectively. Slender-leaf type was distributed in mountainous areas of Vietnam and Laos, and was called *muang khai* in central Laos, *muang kaeo noi* in north Laos and *moi* or *mak chai* in Vietnam. Long-leaf type grew only in the Laotian forests, and names were not consistent. Type with leaves similar to those of the common mango was found constantly, and was called by several names in each area. *Muang kalon* have been explained as *M. caloneura*, while some of the trees were possibly considered to be *M. indica*. The leaves of *muang kasoo* in Laos were used as food and its bark as dye and medicine, while most wild *Mangifera* were mainly used for fruits and woods. In the flatland of Thailand and Laos, trees often grew in croplands. They were assumed to have been conserved from the original forest. In the mountainous areas of Laos, the villagers used wild *Mangifera* trees in the forest, while they had no intention to conserve useful trees. In northwest Vietnam, wild *Mangifera* trees were transplanted into the villages before the forest had been reclaimed for crop fields, possibly representing a last chance to conserve vanishing wild plant resources.

Chapter 3

Two Different Descriptions of *Mangifera caloneura* Kurz

Introduction

In Chapter 2, the dominant wild mango in Northeast Thailand was estimated to be *M. caloneura* Kurz. Its flowers and fruits were observed (Plate 3-1) in the subsequent field surveys in this region (Chapter 4). Usually it has thick, stiff leaves, 5 fertile stamens per flower, and small globose fruits weighing ≃40 g each. However, in formal taxonomic treatments, this species has been assigned to either *M. pentandra* Hook. f. or *M. caloneura* Kurz. The confusion can be traced back to two different descriptions of *M. caloneura*. These two descriptions differ in the number of fertile stamens occurring in each flower of *M. caloneura*: Kostermans and Bompard (1993) described 5 fertile stamens, but Chayamarit (2010)

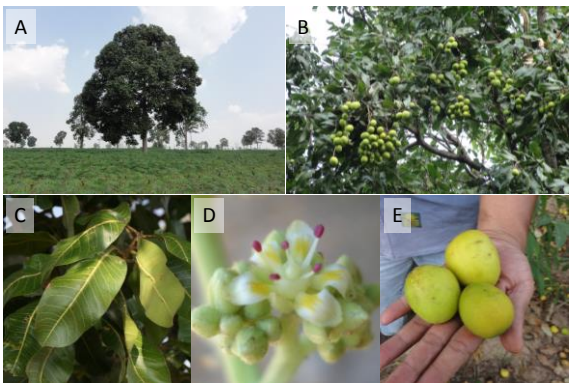

Plate 3-1. A typical wild mango tree found in cassava field in Northeast Thailand: (A) tree shape, (B) fruit on branches, (C) leaves, (D) flower, and (E) fruit. This species has thick, stiff leaves, 5 fertile stamens, and small globose fruits (≃40 g each).

reported only 1. Here, the relevant literature are reviewed to determine the origins of this inconsistency.

Descriptions of *Mangifera caloneura* Kurz

Conflicting reports on the number of fertile stamens

Descriptions of *M. caloneura* Kurz from the original to the latest literature are presented in chronological order in Table 3-1. Hereafter, only on the number of fertile stamens are focused because this is the key trait for diagnosing species.

The first description: M. caloneura *has 1 fertile stamen*

The original description was published by Kurz (1873) (#1 in Table 3-1) in a work entitled "New Burmese plants part II" (in the *Journal of the Asiatic*

Table 3-1. Taxonomic literature on *Mangifera caloneura* presented in chronological order together with details on the number of fertile stamens described; titles of the works are also presented.

Literature	Year	Author	Description on the number of stamens	Titles of the works*
1	1873	Kurz, S.	Stamen 1	New Burmese plants part II
2	1876	Hooker, J. D.	Stamens 1 or 2 fertile	*The Flora of British India, Vol. 2*
3	1877	Kurz, S.	Stamen 1, fertile	*Forest Flora of British Burma, Vol. 1*
4	1883	Engler, A.	Staminibus fertilibus 1–2	*Monographiae Phanerogamarum, Vol. 4*
5	1897	Pierre, L.	Etamines fertiles au nombre de 5	*Flore Forestière de la Cochinchine*
6	1906	Brandis, D.D.	One stamen only perfect, as the description of genus *Mangifera*	*Indian Trees*
7	1948	Fairchild D.	Stamens 5, as translation of Pierre (1897)	The mango relatives of Cochin China; those with five stamen flowers
8	1949	Mukherji, S.	Stamens 5, 1 rarely 2–3 perfect	A monograph on the genus *Mangifera* L.
9	1968	Singh, L. B.	The stamens are five in number, only one, rarely two to three, being perfect	*The Mango: Botany, Cultivation, and Utilization*
10	1993	Kostermans, A. J. G. H. and J. M. Bompard	Stamens 10–12 of which usually 5–6 fertile	*The Mangoes: Their Botany, Nomenclature, Horticulture and Utilization*
11	1997	Bompard, J. M. and R. J. Schnell	The flowers are characterized by the presence of five fertile stamens, as the description of section *Euantherae* Pierre	*The Mango: Botany, Production and Uses*
12	2010	Chayamarit, K.	Stamen 1 fertile	*Flora of Thailand, Vol. 10*

*Titles written in italics indicate titles of books.

Society). Kurz (1873) named the entity *Mangifera caloneura* nov. sp., clearly indicating that it was a previously unrecognized species. The Latin diagnosis contains the following unequivocal information: “stamen 1” (Fig. 3-1).

Descriptions after Kurz (1873)

Descriptions through the next decade refer to 1 or 2 stamens in the species (e.g., Hooker, 1876; Kurz, 1877; Engler, 1883) (Fig. 3-2).

Hooker (1876) (#2 in Table 3-1) described *M. caloneura* flowers with “stamens 1 or 2 fertile” in *The Flora of British India, Vol. 2* (Fig. 3-3). This monograph also contains the original description of *M. pentandra* Hook. f. This is the first work to list both *M. caloneura* and *M. pentandra*. Flowers of *M. pentandra* were described as having “5 perfect” stamens (Fig. 3-3). These early descriptions indicate no overlap in the number of fertile stamens between the species.

Kurz (1877) (#3 in Table 3-1) described *M. caloneura* again (in English) in the *Forest Flora of British Burma, Vol. 1* in which the number of stamens was identical to his previous diagnosis (Kurz, 1873).

Engler (1883) (#4 in Table 3-1) also described *M. caloneura* in the *Monographiae Phanerogamarum, Vol. 4* (Monographs of Flowering Plants) as having “staminibus fertilibus 1–2” (fertile stamens 1–2) and *M. pentandra* as having “staminibus 5” (stamens 5).

Another description: M. caloneura *with 5 fertile stamens*

There exists a different description of *M. caloneura* published by Pierre (1897) (#5 in Table 3-1) in *Flore Forestière de la Cochinchine* (Fig. 3-2). He (*loc. cit.*) divided the genus *Mangifera* into five sections (discussed below in detail). *M. caloneura* Kurz and *M. pentandra* Hook. f. were included in a new section with “etamines 5 à 12 dont dont 5 à 6 fertiles” (stamens 5–12, of which 5–6 are fertile) (Fig. 3-4-1). In the individual species descriptions, members of this section are diagnosed as having 5–6 fertile stamens. *M. pentandra* was described thus: “Etamines 5” (Stamens 5); *M. caloneura* was described thus: “Etamines fertiles au

131. MANGIFERA CALONEURA, nov. sp.

Arbor mediocris, glabra ; folia oblonga ad oblongo-lanceolata, 3-5 pollicaria, petiolo basi valde incrassato 1-½ poll. suffulta, obtuse acuminata, coriacea, glabra, utrinque elegantissime minute et prominenter reticulata, costâ crassa lata præsertim supra prominente et subplana percursa, nervis lateralibus vix curvis 18-20, tenuibus ; flores parvi, sessiles v. subsessiles paniculam terminalem tomentosam amplam formantes ; calyx pubescens ; petala lanceolata, acuta, reflexa, lineam circiter longa, ciliolata, alba, medio linea citrina percursa ; stamen 1, anthera atropurpurea ; discus 5-lobus, lævis ; drupæ ovi gallinacei magnitudine subreniformi-ovoideæ, læves, obtusæ, aurantiacæ v. luteæ, acido-dulces, subteretes.—*Pegu, Martaban.* M. Indicæ affinis, reticulatione elegantissima statim recognoscenda.

N. B.—Bouea Brandisiana, Kurz in Journ. As. Soc. 1871, p. 50, ad B. Burmanicam, Griff. in hocce diario, 1854, p. 634, referenda.

Fig. 3-1. The original description of *Mangifera caloneura* prepared by Kurz (1873). Underlining is that of the authors.

2. **M. caloneura,** *Kurz in Beng. As. Soc. Journ.* 1873, ii. 66; leaves oblong or oblong-lanceolate finely reticulated between the nerves acuminate, panicle spreading tomentose, flowers crowded sessile, petals 5 with 3 ridges, stamens 1 or 2 fertile, ovary rough, style lateral or basal.

MARTABAN, *Kurz.*

A moderate sized tree. *Leaves* 4–6 by 1¼–1¾ in., equally reticulated on both surfaces between the 16–20 pairs of arching nerves ; petiole ⅔–1 in., much thickened at the base. *Panicle* tomentose throughout. *Flowers* much as in *M. indica*, the reflexed petals having 3 ridges. (*Fruit* as large as a hen's egg, subreniform, smooth, obtuse, yellow, sweet and acid, Kurz).—My specimens of this are imperfect ; it is evidently very nearly indeed allied to *M. indica*, differing chiefly in the very fine reticulation of the leaves, as pointed out by Kurz. Wallich's *M. indica*, 8487 H. from Tavoy is possibly the same.

3. **M. pentandra,** *Hook. f.* ; leaves oblong or oblong-lanceolate acuminate reticulated on both surfaces, panicle spreading tomentose, flowers crowded subsessile, petals 5 with 3 ridges, stamens 5 perfect, ovary smooth, style subterminal.

MALACCA, *Griffith, Maingay.*

A tree. *Leaves* 5–12 by 2–4 in., quite similar to those of *M. indica*, as are the panicles and flowers, except that Maingay describes the disk as more fully and fairly developed than in any form he had figured. The 5 stamens are all perfect and unequal. The petals are yellowish-white, with yellow brown ridges. Maingay figures the style as nearly terminal, and the ovule as quite laterally suspended.—The Malay name is 'Mam ploni,' which means mango ripened artificially.

Fig. 3-3. The description of *Mangifera caloneura* and *Mangifera pentandra* prepared by Hooker (1876). Underlining is that of the authors.

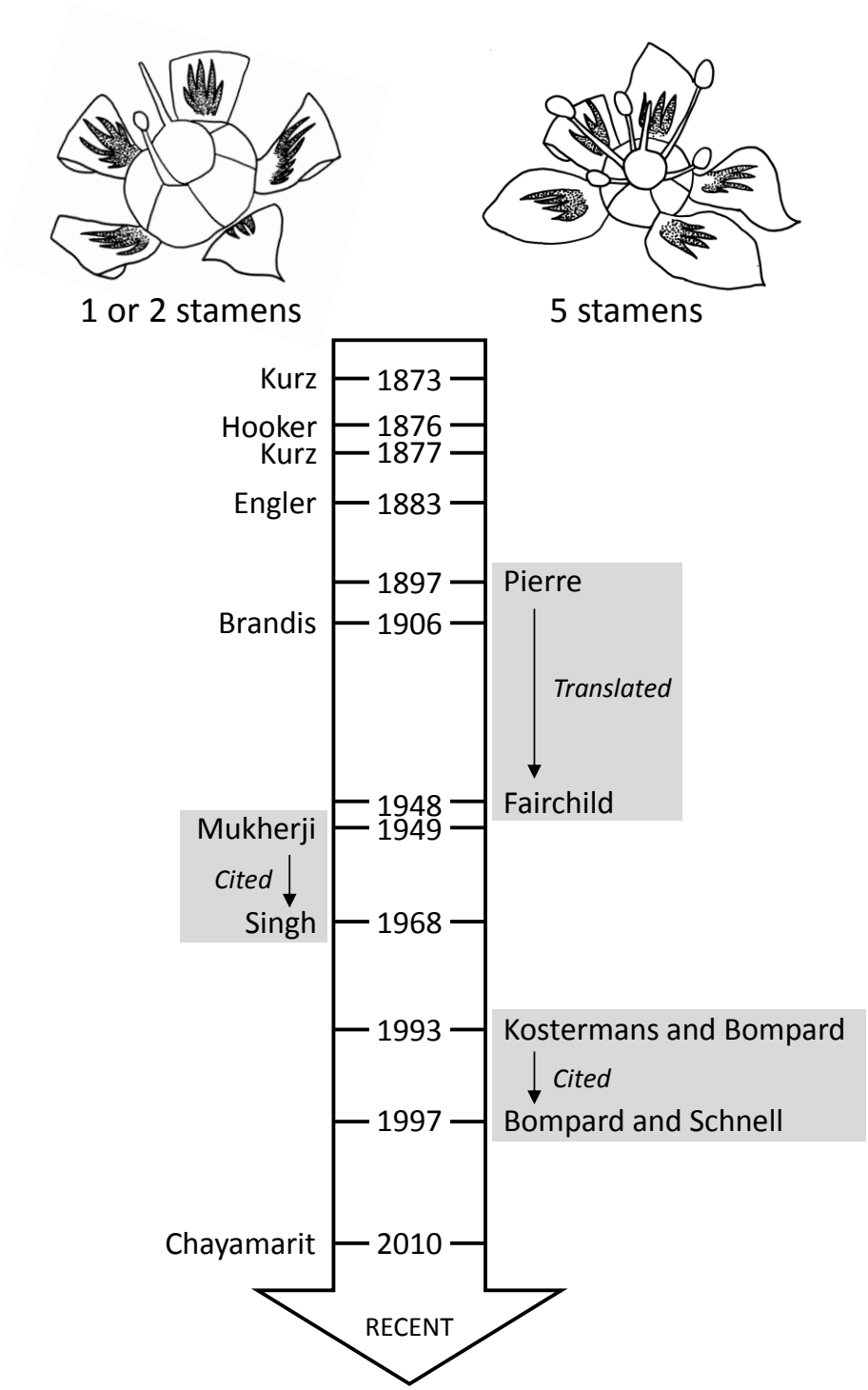

Fig. 3-2. Chronological chart of literature describing *Mangifera caloneura* dichotomized by the number of fertile stamens.

Section I. — Euantherac. Disque court et épais. Etamines 5 à 12 dont dont 5 à 6 fertiles, les autres réduites à des filets.

1. M. Duperreana. [*Voyez t.* 362 *A*].

2. M. pentandra, *Hook. f. Fl. Brit. Ind. II.* 14; — *Engler. Monog. Phanerog. vol. IV.* 198. Feuilles oblongues acuminées, aiguës aux deux extrémités, coriaces, munies de 16 à 18 paires de petites côtes plus élevées en dessous qu'en dessus, à nervation tertiaire finement réticulée. Panicules plus longues que les feuilles, à fleurs tomenteuses presque sessiles et à cymes très condensées. Sépales longs de 3 mm. pubescents dorsalement. Pétales longs de 4,5 mm., larges de 2 mm. connés au disque, à la base, munis de sept nervures glanduleuses dont 3 s'étendant jusque vers le milieu. Etamines 5 longues de 2 mm. à filets subégaux aplatis à la base. Style presque centrique.

Espèce très voisine de la précédente et de la suivante, s'en distingue par les 7 nervures inégales de ses pétales. Son fruit n'est pas décrit, mais ne mûrit pas naturellement. De là son nom malais : *Mam. Ploni*, suivant Mainguay. [*Voyez t.* 364. *F.*]

3. M. caloneura. *Kurz Fl. Burm.* 1. 303 ; — *Hooker. l. c. p.* 14 ; — *Engler l. c. p.* 200. Feuilles oblongues-lancéolées munies de 16 à 22 paires de petites côtes reliées par une nervation tertiaire fortement réticulée. Panicules velues condensées et pédicellées. Sépales longs de près de 2 mm. ciliés, velus en dehors. Pétales longs de près de 4 mm. munis de 3 nervures glanduleuses, très rapprochées, s'étendant jusqu'au milieu du limbe, sensiblement plus étroits que dans le *M. pentandra*. Etamines fertiles au nombre de 5 de même longueur. Une sixième étamine, réduite au filet, ayant la forme d'un éperon un peu excentrique existe comme dans le *M. pentandra*. Style de la longueur des étamines un peu latéral. Drupe longue de 5-6 cm. jaune subacide, un peu réniforme et atténuée en haut.

Espèce largement répandue depuis le Pégu jusqu'à la province de Petchapury, sur la côte orientale du Siam. [*Voyez t.* 364. *G.*]

Fig. 3-4-1. The description of *Mangifera caloneura* prepared by Pierre (1897). Underlining is that of the authors.

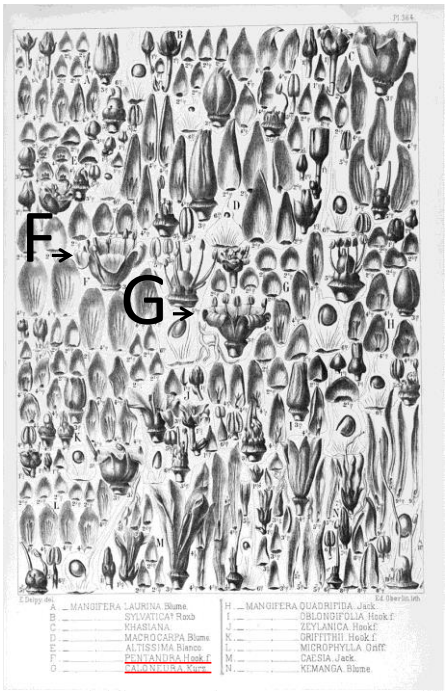

Fig. 3-4-2. The illustration of (F) *Mangifera pentandra* and (G) *Mangifera caloneura* in Pierre (1897). Letters of F and G, arrow, and underlining are those of the authors.

nombre de 5" (The number of fertile stamens 5) (Fig. 3-4-1). The flowers are illustrated by Pierre (1897) in the *Flore Forestière de la Cochinchine* (Fig. 3-4-2).

Five decades later, the descriptions by Pierre (1897) became a focus of attention and were published again in English by Fairchild (1948) (#7 in Table 3-1) in a work entitled "The mango relatives of Cochin China; those with 5 stamen flowers."

Descriptions following Pierre (1897)

The descriptions of Pierre (1897) were not accepted by most subsequent taxonomic works (e.g., Brandis, 1906; Mukherji, 1949; Singh, 1968; Chayamarit, 2010) (Fig. 3-2). Brandis (1906) (#6 in Table 3-1) listed three *Mangifera* species, including *M. caloneura*, and described them as having "1 stamen only perfect". Mukherji (1949) (#8 in Table 3-1) described 41 *Mangifera* species in his work entitled "A monograph on the genus *Mangifera* L." *M. caloneura* Kurz was described as having "stamens 5, 1 rarely 2–3 perfect", and *M. pentandra* Hook. f. as having "stamens 5, all perfect." He also indicated that *M. pentandra* is closely related to *M. caloneura* although the two differ in the numbers of perfect stamens. Mukherji's (1949) descriptions of 15 species, including *M. caloneura* and *M. pentandra*, were incorporated into Singh's (1968) *The Mango: Botany, Cultivation, and Utilization* (#9 in Table 3-1).

Resurrection of Pierre's (1897) mango taxonomy

Kostermans and Bompard (1993) (#10 in Table 3-1) accepted Pierre's (1897) descriptions (the first acceptance since 1897) in their monograph *The Mangoes: Their Botany, Nomenclature, Horticulture and Utilization*. They (Kostermans and Bompard, 1993) described *M. caloneura* as having "stamens 10–12 of which usually 5–6 fertile," and *M. pentandra* as having "stamens (3–)5." Importantly, Kostermans and Bompard (1993) indicated that "The type specimen of *M. caloneura* has abnormal flowers, where stamens have become narrowly petaloid." This note indicates that Kurz (1873) likely missed 5 fertile stamens in his type material. An isotype specimen of *M. caloneura* prepared by Kurz is

available for online viewing[3] (Fig. 3-5). Bompard and Schnell (1997) accepted the taxonomic views of Kostermans and Bompard (1993) in their work *The Mango: Botany, Production and Uses* (#11 in Table 3-1).

Fig. 3-5. Isotype specimen of *Mangifera caloneura* housed in the Royal Botanic Gardens, Kew, UK. (Collector & no.: Kurz, W. S., 2026.)

The latest description

Chayamarit (1994) published a "Preliminary checklist of the family Anacardiaceae in Thailand" in the *Thai Forest Bulletin*. She included *M. caloneura* in the flora of Thailand. Subsequently, she (Chayamarit, 2010; #12 in Table 3-1) revised the descriptions of all species in the Anacardiaceae occurring in Thailand. In this monograph, *M. caloneura* is described as having "stamen 1 fertile", and *M. pentandra* as having "stamens 5, all fertile." This is the latest description of *M. caloneura*.

Changing section assignment of *M. caloneura*

The genus *Mangifera* has been divided into several sections and species assignments within this framework have changed over time. Here, these taxonomic shifts, with particular focus on *M. caloneura* are addressed.

Hooker (1876) was the first to assign *M. caloneura* to a generic section. He (*loc. cit.*) subdivided the genus *Mangifera* into two sections based on the size of the flower disc. Engler (1883) accepted Hooker's sections, and divided one of them into two groups based on differences in the number of petals. Pierre (1897) subdivided the genus *Mangifera* by disc development into no less than five sections; *M. caloneura* was assigned to a new section (section I *Euantherae*

[3] The Royal Botanic Gardens, Kew. [Online] http://apps.kew.org/herbcat/getImage.do?imageBarcode=K000695015 (browsed on Jun. 9, 2015)

Pierre), which contained species with 5 or 6 fertile stamens. Mukherji (1949) rejected Pierre's (1897) subgeneric taxonomy, part of which was also criticized by Kostermans and Bompard (1993). Mukherji (1949) and Singh (1968) ignored Pierre's (1897) subdivisions, and reverted to those of Hooker (1876). However, Kostermans and Bompard (1993) reinstated the *Euantherae*, and assigned *M. caloneura* to this section. This section was diagnosed by "staminibus fertilibus 5–6" (fertile stamens 5–6).

Both Pierre (1897) and Kostermans and Bompard (1993) referred to the number of stamens in their descriptions of the section. The two publications list *M. caloneura* with 5 fertile stamens; accordingly, the species was assigned to a generic section with 5–6 fertile stamens. However, had these authors described *M. caloneura* with a single fertile stamen, the entity would necessarily have been assigned to a different section. Thus, the number of fertile stamens is crucial for the section assignment of *M. caloneura*.

Recent trends in the literature adopting the classification of Kostermans and Bompard (1993)

Most scholarly works describe *M. caloneura* as having only 1 or 2 fertile stamens. Only Pierre (1897) and Kostermans and Bompard (1993) describe 5 or 6 fertile stamens. Nevertheless, there has been wide acceptance of their conclusions in popular literature and online (e.g., Gardner *et al*., 2000; TISTR, 2009). A contributory factor in this wide acceptance may stem from the fact that the work by Kostermans and Bompard (1993) has been widely read. It was published as a report for a project funded by several influential international organizations, including the WWF (World Wide Fund for Nature), and was written for an expected audience of horticulturists and mango growers rather than professional taxonomists. Most readers are unlikely to have delved into taxonomic detail presented in rather difficult literature.

Recent studies dealing with *M. caloneura*

Specimens with 5 stamens assigned to M. caloneura

M. caloneura has recently been subjected to professional taxonomic analysis as follows: Eiadthong *et al*. (1999b) examined 13 *Mangifera* species in Thailand and reported on their morphological and ecological characteristics. They and co-workers analyzed phylogenetic relationships among the *Mangifera* species using a variety of molecular markers, such as RFLPs (restriction fragment length polymorphisms) of chloroplast DNA (Eiadthong *et al*., 1999a), AFLP (amplified fragment length polymorphism) (Eiadthong *et al*., 2000a), and the sequence in the ITS (internal transcribed spacer) region of nuclear ribosomal DNA (Yonemori *et al*., 2002). Specimens of *M. caloneura* sampled in these works appeared to have 5 fertile stamens (Eiadthong *et al*., 2000b).

Specimens assigned to M. caloneura *without reference to previous descriptions*

Sawangchote *et al*. (2009) used leaves of extant *M. caloneura* for comparison with fossil leaves of *Mangifera*. Ecological studies in Thailand on forest species composition have also assigned specimens to *M. caloneura* (Marod *et al*., 1999, 2002; Yahya *et al*., 2008). However, in all of these studies there is no presentation of the evidence used for species assignment.

Inconsistency between the type specimen and subsequent descriptions

Pierre's (1897) description of the number of fertile stamens was radically different from that of Kurz (1873). The difference is so large that the authors were likely not referring to the same species. Nevertheless, Kurz has always been used as the binomial authority. Kostermans and Bompard (1993) supported Pierre's (1897) description and assumed that the type specimen prepared by Kurz (1873) is abnormal in its petal-like stamen structure. Pierre (1897) did not address this issue.

What is *muang paa*?

Finally, the species assignment of *muang paa* in Northeast Thailand should be discussed (Plate 3-1). Identification here is based on the two recent publications: Chayamarit (2010), in which *M. caloneura* is described as having 1

fertile stamen, and Kostermans and Bompard (1993), in which the species is described as having 5 fertile stamens.

On the basis of collections in Thailand, Chayamarit (2010) concluded the existence of four *Mangifera* species with 5 fertile stamens. According to her (*loc. cit.*) classification, *muang paa* is assigned to *M. pentandra* since it has three ridges on petals and no staminodes.

However, according to the classification of Kostermans and Bompard (1993), which reported the existence of three species with 5 fertile stamens in the genus, the leaf shape of *muang paa* indicates possible affinities with *M. caloneura* and *M. pentandra* (among three candidate species). *M. caloneura* was described as follows: “Petals 1.5–2 mm long. Ridges not free from the petals. Flowers white in almost sessile glomerules. Stamens 10–12 of which usually 5–8 fertile,” and *M. pentandra* as follows: “Petals 3–4.5 mm long. The three inner ridges apically (at the reflexion) slightly free from the petal surface. Flowers yellowish. Fertile stamens (3–)5.” Thus, the lengths of the petals and ridges, and the numbers of stamens, including those that are not fertile, distinguish the two species.

In *muang paa*, the ridges are free at the tip of the petal, and no staminode is present in the flower (Plate 3-1). Petal length is ≃4 mm. Thus, *muang paa* is identified as *M. pentandra* by the criteria published by Kostermans and Bompard (1993).

Why is *muang paa* sometimes identified as *M. caloneura*? It is speculated that information on the distribution and ecology of *M. caloneura* and *M. pentandra* may lead to misidentification. Kostermans and Bompard (1993) described the distribution and ecology of *M. pentandra* as follows: “Malay Peninsula, more rare in North Borneo, perhaps also in Thailand. Wet, evergreen tropical forest, lowland,” and those of *M. caloneura* as follows: “From Southern Burma through Thailand to Indochina”; the habitats of the species were described as follows: “Both in ever wet tropical lowland rain forest and in monsoon (deciduous) forest.” The ecology in Northeast Thailand is monsoon deciduous forest. *Muang paa* collected in such habitat is likely to be identified as *M. caloneura* by lay botanists.

Conclusion

This review describes the inconsistencies within the taxonomic literature on *M. caloneura*. The original description was published by Kurz (1873) and accepted by most subsequent taxonomic works other than those of Pierre (1897) and Kostermans and Bompard (1993), who listed different numbers of fertile stamens from those described by Kurz (1873). Thus, a dichotomy exists in the literature, with descriptions based on Kurz (1873) reporting 1 fertile stamen per flower and those based on Pierre (1897) reporting 5 fertile stamens per flower. When an original description is modified, the new version must be identified by changing either the binomial authority or the specific epithet. Kostermans and Bompard (1993) observed the type specimen and concluded that it was abnormal; they then prepared a description that was different from the original. Despite the valuable conclusions of these authors, they (*loc. cit.*) changed neither the authority nor the specific epithet. This incomplete procedure has caused confusion among subsequent studies. Until taxonomic decisions have been finalized, working botanists should reduce potential confusion by either following the original description or by providing alternate descriptions that are comprehensively linked to the existing literature.

Finally it should be noted that *muang paa* in Northeast Thailand can be assigned to *M. pentandra* using either of the extant descriptions. From the following chapter, this species is identified as *M. pentandra*, and *M. caloneura* assigns based on the description of Chayamarit (2010) without an explanation.

SUMMARY Species assignment to *M. caloneura* Kurz is difficult because there are two different descriptions: one indicates the presence of only 1 fertile stamen per flower and the second indicates 5 fertile stamens. Taxonomic developments over 138 years are tracked to demonstrate how inconsistencies have arisen. The type diagnosis by Kurz describes 1 fertile stamen per flower; nevertheless, Kurz has been retained as the binomial authority in all subsequent

literature, even in works describing the presence of 5 fertile stamens. It is suggested that the current identification works should follow the original description, or should provide which descriptions they are based on.

Chapter 4

Mangifera Species in Northeast Thailand —Especially on *Kalon* Mango, a Superior Fruit from *Mangifera pentandra* Hook. f.—

Introduction

M. pentandra is dominantly found in Northeast Thailand, according to the field surveys in Chapter 2. Remnant stands occur frequently along roadsides and in crop fields. The trees are very large, with some trees exceeding 20 m in height. Flowering begins in December at the onset of the dry season. Fruits mature and start falling in mid-April following *Songkran* (Thai New Year), after which the rainy season commences. The fruit of *M. pentandra* is much smaller than that of *M. indica*, but the taste is comparable. Fruit of this species is familiar to local Thai people, who refer to this drupe as *mak muang paa*[4] (*paa* mango).

However, a superior mango known locally as *mak muang kalon* (*kalon* mango) grows in Northeast Thailand. Although the trees are identifiable as *M. pentandra*, the local people are able to distinguish *kalon* mango, which is not found in the forests. It grows near human settlement, but the people do not appear to have been subjected to horticultural breeding programs.

The characteristics of *kalon* mango have not been comprehensively

[4] The word *mak* translates to fruit, and is often abbreviated. The words *muang* and *paa* translate to mango and forest (or wild), respectively.

described in the botanical literature. For example, *kalon* mango trees have sometimes been assigned incorrectly as *M. caloneura* (e.g., Smitinand, 1980), and criteria for distinguishing *kalon* mango from *paa* mango have not been reported. In this chapter, *M. pentandra* was thoroughly investigated in Northeast Thailand, local names and uses were recorded linking to the correct botanical species, and differences between *kalon* and *paa* mangoes were clarified. A discussion on relationships between people and wild fruit trees at the onset of a domestication process were also provided.

The Research Area, Northeast Thailand

Northeast Thailand (Isan)[1] was selected for survey because stands of *M. pentandra* occur densely there, and it is the only region where *kalon* and *paa* mangoes are distinguished by the people (according to broad surveys in Chapter 2). The rainy season in Isan begins at the end of April or in May when southwest monsoons bring humid air from the Indian Ocean. The dry season runs from November, during which dry northeast monsoon air flows. The Khorat Plateau covers a large part of Isan, and the terrain comprises undulating flatlands at elevations of 100–200 m above sea level and is also a basin surrounded by mountains with the Annamite Range (over 2000 m) in the east and the Dong Phaya Yen Mountains (around 1000 m) in the southwest. The main vegetation was originally a mixed dry deciduous forest of dipterocarp trees, except in the northwestern area, where an evergreen hill forest occurs at elevations exceeding 1000 m in some locations (on a gradient continuum extending into North Thailand). The surface of the Khorat Plateau has been weathered to an infertile, sandy soil that retains water and nutrients poorly. In the period 1961–1990, annual rainfalls[5] reached 1070 mm and 1200 mm in Nakhon Ratchasima and Khon Kaen, respectively. Precipitation in this region exceeds 100 mm per month only in the period from May to September, with bimodal peaks in May and September (Nawata *et al.*, 2005).

Isan is a rural area where rice farming predominates in irrigated paddy

[5] Rainfall data were collected at the Meteorological Department in Bangkok.

fields first established during the 1930s in the backwater swamps of the Chi and Mun rivers (Takaya and Tomosugi, 1972). Rain-fed paddy fields were developed after the 1930s (especially in the decades after the 1970s) on undulating slopes behind the backwater swamps (Takaya, 1985). Sparse populations of natural trees, *M. pentandra* among them, remain in these relatively new paddy fields. Originally, low-density woodlands of mixed deciduous species covered the upper slopes, but most were cut by 1980 to create croplands (Takaya, 1985) that now produce maize and cassava. A typical dry dipterocarp forest remains on the hilltops, but *M. pentandra* trees do not grow there.

Most human inhabitants in Isan are immigrants from Laos, and a vernacular of the Lao language (Isanese) is used there. Both Thai and Isanese are now spoken in the region, together with Khmer along the Cambodian border. Interviews were conducted in Thai and Isanese through an interpreter who spoke both.

The Target Species, *Mangifera pentandra*

Farmers in Isan make extensive use of wild plants and animals gathered from croplands including paddy fields, forests, homegardens, rivers, and ponds. Collected plants are used for food, medicine, materials for tools, and timber. Not surprisingly, these relationships between people and wild plants are topics for academic investigation; Cruz-Garcia and Price (2011), and Somnasang and Moreno-Black (2000) have undertaken ethnobotanical studies in the region.

Wild vegetation has been left standing in crop fields of Isan, and the products of this vegetation, including fruits, wood, and other components, are collected and put to use. *M. pentandra*, generally known as *muang paa*, is found in this vegetation and used locally, mainly for its edible fruit. The species is impressive trees because local people for its fruits have a preferable taste which is comparable to that of *M. indica*. Especially, a variation of *M. pentandra* that produces large, superior fruits is called *muang kalon*. This variation is recognized only in the local classification of Isan. *M. pentandra* has not been subjected to ethnobotanical studies in Isan. In Chapter 2 both *muang kalon* and *muang paa*

were recorded as local mango names, but the difference between the two was not clarified. Therefore, an investigation of *M. pentandra* was undertook with a particular focus on *kalon* and *paa* mangoes.

During field surveys, *M. pentandra* can be recognized at a distance by its very straight trunk and dark-green canopy. Trees often grow into very large trees with leaves that are broader, thicker, and harder than those of *M. indica*. *M. pentandra* is diagnosed among its congeners by 5 fertile stamens. Most of the other species have only 1 fertile stamen except for *M. cochinchinensis* Engl., which also has 5 fertile stamens but is identical from *M. pentandra* from its obovate leaves and smaller fruit (3 by 1.5 cm, Chayamarit, 2010). Besides, *M. cochinchinensis* distributes in evergreen forest, and was not found in the survey area. Therefore, flower morphology allows ready identification of *M. pentandra*, and the floral investigations of each *kalon* mango tree were conducted with definitive species assignment.

Methods

Tree surveys

Tree surveys and interviews with local people were conducted in two ways. In the first, villages were visited and the inhabitants were asked whether *kalon* or *paa* mango occurred in the vicinity. If they replied affirmatively, the locations of trees were asked, observations on the trees were conducted, and interviews were conducted further with the villagers. In the second procedure, independent surveys for *M. pentandra* were conducted, and observations and interviews with neighboring villagers were conducted. Both procedures were performed in December 2008, from December 2009 to January 2010, and in June 2010 (survey except for floral observation was conducted), January 2011, December 2012, and February 2013. Overall, the survey included 171 trees at 137 locations across all of Isan (Fig. 4-1). In addition, neighboring regions including North and East Thailand were explored, but no *kalon* mango trees were found there. Thus, no data was present on *M. pentandra* trees beyond the borders of Isan.

Once the occurrence of *M. pentandra* trees had been confirmed, their coordinate locations by global positioning system (GPS) and elevations were determined. Subsequently, tree morphology, bark color, leaf and flower traits, and diameters at breast height (DBH) were recorded; the average leaf lengths and widths were calculated. the height and canopy size of each tree were also determined. Specimens of *kalon* and *paa* mangoes with inflorescences were prepared for preservation and storage in the Forest Herbarium (BKF) of Thailand.

Interviewees provided information on local names, uses, and distinguishing traits of *kalon* and *paa* mangoes.

Fruit analysis

Fruit analyses were performed in April 2011 and May 2013. Among the *M. pentandra* trees that had already been surveyed and identified, *kalon* and *paa* mango trees in Khon Kaen, Buriram, Surin, Maha Sarakham, and Nakhon Ratchasima were revisited. Four or five fruits were collected from each of five *kalon* mango and six *paa* mango trees for totals of 24 *kalon* mango and 30 *paa* mango fruits. The weight, length, width and thicknesses of each were measured, then the seeds were extracted and their weights and linear dimensions were determined. The juice was squeezed out and total soluble solid contents (°Brix) were measured with a handheld refractometer (PR-101, Atago Co., Tokyo, Japan) and titratable acidity (%) by titration against a NaOH solution using phenolphthalein as an indicator. Percent acidity was calculated on a weight basis in citric acid equivalents.

Results and Discussion

Distribution

The 137 locations with confirmed *M. pentandra* trees were widely dispersed (Fig. 4-1). Most grew in crop fields, along roadsides, and in/around house yards. From the composition of the surrounding vegetation, it is surmised that the trees were once components of extirpated mixed dipterocarp forests. *M. pentandra* tended to occur on undulating slopes at altitudes of 100–200 m. The

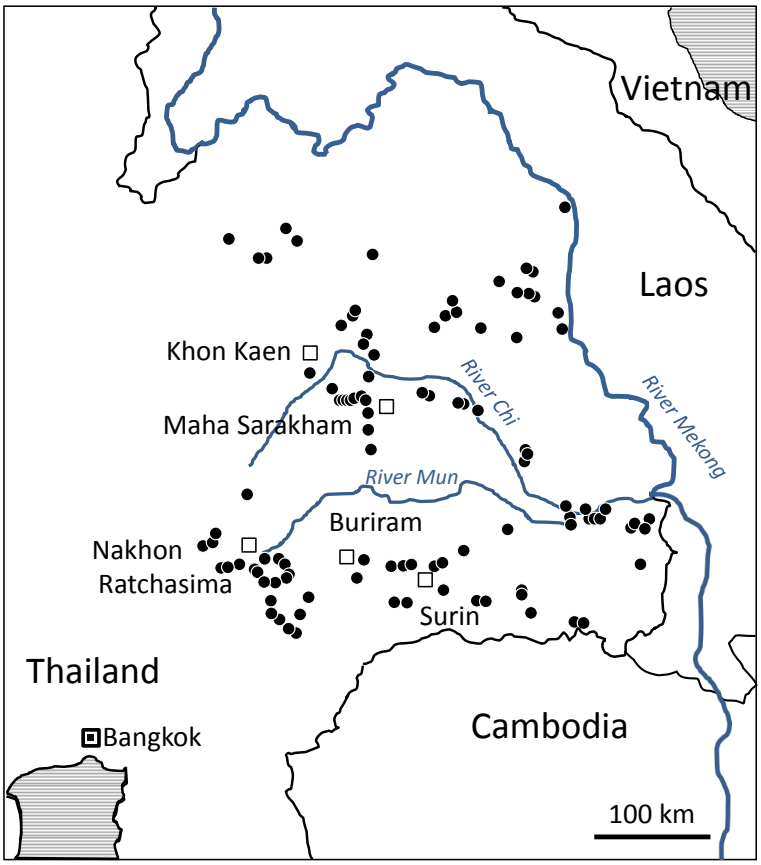

Fig. 4-1. Locations of the *Mangifera pentandra* trees observed in Northeast Thailand; the survey included 171 trees at 137 locations.

trees were very rare on floodplains, dry hilltops, and mountain slopes at high altitudes. They were notably absent on wet lowlands, including floodplains, such as the middle part of the Mun Basin. Thus, preferred habitat conditions for the species do not include very moist environments. *Mangifera* species were not found in the *khok* vegetation, a sparse forest of dry dipterocarp trees often remained on hilltops. *Khok* soil is dry, retains water and nutrients poorly, and is unsuitable for crop production. *M. pentandra* was also absent in evergreen forests on hillslopes at altitudes exceeding 1000 m, where a different congener, likely *M. linearifolia* (Mukherji) Kosterm.[6], was dominant.

[6] The species in question had glabrous inflorescences, yellow, cup-shaped flowers with 1 fertile stamen, 5 (rarely 4) petals 4 mm long, and a 5-lobed disc. The seed was 5 cm long. It was described as bearing yellow, small fruit. Narrowly lanceolate leaves 4 cm in width were particularly distinctive. Among 17 *Mangifera* species listed in *Flora of Thailand* (Chayamarit, 2010), *M. camptosperma* Pierre appears to fit this description. However, Kostermans and Bompard (1993) did not accept the binomial *M. camptosperma* Pierre and reduced it to a synonym of *M. gedebe* Miq. Previously, Mukherji (1949) assigned *M. camptosperma* trees with linear–lanceolate leaves to the new variety "*M. camptosperma* Pierre var. *linearifolia* var. nov." Subsequently, Kostermans and Bompard (1993) distinguished *M. camptosperma* var. *linearifolia* from the nominal variety of *M. camptosperma* with a new nomenclature: "*M. linearifolia* (Mukherji) Kosterm., stat. nov." Thus, the species in question is most likely *M. linearifolia* (Mukherji) Kosterm. However, the fruit of *M. linearifolia* (Mukherji) Kosterm. was described as "*c.* 10 cm," whereas the species in question probably has smaller fruit judging from the measured seed size (5 cm long). For these reasons, identification remains unresolved.

Local names

Local names were assigned by interviewees to 100 of 171 confirmed *M. pentandra* trees. Two-third of these (63 trees) were assigned as *muang paa* and one-third (29 trees) as *muang kalon* (Table 4-1). Six additional local names were assigned to the remainder, although at low frequency.

Muang is the Thai word for mango. *Paa* originally translated to "forest," but its meaning has been extended when used in the *muang paa* combination, which translates to "wild mango."

The meaning of *kalon* is unknown among the Isanese people, although some dictionaries translate the word to "glib-tongued." Smitinand (1980), for example, assigned *muang kalon* to *M. caloneura* Kurz. There is phonetic similarity between '*kalon*' and '*caloneura*.' However, *caloneura* is a connective term in botanical Latin meaning beautiful (*kalos*) nerve (*neuron*). Therefore, no relationship exists between *caloneura* and *kalon*, and *muang kalon* is assigned to *M. pentandra*. *Muang kalon* has a synonym, *muang kigrabong*, which is an Isanese name. The Khmer name for *kalon* mango, *swai kro*, has been recorded in Surin, a Thai province close to the Cambodian border. *Swai* indicates mango. *Kro* corresponds to *kalon* in Thai.

Muang kalon was recorded as a local name for *M. pentandra* in Khon Kaen, Maha Sarakham, Nakhon Ratchasima, Buriram, and Surin, indicating a wide distribution in the southwestern area of Isan. The name was not encountered in the northeast area of Isan along the Mekong River. However, *kalon* mango was known throughout Isan, although *kalon* trees were not found in all areas. The ages of those members of the people who knew of *kalon* mango ranged between 20 and 70 years old. Thus, knowledge of this variation extended throughout the human population without regard to province or age.

The differences between *kalon* and *paa* mangoes were described by local people as follows: "*kalon* mango is more delicious" (Maha Sarakham); "*kalon* mango is bigger and mango-like in shape, while *paa* mango is smaller and roundish" (Surin); "leaves of *kalon* mango are thinner than those of *paa* mango"

(Maha Sarakham) (Table 4-2). Hence, criteria used for distinguishing the two include fruit taste, size, and shape, and leaf thickness.

Table 4-1. Local names of *Mangifera pentandra* in Northeast Thailand; eight local names were assigned among 100 trees observed.

Local names	Meaning	The number of trees[z]	The number of informants
Muang paa[y]	Forest mango	63	50
Muang kalon[x]	(Unknown)	29	22
Muang sii[v]	Hole making mango	5	5
Muang khan	Itchy mango	4	4
Muang kigrabong[wv]	(Unknown)	3	1
Muang khai	Egg mango	1	1
Muang som	Sour mango	1	1
Muang kao kwaang	Nine deer mango	1	1

[z]Total number of trees did not sum up to 100, because plural names could be recorded from single tree.

[y]Six trees that had a Khmer name *swai puri* (meaning "wild mango") were also included.

[x]Three *muang kalon* trees had the Khmer name *swai kro* as well.

[w]*Muang kigrabong* was described as a synonym of *muang kalon*.

[v]Local names in Isanese.

Table 4-2. Description of *Mangifera pentandra* noted by local people in Northeast Thailand.

Provinces	Informants		Description	
	Sex	Age	*Kalon* mango	*Paa* mango
Buriram	Male	70's	Only found near settlements	
Maha Sarakham	Female	30's	Delicious fruit	Itchy fruit
Maha Sarakham	Male	50's	Thin leaves	Thick leaves
Nakhon Ratchasima	Male	40's	Suitable for making *kuan*[z]	Not suitable for *kuan*[z]
Nakhon Ratchasima	Female	50's	Cultivated mango	Wild mango
Nakhon Ratchasima	Male	70's	Not found in forests	Found in forests
Surin	Female	50's	Bigger and mango-like shaped fruit	Smaller and roundish fruit

[z]*Kuan*: mango preserve resembling toffee or jam.

Table 4-3. Morphological and qualitative traits of fruits, seeds, and juice of *Mangifera pentandra*.

Local classification	Fruit					Seed				Juice	
	Weight (g)	Length (mm)	Width to length ratio	Thickness to width ratio	Pulp to fruit weight ratio	Weight (g)	Length (mm)	Width to length ratio	Thickness to width ratio	Sugar content (°Brix)	Acid content[z] (%)
Kalon mango (n=24)	52.8	53.5	0.77	0.94	0.77	12.1	45.0	0.63	0.62	19.2	1.0
Paa mango (n=30)	38.3	43.2	0.87	0.94	0.71	10.6	35.0	0.75	0.70	15.0	1.6
Significance	**	**	**	n.s.	**	n.s.	**	**	**	**	*

**, *, and n.s. indicate significant differences by t-test at $P<0.01$, $0.01 \leq P<0.05$, and not significant, respectively.

[z]Average acid content of several fruits for each tree was measured.

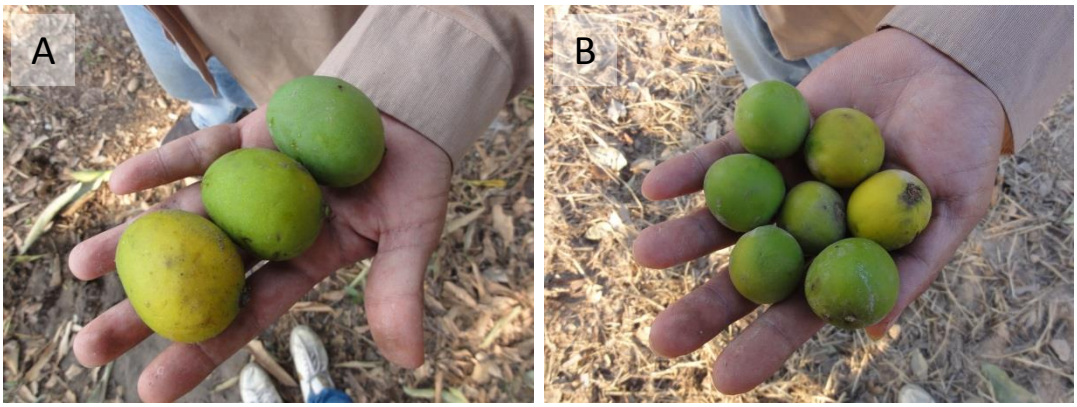

Plate 4-1. Fruits of *kalon* mango (A, Surin) that were significantly larger and longer than those of *paa* mango (B, Buriram).

Plate 4-2. Hanging fruits of *kalon* mango appear greenish in color (A, Surin); fruits of *paa* mango turning yellowish prior to falling (B, Buriram).

Morphology and quality of *kalon* and *paa* mangoes

Significant differences between the two mangoes in some morphological traits and eating quality were detected. *Kalon* fruits were 52.8 g in weight on average and had a low average width/length ratio (0.77), while *paa* fruits weighed 38.3 g on average and had a higher average width/length ratio (0.87) (Plate 4-1 and Table 4-3). In addition, *kalon* fruits tended to be flattened. No significant differences in total seed weight were observed, even though *kalon* fruits were heavier, indicating that they had a higher proportion of edible weight (0.77) compared to *paa* fruits (0.71). Seeds of both were ellipsoidal and flattened in shape, but *kalon* seeds were significantly longer and more flattened.

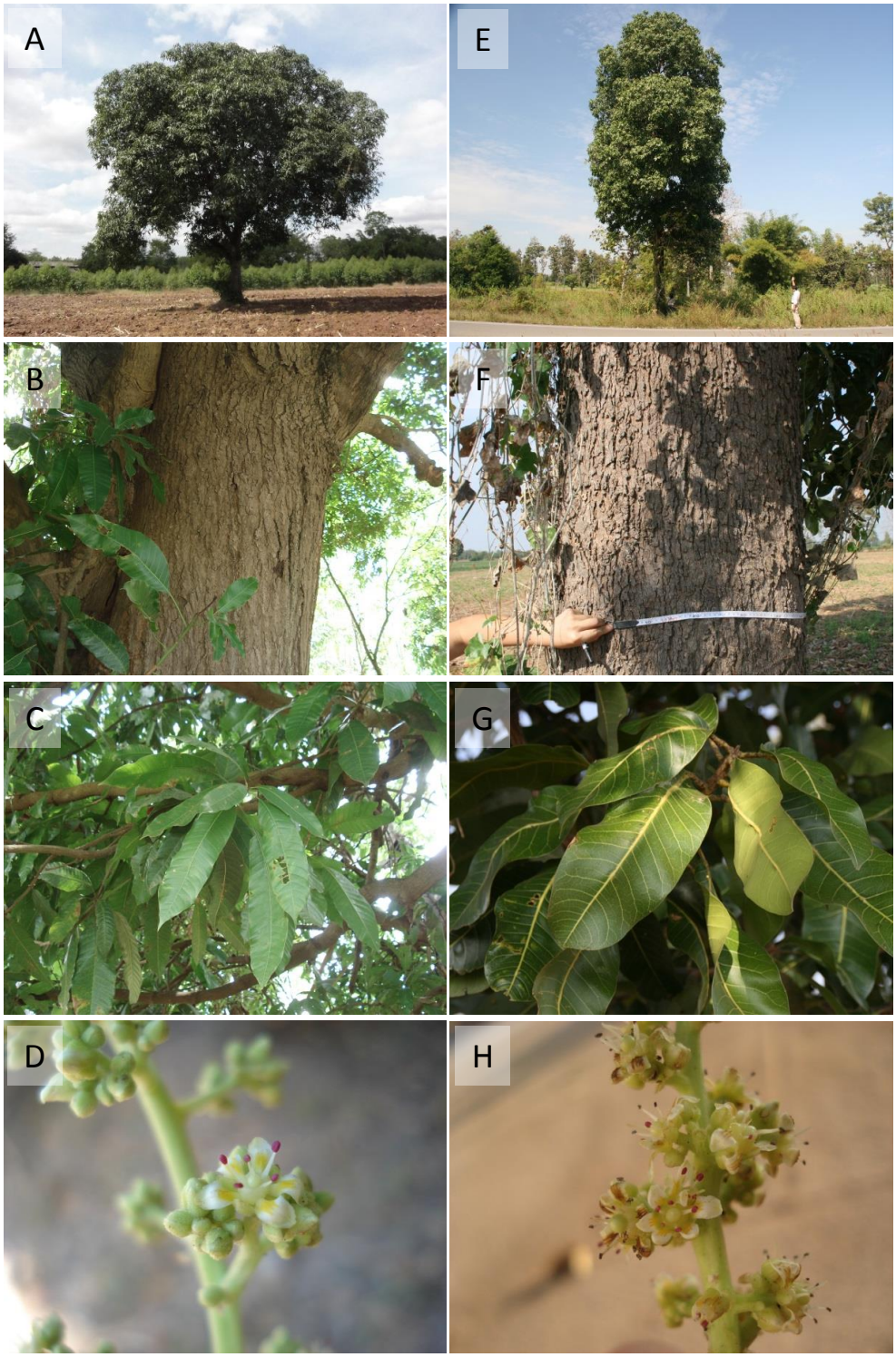

Plate 4-3. Comparative morphology of *kalon* mango (left column) and *paa* mango (right column). *Kalon* mango had dense, dome-shaped canopies similar to those of *Mangifera indica* (A), pale-brown bark (B), lanceolate leaves with pointed apices similar to those of *M. indica* (C), and flowers with 5 fertile stamens (D); *paa* mango had sparse cylindrical crowns or dense, long, globose canopies (E), blackish, gray, or brown bark (F), stiff, wide leaves that were oblong to elliptical with blunt apices (G), and flowers with 5 fertile stamens (H). Images were captured from different trees to display typical characteristics clearly.

Ripe juice of *kalon* mango had a significantly higher sugar content (19.2 °Brix) and lower acid content (1.0%) than *paa* mango (15.0 °Brix and 1.6%, respectively), indicating that *kalon* mango was sweeter. In addition, some *paa* fruits were described as resinous, making the consumer's throat itchy. Therefore, *kalon* fruits are of superior quality for eating. Even though *kalon* fruits tended to have a greenish exterior coloration after falling to the ground (Plate 4-2), the flesh inside was ripe and turned yellow. Several days after ripening, the peel also turned yellowish. *Paa* fruits tended to turn yellowish before falling.

Kalon mango trees were significantly smaller than *paa* mango trees. The respective average heights and DBH values of *kalon* mango trees were 11.5 m and 58.2 cm, while those of *paa* mango were 16.2 m and 68.2 cm (Table 4-4). The differences are likely a function of different tree ages, rather than potential growth characteristics. This issue is discussed in detail later.

Kalon mango trees had dense, dome-shaped canopies similar to those of *M. indica*, while *paa* mango trees had either a rather sparse, cylindrical canopy or a dense, long, globose canopy (Plate 4-3). The canopy shape of *kalon* mango tended to be more rounded (Table 4-4). Bark of *kalon* mango tended toward pale brown, while that of *paa* mango tended to be blackish, gray, or brown. Leaves of *kalon* mango, which were similar to those of *M. indica*, were lanceolate, with pointed apices, thin, soft, and were significantly narrower than those of *paa* mango. Leaves of *paa* mango were oblong to elliptical, with blunt apices, thick, stiff, and wider. Flowers of both had 5 fertile stamens and no staminode; ridges

Table 4-4. Morphological traits of trees of *Mangifera pentandra*.

Local classification	Tree height (m)	DBH (cm)	Canopy height (m)	Canopy shape (width/height ratio)	Leaf length (cm)	Leaf shape (width/length ratio)
Kalon mango	11.5	58.2	9.5	0.960	25.0	0.296
	(n=26)[z]	(n=26)[z]	(n=26)[z]	(n=26)[z]	(n=29)	(n=29)
Paa mango	16.2	68.2	13.0	0.909	22.8	0.367
	(n=55)[z]	(n=61)[z]	(n=55)[z]	(n=55)[z]	(n=54)[z]	(n=54)[z]
Significance	**	*	**	n.s.	*	**

**, *, and n.s. indicate significant differences by t-test at $P<0.01$, $0.01 \leq P<0.05$, and not significant, respectively.

[z]The number of samples with irregular shape (e.g. hard training, lightning strike) or devided trunk were eliminated. Leaves could not obtained from trees with too high branches.

were free at the tips of the petals. Thus, floral morphology was similar between the two mangoes.

The morphological differences between *kalon* mango and *paa* mango that I detected were corroborated by the local people (Table 4-2) and by the measurements on fruits, trees, canopies, and leaves (Tables 4-3 and 4-4). Common traits of *kalon* mango were larger, longer fruits, sweeter juice, dense, dome-shaped canopies, thin, narrow leaves, and pale-brown bark. *M. pentandra* trees with these characteristics would be recognized as *kalon* mango by the local people and regarded as superior because of the sweeter, larger fruits containing a higher edible proportion of pulp than those of *paa* mango.

M. pentandra tree with a morphology intermediate between *kalon* and *paa* mangoes were found. This tree was assigned locally as *muang kalon*; it was 18.7 m tall, exceeding the average height of *paa* mango. The canopy was relatively sparse, and the leaves were thick and stiff like those of *paa* mango. The fruit was small like that of *paa* mango, but ellipsoidal in shape, rather than rounded. The average fruit weight of 31.1 g was the lowest among the all trees surveyed. However, the average sugar content was highest (22.9 °Brix). Therefore, this *kalon* mango had a *kalon*-like fruit shape and high sugar content, but the sizes of the tree and fruit, and leaf morphology were *paa*-like, a combination of characteristics that was intermediate between those of *kalon* and *paa* mangoes. The existence of an intermediate tree indicates that *kalon* and *paa* mango trees are not clearly differentiated in nature and that they are part of a range of variation.

Local uses

Fresh fruit consumption was the most common use of both *kalon* and *paa* mangoes (Table 4-5). Some of the local people ate fruit without regard to ripeness, while others had preferences for mature green or fully ripe fruit. Seasonings were often added to fresh fruit before consumption. People used a range of seasonings with a base of salt, chili, and *namplaa* (Thai fish sauce extracted from salted and fermented fish), e.g., *nam phrik* (*namplaa* with chili, garlic, calamondin, and sugar), *jeo* (chili sauce or paste mixed with vegetables, meats, or fish and some

condiments, such as fish sauce and calamondin), and *laap* (ground meat stirred with herbs and roasted rice and flavored with fish sauce, garlic, and calamondin). *Kuan* (mango preserve resembling toffee or jam; Plate 4-4) is made from ripe *kalon* mango, but not from *paa* mango. Preparation of *kuan* allows fruit pulp storage over periods of months. When an overabundance of mango occurs, fruits that are not consumed immediately can be preserved in this way for later use. The superior taste of *kalon* mango may account for their preferential use in *kuan*, but convenience may also be an issue: many *kalon* mango trees occur close to human homes whereas many *paa* mango trees are located in more distant crop fields (see

Table 4-5. Local food uses of *Mangifera pentandra* in Northeast Thailand.

Local classification	How to eat	Count (breakdown)
Kalon mango	Fruit are eaten fresh	5
	Eaten regardless of ripeness	(3)
	Only ripe fruit are eaten	(2)
	Ripe fruit are eaten with chili and salt	3
	Ripe fruit are eaten with sticky rice cooked with coconut milk	3
	Ripe fruit are cooked for *kuan*[z]	2
	Fruit are pickled	1
	Mature-green fruit are sliced and put into *laap*[z]	1
Paa mango	Fruit are eaten fresh	31
	Eaten regardless of ripeness	(24)
	Only mature-green fruit are eaten	(4)
	Only ripe fruit are eaten	(3)
	Fruit are eaten with seasonings	13
	Both Unripe and ripe fruit are eaten with *nam phrik*[z]	(4)
	Ripe fruit are eaten with chili and salt	(3)
	Ripe fruit are eaten with *plaadaek*[z]	(2)
	Mature-green fruit are eaten with *jeo*[z]	(1)
	Fruit are eaten with *namplaa waan*[z]	(1)
	Fruit are eaten with chili, sugar, and salt	(1)
	Fruit are eaten with salt	(1)
	Fruit are unpalatable for people (only animals eat fruit)	5
	Fruit are pickled	2
	Ripe fruit are eaten with sticky rice cooked with coconut milk	1
	Young leaves are eaten with seasonings	1

Information on *sii* mango and *khan* mango were included into that of *paa* mango; the two had neither morphological difference from *paa* mango nor unique way to eat.

[z]*Kuan*: mango preserve resembling toffee or jam; *laap*: ground meat stirred with herbs and roasted rice and flavored with fish sauce, garlic and calamondin; *nam phrik*: *namplaa* (Thai fish sauce extracted from salted and fermented fish) with chili, garlic, calamondin, and sugar; *plaadaek*: fermented fish (or generally called plaalaa in Thailand); *jeo*: chili sauce or paste mixed with vegetables, meats or fish and some condiments such as fish sauce and calamondin; *namplaa waan*: *namplaa* with chili and sugar.

description below).

Kalon and *paa* mangoes were sometimes eaten with sticky rice steamed sweetly with coconut, or they were sometimes pickled. Occasionally, young leaves of *paa* mango were eaten fresh with seasonings. All of these foods are prepared in the same manner as *M. indica* is used. Some of the *paa* mango fruits collected were designated “unpalatable” (Surin) due to their high resin content.

In addition to their use as food, mango plants provide diverse resources, including timber, fuel, rootstocks (for grafting), medicines, and shade from the sun (Table 4-6). *M. indica* does not form heartwood and its timber is soft, while *M. pentandra* “forms heartwood which is useful in building materials” (Khon Kaen). The heartwood of *M. pentandra* was not strong enough for use in framing poles in house construction, but was adequate for the assembly of furniture and floorboards. Branches and trunks were also used as firewood.

Kalon mango was used as rootstock for *M. indica* grafts as the two species are compatible. This procedure may promote disease resistance in the grafts. Mango trees are also used in folk medicine, as studied in Chapter 2. Large trees left standing in crop fields, including *paa* mango trees, provide shade for resting farmers (Plate 4-5). Some of the *M. pentandra* trees were decorated for animistic religious purposes; spirits (*phii*) are believed to dwell in a diversity of large trees.

Plate 4-4. *Kuan* (preserved mango in the form of toffee or jam) made from *kalon* mango (Maha Sarakham).

Plate 4-5. Farmers in a cassava field resting beneath a *paa* mango tree that provided shade and fruit (Buriram).

Table 4-6. Local uses other than food of *Mangifera pentandra* in Northeast Thailand.

Local classification	How to use	Part used	No. of informants
Kalon mango	Building materials	Trunk, heartwood	1
	Rootstock for *M. indica* grafts	Seedling	1
	Medicine (for colds)	Peel	1
	Ornament	Tree	1
Paa mango	Building materials	Heartwood of trunk	7
	Firewood	Branch	4
	Medicine (revitalizer)	Root	1
	Ornament	Whole tree	1
	For shade	Canopy	1

Information on *khan* mango were included into that of *paa* mango; *khan* mango had neither morphological difference from *paa* mango, nor unique way of use.

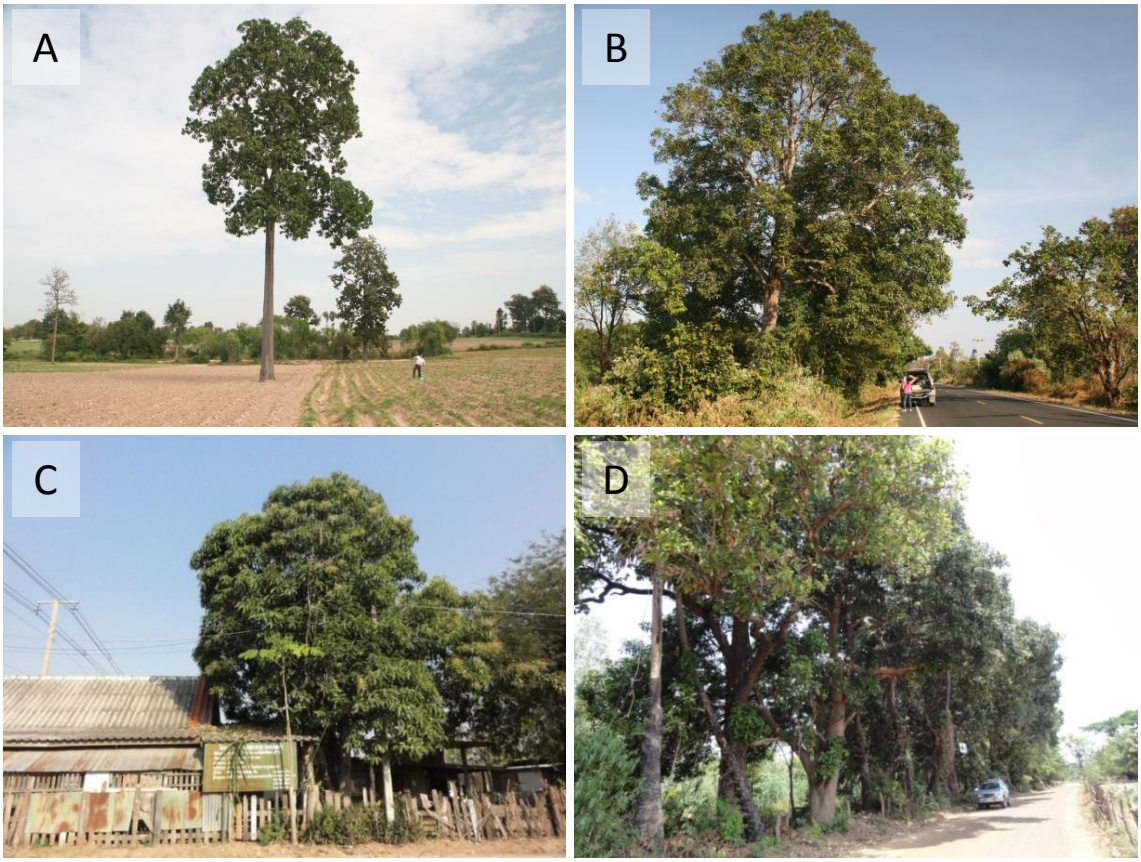

Plate 4-6. Growing environments of *Mangifera pentandra* trees we studied in Northeast Thailand; A: tree (local name not recorded) in a cassava field (Khon Kaen), B: tree (local name not recorded) on a roadside (Surin), C: a *kalon* mango tree close to a home (Nakhon Ratchasima), D: *kalon* mango trees planted along a crop field boundary (Maha Sarakham).

Growing Environments

Habitats of most *M. pentandra* trees in the survey included crop fields (44%), roadsides (23%), and house yards (22%) (Plate 4-6). Crop fields comprised upland fields, paddy fields, and fruit orchards. House yards included all outdoor space in the proximity of houses and offices. Other habitats occurred in woodlands and public places, such as schools and temples. According to local classification, more than half of *kalon* mango trees (55%) grew in/around yards, while more than half of *paa* mango trees (53%) were found in crop fields (Table 4-7). Thus, the habitats of *kalon* and *paa* mangoes differ.

Kalon mango trees tended to be relatively small and frequent in/around yards, while *paa* mango trees tended to be very large and frequent in crop fields, suggesting that the *kalon* mango population is maintained by conscious or unconscious planting of its seed by local residents, while *paa* mango population grows naturally.

Large area of the original Isanese forest were converted to arable land after the 1970s (Takaya, 1985), but some of the trees were left standing in the new rural landscape and provided timber, resin, and charcoal (Kosaka *et al*., 2006). Very large, old *paa* mango trees may also be remnants of the forest that existed before relatively recent agricultural transformation in Isan (Plate 4-7), and they provide edible fruit and shade for farmers, although stands of wild trees in

Table 4-7. Growing environment of *Mangifera pentandra* in Northeast Thailand.

Growing environment[z]	*Kalon* mango		*Paa* mango		Significance
Crop fields	10	(34)[y]	33	(53)	*
House yards	16	(55)	12	(19)	*
Roadsides	1	(3)	8	(13)	n.s.
Woodlands	0	(0)	5	(8)	n.s.
Others	2	(7)	4	(6)	n.s.
Total	29	(99)	62	(99)	

* and n.s. indicate significant differences by Fisher's exact test at $P<0.05$ and not significant, respectively.

[z]Crop fields include upland fields, paddy fields, and fruit orchards. House yards include all outdoor space in the proximity of houses and offices such as yards, surrounding of houses, and parking lots. Others include schools, temples, and so on.

[y]Values in parenthesis indicate percentage of the number of trees growing in each environment to the total trees.

cultivated fields may decline as agriculture modernizes.

Small *kalon* mango trees growing in the vicinity of human habitation are not likely remnants of natural forests, but most probably the products of plantings. Some *kalon* mango trees were known to have been intentionally planted on the borders of crop fields (Plate 4-6D), but *paa* mango trees were not. Local people reported that "*kalon* mango cannot be found in forests, while *paa* mango can be found only in forests" (Nakhon Ratchasima) and "*kalon* mango can be found only near settlements" (Buriram) (Table 4-2). This information leads to a strong deduction that: people first found a variation of superior fruit among the wild *M. pentandra* trees; then people may have planted its seed in their yards; this practice encouraged the selection of much superior variation; and finally it is recognized as *kalon* mango. Such processes would result in maintaining *kalon* mango trees closely to human habitation.

Deducing relationships between people and wild fruit trees

The first utilization of wild fruit trees by human beings likely began with collecting forays into natural forest stands. Trees with superior fruits must have been recognized and identified through a naming procedure. Thereafter, the human population likely initiated selection programs to ensure more frequent

Plate 4-7. Sparse remnant stands of wild *Mangifera pentandra* in a cassava field.

access to better-quality fruit. I believe that the early stages of this process were observed in Isan, where a superior mango has been recognized.

How are the relationships between people and the wild ancestors of domesticated fruit varieties initiated and how do they develop over time? Unfortunately, this is largely a matter of speculation. The domestication of popular fruit crops (e.g., grapes, olives, apples) began usually several thousand years ago, up to 7000 years ago (Zohary *et al.*, 2012). Archaeological investigations provide clues, but substantive evidence on the relationships between people and fruit trees at the onset of domestication is very difficult to obtain. Much more information is available for cereal crops. Focusing on recently domesticated species is potentially useful to understand processes and patterns of domestication of fruit trees. Wild macadamia (*Macadamia integrifolia* Maiden & Betche), for example, was discovered during a botanical expedition in Queensland, Australia, then many varieties were selected over 150 years from among germinated seedlings, and now the varieties are propagated worldwide by grafting (Ladizinsky, 1998). Breeding of fruit trees such as starfruit, dragonfruit, and salak also resulted in continual production of new varieties, some of superior quality. Thus, domestication of fruit crops has been in progress for thousands of years, becoming more rapid and efficient in recent times. However, the domestication of

ancient fruits was not documented.

In addition to observing recent domesticated fruits, it is important to focus on wild fruits that are still collected from forests. For example, *Actinidia* species occur naturally in Japanese forests, and the fruits have been consumed locally over lengthy periods of human history. Scions of desirable wild trees have been taken and planted in house yards for later propagation by cutting. Local names vary by region; *A. arguta*, for example, is reported to have 38 names (Uehara, 1961). Ploidy and morphology vary intraspecifically (Kataoka, 2011), but the varieties have not been named in folk taxonomies, even though morphological differentiation is recognized. However, no record exists of local people using names for variants of *A. arguta*, even though they recognize morphological differentiation within the species. In Kagawa Prefecture, Japan, a scientific program of *Actinidia* breeding is under way. Superior varieties were sought among wild species; these have been subjected to intensive breeding procedures, including hybridization between species. Superior cultivars were generated in a process that was much faster than the rather disorganized folk selection of unnamed varieties for domestication. Modern procedures are replacing largely undocumented ancient domestication methods. However, *kalon* mango has never been part of a modern breeding program. The early stages of its domestication may be observed today and will surely provide insight into ancient practices of crop plant breeding. Few other species provide this opportunity.

Gradual changes in fruit trees during domestication

Domestication of *kalon* mango may already be under way. *Kalon* mango has often been recognized as “cultivated mango” (Nakhon Ratchasima) (Table 4-2), although no scientific unanimity on this matter exists. During domestication, fruit trees are modified in both reproductive and vegetative traits. One type of breadfruit, *Artocarpus altilis* (Parkinson) Fosberg, for example, has seedless fruit over thousands of years of cultivation and selection, and is therefore unable to reproduce without human intervention. Other changes in fruit trees under domestication include the development of hermaphroditism in grape, elimination

of bitterness in almond, self-compatibility in peach, and lower resin content in mango (Spiegel-Roy, 1986).

Kalon mango was found to be morphologically differentiated from other *M. pentandra*, and it differs in taste as well. These changes were gradual and confirm that *kalon* mango has been selected from other *M. pentandra*. *Kalon* mango trees are propagated from seeds, indicating that the superior attributes of these plants are transmitted between generations. The polyembryony of *M. pentandra* also contributes to intergenerational retention of traits. Except for the zygote that results from fertilization, all embryos are genetically identical to the parent, which enables true transmission of selected traits from generation to generation. Gradual changes in fruit trees over lengthy periods are the hallmark of the domestication process, even when differences between plants first chosen for cultivation and their wild progenitors are minimal.

The prospects for *kalon* mango domestication are presently unknown. The human society in Isan is not static, therefore it is not known whether future populations will value this superior fruit and develop its desirable properties, or discard it in favor of other food items.

In the following chapters, the research area is expanded into other regions in Thailand, i.e. North Thailand (Chapter 5) and South Thailand (Chapter 6) in order to investigate the current folk taxonomies and local uses on *Mangifera* species, and whether superior forms like *kalon* mango exist or not.

SUMMARY *Mangifera pentandra* trees are common in Northeast Thailand, where they are known locally as *kalon* mango or *paa* mango. *Kalon* mango is recognized as being better-tasting than *paa* mango, although both belong to the same species. The differences between *kalon* and *paa* mangoes were examined. This survey included 171 trees of *M. pentandra* found growing in crop fields, along roadsides, and in close vicinity to human habitats. All of these sites had been transformed from an original vegetation of mixed dipterocarp forest.

One-third of the *M. pentandra* trees in the survey were recognized locally as *kalon* mango, while most of the remaining trees were *paa* mango. *Kalon* mango fruits were larger than those of *paa* mango and had a higher sugar content. A dense, dome-shaped canopy, thin, narrow leaves, and pale-brown bark distinguished *kalon* mango trees from *paa* mango. Many *paa* mango trees found growing in crop fields were very large; the smaller *kalon* mango trees tended to occur near human settlement. Therefore, it is proposed that *paa* mango trees are remnants of natural forest and that *kalon* mango trees have been planted recently. *Kalon* mango may be the product of subconscious selection for superior fruits that are larger and better-tasting than the wild type.

Chapter 5

Mangifera Species in North Thailand —Four *Mangifera* Species Growing Wild—

Introduction

In Chapter 4, an ethnobotanical study of mangoes in Northeast Thailand was conducted. In neighboring North Thailand, *M. caloneura* Kurz, *M. odorata* Griff., and *M. sylvatica* Roxb. in addition to *M. indica* L. are distributed (Chayamarit, 2010; Gardner *et al*., 2000). North Thailand is largely covered by mountainous forests composed of four types of vegetation: evergreen forest, mixed deciduous forest, dry dipterocarp forest, and pine forest. The total area of forest coverage is 5317191 ha (FAO, 2010), covering 57% of the land. Shifting cultivation used to be practiced in this region, although permanent cultivation is now most prevalent. Mountainous forests continue to neighboring north Laos where three *Mangifera* species are distinguished with different vernacular names and utilized not only as food but also as medicine (Chapter 2). *Mangifera* species are neither protected nor cultivated there, but people are familiar with the mangoes in the region.

People in North Thailand may also have utilized *Mangifera* species. However, there have been no ethnobotanical studies of edible mangoes in this region. In this chapter, *Mangifera* trees in North Thailand were explored and local

names and uses were recorded to understand the current utilization of *Mangifera* species in this region, and compared to Northeast Thailand and North Laos.

Research Area and Methods

North Thailand is geographically characterized by mountain ranges, and is bordered by Myanmar and Laos (Fig. 5-1). The field survey was conducted in five provinces: Loei, Nan, Phayao, Chiang Rai, and Chiang Mai. Loei is administratively divided as Northeast Thailand, but was included in the study area due to its ecological similarity to North Thailand.

Tree surveys and interviews were conducted in two ways. First, villages were visited and local people were asked whether wild mangoes grew in the vicinity. If they replied affirmatively, the locations of trees were asked, observations on the trees were conducted, and further interviews with the villagers were performed. In the second, independent surveys were conducted by exploring the trees by car. When trees were found, observations and interviews with neighboring villagers were conducted. Both procedures were performed in the flowering season (January 2011 and January 2012). Overall, 184 trees were observed. And then 129 were identified as *M. caloneura* Kurz (n = 58), *M. pentandra* Hook. f. (n = 67), *M. sylvatica* Roxb. (n = 2), and *M. linearifolia* (Mukherji) Kosterm[6] (n = 2). Fifty-five trees were unidentified and were excluded from the study.

Once the *Mangifera* trees were confirmed, their global positioning system (GPS) coordinates and elevations were determined. Subsequently, tree morphology as well as leaf and flower traits were observed and photographed. The diameter at breast height (DBH) and leaf size were measured. The height and canopy size were also determined. If seeds seemed to have been left since the previous fruit season, their sizes were calculated. Specimens of *M. caloneura* and *M. pentandra* with inflorescences were prepared for preservation and storage in the Forest Herbarium (BKF) of Thailand.

Interviewees provided information on local names and distinguishing traits, fruit taste, and uses of each tree. Thai (dialect of North Thailand) is spoken

in lowland areas of the region, although minority languages are also spoken in the mountainous areas by various ethnic minorities (e.g., Karen, Hmong, Yao, Lahu, and Lisu). The interviews were conducted in Thai with an interpreter where necessary.

Fruit analysis was performed in May 2012. A total of 25 trees (*M. caloneura*, *n* = 17; *M. pentandra*, *n* = 7; and *M. sylvatica*, *n* = 1) were revisited among the *Mangifera* trees that had already been surveyed and identified during the previous survey. Two to five fruits per individual tree were collected, and in total 76 *M. caloneura* fruits, 32 *M. pentandra* fruits, and 5 *M. sylvatica* fruits were obtained. The weight per fruit was determined by dividing the total weight of fruits by the number collected from a tree. Fruit length, width, and thickness were measured, and then the seeds were measured to determine the size in the same way. The juice was squeezed out to measure total soluble solid contents (°Brix) with a handheld refractometer (PR-101; Atago Co., Tokyo, Japan).

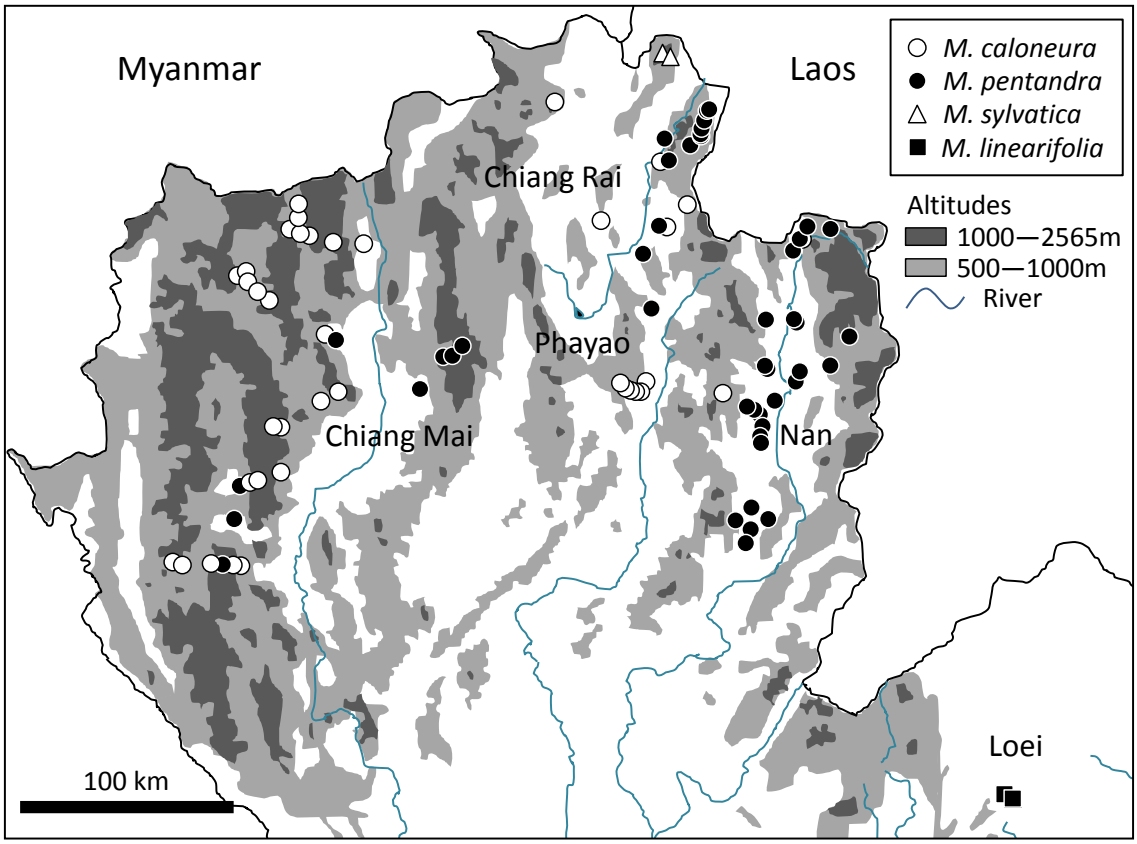

Fig. 5-1. Locations of four *Mangifera* trees studied in North Thailand.

Results and Discussion

Distribution

Two species, *M. caloneura* and *M. pentandra*, were found frequently (Fig. 5-1). *M. sylvatica* and *M. linearifolia* were also observed but they were quite rare. *M. caloneura* and *M. pentandra* were distributed throughout North Thailand. The distribution ranges of the two species overlapped, and they were sometimes found growing in the same location. Of 58 *M. caloneura* trees, 36 (62%) were found in Chiang Mai, while 47 of 67 *M. pentandra* trees (70%) were found in Nan and Loei, as if the two species were separately distributed westward and eastward, respectively. However, the uneven distribution appeared to occur more in terms of elevation (in a vertical direction) rather than in an east–west direction. *M. caloneura* was often found in evergreen/deciduous forests at altitudes of 500–1000 m. Such high-altitude areas are prevalent in the western part of North Thailand. On the other hand, *M. pentandra* was often found in evergreen/deciduous forests and mixed dry dipterocarp forests at altitudes of less than 500 m. The east part of North Thailand consists largely of such low-lying land. *M. sylvatica* was found growing in evergreen/deciduous forests at an altitude of 580 m in Chiang Rai. *M. linearifolia* was growing in evergreen/deciduous forests at an altitude of 400 m in Loei.

Chayamarit (2010) reported that 17 species of *Mangifera* were distributed in Thailand, and referred to three species (*M. indica*, *M. sylvatica*, and *M. odorata*) being distributed in North Thailand. However, in this survey, *M. caloneura* and *M. pentandra* were found predominantly in the vicinity of human

Table 5-1. Growing environments of four *Mangifera* species in North Thailand.

Species	Total	The number of trees growing in each environment							
		Settlement[z]	School	Temple	Crop field	Crematorium	Riverside	Forest	Others
M. caloneura	58	5	3	1	7	0	1	39	2
M. pentandra	67	11	7	2	8	5	2	30	2
M. sylvatica	2	0	0	0	1	0	0	1	0
M. linearifolia	2	0	0	0	0	0	0	2	0
Unidentified	55	9	0	1	6	1	1	37	0
Total	184	25	10	4	22	6	4	109	4

[z]The designation "settlement" includes all outdoor space in close proximity to human habitat such as houses.

habitats, and *M. odorata* was not confirmed. A total of 109 of 184 trees (59%) were found in mountainous forests (Table 5-1). Not only the trees growing in forests or riversides but also the trees found in crematoriums, crop fields, and in the vicinity of settlements seemed to be remnants of natural vegetation, because they were huge trees or they were in places that were difficult for people to approach. The trees in schools and temples were said to have been left in place because they were too large to cut down. These trees may have been left deliberately, but no information was obtained indicating that they had been transplanted or propagated. Small trees (≤7 m) on the margins of crop fields and in the vicinity of settlements were thought to have grown spontaneously after people or animals had eaten the fruits and discarded the seeds. The *Mangifera* species in North Thailand are likely to be growing wild and people have not engaged in propagation, with the exception of *M. indica*.

Local names

Sixteen Thai names were assigned to 82 trees (Table 5-2) by interviewees. There were 85 responses because multiple names were recorded for single trees, and multiple interviewees provided an answer for a single tree. Names in other languages were also recorded, but not included in the table to maintain the uniformity of the data.

Muang paa means “forest mango” or “wild mango” in Thai. This name was recorded for all species in all provinces included in the survey, especially in Chiang Mai. *Muang khai* (egg mango), *muang kwaang* (deer mango), *muang faai* (cotton mango), *muang cingriit* (cricket mango), *muang khii yaa* (grandmother excrement mango), and *muang kluai* (banana mango) were names counted more than twice in addition to *muang paa*. These seven names are thought to be the major vernacular names of *M. caloneura* and *M. pentandra*. The distributions of the major names are shown in the maps (Fig. 5-2). *M. caloneura* had five major names: *muang faai* tended to be used northward from Chiang Rai to Phayao, *muang cingriit* from Chiang Rai to Chiang Mai, and *muang paa* was commonly used in Chiang Mai (Fig. 5-2A). *M. caloneura* with long and elongate fruit was

distributed northward as *muang kluai*, and westward as *muang khii yaa* (Fig. 5-2B). Details on fruit traits are described in the following subsection. *M. pentandra* had three major names: *muang khai* was used eastward from Loei to Nan, *muang kwaang* was northeastward from Nan to Chiang Rai, and *muang paa* was commonly used in Chiang Mai (Fig. 5-2C).

Table 5-2. Local names of four *Mangifera* species in North Thailand; sixteen local names were assigned to 82 trees identified.

Provinces	Species							
	M. caloneura	Count	*M. pentandra*	Count	*M. sylvatica*	Count	*M. linearifolia*	Count
Loei			*muang khai*	4			*muang paa*	1
			muang paa	3				
			muang ku	2				
			muang sii	1				
Nan	*muang khai*	1	*muang khai*	8				
			muang kwaang	6				
			muang paa	3				
			muang kham	1				
			muang suk kiao	1				
Phayao	*muang paa*	5	*muang paa*	1				
	muang faai	3						
	muang kluai	1						
Chiang Rai	*muang cing riit*	4	*muang kwaang*	4	*muang priao*	1		
	muang faai	2	*muang paa*	3	*muang paa*	1		
	muang paa	1						
	muang kalon	1						
	muang kluai	1						
	muang hiib	1						
Chiang Mai	*muang paa*	14	*muang paa*	5				
	muang cingriit	2	*muang khii yaa*	1				
	muang khii yaa	2	*muang khaao*	1				
	muang kham	1						

Meanings are as follows: *muang cingriit*, cricket mango; *muang faai*, cotton mango; *muang hiib*, flat mango; *muang khaao*, white mango; *muang khai*, egg mango; *muang kham*, golden mango; *muang khii yaa*, grandmother excrement mango; *muang kluai*, banana mango; *muang kwaang*, deer mango; *muang paa*, forest mango; *muang priao*, sour mango; *muang sii*, resin mango; *muang suk kiao*, green ripe mango. Meanings of other names are unknown.

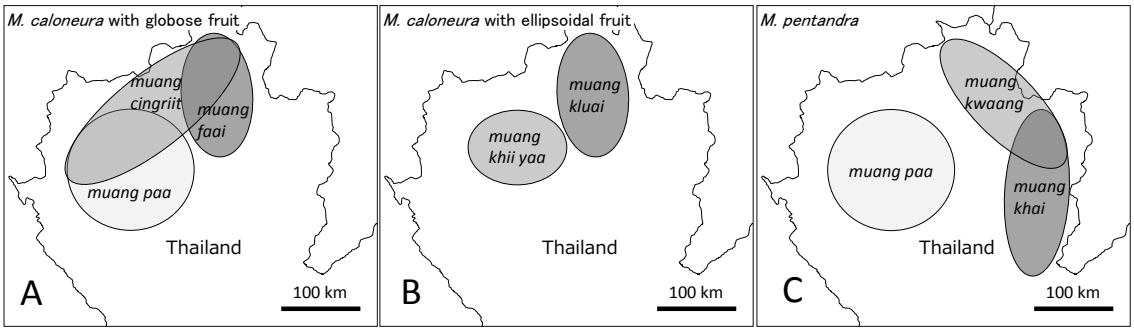

Fig. 5-2. Distributions of the major local names of *Mangifera caloneura* with globose fruit (A), *Mangifera caloneura* with ellipsoidal fruit (B), and *Mangifera pentandra* (C).

Table 5-3. Morphological and qualitative traits of fruits and seeds of three *Mangifera* species in North Thailand.

Species Folk classification	Provinces	No. of fruit	Fruit morphology and quality					Seed morphology		
			Weight (g)[y]	Length (mm)	Width to length ratio	Thickness to width ratio	Brix (°)	Length (mm)	Width to length ratio	Thickness to width ratio
M. caloneura		76	40.9	50.0	0.74 b	0.90	12.7	40.5	0.58 b	0.71
muang paa	Phayao	10	29.0	42.3	0.83	0.96	12.0	40.0	0.53	0.76
	Chiang Mai	27	35.7	47.2	0.77	0.93	12.0	38.7	0.57	0.74
muang khii yaa	Chiang Mai	10	66.1	61.6	0.73	0.90	11.7	52.0	0.54	0.67
muang kluai	Phayao	5	44.0	55.2	0.63	0.99	10.2	—	—	—
	Chiang Rai	5	39.5	54.8	0.66	0.88	14.8	45.0	0.49	0.82
muang faai	Phayao	5	27.0	41.4	0.78	0.94	17.4	33.0	0.62	0.78
	Chiang Rai	5	41.7	48.8	0.83	0.85	14.5	41.0	0.63	0.07
M. pentandra		32	55.2	52.2	0.83 a	0.91	13.9	37.4	0.66 a	0.67
muang paa	Chiang Mai	14	58.1	53.5	0.82	0.90	13.2	42.3	0.66	0.62
	Nan	—	—	—	—	—	—	41.7	0.69	0.70
	Chiang Rai	—	—	—	—	—	—	32.0	0.69	0.68
muang kwaang	Chiang Rai	10	43.8	49.7	0.80	0.95	15.5	39.0	0.62	0.83
	Nan	—	—	—	—	—	—	37.6	0.64	0.74
muang khaao	Chiang Mai	5	77.0	54.4	0.93	0.87	12.8	46.0	0.67	0.55
muang khai	Nan	—	—	—	—	—	—	34.4	0.70	0.73
M. sylvatica	Chiang Rai	5	31.3	46.8	0.75 b	0.94	14.7	39.5	0.62 b	0.70
Significance[z]			n.s.	n.s.	**	n.s.	n.s.	n.s.	**	n.s.

[z]**, *, and n.s. indicate significant differences among species at $P<0.01$, $P<0.05$, and not significant, respectively. Different letters within columns indicate statistical significance by Tukey's test at $P<0.05$.

[y]The weight per fruit was determined by dividing total weight of fruits by the number of fruit collected from a tree.

Morphology and quality of mangoes

The fruits studied varied in both size and shape (Table 5-3). Weight per fruit of *M. caloneura* varied among trees (22.2–93.0 g). *M. pentandra* fruits ranged from 37.5 to 77.0 g (Plate 5-1). *M. pentandra* fruits were the largest in both weight and length, while *M. sylvatica* fruits were smallest. These three species tended to be distinguishable by fruit shape: *M. caloneura* fruits were narrow, flattened, and curved, as if the common mango was miniaturized (Plate 5-2E); *M. pentandra* fruits had a broad and flattened disc-like shape (Plate 5-3E); and *M. sylvatica* fruits were narrow but thickened like a cylinder (Plate 5-4C).

Among *M. caloneura* fruits, *muang khii yaa* and *muang kluai* were longer and elongate (Plate 5-5). *Kluai* translates as "banana," and therefore *muang kluai* was probably so named because of its elongated yellow fruit. Among *M. pentandra*, folk classification did not seem to be related to fruit traits. A previous survey in Northeast Thailand indicated that *M. pentandra* is referred to by two names: *kalon* mango has fruits of 52.8 g in weight and 53.5 mm in length on average, and *paa* mango weighs 38.3 g and is 43.2 mm long on average (Chapter 4). In the present survey in North Thailand, *M. pentandra* fruits were 54.5 g and 52.5 mm long on average. Therefore, *M. pentandra* fruits of North Thailand are comparable to *kalon* mango. However, they were not distinguished intraspecifically by local people regardless of their different sizes.

Plate. 5-1. Fruits of *Mangifera caloneura* and *Mangifera pentandra* varied in size. (A) The largest fruit among those of *M. caloneura* in this study (average weight per fruit was 93.0 g, collected in Chiang Mai); (B) The smallest fruit of *M. caloneura* (22.2 g, Chiang Mai); (C) The largest fruit among those of *M. pentandra* (77.0 g, Chiang Mai); (D) The smallest fruit of *M. pentandra* (37.5 g, Chiang Rai).

Despite having the highest sugar content, *M. sylvatica* tasted sour, while *M. pentandra* was the sweetest. Seeds of *M. caloneura* tended to be largest, while those of *M. pentandra* tended to be smallest.

Therefore, *M. pentandra*, which had larger fruit and the smallest seed, had the highest ratio of edible parts among the three species.

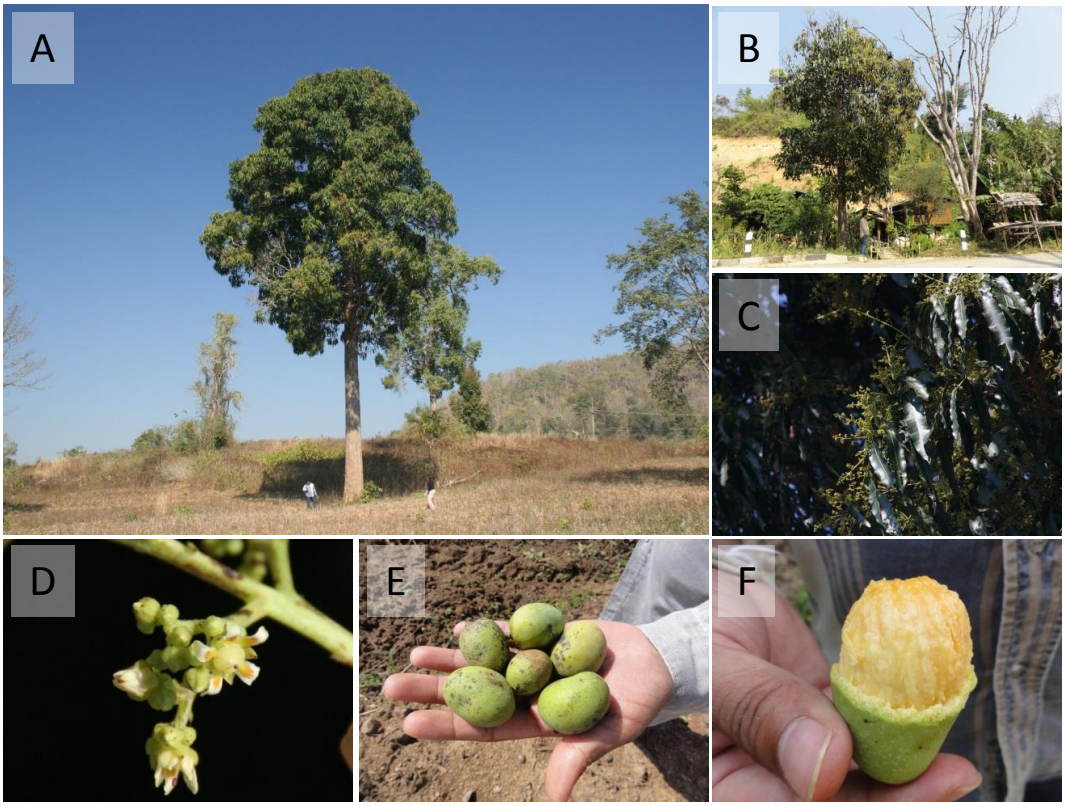

Plate. 5-2. Tree shape, leaves, flowers, and fruits of *Mangifera caloneura*. The average heights and DBH values were 14.8 m and 0.7 m, respecitively. The canopy was globose, 9.3 m in height on average, with a width/height ratio of 1.03. Leaves were linear-oblong, 24.4 cm in length on average, with a width/height ratio of 0.30. (A) Huge tree of *muang faai* (Phayao); (B) Small tree of *muang cingriit* (Chiang Mai); (C) Leaves and inflorescence of *muang faai* (Nan); (D) Flower of *muang faai* (Nan); (E) Fruit of *muang faai* (Nan); (F) Flesh of *muang cingriit* (Chiang Rai).

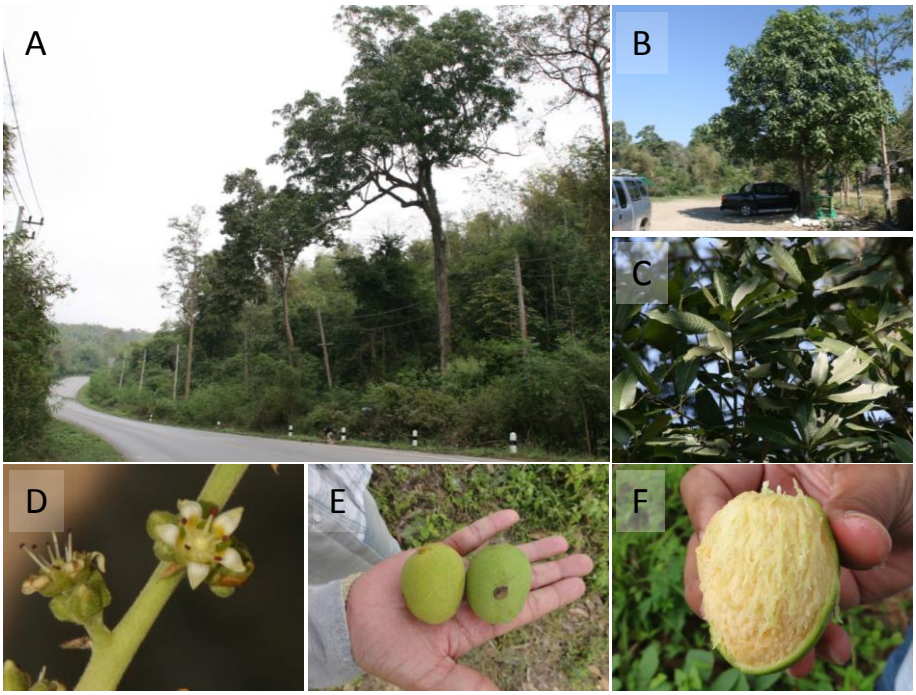

Plate. 5-3. Tree shape, leaves, flowers, and fruits of *Mangifera pentandra*. The average heights and DBH values were 15.4 m and 0.8 m, respectively. The canopy was globose, 10.7 m in height on average, with a width/height ratio of 0.96. Leaves were oblong, 23.6 cm in length on average, with a width/height ratio of 0.36. (A) Huge tree of *muang khai* (Nan); (B) Small tree of *muang khai* (Nan); (C) Leaves of *muang khai* (Loei); (D) Flower of *muang paa* (Chiang Rai); (E) Fruits of *muang kwaang* (Chiang Rai); (F) Flesh of *muang paa* (Chiang Mai).

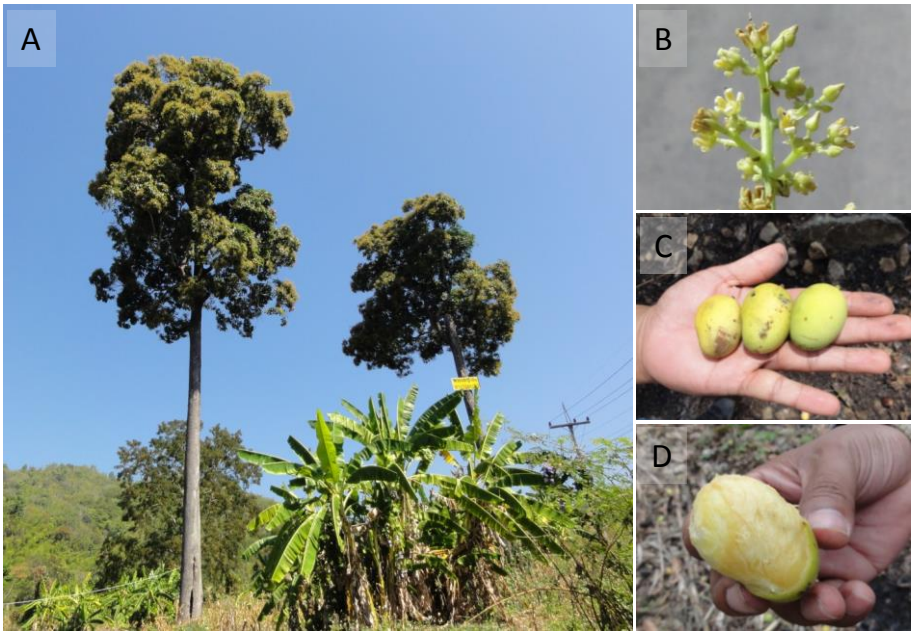

Plate. 5-4. Tree shape (A), flowers (B), fruits (C), and flesh (D) of *Mangifera sylvatica* (Chiang Rai). The average heights and DBH values were 20 m and 1.3 m, respectively. The canopy was cylindrical, 10.0 m in height, with a width/height ratio of 0.77. Leaves were linear-oblong, 16.6 cm in length, with a width/height ratio of 0.33.

Plate. 5-5. Long and elongate fruits of *Mangifera caloneura*; A: *muang kluai* (Chiang Rai), B: *muang khii yaa*, (Chiang Mai).

Plate. 5-6. Tree shape (A) and leaves (B) of *Mangifera linearifolia* (Mukherji) (Loei). The average heights and DBH values were 24.8 m and 0.8 m, respectively. The canopy was globose, 20.3 m in height on average, with a width/height ratio of 1.03. Leaves were small, 13.0 cm in length with a width/height ratio of 0.27.

Impressions regarding fruit traits by local people

The local interviewees seemed to recognize differences in fruit traits between species (Table 5-4). However, they did not recognize intraspecific differences based on fruit traits (data not shown). *M. caloneura* fruits were recognized as "ellipsoidal," while *M. pentandra* fruits were "globose." *M. pentandra* tended to be well appreciated as "palatable," although *muang paa* tended to be judged as "sour" and inferior to the others, such as *muang kwaang* and *muang khai*. On the other hand, evaluation of fruit taste of *M. caloneura* varied. This was also supported by the comment, "taste varies by tree." Variation in fruit quality among trees may not be recognized by local people, or may prevent a consistent evaluation.

Tree and leaf morphology

Tree height, DBH, canopy size and shape, and leaf size and shape were also examined for 46 *M. caloneura* trees and 47 *M. pentandra* trees (Plates 5-2 and 5-3). However, they did not show characteristics of folk types (data not shown). Tree and leaf morphology of *M. linearifolia* were distinctive; they were huge trees that exceeded 20 m in height, and had much smaller leaves (13 × 3.2

Table 5-4. Impressions regarding morphological and qualitative traits of *Mangifera caloneura* and *Mangifera pentandra* fruits noted by 55 local people in North Thailand.

Description on fruit traits		The number of responses	
		M. caloneura	*M. pentandra*
Fruit size and edible portion	Large	2	1
	Small	17	12
	Less edible portion	7	2
Fruit shape	Ellipsoidal	5	0
	Globose	2	6
Taste, flavor, and texture	Sweet	9	8
	Sweet and sour	10	4
	Sour	9	5
	Good aroma	6	8
	Acrid	2	0
	Itchy	1	1
	Taste varies by tree	4	0
	Fibrous	2	1
People's preference	Palatable	6	5
	Not palatable	5	0

cm on average) than the other congeners (Plate 5-6). *Kalon* mango trees in Northeast Thailand tended to be small (11.5 m in height on average), suggesting human intervention in their propagation (Chapter 4). However, in North Thailand, many *Mangifera* trees were huge (15 m in height on average) regardless of species or folk type. Some were young trees (≤7 m), but they did not seem to have been planted by people (see the subsection Distribution for explanation). Non-*indica* mangoes in North Thailand were wild.

Local uses

Fresh consumption of ripe fruit was the most common use of *M. caloneura*, *M. pentandra*, and *M. sylvatica* (Table 5-5). The fruits were eaten in other ways, but they were the same as those for *M. indica*. Ripe fruit of *M. caloneura* and *M. pentandra* were eaten with steamed sweet sticky rice with coconut or made into *kuan* (mango preserve resembling toffee or jam). Mature green fruit of *M. caloneura* were eaten as *yam* salad (Plate 5-7A). Young leaves of *M. caloneura* were also eaten. Occasionally, people commented that they did not eat fruits of *M. caloneura* or *M. pentandra*. A woman in Nan said that only children eat *M. pentandra* fruits. *M. sylvatica* fruits were collected by a father (Plate 5-7B) because “children like to eat them” (Chiang Rai).

M. caloneura and *M. pentandra* were used in other ways. Their timber was used for the assembly of furniture, as building materials, and as firewood. Seedlings of *M. caloneura* were used as rootstock for *M. indica* grafts, especially for Kaeo, a Thai cultivar in Chiang Mai. *Kalon* mango (*M. pentandra*) in Northeast Thailand was also reported as a rootstock for *M. indica* (Chapter 4). Bark of *M. pentandra* was used as a pale brown fabric dye, and the bark of *khai* mango was often used in Nan. The bark of *kasoo* mango (species unidentified) was also reported to be used to produce a light brown dye in central Laos (Chapter 2).

The people-plant relationships of wild *Mangifera* species in North Thailand were relatively tenuous. Various folk names were recorded, but they did

not seem to be classified according to differences in morphology or fruit taste regardless of variation in fruit size. Some *M. pentandra* trees that produced large and delicious fruit, such as *kalon* mango of Northeast Thailand, were also found in North Thailand, but such trees were not distinguished as a superior form like *kalon* mango and were not especially protected. People had no particular interest in uses or folk classification of wild mangoes, which characterizes the utilization of *Mangifera* species in North Thailand.

There is sufficient morphological variation among wild mangoes in North Thailand, though superior varieties have not been selected. Furthermore, accessibility to wild *Mangifera* trees seems to be easier in North Thailand than in Northeast Thailand, because the former is much more highly forested. Since the 13th century, North Thailand has been the site of various kingdoms in intermountain basins of Chiang Rai, Chiang Mai, and Nan (Wyatt, 1984). Therefore, Thai people have a long history of living in this region. Here, factors responsible for the lack of consistent selection of superior mangoes in this region are suggested.

One factor is the lack of a need to select superior varieties by the inhabitants. In Northeast Thailand, the original forests were mostly lost due to conversion to arable land, but people still gather wild edible plants for daily food from crop fields (Cruz-Garcia and Price, 2011), and utilize the timber and fruits from the remnants of natural trees that have been left sporadically in crop fields and in the vicinity of settlements, even after the limitation of access to natural forests. *M. pentandra* is one such tree, and its superior form is common (Chapter 4). After the decline of accessibility to useful plants, people may have intended to protect such trees in the vicinity of their homes, and may have been motivated to select superior fruits. On the other hand, a large percentage of the land in North Thailand is still covered by mountainous forests, which are often close to villages, and villagers can easily access forest resources. Therefore, people do not need to intentionally obtain and save wild edible fruits. As a result, wild *Mangifera* trees would have been rarely protected or transplanted into the vicinity of settlements, and then superior varieties would not be fixed.

Table 5-5. Local food uses and the other uses of three *Mangifera* species in North Thailand.

Species	How to eat	Count	The other uses	Count
M. caloneura	Ripe fruit are eaten fresh	18	Building materials[y]	2
	Ripe fruit are eaten with sticky rice cooked with coconut milk	2	Firewood	1
			Rootstock for *M. indica* grafts[x]	1
	Mature-green fruit are eaten as *yam* salad[z]	1		
	Ripe fruit are cooked for *kuan*[z]	1		
	Young leaves are eaten with *nam phrik*[z]	1		
	Fruit are eaten without peeled off	1		
M. pentandra	Ripe fruit are eaten fresh	21	Building materials[y]	1
	Ripe fruit are cooked for *kuan*[z]	6	Dye[w]	1
	Ripe fruit are eaten with sticky rice cooked with coconut milk	3		
	Mature-green fruit are eaten fresh	1		
M. sylvatica	Ripe fruit are eaten fresh	2		

[z]*Yam* : Thai salad made with a various kinds of ingredients such as shrimps, meats, vegetables, and fruits which flavored with *nam plaa* (Thai fish sauce extracted from salted and fermented fish), dried chili peppers, sugar, and garlic; *kuan* : mango preserve resembling toffee or jam; *nam phrik* : dip made with *nam plaa*, chili, garlic, calamondin, and sugar.

[y]The heartwood is available.

[x]Seedling of *M. caloneura* was used as rootstock for *M. indica* grafts, especially for 'kaeo' variety.

[w]Bark of *M. pentanera* , especially of *muang khai* , is available as a dye of pale brown for fabrics.

Plate. 5-7. Uses of fruit of wild *Mangifera*. (A) Fruit of *M. caloneura* for preparing *yam* salad (Phayao); (B) Fruit of *M. sylvatica* collected to eat fresh (Chiang Rai).

Another factor would be decreased access to forests. Mountainous forests also cover a large part of the land in north Laos, but wild mangoes have been well utilized by local people (Chapter 2). Shifting cultivation is still practiced in the region, and farmers commonly go into the forests for hunting and gathering. Hence, wild plant use is part of their daily lives, and related knowledge would be maintained to the present. Shifting cultivation also used to be practiced in North Thailand by ethnic minorities, but it has been restricted since the 1980s. Finally, farmers changed from shifting to permanent cultivation. Today, forests are reserved, and access to forests is reduced. Historical forest resources (e.g., medicinal plants and timber) are being replaced by alternatives, such as scientific medicines and industrial products. In this way, the changes in lifestyle or sense of value may also accelerate the decline of wild plant use. Indigenous knowledge regarding wild plant use may have been gradually lost, resulting in a decline in people-plant relationships in North Thailand.

SUMMARY *Mangifera* trees were explored and their local names and uses were record to understand their current utilization in North Thailand. *M. caloneura* and *M. pentandra* occurred frequently. *M. sylvatica* and *M. linearifolia* were also observed although they were quite rare. Average fruit weight of *M. caloneura* and *M. pentandra* varied widely among trees (22.2–93.0 g and 37.5–77.0 g, respectively). *M. caloneura* had five major local names, while *M. pentandra* had three. Intraspecific variation was not clearly recognized although fruit morphological traits varied, and neither intentional conservation nor cultivation of superior varieties was observed. People-plant relationships regarding wild *Mangifera* species in North Thailand were relatively tenuous compared to those in Northeast Thailand.

Chapter 6

Common *Mangifera* Species Utilized in South Thailand as Compared with Java

In Chapter 6, Mangifera species in South Thailand, especially M. foetida Lour. and M. odorata Griff. under local cultivation, is studied. Firstly, folk taxonomy and local uses in Java where the same two species are utilized are described in Section 1. Subsequently, those in South Thailand are described and compared to Java in Section 2.

Section 1

Folk Taxonomy and Uses of Local Mangoes in Java

—Especially on a Difference between Folk and Botanical Taxonomies—

Introduction

Edible *Mangifera* species are found in Java. In particular, *M. foetida* Lour. and *M. odorata* Griffith, in addition to *M. indica*, are utilized and cultivated in this region. The two species have large fruits that are comparable to those of *M. indica*, although these fruits have a strong turpentine smell.

However, folk taxonomy and local uses of non-indica mangoes in Java have not been well-documented. Some information regarding intraspecific variation among *M. foetida* and *M. odorata* in West Java is available: *M. foetida* has been subdivided into 'limus piit', with small and globose fruit, and 'limus tipung', with large and oblong fruit (Bompard, 1992a); *M. odorata* was subdivided into the inferior 'bembem', 'kaweni', with less fibrous flesh and a

mild turpentine taste, and the superior but rarer ‘gandarassa’ (Bompard, 1992b).

In this section, an ethnobotanical study was conducted to increase our understanding of folk taxonomy and the local uses of non-indica mangoes in Java.

Research Area and Methods

The field survey was conducted mainly in the province of West Java in addition to the provinces of Central Java and Yogyakarta (Fig. 6-1-1). *Mangifera* species (excluding *M. indica*) were explored. After the trees were identified, their coordinate locations using the global positioning system (GPS) were recorded. Tree morphology and leaf and flower traits were observed and photographed for species identification. If there were neighboring villagers, interviews were conducted in the Indonesian language with interpreters. Interviewees provided information on the local names, uses, fruit morphology, and fruit taste of each *Mangifera* tree. In addition, if they knew of locations where *Mangifera* trees were growing, the locations were asked and observations and interviews were conducted in the same manner. All surveys were conducted during the flowering season in early August 2012.

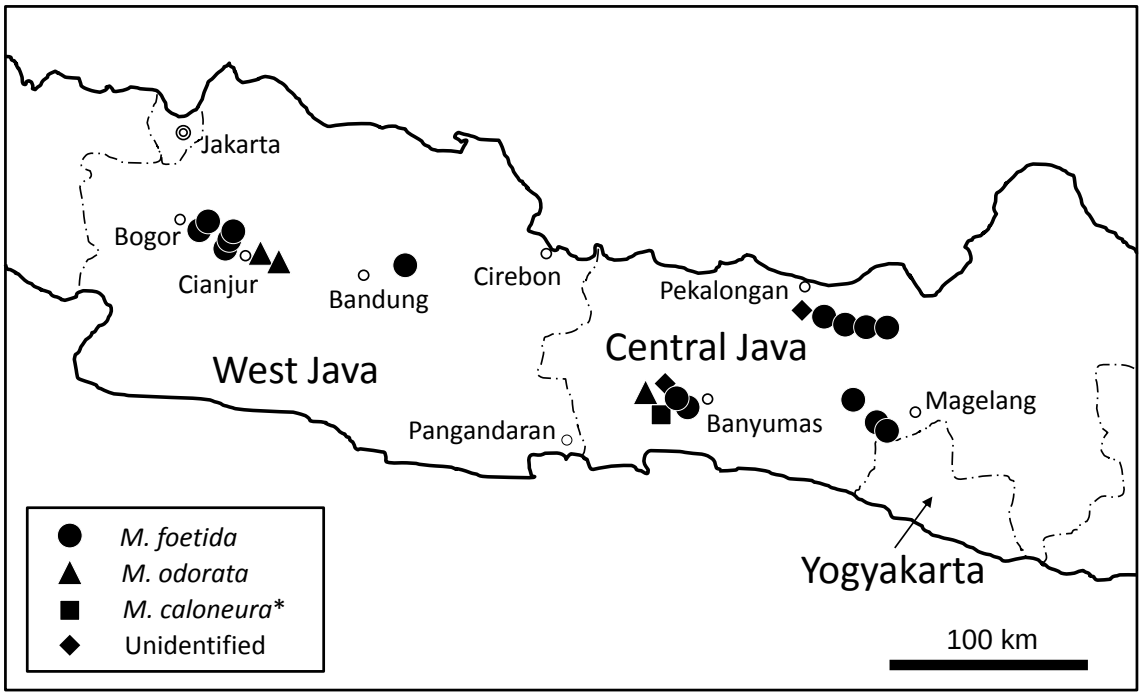

Fig. 6-1-1. Locations of the *Mangifera* trees in Java. *One tree was likely *M. caloneura* but remained unidentified due to the lack of floral observation.

Plate 6-1-1. Tree shape (A), leaves (B), inflorescences (C), flowers (D), and fruit (E) of *Mangifera foetida* in Java.

Plate 6-1-2. Tree shape (A), leaves (B), inflorescences (C), flowers (D), and fruit (E) of *Mangifera odorata* in Java.

Results and Discussion

Growing environment

A total of 28 trees of non-indica mangoes were confirmed and identified as *M. foetida* (n=22) (Plate 6-1-1) and *M. odorata* (n=3) (Plate 6-1-2). The remaining three trees were not identified: one was likely *M. caloneura*, and the two others were likely *M. foetida* or *M. odorata*. The *M. caloneura*-like tree was a straight, huge tree exceeding 15 m in height, and its small seeds (3 cm in length) were remained on the ground. *M. foetida* was found extensively throughout the research area (Fig. 6-1-1) and at a more frequent tendency than *M. odorata*. Half of the trees (15 of 28) were found in the vicinity of settlements and homegardens (Plate 6-1-3) and were believed to be planted by the local people. Several *M. foetida* trees were documented to have grown spontaneously, such as in bushes and on river banks. Wild-type *M. foetida* is found in Java (Bompard, 1992a), but the natural forests that are accessible to the local people have been mostly lost and are limited, such as in national parks. Five trees were growing in bushes. Bush designates not natural vegetation but rather secondary forests that are easily

Plate 6-1-3. Growing environments of the non-indica mangoes investigated in Java. (A) In front of a house (Pekalongan); (B) in the entrance of a house (Yogyakarta); (C) in a homegarden (Bandung); (D) in a school (Pekalongan).

accessible to local residents, e.g., along roads. Someone may have eaten non-indica mangoes and left the seeds in these bushes. Six *M. foetida* trees were growing on river banks. Some of these sites were difficult to approach, and no trees seemed to have been planted intentionally. Therefore, such river banks can be considered locations where natural vegetation tends to be partially retained, and *M. foetida* trees may occur spontaneously along the river banks. All *M. odorata* trees were considered to be planted by people. A *M. caloneura*-like tree was observed in a graveyard where the natural vegetation was remained.

Local uses

M. foetida and *M. odorata* fruits were commonly eaten in different ways. Ripe fruits were eaten fresh or preserved in syrup (*manisan*). Less preferable fruits with fibrous flesh or a sour taste were made into juice. Both ripe fruits and mature green fruits were added to *rujak* salad along with cucumber, pineapple, and chili. Ripe fruits were eaten with ice (*es buah*) in the same manner as other types of fruits.

Folk taxonomy

A total of 10 names were recorded for 17 non-indica mango trees (Table 6-1-1). The name *keweni*, which included both *M. foetida* and *M. odorata*, was most common. *M. foetida* was also called *limus* or included an adjective. *Bembem* had been reported as an inferior form of *M. odorata*, whose fruit has a "strong smell and taste of turpentine reminiscent of the fruit of *M. foetida*" (Bompard, 1992b). However, in the present survey, *bembem* was recorded for *M. foetida*. *M. odorata* had been also reported to be distinguished as the inferior 'bembem', 'kaweni' with less fibrous flesh and a mild taste of turpentine, and the superior 'gandarassa' (Bompard, 1992b), but *bembem* and *gandarassa* were not confirmed for *M. odorata* in this survey.

Table 6-1-1. Indonesian local names of non-indica mangoes studied in Java.

Species	Local name	Count
M. foetida[y]	*keweni*	4
	limus	4
	(*limus piit*[z])	(2)
	(*limus*)	(1)
	(*limus ageng*[z])	(1)
	mbawang	3
	pakel	2
	bembem	1
	kerikel	1
M. odorata	*keweni*	3
(*M. caloneura*)	*poh*	1

[z]*Piit* means a kind of small bird, and *ageng* means large.

Impressions regarding fruit traits were noted by 14 informants (data not shown). *Keweni* tended to be highly valued for its fruit taste as "palatable", "sweet", "having good aroma", and "less fibrous". There were also comments such as "*keweni* has softer flesh than *limus*" (Bogor) and "*keweni* is palatable, so there is no need to make into juice" (Yogyakarta). On the other hand, the taste of *limus* fruit was relatively negatively evaluated as "not palatable" and "sour". The results from interviews on fruit traits indicated that the trees with relatively more favorable fruits are recognized as *keweni* among the species of *M. foetida*.

Keweni has been interpreted as the vernacular name of *M. odorata*. Regions where *M. odorata* is called *keweni* range widely across countries in Indonesia, Malaysia, and the Philippines (Lim, 2012). However, *keweni* in Java was assigned to both *M. odorata* and *M. foetida*. Furthermore, the *M. foetida* trees called *keweni* tended to be recognized to produce superior fruits to those of *limus*. Therefore, *keweni* would refer to the form with the preferred fruit quality among *M. foetida*. On the other hand, *limus* included *M. foetida* only. *Bembem* was found to belong to *M. foetida* in the present survey, although *bembem* has been recorded previously as an inferior form of *M. odorata*. Thus, the folk taxonomy of non-indica mangoes in Java seems to be based primarily on fruit quality and does

not correspond to botanical taxonomy (Fig. 6-1-2).

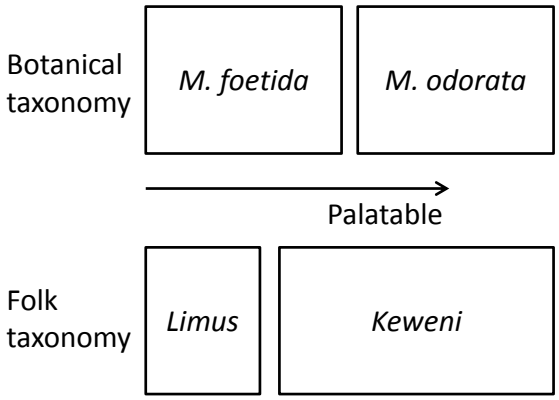

Fig. 6-1-2. Comparison of botanical and folk taxonomies in the present study conducted in Java.

M. odorata is considered a hybrid between *M. foetida* and *M. indica* based on morphological similarities (Hou, 1978) (The morphological intermediacy of *M. odorata* is precisely described in Section 2 in this chapter). Genetic similarity based on AFLP (amplified fragment length polymorphism) analysis also supported this conclusion (Teo *et al*., 2002). Therefore, folk taxonomy in Java, which showed vague distinction between *M. foetida* and *M. odorata*, might be appropriate.

Chapter 6

Section 2

Folk Taxonomy and Uses of Local Mangoes in South Thailand
— Especially on Corresponding Folk and Botanical Taxonomies —

Introduction

Mangifera species utilized in South Thailand are different from those in North and Northeast Thailand. In particular, *M. foetida* Lour. and *M. odorata* Griff. are cultivated in South Thailand. The vernacular names were reported previously (Chayamarit, 2010), but whether intraspecific variation is recognized and how local people distinguish them remain unknown.

In this section, field surveys were conducted to explore folk taxonomy and record the current utilization and cultivation of non-indica mangoes in South Thailand.

Research Area

South Thailand is located on the Malay Peninsula between the Andaman Sea and the Gulf of Thailand, bordering Malaysia on the south. Plains are limited and the mountain chains run roughly north to south. The climate of the South is influenced by two monsoons: the southwest winds bring heavy rains from the Indian Ocean, whereas the northeast winds carry more modest rains from the Gulf of Thailand. Therefore, South Thailand has more rainfall than the other regions

throughout the year. Average annual rainfall in the past 30 years (1968–1997) was 2,176 mm in Trang Province on the west coast and 2,335 mm in Nakhon Si Thammarat on the east coast[7]. The main vegetation is tropical rain forest. The original forest is limited, although it is conserved as forest reserves in national parks. Therefore, wild mangoes in natural forests were not studied due to their low frequency. Para rubber, oil palm, fruits, and coconut palm are major crops cultivated in a large area. Para rubber and oil palm are typically monocultured in estates, while the production of fruits and coconut palm tends to be mixed cropping. Fruits and flowers are diversified and densely planted in well-developed homegardens.

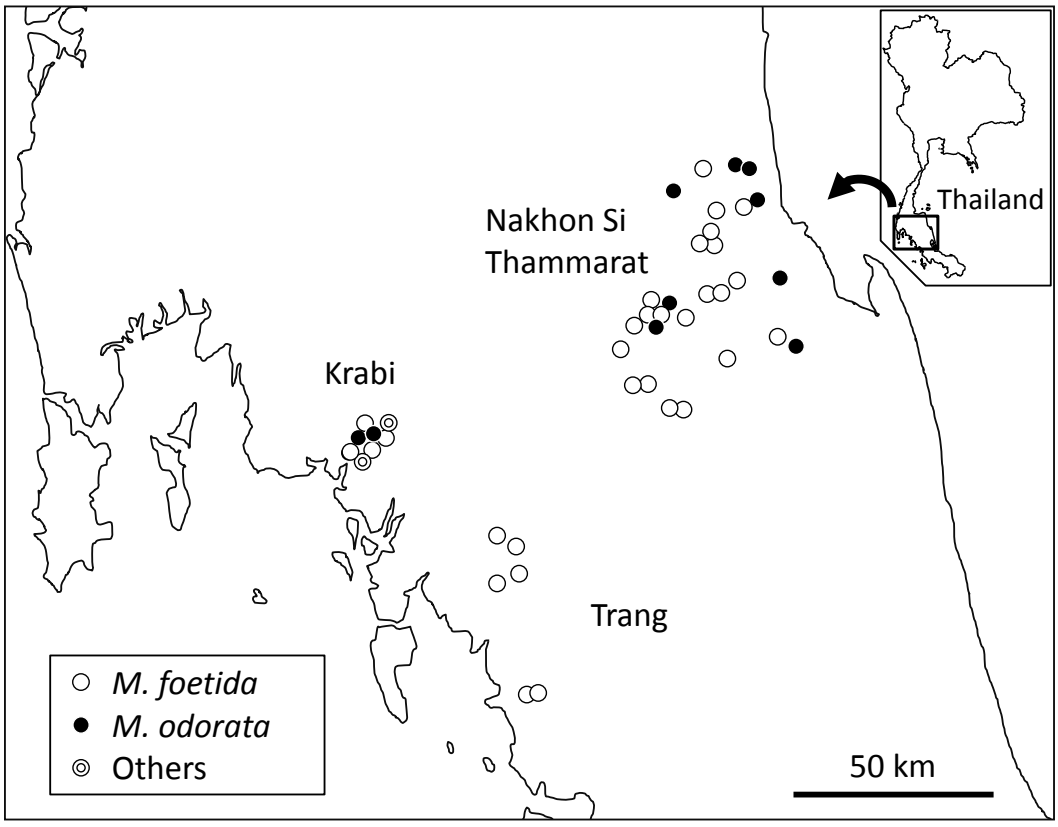

Fig. 6-2-1. Locations of the *Mangifera pentandra* trees observed in Northeast Thailand; the survey included 171 trees at 137 locations.

[7] Rainfall data were collected at the Meteorological Department in Bangkok.

Methods

The field survey was conducted in Krabi, Trang, and Nakhon Si Thammarat Provinces in South Thailand. *Mangifera* species (excluding *M. indica*) were explored. When the trees were found, their coordinate locations using the global positioning system (GPS), and elevations were recorded. Tree morphology, leaf, and flower traits were observed and photographed for species identification. If there were neighboring villagers, interviews were conducted in Thai with an interpreter. Interviewees provided information on local names, uses, fruit morphology, and fruit taste of *Mangifera* trees. In addition, if they knew of other locations of *Mangifera* trees, the locations were asked and observations and interviews were conducted in the same way. All surveys were conducted in the flowering season of early March 2013. Overall, 49 trees of non-indica mangoes were confirmed and 35 were identified as *M. foetida*, 12 as *M. odorata*, and 2 as another congener that remained unidentified. A specimen of *M. odorata* with inflorescences was prepared for preservation and stored in the Forest Herbarium (BKF) of Thailand.

Results and Discussion

Distribution and growing environment

M. foetida was distributed in all three provinces surveyed, and *M. odorata* was often found in Nakhon Si Thammarat (Fig. 6-2-1). Most trees (37 of 49) were cultivated in the vicinity of settlements (Plate 6-2-1A·B) or homegardens where various plants were densely planted (Plate 6-2-1C). Non-indica mangoes tended to be cultivated in well-developed homegardens. Together with non-indica mangoes, common mango, rambutan, longkong, calamondin, durian, dragon fruit, and papaya were planted in homegardens. The density and variation of plants of homegardens differed by area, and non-indica mangoes were not found in less-developed homegardens where fewer species were planted sparsely, such as coastal areas in Nakhon Si Thammarat. However, *M. foetida* was known as *ma mud*, even in areas in which the species was not planted. *M. foetida* was also cultivated at the edge of commercial orchards (Plate 6-2-1D). The term “orchards”

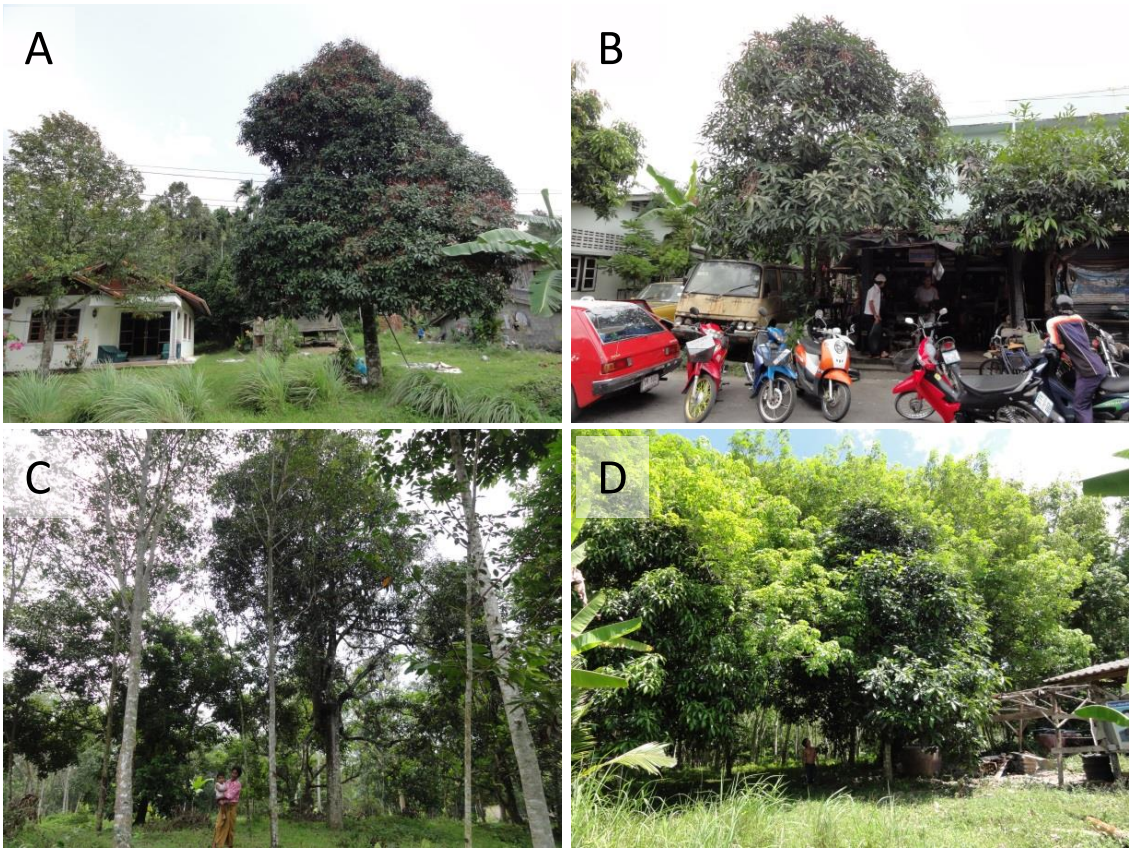

Plate 6-2-1. Growing environments of non-indica mangoes in South Thailand. A: *Mangifera foetida* tree in the vicinity of a house (Nakhon Si Thammarat); B: *M. odorata* tree planted beside a shop (Nakhon Si Thammarat); C: *M. foetida* tree in a well-developed homegarden (Nakhon Si Thammarat); D: *M. foetida* tree at the edge of the a para rubber estate (Trang).

in this section includes estates of para rubber and oil palm, according to classification by the National Statistical Office of Thailand. *M. odorata* was not found in such orchards.

About 80% of *M. foetida* and *M. odorata* surveyed were intentionally planted from seeds or seedlings based on comments such as: “I bought a *M. odorata* fruit and planted the seed because it was delicious” (Nakhon Si Thammarat).

Uses

The primary use was fruit consumption (Table 6-2-1), and there were no differences in usage among folk types (data not shown). Both mature-green and fully ripe fruits were eaten fresh. Mature-green fruits were eaten fresh with seasonings or put into *yam* salad as a vegetable in the same manner as *M. indica*.

However, mature-green fruits of *M. foetida* and *M. odorata* were also prepared as vegetables for Thai curries, although *M. indica* fruit is not used for curries (see the subsection Parallel use of three mangoes). *M. foetida* fruit were said to be sold for 5–25 bahts/kg at local markets, while *M. odorata* fruit were said to be more expensive. *M. indica* fruit are generally sold for 30 bahts/kg.

Local names and impressions of fruit

A total of 16 names were assigned to non-indica mangoes (Table 6-2-2). There were more names than the total number of trees studied because multiple names could be used for single trees. There were seven local names for *M. foetida*. *Ma mud* was common in the three provinces. *Ma* means fruit and *mud* directly means *M. foetida*, and was previously reported as a common vernacular name of *M. foetida* (e.g., Chayamarit, 2010; Kostermans and Bompard, 1993; Smitinand, 1980). In Nakhon Si Thammarat, *som mud* was a typical name for *M. foetida*. *Som* translates to sour, but *som mud* did not seem to be a sour type of *M. foetida*, based on comments such as: "*ma mud* is in standard Thai, while *som mud* is in a dialect of South Thailand" (Nakhon Si Thammarat). *Som mud* would not be distinguished from *ma mud* as a different folk type.

Intraspecific variation in *M. foetida* was recognized based on fruit size, but not completely as cultivars had been established. Five of six *M. foetida* trees observed in Trang were called either *mud phrik* or *mud khaa khwaai*. *Phrik* means chili and *khaa khwaai* means leg of buffalo. Local informants recognized that *mud phrik* fruit was smaller than that of *mud khaa khwaai* or *ma mud* (Table 6-2-3).

Table 6-2-1. How to eat fruits of *Mangifera foetida* and *Mangifera odorata* in South Thailand.

How to eat	*M. foetida*	*M. odorata*	(*M. indica*)
Ripe fruit are eaten fresh as table fruit	○	○	○
Mature-green fruit are eaten fresh with sources[z]	○	○	○
Mature-green fruit are eaten as vegetable for Thai curries[y]	○	○	×
Mature-green fruit are eaten as vegetable for Thai salad (*yam*)	○	○	○

"○" and "×" designate which species were used in each way of eating.

[z]*Kapi waan* is dip mixed with *kapi* (Thai shrimp paste fermented with ground shrimp and rice), shrimp, palm sugar, shallot, and bird's eye chilli; *nam plaa waan* is dip mixed with *nam plaa* (fish source made from fermentation of salted anchovies), shrimp, palm sugar, shallot, and bird's eye chilli.

[y]*Kaeng som* is Thai sour curry with tamarind; *kaeng kati* is Thai curry with coconut.

Table 6-2-2. A total of 16 local names were assigned to 49 trees of non-indica mangoes observed in South Thailand.

Province	*M. foetida*	Count	*M. odorata*	Count	Unidentified	Count
Krabi	*ma mud*	6	*mud muang*	3	*muang kaem daeng*	2
	mud baan	2				
	mud phrik	1				
Trang	*mud phrik*	3				
	mud khaa khwaai	2				
	ma mud	1				
Nakhon Si	*som mud*	13	*mud muang*	5		
Thammarat	*la mud*	4	*muang mud*	2		
	ma mud	4	*huailii*	2		
	luuk mud	1	*kluaimii*	1		
	mud baan	1	*kuainii*	1		
			kluainii	1		
			kluai muang	1		

Meanings are as follows: *baan*, cultivated; *kaem daeng*, flushed cheeks; *khaa khwaai*, leg of baffalo; *la mud*, sapodilla (*Manilkara zapota*); *luuk*, numerative noun for fruits; *ma*, prefix denoting fruits; *muang*, mango or *Mangifera indica*; *mud*, *Mangifera foetida*; *phrik*, bird's eye chili; *som*, sour. *Huailii*, *kluaimii*, *kuainii*, *kluainii*, *kluai* seemed to be originating in *kewini*, which is a Malay vernacular name for *Mangifera odorata*.

Table 6-2-3. Impressions regarding fruit size of *Mangifera foetida* and *Mangifera odorata* noted by local people in South Thailand.

Species	Province	Local name	The number of informants			
			Big (>500g)	Middle (≃350g)	Small (≃250g)	Not reffered
M. foetida	Krabi	*ma mud*		1	1	4
		mud phrik			2	0
	Trang	*mud phrik*			2	1
		mud khaa khwaai	1			1
		ma mud	1			0
	Nakhon Si	*ma mud*		2		2
	Thammarat	*som mud*	1	3	2	7
		la mud				4
		mud baan		1		0
		luuk mud				1
M. odorata	Krabi	*mud muang*				3
	Nakhon Si	*mud muang* [z]		4		3
	Thammarat	*kuainii* [y]		1	1	4

[z] *Muang mud* was included.

[y] *Kluainii*, *kluaimii*, *huailii*, and *kluai muang* were included.

Hence, *M. foetida* in Trang seemed to be distinguished based on fruit size. *Mud phrik* fruit was said to be smaller than that of *ma mud* also in Krabi. Thus, *mud phrik* would be recognized as a variation of *M. foetida* with small fruit.

M. odorata had no classification based on fruit traits. There were a total of seven local names for *M. odorata* (Table 6-2-2), which were separable into two groups. One included *mud muang* and *muang mud*. *Mud* represents *M. foetida* and *muang* represents *M. indica*. Therefore, *mud muang* is a combined name for *M. foetida* and *M. indica*. The second group includes *huailii*, *kluaimii*, *kuainii*, and *kluainii*. These names have phonetic similarity with *keweni*, a Malay vernacular name of *M. odorata*. Therefore, these names are thought to have been imported as foreign words. *M. odorata* in Narathiwat Province was reportedly called *kinning* (Chayamarit, 2010; Smitinand, 1980), which was the only vernacular name recorded for *M. odorata* in South Thailand.

Different forms of *M. foetida* were recognized based on the fruit size, shape, or texture in other regions; for example, small and globose ‘limus piit’ and large and oblong ‘limus tipung’ in West Java; and ‘asem linggau’ with large and oblong fruit with abortive seeds in East Kalimantan (Bompard, 1992a). *M. odorata* was also distinguished by fruit traits; e.g., inferior ‘bembem,’ palatable ‘kaweni’ and superior ‘gandarassa’ in West Java, and yellow ‘sagay’ and greenish ‘huani’ in the Philippines (Bompard, 1992b). In South Thailand, some *M. foetida* was distinguished by fruit size, but was not commonly established as a cultivar.

Folk taxonomy

Folk taxonomy of non-indica mangoes in South Thailand has two key features. One is the status of *M. odorata*, which was recognized between *M. indica* and *M. foetida* because it was called *mud muang*. Both *M. foetida* and *M. odorata* have reddish inflorescences (Plate 6-2-2A1·B1) and appear similar from a distance during flowering season. They are easily distinguished by inflorescences from *M. indica* (Plate 6-2-2C1). However, when closely observed, the flower shape of *M. odorata* appeared more similar to that of *M. indica* than *M. foetida*. Flowers of *M. foetida* point upward and have long petals (≃10 mm) (Plate

6-2-2A2), while flowers of *M. odorata* point forward and have shorter petals (≃5 mm) (Plate 6-2-2B2), similar to *M. indica* (Plate 6-2-2C2). In addition, leaves of *M. foetida* are stiff, thick, and raised between nerves (Plate 6-2-2A3), while leaves of *M. odorata* are relatively soft, thin, and flat (Plate 6-2-2B3). An intermediate morphology of *M. odorata* was noted by Hou (1978). A molecular genetic study (Teo *et al*., 2002) also indicated the hybrid status of *M. odorata*.

Another feature was the clear distinction between *M. foetida* and *M. odorata*. *Keweni* in Java included not only *M. odorata*, but also some *M. foetida* with an improved eating quality (Section 1 in this chapter). The latest taxonomy accepts *M. foetida* and *M. odorata* as independent species, assigned to the same subgenus (Kostermans and Bompard, 1993). However, *M. odorata* had been

Plate 6-2-2. Inflorescences, flowers, and leaves of *Mangifera foetida* (A1–3), *M. odorata* (B1–3), *M. indica* (C1–3). Inflorescences of *M. foetida* (A1) and *M. odorata* (B1) were characterized based on their red coloration and appeared similar from a distance. Inflorescences of *M. indica* (C1) were not reddish. However, upon closer observation, flowers of *M. foetida* pointed upward with 10-mm-long petals (A2), while flowers of *M. odorata* pointed forward with 5-mm-long petals (B2), which was similar to flowers of *M. indica* (C2). Leaves of *M. foetida* were stiff, thick, and raised between nerves (A3), but leaves of *M. odorata* were relatively thin, soft, and flat (B3), similar to those of *M. indica* (C3). Therefore, the morphologies of *M. odorata* were intermediate between those of *M. foetida* and *M. indica*.

assigned as one variety of *M. foetida* (e.g., Blume, 1850) before being described as a new species by Griffith (1854). *M. foetida* and *M. odorata* were distinguished clearly in South Thailand, while the folk taxonomy in Java did not separate them. This situation indicates that *M. odorata* started to be utilized relatively recently in South Thailand, although the dispersal date is unknown. Indeed, the origin of *M. odorata* is unknown because it has never been found in the wild anywhere on the globe. On the other hand, *M. foetida* is distributed naturally in South Thailand, and has been utilized since early times. Therefore, people in South Thailand would recognize *M. odorata* obtained from outside the region as a different fruit tree from *M. foetida*.

Folk taxonomy increases our understanding of the relationships between people and plants. Four *Mangifera* species in North Thailand were utilized as wild edible fruits, but the intraspecific variation was not distinguished by local people (Chapter 5). On the other hand, *M. pentandra* in Northeast Thailand had a superior variation, *kalon* mango, which had been selected among wild *M. pentandra* (Chapter 4), and some were even cultivated. This *kalon* mango was obviously distinguishable from other *M. pentandra* by its fruit size, taste, and morphologies of the canopy, leaf, and bark. Therefore, the people-plant relationship on *Mangifera* species in Northeast Thailand is developed more than in North Thailand. In South Thailand, all *M. foetida* and *M. odorata* were under cultivation; wild-grown individuals were not found in this survey. The relationship between people and mangoes is more developed in South Thailand than in Northeast Thailand. Intraspecific variation in *M. foetida* in terms of fruit size was recognized, albeit only vaguely. Further development of the utilization of these mangoes may lead to selection and breeding of new, improved cultivars, such as *M. indica*, the common mango.

Parallel use and cultivation of three mangoes

Local people in South Thailand have cultivated three *Mangifera* species; i.e., *M. indica*, *M. foetida*, and *M. odorata*, although *M. foetida* and *M. odorata*

were not produced on a large scale. Neither selection of *M. indica* nor elimination of non-indica mangoes had occurred. The main factors would be the preferable ecological conditions for *M. foetida* and *M. odorata*, and food preference. Cultivation of *M. indica* is not feasible in wet climates because *M. indica* is vulnerable to anthracnose and has roots that are susceptible to excessive soil humidity. For stable production of *M. indica* under wet conditions, roof protection from rain such as in Okinawa or breeding programs for anthracnose-resistant varieties such as in Florida are required. On the other hand, *M. foetida* and *M. odorata* are adapted to areas with abundant rainfall distributed uniformly throughout the year. South Thailand is situated in a tropical monsoon area due to the influence of both the northwest monsoon from the Pacific Ocean and the southwest monsoon from the Indian Ocean. Therefore, *M. foetida* and *M. odorata* would grow well and produce fruits constantly, even in the wet climate of South Thailand. In this way, *M. foetida* and *M. odorata* have become highly valued and become popular local fruits, and *M. indica* would not become dominant. *M. foetida* is also considered a suitable rootstock for *M. indica* grafts in wet climates (Bompard, 1992a). Besides, *M. foetida* and *M. odorata* fruits are preferred as ingredients for curries, which are eaten daily in South Thailand. Both fruits have strong and pronounced flavor even in curries and may be more suitable than *M. indica*. In addition, there may be demand in the other regions in which curries are commonly consumed. The production of *M. foetida* and *M. odorata* has the potential to become popular in other wet tropical regions.

SUMMARY Local names and uses of non-indica mangoes in Java and South Thailand were investigated. A total of 77 trees were observed and identified as 57 *M. foetida*, 15 *M. odorata*, and 5 trees were not identified. The majority of trees were planted in homegardens and in the vicinity of settlements. The popular use of *M. foetida* and *M. odorata* was fruit consumption, similar to *M. indica*, except for use of the mature green fruits in curries in South Thailand. *M. foetida* in Trang

Province, Thailand, was distinguished into *mud khaa khwaai* with larger fruit and *mud phrik* with smaller fruit, although no cultivars were established in South Thailand. *M. odorata* had two kinds of names in South Thailand; *mud muang*, a combined name of *M. foetida* (*mud*) and *M. indica* (*muang*), and *kuainii* or *kuainii*-like name, probably originating in *kewini*, a Malay name of *M. odorata*. *Keweni* in Java included not only *M. odorata* but also some *M. foetida* with a better eating quality. However, in South Thailand, *M. odorata* was clearly distinguished from *M. foetida*, and believed as an intermediate of *M. foetida* and *M. indica*. *M. foetida* and *M. odorata* were all cultivated in South Thailand; therefore, utilization of non-indica mangoes is more developed than any other regions in Thailand. *M. foetida* and *M. odorata* were likely cultivated in South Thailand due to their good productivity under wet conditions and their use as ingredients in curries for their pronounced aroma.

Chapter 7

Summary and Conclusion

The current uses of *Mangifera* trees in Southeast Asia were investigated, thereby handing down information on local peoples to future generations. A total of six species (*M. caloneura*, *M. pentandra*, *M. linearifolia*, *M. sylvatica*, *M. foetida*, and *M. odorata*) were confirmed as growing in Northeast Thailand, North Thailand, north Laos, central Laos, northeast Vietnam, South Thailand and Java, Indonesia.

In Chapter 1, the background of the study was provided, including basic information regarding origin, distribution, and morphology of the genus *Mangifera*. Next, the objectives of the study were provided. In Chapter 2, extensive surveys on *Mangifera* species conducted in Mainland Southeast Asia were introduced. A total of 260 *Mangifera* trees in Northeast Thailand, north and central Laos, and northeast Vietnam were classified into four groups based on the morphological characteristics of leaves and tree shape, and their local names and uses were recorded. In Chapter 3, taxonomic developments regarding *M. caloneura* Kurz, which is distributed widely in Southeast Asia, were tracked over 138 years to demonstrate the existence of two different descriptions; one indicates the presence of only 1 fertile stamen per flower, and the second indicates 5 fertile

stamens. From this review, I conclude that I should follow the former description corresponding to the original description by Kurz (1873). *Kalon* mango in Northeast Thailand has palatable fruits, although its species identification is not yet completed, as discussed in Chapter 2. Therefore, in Chapter 4, intensive surveys conducted on *Mangifera* species including *kalon* mango in the region were introduced. The results discussed in Chapters 4–6 offer a series of ethnobotanical records of *Mangifera* species in Thailand (Fig. 7-1–7-6).

Mangifera species in Northeast Thailand were discussed in Chapter 4. *M. pentandra* was found to be the dominant *Mangifera* in the region and was distinguished intraspecifically into *kalon* and *paa* mangoes. Morphological and qualitative differences in tree shape, bark, and fruits were also observed between *kalon* and *paa* mangoes. *Kalon* mango fruits (52.8 g, 19.2°Brix) had a higher sugar content and were larger than those of *paa* mango (38.3 g, 15.0°Brix). A dense, dome-shaped canopy, thin narrow leaves, and pale-brown bark distinguished *kalon* mango from *paa* mango; they are distinguishable even when they are not fruiting. Many *paa* mango trees were very large and were found growing in crop fields, while the *kalon* mango trees tended to be smaller and to grow near human settlement. Therefore, *paa* mango trees are supposed to be remnants of natural forest and *kalon* mango trees to have been planted recently. *Kalon* mango may be the product of unintentional selection for superior fruits.

Mangifera species in North Thailand were discussed in Chapter 5. *M. caloneura* and *M. pentandra* were found to be common in this region. *M. sylvatica* and *M. linearifolia*-like trees were also observed although quite rarely. *M. caloneura* had five major local names, while *M. pentandra* had three. The average fruit weight of *M. caloneura* and *M. pentandra* varied widely among trees (22.2–93.0 g and 37.5–77.0 g, respectively). However, intraspecific variation was not clearly recognized by the local people. Only *M. caloneura* with long and elongate fruits was distinguished as *muang kluai* or *muang khii yaa*, but they were not established as cultivars. Neither intentional conservation nor cultivation of superior varieties was observed.

Mangifera species in South Thailand were discussed in Chapter 6. *M.*

foetida and *M. odorata* were planted in homegardens and in the vicinity of settlements. According to folk taxonomy in Java, *keweni* would refer not only to *M. odorata* but also to *M. foetida* with the preferred fruit quality; therefore, this folk taxonomy did not correspond to botanical taxonomy. On the other hand, in South Thailand, *kuainii* or *kuainii*-like names were used, but they included *M. odorata* only. Therefore, *M. odorata* was clearly distinguished from *M. foetida*, and the folk and botanical taxonomies correspond to each other in South Thailand. In addition, *M. foetida* in Trang Province, South Thailand was categorized into *mud khaa khwaai* with large fruit and *mud phrik* with small fruit, although no cultivars were established.

Folk taxonomy increases our understanding of people-plant relationships which were found to differ among regions as discussed in Section 2 of Chapter 6. Four *Mangifera* species in North Thailand were utilized as wild edible fruits, but the intraspecific variation was not distinguished by local people. People-plant relationships in this region are tenuous. On the other hand, *M. pentandra* in Northeast Thailand has a superior form, *kalon* mango, which likely has been unintentionally selected for among wild *M. pentandra*. People-plant relationships in Northeast Thailand are more developed than those in North Thailand. The relationship is further developed in South Thailand, where *M. foetida* and *M. odorata* are all under cultivation. However, intraspecific variation is only vaguely recognized. Such gradual developments in people-plant relationships would overlap the evolutionary process of fruit tree domestication.

It is most notable that *kalon* mango is obviously distinguishable from wild *M. pentandra* and likely represents the first step of domestication as discussed in Chapter 4. This intraspecific differentiation was quite apparent, and was the only case confirmed in this study. It is unknown whether future populations will value *kalon* mango or discard it. However, I hope that the results of this study become a trigger for *kalon* mango to increase its visibility and utilization as it is considered as one of the important local fruits.

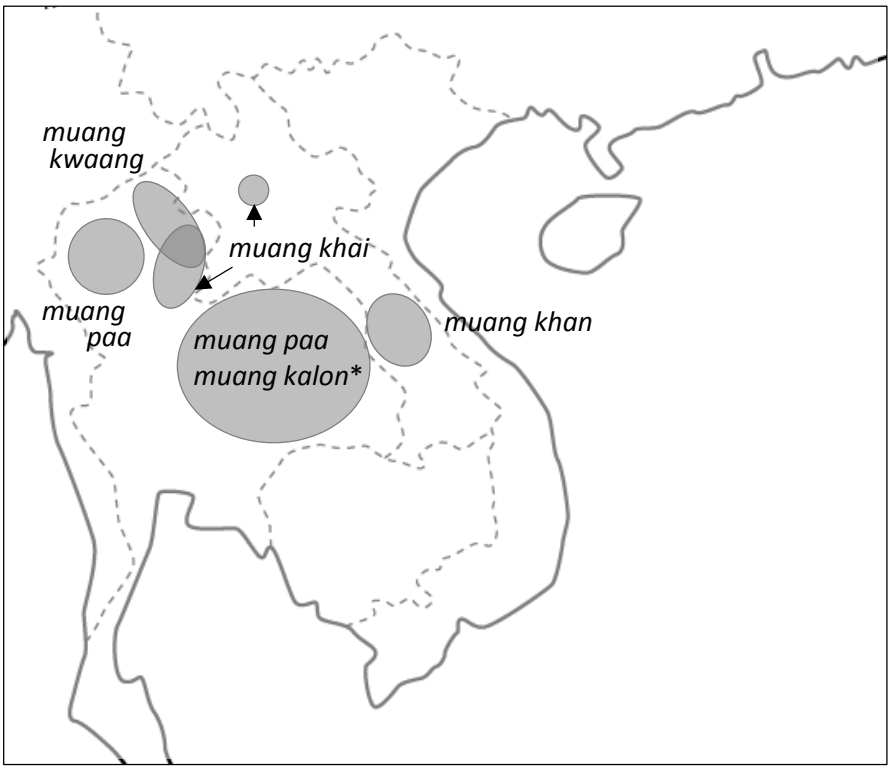

Fig. 7-1. Distributions of the major local names of *Mangifera pentandra*. *Among this species, *muang kalon* in Northeast Thailand had larger and palatable fruits.

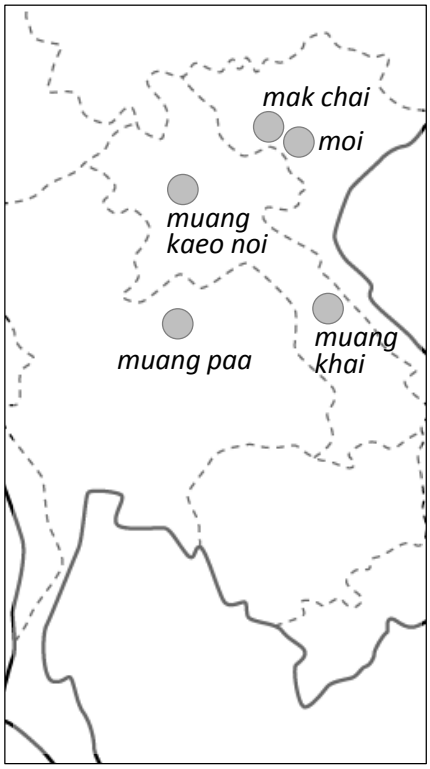

Fig. 7-2. Distributions of the major local names of *Mangifera linearifolia*.

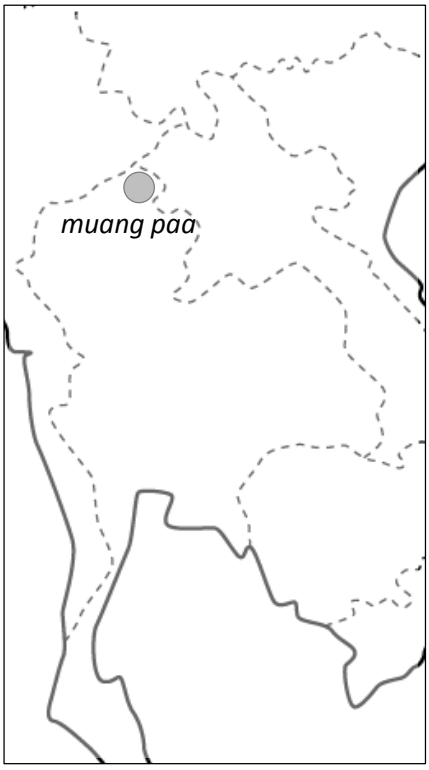

Fig. 7-3. Distributions of the major local names of *Mangifera sylvatica*.

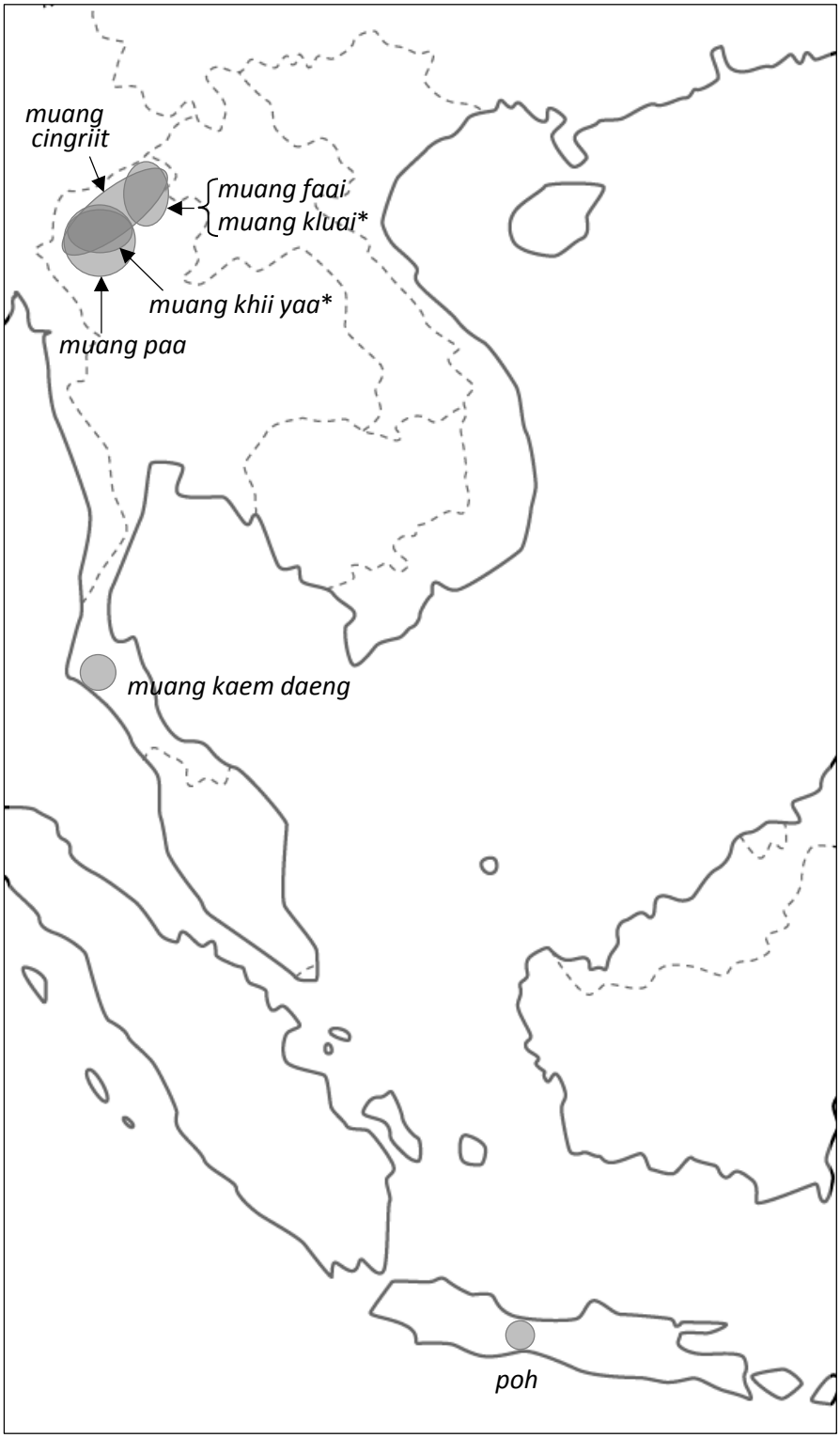

Fig. 7-4. Distributions of the major local names of *Mangifera caloneura*. **Muang kluai* and *muang khii yaa* in North Thailand had long and elongate fruits.

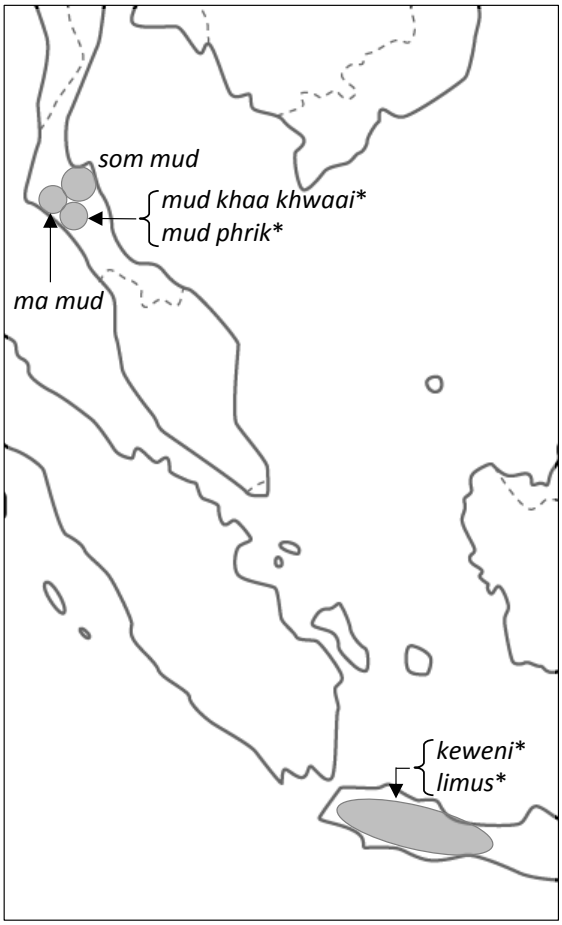

Fig. 7-5. Distributions of the major local names of *Mangifera foetida*. **M. foetida* with relatively better eating quality was recognized as *keweni* in Java; *M. foetida* in Trang province, South Thailand, was distinguished into *mud khaa khwaai* with larger fruits and *mud phrik* with smaller fruits.

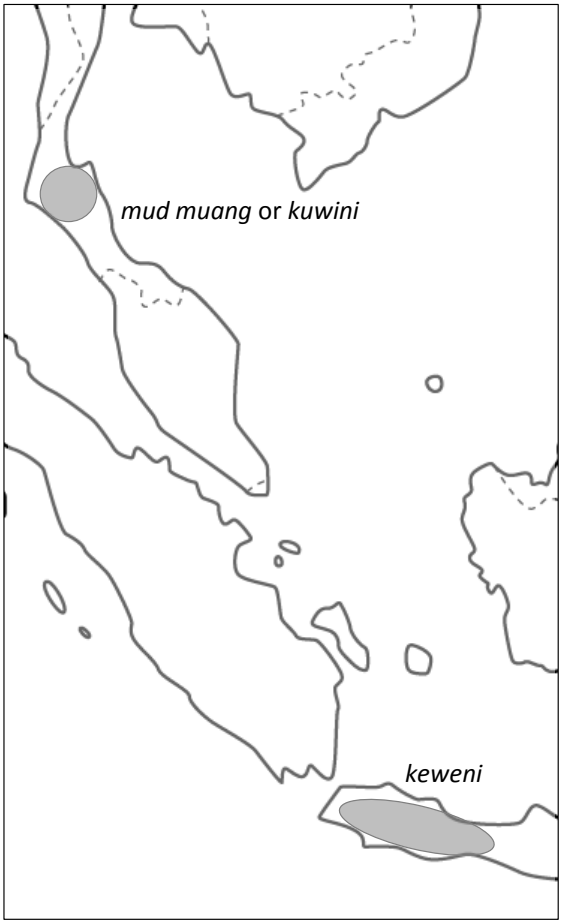

Fig. 7-6. Distributions of the major local names of *Mangifera odorata*.

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