THESIS APPROVAL

GRADUATE SCHOOL, KASETSART UNIVERSITY

Master of Science (Forest Biological Science)

DEGREE

Forest Biological Science | Forest Biology

FIELD | **DEPARTMENT**

TITLE: Morphology and Anatomy of Bamboos and Rattans Commonly Used in Lao People's Democratic Republic

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THESIS

MORPHOLOGY AND ANATOMY OF BAMBOOS AND RATTANS COMMONLY USED IN LAO PEOPLE'S DEMOCRATIC REPUBLIC

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A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
Master of Science (Forest Biological Science)
Graduate School, Kasetsart University
2012

Singkone Chaiyalad 2012: Morphology and Anatomy of Bamboos and Rattans Commonly Used in Lao People's Democratic Republic. Master of Science (Forest Biological Science), Major Field: Forest Biological Science, Department of Forest Biology. Thesis Advisor: Assistant Professor Sarawood Sungkaew, Ph.D. 115 pages.

Bamboos and rattans have been intimately associated with the livelihoods and traditions of the Lao people for centuries. These two groups of plant have provided many raw materials and products widely used in Lao PDR. Those divers make a confused in local names of bamboos and rattans. Moreover, matching a product to the right species based on their raw material composition can be problematic. This study aimed to use a combination of morphological and anatomical procedures to identify the bamboos and rattans commonly used in the Lao PDR. Bamboo and rattan specimens were collected from the wild and the semi-processed products to provide materials for studying their morphology and anatomy. Morphological characteristics were studied by using the specimens collected and compared with herbarium specimens and taxonomic books. Anatomical characteristics were studied by using a compound microscope. Ten species from six bamboo genera and seven species from two rattan genera were found. Descriptions of the morphology and anatomy of these species are provided. The culm cross-section of bamboos fall into three types (out of four) described by Wong (1995) as follows: Type I (*Indosasa sinica*); while Type II was not found in this study; Type III (*Bambusa blumeana*, *B. polymorpha*, *B. tulda*, *Dendrocalamus membranaceus*, *Gigantochloa albociliata*, *Schizostachyum virgatum*, *Schizostachyum* sp., and *Thyrsostachys siamensis*); and Type IV (*Dendrocalamus brandisii*). The cane cross-section of rattans fall into two types, out of the total three, described by Siripatanadilok (1986) as follows: Type I (all six species of *Calamus*); while Type II was not found in this study; and Type III (one species of *Plectocomiopsis*). This study provides a potential reference source for the identification of bamboos and rattans in their products. The information can be used for the matching of products with the raw materials in specific species.

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Student's signature Thesis Advisor's signature

ACKNOWLEDGEMENTS

The completion of this research was made possible by the contributions, encouragement and support from many individuals. I would like to thank my major advisor, Assistant Professor Sarawood Sungkaew (Ph.D), and co-advisor Associate Professor Somkid Siripatanadilok (Ph.D), who provided constant supports, and many opportunities, throughout the period of my study.

I would like to express my profound gratitude to individuals and institutions for their assistance in the course of undertaking this research. My thanks are also due to the Science and Education for Agriculture and Development-Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEAMEO-SEARCA), National Agriculture and Forest Research Institute, and Forestry Research Center, for the support and interest these institutions showed during the course of my work studies.

The lessons that I have learnt from this research will be very much useful for my future work in Lao PDR, and I plan to share this knowledge with Lao farmers.

I would also like to dedicate this work to my wife Eravanh Nitiphong, my daughter Silaphone Chaiyalad, and my son Adisone Chaiyalad, each of whom provided generous and ongoing support and encouragement to me, undying which enabled me to complete this challenged study.

Singkone Chaiyalad

February, 2012

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INTRODUCTION

More than 80% of the population of Lao PDR lives in rural areas, where Non-Timber Forest Products (NTFPs) are usually used for food security and a range of other uses. As bamboos and rattans are among the most popular NTFPs, villagers collect them for a range of potential uses, including the construction of houses, and rice stores, making rafts, mooring ropes, fences, bridges, animal and birds traps, fish traps, chicken cages, containers for steamed rice, sticks for roasting meat and vegetables, chopsticks, toothpicks, and many others. Bamboo or rattan shoots have long been regarded as important food items for household consumption. These groups of plants are in the heart of many subjects including: culture, tradition, religion, art, construction, and daily life.

The Lao PDR has many bamboo species, including *Dendrocalamus* spp., that are regarded as having good flavor and which is sold locally at prices between US$ 0.15-0.3 per kilogram (kg), depending on season. The culms provide many uses, including the production of chopsticks, toothpicks, *etc*., which are made from culm of *Dendrocalamus membranaceus* (culm length 5-7 m, 8-12 cm in diameters) is sold locally at prices US$ 0.4-0.8. Other species are used to make baskets, trays, sticky rice containers (Eeapkhao), bamboo strips, *etc*. Traditional musical instruments (the Khène and flute) are sold at prices at least up to US$ 8 (depending on their design). Domestic markets, as well as export markets, have the potential and help in maintaining the continuous traditional production of these items throughout the year.

Rattan products in Lao PDR are used domestically and are also exported. Rural households earn money from the harvest of rattans and sold to traders or representatives of processing factories. Canes of *Calamus poilanei* are sold locally at prices in the range US$ 1.4-1.5 (cane length 5 m, 3 cm in diameter). Other species

are used to make baskets, trays, rattan seats, cradles, *etc*. and the prices depend on the materials used. Some species, *Calamus rhabdocladus* and *Calamus tenuis* are used to provide tips for consumption, which are sold locally at prices between US$ 0.1-0.2 per tip. Domestic markets selling these products can be found along the road sides of rural villages in areas where the rattans are harvested.

With the potential of the bamboo and rattan industries in Lao PDR showing increasing promise, the selection of the most appropriate species to meet market demand is becoming increasingly important. The products of bamboo and rattan can be used as materials or tools may differ region by region, reflecting the tradition of tribes, cultures and societies. The diversity of sources is sometimes reflected in confusion in the use of local names. The current problem is mainly one after processing, when it can be very difficult to identify the raw materials which have been used for the manufacture of different products. This thesis project was aimed at a study these problems and might be potentially overcoming through the combined use of morphological and anatomical approaches.

Unfortunately, the rapid growth of the Lao economy and related industry development, including rubber plantation development, combined with the expansion of the land area planted to a range of other crops, and land use for mining and hydropower related developments, have resulted in the destruction of large areas of forest cover (Vongkhammounty, 2005). As a result, the area under natural bamboo and rattan resources has been reduced. National forest development policy is now aiming to address these issues and provide strategic guidance for the forestry sector for the future (Saphangthong, 2005). The implementation of this policy is expected to help increase the bamboo and rattan resources in the country.

It was hoped that the results from this study will be able to be used to provide standards for species identification in bamboo and rattan products. Further, it is anticipated that the information generated will be potentially useful for identifying the species used in finished items based on the use of illegal or prohibited materials.

OBJECTIVES

The objectives of the thesis project were to:

Primary objectives:

1. Study the morphology and anatomy of bamboos and rattans commonly used in Lao PDR.
2. Make use of the culm and cane anatomy for identification of the raw materials in finished products.

Secondary objectives:

1. Collect specimens of all bamboos and rattans commonly used in Lao PDR.
2. Gather information on the utilization of bamboos and rattans in the country for potential future extension of their uses and related appropriate managements.

LITERATURE REVIEW

Non-Timber Forest Produces serve a wide range of subsistence needs and provide opportunities for earning cash income. In Lao PDR, over 700 NTFPs items, that are plant and animal products, have been reported to be used and consumed (Foppes and Ketphanh, 2001; Soydara and Ketphanh, 2001). From point of view of the local peoples, these NTFPs products are equally important to the cropped plants (Greijmans *et al*., 2007; Xaidara and Lamxay, 2000; An Van Bay, 2002). Bamboo and rattan are widely regarded as the most important among the NTFPs. They represent not just one or two commodities, but dozens. They have a high value in a wide range of applications as structural materials and food. For many reasons both of these plant groups can be regarded as essential resources in everyday rural life in Lao PDR (Belcher, 1999; Soydara and Ketphanh, 2001). Basically, people collected bamboos and rattans only from the forests (Vongkhamhor and Ketphanh, 2007).

In 2002, it was estimated that 71.6% (16,846,000 hectares) of the land area of Lao PDR was classified as "forest land" which includes evergreen, mixed deciduous, dry-dipterocarp forests, and plantation forests accounting for 41.5% of the area, potential forests including abandoned shifting cultivation areas 2.2%, bamboo brakes 2.3%, while 25.6% was classified as of temporarily unwood forest (*i.e*. without trees) that could be naturally regenerated (Vongkhammounty, 2005).

The important NTFPs to the household economies of 28 representative villages in three provinces (Oudomxay, Borikhamxay, and Champasak) of Lao PDR is summarized in Table 1. When ranked against other NTFPs, bamboo stands out as the single most important NTFP. It is acknowledged that wild plant and animal species provide a wide range of products for consumption and use, including animal protein from wild animals, fish, frogs, shrimps, soft-shelled turtles, crabs and mollusces; plant foods in the form of mushrooms, bamboo shoots, wild fruits and vegetables, and honey; materials for constructing houses and handicraft production from bamboo, rattan, pandanus, broom grass and paper mulberry; and traditional medicines (Foppes and Ketphanh, 1997).

Table 1 Villagers' ranking of the 50 most important NTFPs**.

Ranking	Product	Percent
1	Bamboo	13
2	Fish	10
3	Vegetables	9
4	Wildlife	8
5	Cardamom	7
6	Rattan canes	6
7	Damar resin	5
8	Frogs	5
9	Mushrooms	4
10	Yang oil	4
	other 40 products	29
	Total 50 products	**100**

** Based on a survey of households of 28 villages in three provinces (Oudomxay, Borikhamxay, and Champasak).

Source: Foppes and Ketphanh (1997).

1 Morphology of Bamboo and Rattan

1.1 Bamboo

Bamboo is a particular taxonomic group of large woody grasses belonging to the subfamily Bambusoideae of the family Poaceae (or so-called Gramineae). Bambusoideae encompasses of over 75 genera and 1,250 species world wide (Sharma, 1985; Thaiutsa, 2000; Wong, 2004). The taxonomy and classification of bamboos have been proposed by several researchers (McClure, 1966; Gamble, 1986; Dransfield and Widjaja, 1995; Ohrnbeger, 1999; Li *et al*., 2006). Such work is

usually tricky due to the difficulties in preparing scientific specimens (Wong, 2004). Subtribal classification is still actively being pursued, and it is expected that advances in understanding of DNA characterization will shed more light on the relationships (Wong, 2004).

During 1992-1994, surveys of the bamboos in Lao PDR were supported by the International Department Research Center (IDRC), as part of which specimens and information/data were collected. Until 2012, a total of 52 species from 15 genera (Appendix 1) had been documented from different forest types of nine provinces (seven provinces in Central and Southern Regions, and two provinces in the Northern Region). The mountainous northern part of the Lao PDR is one of the richest areas for bamboos (Ketphanh *et al*., 1994a).

1.1.1 Morphology

Bamboo morphologies reflect a combining of the following the patterns of growth of the rhizome system; culm development and associated patterns of growth; variations in the branch complement at culm nodes; variations in the sheathing organs, especially those developed as culm sheaths; the spikelet and pseudospikelet as the basic units of the inflorescence (McClure, 1966; Wong, 1995; Sungkaew, 2008). To be able to identify a bamboo, it is important to know the fundamentals of bamboo morphology.

1.1.1.1 Rhizomes

Bamboo has an underground part called the rhizome. A rhizome consists of two parts, the rhizome proper and the rhizome neck. It is consisted of many repeating units called a node and an internode, where the node bears a leaf (rhizome sheath), and usually a bud and more roots. In reference to the pattern of rhizome system, there are two basic types of rhizomes, the pachymorph rhizome (sympodial, determinate) and the leptomorph rhizome (monopodial, indeterminate) (McClure, 1966; Wong, 1995; Sungkaew, 2008).

1.1.1.1.1 Pachymorph Rhizome

The pachymorph rhizomes are typically solid, thickened, usually short and spindle-shaped. Buds are produced from new rhizomes, this enables the above-ground component to become the culm, which usually develops every year directly from the rhizomes (Figure 1A) (McClure, 1966; Wong, 1995; Wong, 2004; Sungkaew, 2008).

1.1.1.1.2 Leptomorph Rhizome

The leptomorph rhizome is typically slender, cylindrical, and usually hollow; it is longer than broad and this reflects its continuous horizontal growth until constrained. Solitary buds grow horizontally and can stay underground with indefinite growth (Figure 1B) (McClure, 1966; Wong, 1995; Wong, 2004).

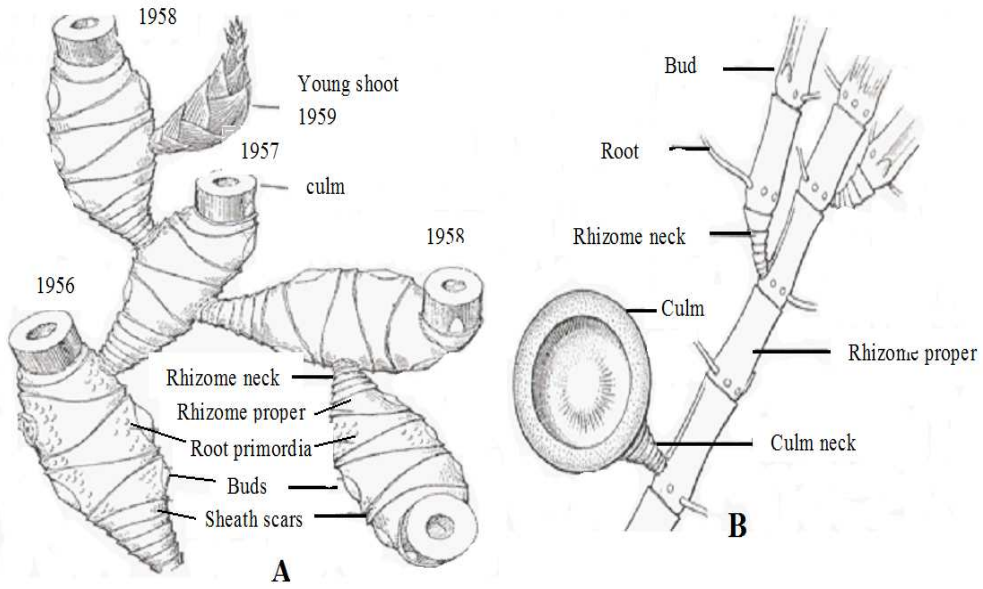


Figure 1 A. Pachymorph rhizome system of *Bambusa tuldoides*, B. Leptomorph rhizome system of *Phyllostachys bambusoides*.

Source: Adapted from McClure (1966).

1.1.1.2 Shoots

The buds on rhizome-nodes become enlarged over many months underground, and then emerge as tender shoots, covered with imbricate sheaths for the each node (Figure 2). These shoots elongate rapidly and in a period of 3-4 months, the young culm grows to its full high before branching. This stage is also referred to as "flying shoots" (Sungkaew, 2008) (Figure 3). At this stage, the culm sheaths cover each internode, it provides the characteristics useful for comparisons within the species (*e.g*. colour of materials covering the culm sheaths, blade orientation, details of auricles and ligules) (McClure, 1966), with the exposed upper part of the internodes sometimes being covered with waxy powder and hairs.

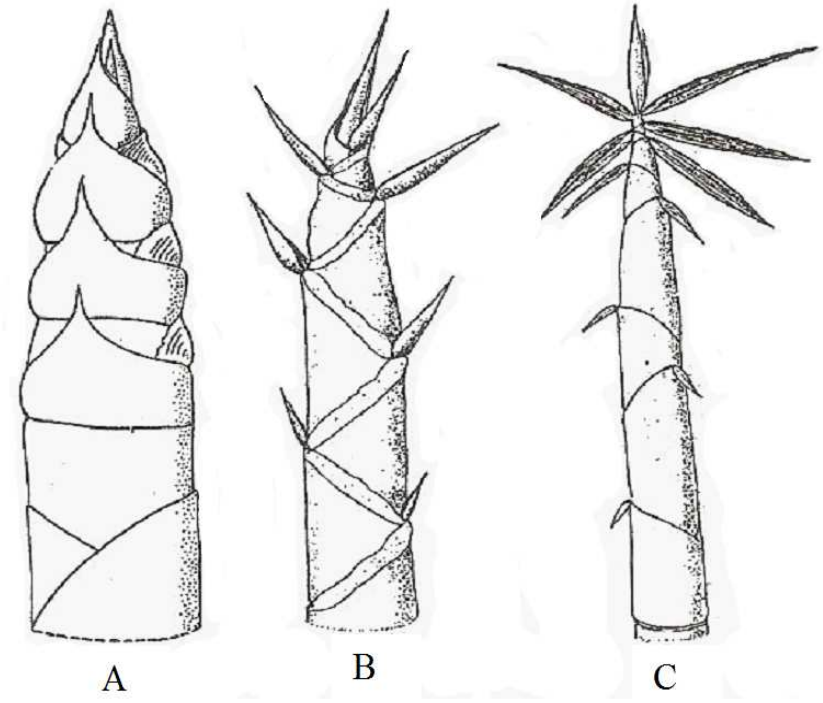


Figure 2 Top of culm shoots, showing differences of shape and position of culm sheath blade: A. *Schizostachyum zollingeri* (blade erect, broad, convex); B. *Dendrocalamus pendulus* (blade narrow, partly reflexed (deflexed)); C. *Gigantochloa scortechinii* (blade leaf-like, spreading or reflexed).

Source: From Holttum (1958).

Figure 3 Flying shoots of different bamboo species: 1. *Bambusa vulgaris* '*vittata*'; 2. *Cephalostachyum virgatum*; 3. *Dendrocalamus sinicus*; 4. *Phyllostachys edulis*; 5. *Dendrocalamus membranaceus*; 6. *Dendrocalamus asper*; 7. *Dendrocalamus latiflorus*; 8. *Bambusa bambos*; 9. *Thyrsostachys siamensis*; 10. *Phyllostachys makinoi*; 11. *Gigantochloa albociliata*; 12. *Bambusa beecheyana*.

Source: From Sungkaew (2008).

1.1.1.3 Culms

Most species have culms that are cylindrical with hollow internodes and may have hard, thick wall on the base and thin wall on the top; however a few species have short internodes, thick wall with small hollow. The nodes give the culm great mechanical strength. The culms of most bamboos are erect and arch outward; a few are semiscandent or scandent (Dransfield and Widjaja, 1995). The internodes are usually glabrous and smooth, or rough and hairy when young, becoming glabrous at maturity (Wong, 2004). The nodes may be swollen, with the lower ones often bear aerial roots (McClure, 1966; Wong, 1995; Sungkaew, 2008). However, the culm is usually not a reliable characteristic in recognizing a bamboo species.

1.1.1.4 Leaves

Leaves can be classified into three forms, depending on their positions and functions, they are; culm leaf or culm sheath; foliage leaf, and rhizome leaf. A bamboo leaf is basically composed of a sheath proper, a blade, a ligule, and one or two auricles (Figure 4) (McClure, 1966; Dransfield and Widjaja, 1995; Wong, 1995; Sungkaew, 2008). The ligule and auricle may sometimes be tiny or absent. The sheath proper also varies in color. It may be green, bluish or purplish-green, or yellow tinged with orange *etc.* The inside of the sheath is smooth and shiny. When young, the outside is usually covered with irritant hairs which are pale brown, golden brown or black. The blade is attached to the sheath along the narrow top part of the sheath. The auricle has rims at the base of the blade margin on both sides. The ligule is a growth from the top of the sheath, and can either be erect or deflexed (reflexed) (McClure, 1966; Wong, 2004; Sungkaew, 2008).

The culm sheaths (or culm leaves) are modified leaves which embrace the developing internodes to protect the young shoot or young culm and the buds. They usually fall off when the culm becomes mature. The structure of the culm sheath is very important for recognizing bamboo species (McClure, 1966; Dransfield and Widjaja, 1995; Wong, 2004; Sungkaew, 2008). The foliage leaves are

located on the finer branches, with a conspicuous, green blade, whose role is for photosynthesis (Wong, 2004; Sungkaew, 2008). The rhizome leaves or rhizome sheaths are often scale-like or ensheathing structures, and papery in texture. The function is to protect the rhizome buds (Wong, 2004; Sungkaew, 2008).

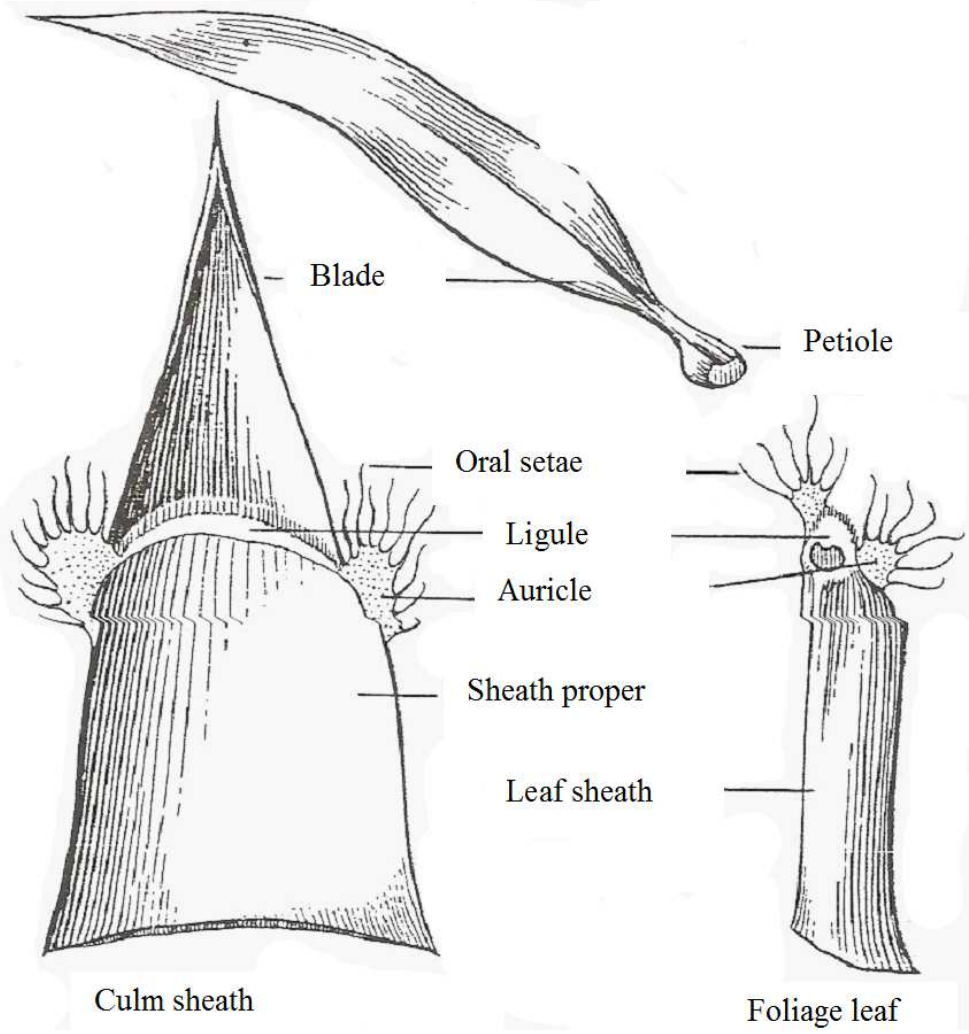


Figure 4 Diagrammatic representation of culm sheath and foliage leaf in the genus *Bambusa*, showing the several component parts. The dimorphism that prevails between the two types of sheath is generally much more marked in the Bambuseae than in the other tribes of the Gramineae. Oral setae are sometimes referred to as shoulder bristles, when auricles are absent.

Source: McClure (1966).

1.1.1.5 Branches

Branches develop while the culm is still growing, or after the culm reaches its full high. They develop from multiple branch-buds or a single branch-bud. Each node bears a branch bud just above the culm sheath scar. The branch buds are arranged on alternate sides of the culm, and may be found from the lowermost node upwards or from the midculm node upwards (McClure, 1966; Dransfield and Widjaja, 1995; Wong, 2004; Sungkaew, 2008). Branches are a characteristic feature of bamboos.

1.1.1.6 Inflorescences

Bamboo inflorescences consist of many flowers. There are two types of inflorescences (McClure, 1966; Dransfield and Widjaja, 1995; Wong, 2004; Sungkaew, 2008). The first comprises spikelets born in a raceme or a simple panicle, each flower emerging and dying almost simultaneously, indicating it to be determinate inflorescence called ‘semelauctant type’ (Figure 5A). The second type of inflorescence comprises pseudospikelets develop into a tuft; the buds start to produce more pseudospikelets. This is indicating an indeterminate inflorescence called ‘iterauctant type’ (Figure 5B). The spikelet not only lacks the branch at their base; but also remains as single units as they mature (Figure 5C). The spikelet bearing branch with bracts subtending buds at the base, also called pseudospikelets (Figure 5D).

A single spikelet typically has one to several (empty) scales or bracts at its base, these bracts are called “glumes”, with are below the flowers or florets. Florets are very small, 2-15 mm long. Each floret comprises; a lemma, a palea, usually three lodicules (sometimes absent), 3 or 6 stamens, and an ovary with 1 or 3 stigmas (McClure, 1966; Dransfield and Widjaja, 1995; Wong, 2004; Sungkaew, 2008). The flower is sometimes described as perfect when it has both male and female components.

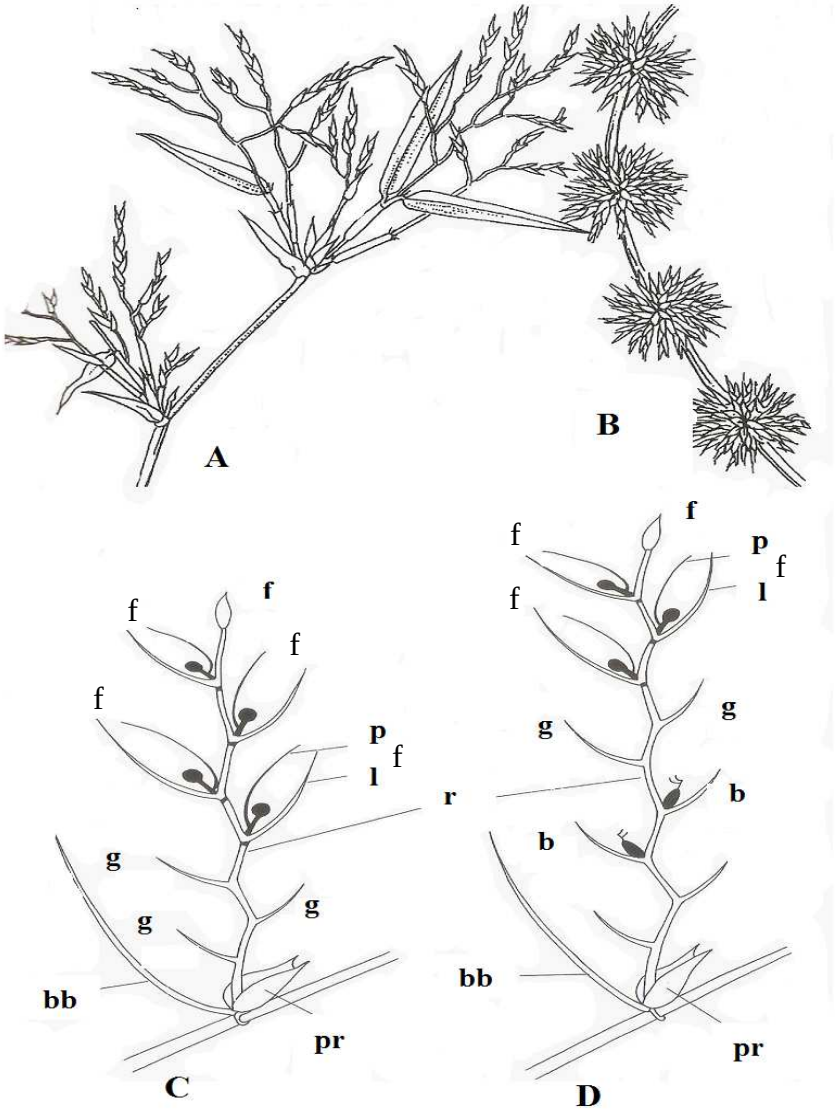


Figure 5 Inflorescences: A. the determinate (semelauctant) inflorescences; B. the indeterminate (iterauctant) inflorescences; C. spikelet; D. pseudospikelet (dark dots represent flower structures inside the palea); pr. specialized initial bract of the rachilla; bb. bract subtending the spikelet or pseudospikelet; g. glum; b. bracts protecting buds (dark structures with double-barred tips) that potentially repeat the structure of the pseudospikelet; l. lemma; p. palea; r. rachilla; f. floret.

Source: A and B adapted from Dransfield and Widjaja (1995), C and D adapted from Wong (2004).

1.1.2 Utilization of Bamboos

The total world trade in bamboo was about US$ 44.9 million in 1992. Of this, China supplied 65.7% of exports and Thailand shared 10.1%. In the same year, France, Germany and the Netherland were the major markets for bamboo, collectively accounting for 53% of the world's total imports (Greijmans *et al*., 2007; Khammon, 2007). No statistics are available for Lao PDR, while it is also acknowledged that neighboring countries imported bamboo from Lao PDR and then re-exported (Chaiyalad, *personal observation*).

In Lao PDR, the utilization of bamboo culms for construction as well as for non-construction purposes, has been recognized for long time ago (Xaidara and Lamxay, 2000). There is much history (sometimes oral) confirming this. They can be used in a variety of ways (Foppes and Ketphanh, 2001; Greijmans, 2007; Greijmans *et al*., 2007; Vongkhamhor and Ketphanh, 2007).

The culm of the popular bamboo species in Lao PDR known as *Dendrocalamus membranaceus* is sold in lengths of 5-7 m at prices between US$ 0.5-0.6 each. Some products such as bamboo mats, walls or panels, are sold in Vientiane province to traders at US$ 0.4-0.6 per piece and re-sold in Vientiane capital and Khammuone province for US$ 1.4 (Greijmans *et al*., 2007). A mat (wall) size 2 m x 1.5 m, made from the culm of *Schizostachyum* sp., this is locally sold at prices between US$ 0.5-0.7 (Foppes and Ketphanh, 2001; Greijmans, 2007; Greijmans *et al*., 2007). A mat (panel) size 3 m x 2 m, made from the culm of *Schizostachyum virgatum*, is sold locally at prices between US$ 1-1.5. This kind of mat is very light and popular because of its durability, and it could last for 20 years (Foppes and Ketphanh, 2001; Greijmans, 2007; Greijmans *et al*., 2007).

Other uses of bamboo culms include house construction, bamboo beds, bamboo stairs, chopsticks, toothpicks, cages, baskets, trays, sticky rice steamers (lam), cradles, sticky rice containers (Eeapkhao), bamboo strips, traditional music instruments (Khène and flute), cowbells, *etc*. (Ketphanh *et al*., 1994a; Foppes and

Ketphanh, 2001; Pungbun Na Ayudhya, 2000; Xaidara and Lamxay, 2000; An Van Bay, 2002; Greijmans *et al*., 2007; Greijmans, 2007; Vongkhamhor and Ketphanh, 2007). Materials used to make these items vary from place to place, depending on what species are available in the areas.

Most of Lao people like to eat young bamboo shoots. The shoots of *Gigantochloa albociliata* is among the popular species. Its shoots can be sold in local markets for US$ 0.15-0.3 per kg in the Central and Southern Regions, whilst that of *Dendrocalamus brandisii* is about US$ 0.3-0.5 per kg. That of the latter species are harvested heavily every year and sold to the markets in Huaphanh province in northern, Kasy district of Vientiane province and Vientiane capital in the Central Region (Ketphanh *et al*., 1994a; Greijmans, 2007). Shoots of *Indosasa sinica* are sold locally for US$ 0.15-0.4 per kg in the Northern Region and also exported to China (Foppes and Ketphanh, 2001; Soydara and Ketphanh, 2001).

The official annum quota for harvesting bamboo shoots is about 3,500 tones. However, this figure is generally very much under-estimate of the actual harvest. The fact is that the Vongxay Company, a bamboo shoot canning factory, alone requires more than 2,000 tones per year (Foppes and Ketphanh, 2001; Greijmans, 2007; Vongkhamhor and Ketphanh, 2007). The bamboo shoots can be eaten in a large number of ways *e.g*. steamed, boiled, mixed with other vegetables, fermented, and sun dried, *etc*.

1.1.3 Ecology and Distribution

In terms of the natural geographical distribution, bamboos occur in the tropical, subtropical, and temperate regions of all continents except Europe, Antarctica, and western Asia, from the lowlands up to an altitude of 4,000 m above sea level (Figure 6) (Ohrnbeger, 1999; Wong, 2004; Sungkaew, 2008). Tropical forests are proving a real paradise for this group of plants. Asia is the continent where bamboo is most integrated into plantation systems (Pungbun Na Ayudhya, 2000).

In Lao PDR, bamboos can grow virtually everywhere. They can be found on hills, in dry and evergreen environments, periphery of forest land, along creeks, in mixed forests; they can also be found in every park and national forest area at 100-1,000 m above sea level. Across Lao PDR around 2.3% of the land area consists of bamboo forests with genera of *Dendrocalamus*, *Cephalostachyum*, and *Oxytenanthera* being the dominant species, *Gigantochloa*, *Schizostachyum*, *Bambusa*, *Thyrsostachys* and other genera are frequently found in mixed deciduous forests and in areas of reforestation (Vongkhammounty, 2005; Greijmans, 2007; Greijmans *et al*., 2007).

Figure 6 Map of world distribution of woody bamboos.

Source: Adapted from Ohrnberger (1999).

1.2 Rattan

Rattan is a group of climbing spiny plants belonging to the large sub-family known as Calamoideae, of the palm family (Arecaceae, also called Palmae). The subfamily Calamoideae can be divided into five subtribes. There are 13 genera, about 600 rattan species world wide (Dransfield, 1996; Evans *et al*., 2001; Boonsermsuk *et al*., 2007; Henderson, 2008). A range of studies have been done on the morphology and anatomy of rattan and the earliest, known to me is by Tomlinson (1961). This was followed by other pilots' studies, there are Siripatanadilok (1986); Liese and Weiner (1987); Dransfield and Manokaran (1994); Ketphanh *et al*. (1994b); Dransfield (1996); Evans *et al*. (2001). All of these studies have shown significant morphological and anatomical differences among most of the rattan genera.

The diversity of rattans in the Lao PDR has been demonstrated in a survey supported by the Darwin Initiative (Ketphanh *et al*., 1994b; Evans *et al*., 2001). There are at least 50 species from six genera (Appendix 2). This in formation is based on a study of wild plants and herbarium specimens from Indochina.

1.2.1 Morphology

1.2.1.1 Methods of growth

Whether the rattans behave as a shrub, a vines or climbing spiny plants, they have two methods of growth, solitary or in clusters (Figure 7). The stem is supported by a series of spines that function like glochid on internode. The leaf-sheath is almost always spines. The leaf is consisted of five parts. The climbing organs (flagellum or cirrus) can help in species identification. The overall appearance of the inflorescence is of great importance in separating genera (Ketphanh *et al*., 1994b; Dransfield and Manokaran, 1994; Dransfield, 1996; Evans *et al*., 2001). To be able to identify a rattan, it is important to know the fundamentals of rattan morphology.

A B

Figure 7 Rattan methods of growth: A. clustering stems; B. solitary stem.

Source: From Evans *et al.* (2001).

1.2.1.2 Stems

In this thesis, the term “stem” is used when refered to the rattan stem that covered with the leaf-sheath(s), which is usually covered with dense spines. On the other hand, it is called a “cane” when refered to the stem that the leaves (or the leaf-sheath(s)) dropped off naturally or have been taken off after havested (Dransfield and Manokaran, 1994; Dransfield, 1996; Evans *et al*., 2001).

1.2.1.3 Leaf

A rattan leaf is consisted of five parts; the sheath, petiole, rachis, leaflets and climbing organ (Figure 8). The sheath is covered with spines, presence or absence of the knee, at the mouth of the leaf-sheath covered with ocrea. The petiole from the lower nodes has no leaflet. The rachis is a long main axis which has many leaflets along it. The leaflets (both positions and shapes) can help in species identification (Ketphanh *et al*., 1994b; Dransfield, 1996; Evans *et al*., 2001). The climbing organ (see section 1.2.1.4).

1.2.1.4 Climbing Organs

Climbing organs usually develop when the aerial stem begins to develop. There are two whip-like organs associated with climbing in rattans, superficially very similar, but not homologous. Basically, two types of climbing organs can be distinguished (Figure 8). The “cirrus” is an extension of the leaf-rachis beyond the terminal leaflets while the “flagellum” is a sterile inflorescence borne on the leaf-sheath near the knee. Both are whip-like and bear groups of short reflexed spines. The type of climbing organs can help in species identification (Ketphanh *et al*., 1994b; Dransfield, 1996; Jintana, 1988; Evans *et al*., 2001).

1.2.1.5 Inflorescences

The inflorescence arises in the axile of a leaf and bears a series of bracts. There are two major types of flowering. All species of genera namely *Korthalsia*, *Plectocomia*, *Plectocomiopsis* and *Myrialepis* are monocious, bearing male and female flowers in tight clusters on the same plant. All other rattan genera are diocious, with male and female flowers being born on separate plants (Ketphanh *et al*., 1994b; Dransfield and Manokaran, 1994; Dransfield, 1996; Evans *et al*., 2001). In most rattans, the male inflorescence is more highly branched than the female. All rattan flowers have three sepals, three petals, six stamens or staminodes, and an ovary (capsule) (Dransfield, 1996; Evans *et al*., 2001).

1.2.1.6 Fruit

All rattan fruits are alike; the fruit bark comprises vertical rows of reflexed overlapping scales which are often hard and shiny. The scales are very attractive and usually colored with various shades of yellowish brown, red-brown, mid-brown to dark blackish brown (Figure 9) (Ketphanh *et al*., 1994b; Dransfield, 1996; Evans *et al*., 2001). The fruit usually has just one seed (a few species have more than one seed) (Ketphanh *et al*., 1994b; Dransfield, 1996; Evans *et al*., 2001).

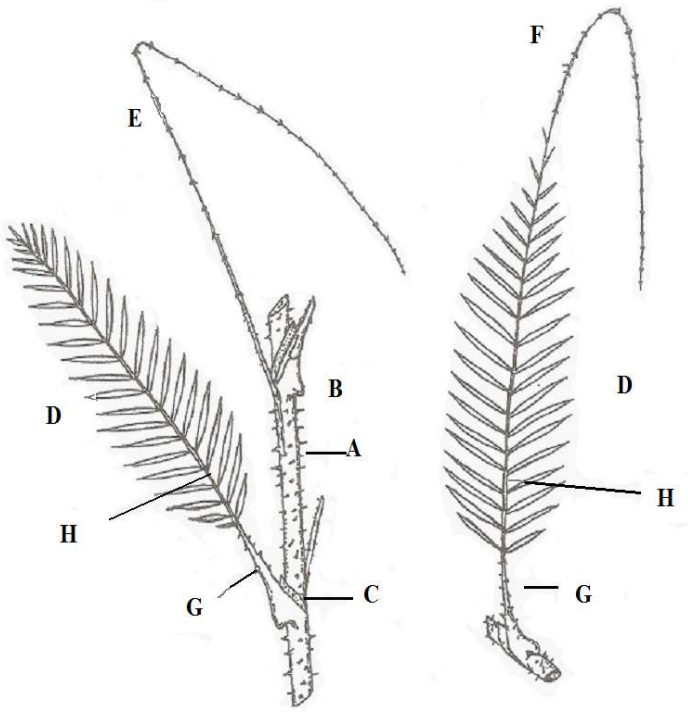


Figure 8 Leafy stems and climbing organs: A. stem; B. knee; C. ocrea; D. leaflets; E. flagellum; F. cirrus; G. petiole; H. rachis.

Source: Adapted from Jintana (1988).

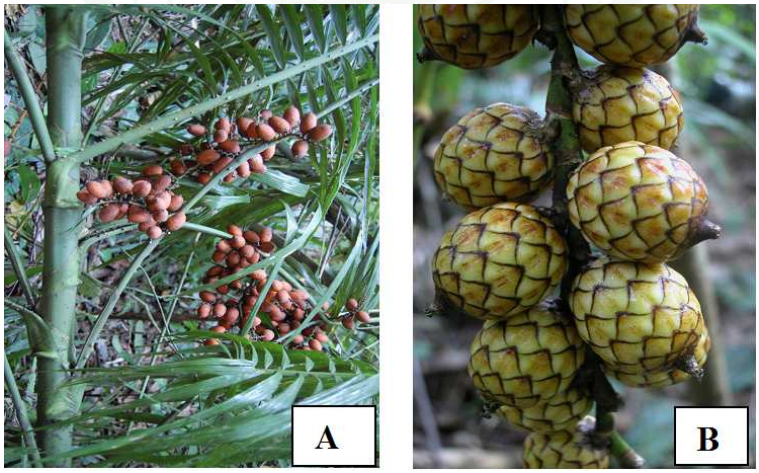


Figure 9 Rattan fruits: A. *Calamus lateralis*; B. *Calamus* sp.

Source: Adapted from Henderson (2008).

1.2.2 Utilization of Rattans

In terms of utilization, rattan is superficially similar to bamboo, where many species are being used commercially. Their advantageous characteristics relative to other plants include their strength, flexibility, uniformity and durability. The development of rattan arts and crafts, based on a combination of technology and unique designs, has brought to local markets and for export, items such as furniture, peels and cores for basketry, bird cages, *etc.* Some rattan shoots/tips are also used for human consumption (Boonsermsuk *et al*., 2007; Evans *et al*., 2001; Dransfield and Manokaran, 1994).

Rattan tips (shoots) can be consumed locally or are exported as dry shoots to Southeast Asian communities in France, USA, and other countries. Dry shoots of *Calamus tenuis* are worth up to US$ 100 per kg in the USA (Greijmans *et al*., 2007; Vongkhamhor and Ketphanh, 2007). Locally, a single rattan shoot is usually sold for between US$ 0.05-0.1, although the shoots of some species can be priced at US$ 0.3-0.4 per shoot.

In Lao PDR, the domestic markets for rattans is relatively small, so that the good quality rattan canes of *Calamus poilanei*, *Calamus gracilis*, and *Calamus solitarius* are mainly exported as semi-processed products (Vongkhamhor and Ketphanh, 2007). These species are listed by the handicraft industries as one of the best quality rattan species found in Lao PDR, and therefore in high demand within the country and by neighboring countries. Factories or middlemen buy rattan canes from farmers for between US$ 0.1-0.6 per kg (Evans *et al*., 2001; Greijmans *et al*., 2007).

1.2.3 Ecology and Distribution

Rattans can be found in lowland evergreen forests, in periodically flooded swamps, in mountain forests up to elevations of 2,500 m above sea level. The main points of origin of rattans species are in the Asia-Pacific Region. So far known are in South and Southeast Asia, Papua New Guinea, Australia. These

rattans include some species which are also found in Southeast-China and Northeast India, and can be found in Africa and South America (Figure 10) (Rao, 1996; Dransfield, 1996; Evans *et al*., 2001; Henderson, 2008).

In Lao PDR, the largest concentrations of rattans are found in various types of evergreen forests and along streams where some light is available. Their natural habitats range from swamp forest to evergreen forest, dry evergreen and mixed deciduous forest, up to 1,000 m above sea level (espcially in Vientiane province and Southern Region) (Ketphanh *et al*., 1994b; Evans *et al*., 2001; Greijmans *et al*., 2007).

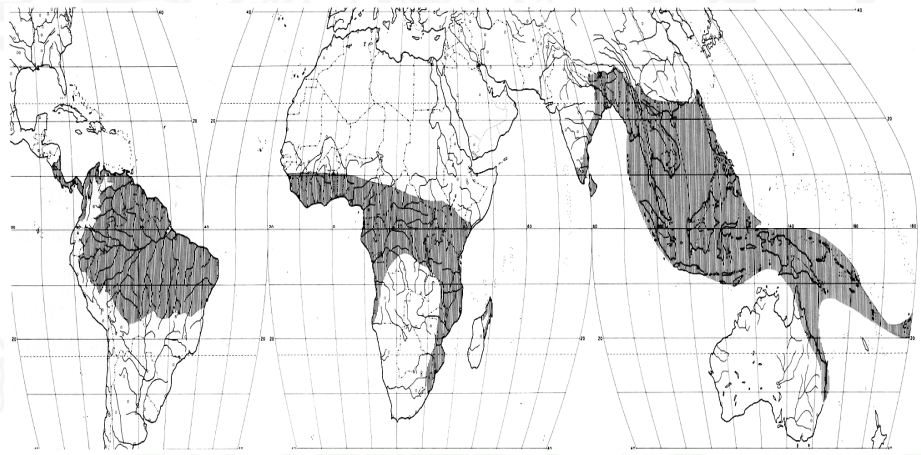


Figure 10 Map of global distribution of rattans.

Source: From Henderson (2008).

2. Anatomy of Bamboo Culm and Rattan Cane

2.1 Bamboo Culm Anatomy

A cross-section of the internode of a bamboo culm is illustrated in Figure 11. A culm cross-section consists of approximately 50% parenchyma, 40% fibers and 10% conducting cells (vessel and sieve tubes) (Liese, 1985; Taihui and Wenwei, 1985; Dransfield and Widjaja, 1995; Liese, 1998). As the bamboo culm generally has lacuna from base to tip, the walls of the internodes become smaller with increasing height.

The exterior of the culm is bounded by epidermis cells. On the inner side there are scattered vascular bundles (a vascular bundle is a part of the transport system in vascular plants) of fibers with very thick walls and narrow lacuna; the vascular bundles nearest to the epidermis are always smaller than those nearest to the center of the culm. The xylem of each vascular bundle usually has two large cells called metavessel, while slightly closer to the phloem in upper level, and the protovessel in lower level, which normally breaks down to form an intercellular canal at the inner pole of each vascular bundle (Siripatanadilok, 1986; Liese and Grosser, 2000).

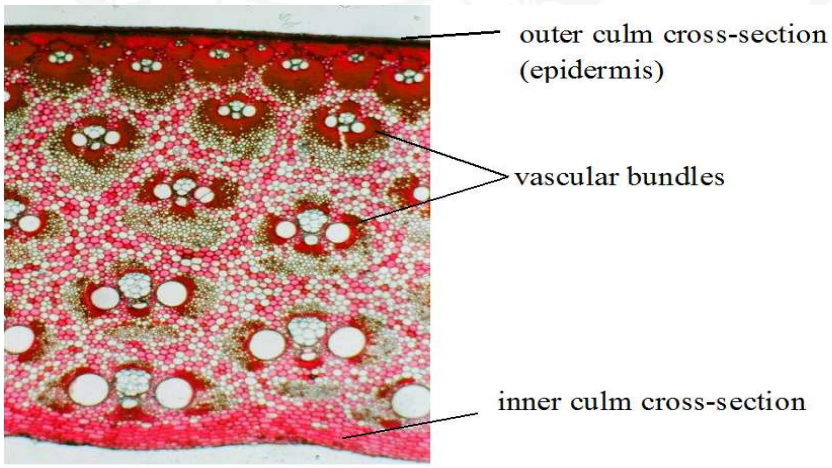


Figure 11 Culm cross-section of *Schizostachyum virgatum* showing scattered vascular bundles.

The exterior of the culm, which is the outermost layer of the epidermis cells and cortexes, contains axially elongated cells. Many large, thin-walled parenchyma cells exist under the stomatas. At the inner side of the culm wall, cellular layers surround the pith cavity, with the pith periphery or "bamboo yellow" comprising non-vascular parenchyma cells, which are often heavily thickened and lignified. The ground tissue of a culm consists of parenchyma cells, with embedded vascular bundles composed of metavessel vessels, sieve tubes with companion cells, and fibres (Wong, 1995; Liese, 1998; Liese and Grosser, 2000).

Studies of bamboo culm anatomy have always considered the appearance of vascular bundles as important and determined the differences between bamboo species. The differences between species is influenced by the thickness of the culm wall, which reflects the type of vascular bundles with their xylem sheaths, and dark sclerenchyma cells against the lighter ground parenchyma (Siripatanadilok, 1986; Liese, 1985; Taihui and Wenwei, 1985; Dransfield and Widjaja, 1995; Wong, 1995; Liese, 1998; Liese and Grosser, 2000). The vascular bundles of culm internodes consist of two large of metavessels, phloem, protovessel, attached sclerenchyma sheaths and additional fiber strand (Figure 12). The appearances of a culm in cross-section are determined by the shape, size and concentration of vascular bundles.

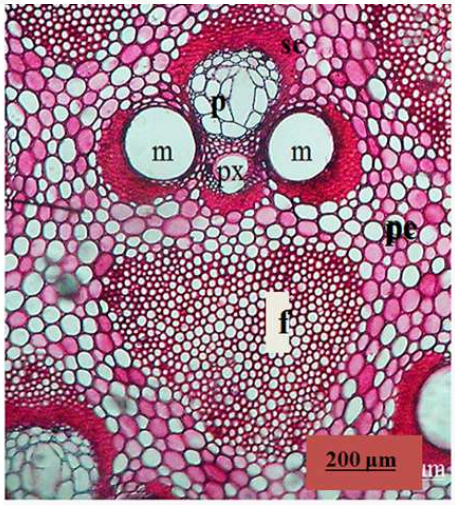
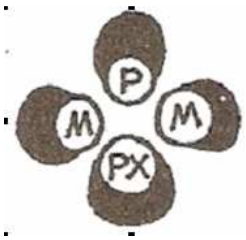


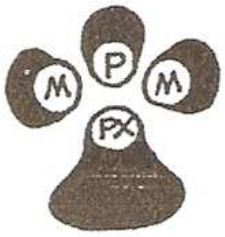
Figure 12 A vascular bundle of *Schizostachyum* sp. (p=phloem; m= metavessel; px=protovessel; pc=parenchyma; sc=sclerenchyma sheaths; f=fiber strand).

Metavessel which originates from the primary xylem consists of two large vessels separated by parenchyma. Phloem consists of large lumen, thin-walled sieve tubes and smaller companion cells originating from the same mother cells, which reflect the initially formed primary or protophloem. Protovessel is located between the two large metavessels, towards the pith cavity, with size varying according to its location within the culm wall. Sclerenchyma sheaths smaller consists of two types of cells, that is smaller sized cells with very small lumens located close to the metavessels, phloem, and protovessel in inner, and the larger cells with lumens are outer. Fibers strand constitutes about 40% of sclerenchyma tissue volume of the culm (Siripatanadilok, 1986). They are surrounded the conducting elements and, in some genera, also as isolated fiber bundles (strands). Parenchyma cells are small sizes at the outer of culm wall and become larger, especially in length, towards the inner part, and get smaller again near the pith cavity. They are characterized by thicker walls that become lignified in the early stages of internode development.

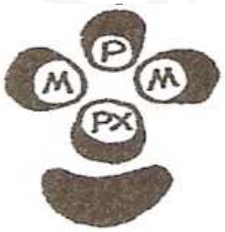
Culm anatomy is useful for identification by their vascular bundle types (Siripatanadilok, 1986; Liese, 1985; Taihui and Wenwei, 1985; Dransfield and Widjaja, 1995; Wong, 1995; Liese, 1998; Liese and Grosser, 2000). The cross-sections of culms can be divided into four types (Figure 13). The analysis of the variability of vascular bundles in terms of form and size, and grouping of them into the four basic types, has often been used in bamboo studies. This is considerable variability in the appearances of the vascular bundles within one culm. The four basic types of vascular bundles are described below (Wong, 1995).



Type I Sclerenchyma sheath at inner (protovessel) pole to small, tyloses present in the protovessel space. Genera of this type have leptomorph rhizomes: *Arundinaria, Phyllostachys.*



Type II Sclerenchyma sheath at inner (protovessel) pole to strikingly larger than others types, tyloses absent. Genera of this type have pachymorph rhizomes: *Cephalostachyum, Melocanna, Schizostachyum, Teinostachyum*.



Type III Sclerenchyma sheath at inner (protovessel) pole as in Type I but with additional, separate fiber strand to the vascular bundle. Genera of this type have pachymorph rhizomes: *Melocanna, Schizostachyum, Teinostachyum, Bambusa, Dendrocalamus, Gigantochloa, Thyrsostachys, Oxytenanthera*.

Type IV Sclerenchyma sheath at inner (protovessel) pole as in Type III but with additional, separate fiber strand on both inner and outer sides. Genera in this type have pachymorph rhizomes: *Bambusa, Dendrocalamus, Gigantochloa, Thyrsostachys*.

Figure 13 Types of vascular bundle of different bamboos: (p=phloem, m= metavessel, px= protovessel).

Source: From Wong (1995).

2.2 Rattan Cane Anatomy

A cross-section of rattan cane consists of a periphery zone (epidermis and cortex cells), and central corpus (ground tissue and vascular bundles) (Figure 14) (Siripatanadilok, 1986; Pipitvittaya, 1985; Bhat *et al*., 1993; Pipitvittaya, 2003).

The epidermis is the outermost layer of the cells, which are broad and rectangular in shape, with lateral walls and oblong lumen layer between 1/4-3/4 of the epidermal height. The cortex region of the tissue lies between the epidermis (the outermost layer) and the vascular tissue in the cane (Figure 16). It is composed of collenchyma, parenchyma, and sclerenchyma (Siripatanadilok, 1986; Pipitvittaya, 1985; Liese and Weiner, 1987; Bhat *et al*., 1993; Pipitvittaya, 2003). The cortex transfers water and minerals from the epidermis to the vascular tissues, which distributes them to other parts of the plant; the wide of the cortex within the cane and between the species.

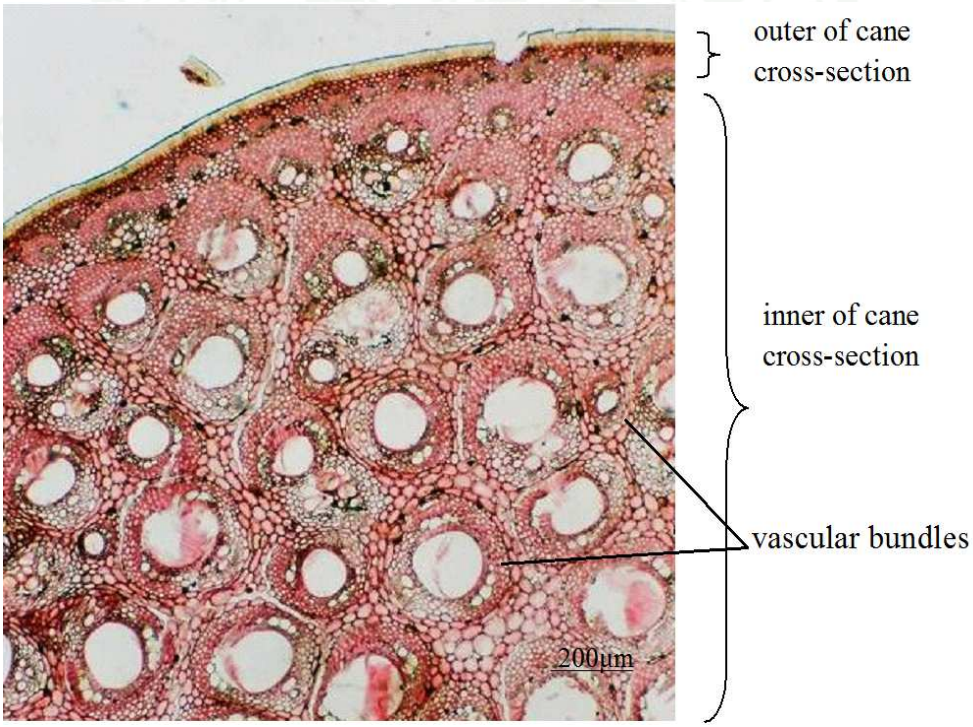
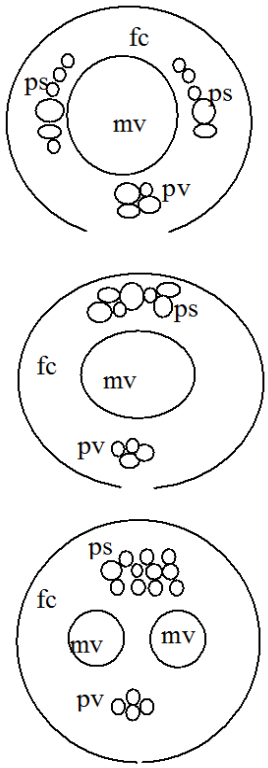


Figure 14 Rattan cane cross-section of *Calamus palustris* shows the stracture of outer layer.

The rattan cane anatomy is also used for identification, with the arrangements of the fiber cap, phloem strand, metavessel and protovessel, being divided into three types (Siripatanadilok, 1986) (Figure 15).



Type I A large metavessel with lateral phloem strands on both lateral sides: *Calamus, Daemonorops, Korthalsia.*

Type II A large metavessel with a phloem strand above it: *Plectocomia.*

Type III Two large metavessels with a phloem strand above them: *Plectocomiopsis* and *Myrialepis.*

Figure 15 Types of vascular bundle of different rattans: (fc=fiber cap; ps=phloem strand; mv=metavessel; pv=protovessel).

Source: Adapted from Siripatanadilok (1986).

The vascular bundle forms a part of the transport system in vascular plants. A vascular bundle usually consisted of conducting cells (the xylem and the phloem) which are surrounded by a fiber sheath (cap) and parenchyma (Figure 16). The main parts of the xylem is formed by one or two metavessels (sometimes called metavessel) (Siripatanadilok, 1986; Pipitvittaya, 1985; Bhat *et al*., 1993; Pipitvittaya, 2003). The metavessel at the inner core is oval shapes and originates from the primary xylem. The phloem strand of the vascular bundle is at the center core line in the upper part of the metavessel in reverse bowl mode. Sieve tube members, mostly

comprising more than three cells per phloem strand are located closely to metavessel. The fiber cap is thick wall fiber cells, the wall thickness of the fiber cap cells are almost uniform from the periphery vascular bundles through the center vascular bundles. The protovessel component of the vascular bundle is at the core center under part the metavessel. Stegmata are characteristically present, with their frequency being is relatively high in large diameter species. Ground tissue is composed of isodiametric or slightly elongated and stellate parenchymatous cells with intercellular spaces.

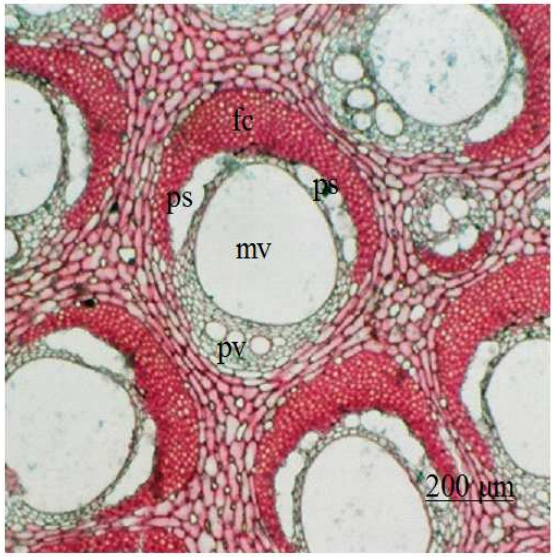


Figure 16 Vascular bundles of *Calamus poilanei*. (fc=fiber cap; ps=phloem strand; mv=metavessel; pv=protovessel).

STUDY SITES

This study focused on three locations which are regarded as the representives of the three regions of the country; Northern, Centre, Southern Regions (Figure 17). Three locations were collected also because they would have different biodiversity, cultures, economies, ways to use the resources, *etc.* In Northern Region, the study area is in Nampheng village, Namor district of Oudomxay province. Oudomxay province shares its borders with China, Vietnam, and Thailand. In Central Region, the study concentrated in the area of the Phouphanang Mountains in Napor village, Sangthong district, Vientiane Capital. Vientiane Capital shares its borders with Nongkai province of Thailand. In Southern Region, the study area is in Sanamxai village, in Pakse district of Champasak province. Champasak province shares its borders with Ubon Ratchathani province of Thailand, and Cambodia.

Figure 17 Locations of the three main study sites.

Source: Adapted from Servics Fraternel d'Entraide (2011).

The Northern Region is characterized by steep, mountainous terrain. About 5% of the area has slopes of less than 20%, while 46% has slopes of more than 30%, including areas with slopes of more than 65% (Vongkhammounty, 2005; Saphangthong, 2005). Most of the land surrounding the study site of Nam Peng village is covered by "hill dry-evergreen forest" and a few of "upland rice field" (Figure 18 top). The main of tree are member of the family of *Fagaceae* and *Lauraceae* in the top canopy and *Amomum* spp. in the lower canopy. The bamboos in this area are genera of *Dendrocalamus, Indosasa,* and *Semiarundinaria*. The rattans are genera of *Calamus* and *Daemonorops* (Vongkhammounty, 2005; Xaidara and Lamxay, 2000; Chaiyalad, *personal observation*). The inhabitants of the survey area are primarily members of the "Lao Song" and "Lao Theung" ethnic groups. Most have traditionally cultivated upland rice, but rice production from this system of production is no longer able to meet their food consumption needs. They have increasingly become reliant on NTFPs for food security. More than 40% of household income is currently coming from the harvest and sale of bamboo shoots (Chaiyalad, *personal observation*).

The Central Region is located along the Mekong River. Most of the population in Sangthong district are settled in the areas between the Phou Pha Nang and Phou Pha Deun Valleys (Figure 18 middle). About 63% of the area is now open forest, with the remainder covered by semi-dense forest and bamboo (Saphangthong, 2005; Vongkhammounty, 2005). The forest cover is composed mainly of dry dipterocarp forest, mixed deciduous forest, and potential forest (including bamboos). The main tree species are members of the families *Dipterocarpaceae*, *Fabaceae*, *Lythraceae*, including bamboos and grasses. The bamboos in this area are members of *Dendrocalamus*, *Gigantochloa*, *Bambusa*, *Schizostachyum*, and *Thyrsotachys* (Vongkhammounty, 2005; Xaidara and Lamxay, 2000; Chaiyalad, *personal observation*). The rattans were not identified as indigenous species, those being cultivated or growing in the wild come from other provinces. The inhabitants of the preliminary surveyed areas are primarily members of the "Lao Luum" ethnic groups. Most villagers work in rice paddy fields and raise livestock. Small paddy fields for rice cultivation in the valleys of small streams are supplemented by upland fields used

for shifting cultivation. Some villagers spend much of their times making woven bamboo mats, baskets, and cages, about 70% of which are exported to Thailand, with the remaining 30% being sold to handicraft shops in Vientiane (Chaiyalad, *personal observation*).

The Southern Region is generally regarded as having a high level of forest cover and low population density, with 53% of the area being semi-evergreen forest, 26% deciduous dipterocarp forest and 14% mixed deciduous forest (Vongkhammounty, 2005; Saphangthong, 2005). In many respects these forests represent a deciduous form of semi-evergreen forest and therefore are similar to the dry forests found in northern Cambodia. There is a transition between mixed deciduous forest and forms of semi-evergreen forest, where deciduous species exhibit a strong co-dominance over evergreen species (Figure 18 bottom). The main of trees are in the families *Lythraceae*, *Fabaceae,* and *Ebenaceae* (Vongkhammounty, 2005; Chaiyalad, *personal observation*). The bamboos in this area are in *Bambusa*, and *Schizostachyum*. The rattans are in *Calamus* and *Plectocomiopsis* (Xaidara and Lamxay, 2000; Chaiyalad, *personal observation*). The inhabitants of the survey area are primarily members of the “Lao Luum” and “Lao Theung” ethnic groups. Handicrafts are a popular and profitable source of income for groups of villagers. The products are depended on traders, but include trays, baskets, ratta sits, rattan balls, *etc.* with traders selling these goods to local markets or in Lao-Thai border area traders. The raw materials used in the production of some of these items come from other districts, including the districts of Patumphone and Moumlapamok (Chaiyalad, *personal observation*).

Figure 18 Forest Cover in Lao PDR: Top. Northern Region (Numpeng Valley); Middle. Central Region (Phou Pha Deun); Bottom. Southern Region (Tad Faan). (The lowest picture was taken by Bounxian PHETLUMPHUN).

MATERIALS AND METHODS

Materials

1. Bamboo and rattan specimens

After preliminary observations, the commonly used bamboo and rattan specimens, both from the wilds and from (semi-processed) products, were collected for study of their morphology and anatomy.

2. Equipment

2.1 Equipment for specimen collection

1. Plant presses
2. Used newspapers
3. Knives
4. Ropes
5. Labels
6. Plastic bags
7. Alcohol
8. Cardboard

2.2 Equipment and chemicals for morphological and anatomical studies

1. Computer and stationery
2. Herbarium specimens and taxonomic books
3. Compound microscope and photomicroscope
4. Sliding microtome and disposable knife plates
5. Other equipment as necessary for preparation of permanent slides
6. Staining chemicals (Safranin, Fast green, and Hematoxylin)
7. Water bath
8. Hot plate or slide warmer
9. Microscopic glass slide and glass cover

10. Petri-dishes
11. Standard coplin jars
12. Ethanol and butyl alcohol
13. Chemicals for plastic embedding (Mordant, NH_4OH, Xylin, Hydro fluoric acid 50%, *etc*.)
14. Glue

Methods

1. Data collection and preparation

In order to gain as much information as possible on the commonly used bamboos and rattans in the Lao PDR, visits were made to local markets, shops, and bamboo or rattan processing factories, to check for products made from bamboos or rattans. Samples of bamboo and rattan raw material (hereafter, before processing called material; after processing called product) were collected for anatomical study. Collections of specimens from the natural habitats of the bamboos and rattans, using classical herbarium techniques, were also undertaken for comparison with the samples being processed. Information collected during the sampling process included local names, the part used, collecting period, location, *etc.*

2. Specimen collection

All parts of both bamboos and rattans need to be collected to provide herbarium specimens. Each specimen set should include samples of leaves, flowers and fruits (if possible). If flowers and fruits samples are not available, other important vegetative parts can be useful for species identification, these parts include culm sheaths, branch components, and particularly the flying shoots (in the case of bamboos) as suggested by Sungkaew (2008). Some vegetative parts which are good for rattan species identification include leaflets, presence or absence of knee, and flagellum or cirrus. Any information can not be collected as part of the herbarium specimens needs to be noted (for example, colour of leaf/leaflet or culm/cane, height of plant, *etc*.).

2.1 Bamboos

Bamboo herbarium specimens were collected and prepared followed the method of Lamxay (1999). The specimens collected were based on more than one year old culms, in which all the diagnostic characteristics were fully developed. The information on plant parts for bamboo specimens which needed to be collected or noted (for two to six duplicates within between 2-3 m from the ground) included the following:

1. Clustering or creeping growth habit
2. Internodes (size and wall thick), with nodes, and branches
3. Culm sheaths (sheath, auricles, ligule, and blade)
4. Shoots (if present)
5. Leaves (sheath, auricles, ligule, and blade) characteristics and size
6. Flower and fruit (if present)

2.2 Rattans

As done with bamboos, specimens of rattans were collected and prepared followed the method of Lamxay (1999) and Evans *et al.* (2001). The specimens collected were based on two year old canes, in which all the diagnostic characteristics were fully developed. The plant parts/information of a rattan specimens needed to be collected/noted included:

1. Solitary or clustered growth (including size and height/length of plant)
2. Pieces of stem (including leaf-sheath(s), spines, knee(s), and ocrea)
3. Pieces of leaf taken from the petiole, middle and tip of the rachis (with leaflets on one side removed to save space, but with the bases retained to show the leave arrangement)
4. The cirrus or flagellum
5. The inflorescence (if presence, if too large, a portion of the axis which bears a major branch and all its sub-branches is enough)

3. Taxonomic identification

This floristic work was undertaken, based on traditional herbarium techniques, at The Forest Herbarium, Department of National Parks, Wildlife and Plant Conservation, Bangkok, Thailand (BKF); The Botany Section, Botany and Weed Science Division, Department of Agriculture, Bangkok, Thailand (BK); The Forest Biology Department, Faculty of Forestry of Kasetsart University, Thailand (KUFF); The Faculty of Science, National University of Lao PDR (NUOL); and The Forest Research Center, Lao PDR (FRC).

In the species descriptions that follow in the following sections, the taxa are arranged alphabetically. All specimens cited under each species have been observed (and examined in detail) and are alphabetically arranged by the name of the countries where they were observed and collected, collector names, collector numbers, status of the specimen(s) either it is fertile (with reproductive organ(s)) or sterile (without reproductive organ(s)), localities where collected, year of collection, (herbarium or herbaria), respectively. The species descriptions have based on herbarium specimens, current records, and on living plants, supplemented by observations of plants made in the field. However, the characters of the reproductive parts were based mainly on specimens examined in BKF, BK, NUOL, and FRC.

Vernacular names and distributional information in the Lao PDR were based on information collected during fieldwork, herbarium specimen labels and from the literatures. Ecological information was taken from label information of the herbarium specimens and from field observations.

Publication titles and author abbreviations cited follow The International Plant Names Index (2004) (published on the internet: http//www.ipni.org/index.html.). Abbreviations of publications that are not included in the web-site above, follow those commonly used in botanical literature. Sometimes journals have not been abbreviated for clarity and because no commonly used abbreviation exists.

4. Bamboo culm and rattan cane sectioning and permanent slide preparation

The preparation of permanent slides of bamboo culms and rattan canes followed the process outlined by Siripatanadilok (1986), and involved the following sequence of steps. For preparation of the samples transversal and longitudinal sections of 18-20 μm thick were cut using a sliding microtome, following by double staining:

1. Washing of micro section using clean water;
2. Immersion in Mordant solution for 30 minutes;
3. Washing in water 2-3 times and checking under microscope;
4. Immersion in Hematoxylin and leave 30 minutes, following by washing in water 2-3 times;
5. Immersion in NH_4OH for change pH of Hematoxylin;
6. Dehydration in alcohol solution at 10, 20, 40 and 50% concentration, in sequence;
7. Immersion in Safranin (about 2- 3 drops mixed with 50% alcohol mixed) for 30 minutes, followed by checking under microscope;
8. Dehydrated in alcohol at 50, 75, 95, and 95%, and pure alcohol;
9. Immersion in xylin;
10. Place on microscopic glass slide with a drop of xylin and glue, and then covering with a cover slip;
11. Over drying of slides at 60°C for at least two days

5. Microscopic investigation

Anatomical studies on microscopic permanent slides of bamboo and rattan were carried out according to the methods outlined by Siripatanadilok (1986). The vascular bundles were determined by measuring the number of epidermis size, cortex, vascular bundle (metavessel, phloem, protrovessel, fibre strand, sclerenchyma sheath, and lumens), parenchyma, ground tissue, *etc.* Pictures of some representive characteristics were taken using a photomicroscope.

RESULTS AND DISCUSSION

In my visits to the regions (north, central and south) of Lao PDR, there were many of NTFPs to provide raw materials and food, especially bamboos and rattans. They serve a source of food (shoots), materials for house construction, handicrafts, and the basis cash incomes. Villagers have long traditions of bamboo and rattan handicraft production. They are very skillfully engaged in bamboo and rattan weaving, they made bamboo wall mats, bamboo mats for tobacco drying, bamboo fences, bamboo roof tiles, baskets, trays, furniture, rattan sat, rattan balls, and other handicraft products.

The morphological and anatomical characteristics are the most important means used to identify the key species of bamboos and rattans in the Lao PDR (and elsewhere). Based on morphological information, ten species from six genera of the bamboos, and seven species from two genera of the rattans commonly used in the country have been found. However, some were not able to be identified at the species level, due to the lack of reproductive parts (flowers and fruits).

1. Morphology of Bamboo and Rattan

1.1 Bamboo

In total, ten species from six genera of bamboos commonly used in the Lao PDR were found. They are three species of *Bambusa* (*B. blumeana*, *B. polymorpha*, *and B. tulda*); two species of *Dendrocalamus* (*D. brandisii* and *D. membranaceus*); one species of *Gigantochloa* (*G. albociliata*); one species of *Indosasa* (*I. sinica*); two species of *Schizostachyum* (*S. virgatum* and *Schizostachyum* sp.); and one species of *Thyrsostachys* (*T. siamensis*). Detail of the species descriptions of morphological characteristics are provided as follows:

Species 1

Specimens examined: LAO PDR: *Chaiyalad P-5* (from wild), sterile, Vientiane capital, 2009 (KUFF, FRC); THAILAND: *Larsen 9837*, sterile, Chanthaburi province, 1963 (BKF); *Maxwell 86-67*, sterile, Songkla province, 1986 (BKF); *Smitinand 511*, fertile, Chiang Rai province, 1986 (BKF).

Scientific name: ***Bambusa blumeana* Schultes**, Syst. Veg. 7(2): 1343. 1830; Gamble, Ann. Roy. Bot. Gard. Calc. 7: 50. 1896; S. Dransfield and E.A. Widjaja, Pl. Resources S. E. Asia 7: 60. *illustration on page 61*. 1995; S. Ketphanh *et al*., A Manual of the Bamboos of the Lao PDR: 33. *illustration on page 34*. 1994; D.Z. Li *et al.*, Flora of China 22: 10, 12, 24. *illustration on page 2*. 2006. (Figure 19).

Vernacular name: Mai phai banh.

Species description: Rhizomes pachymorph. Culms straight, densely tufted, 12-18 m high, *ca*. 10-15 cm in diameter (mid-culm portion); internodes 20-35 cm long; walls 1.5-2 cm thick; nodes prominent, lower ones with a ring of aerial roots; buds cordate. Culm sheaths tardily deciduous, 32-35 cm long, 22-24 cm wide, covered with densely stiffly brown hairs; auricles reflexed, deciduous, covered with dark brown hairs; ligule stiff, the middle tallest and fringed; blade narrowly linear-lanceolate, erect in basal node(s), margins incurved. Branches solitary on lower nodes, abundantly armed with short recurved spines in group of three and densely interwoven; 3 to several on upper nodes, central markedly longer and thicker. Leaf-blades linear-lanceolate, 12-17 cm long, 1.5-2.5 cm wide, hairy both sides; auricles small, bearing stiff hairs; ligule truncate, fringed, margin dentate to lacerate. Inflorescences consisting of pseudospikelets, laterally compressed, up to 5 cm long. Spikelets pale purple-green, linear, 2-4 cm long, 0.2-0.4 cm wide; florets 5-12; glumes 1-2; lemma ovate-oblong, 6-8 mm long, 2-4 mm wide, 9-10-veined, margins glabrous, apex acute; palea *ca*. 6 mm long, 1.5 mm wide, 3-veined between and 3-veined on either side of keels.

Ecology and Distribution: This species can be found on hills and in the mixed forests in the Central and Southern Regions of Lao PDR. However, it is not clear whether or not this species is native to the country because it is usually found, even though in the wild, not very far from village.

Utilization: The culms can be used for house frame construction, furniture structure, rice farm house, chicken house, bed, baskets, chicken cages, *etc*. In Southern Region it was used to make a kind of fish trap called “Lee”. The shoots are edible and usually harvested in May-July. This species is suitable for planting on the land as boundaries and wind breaks.

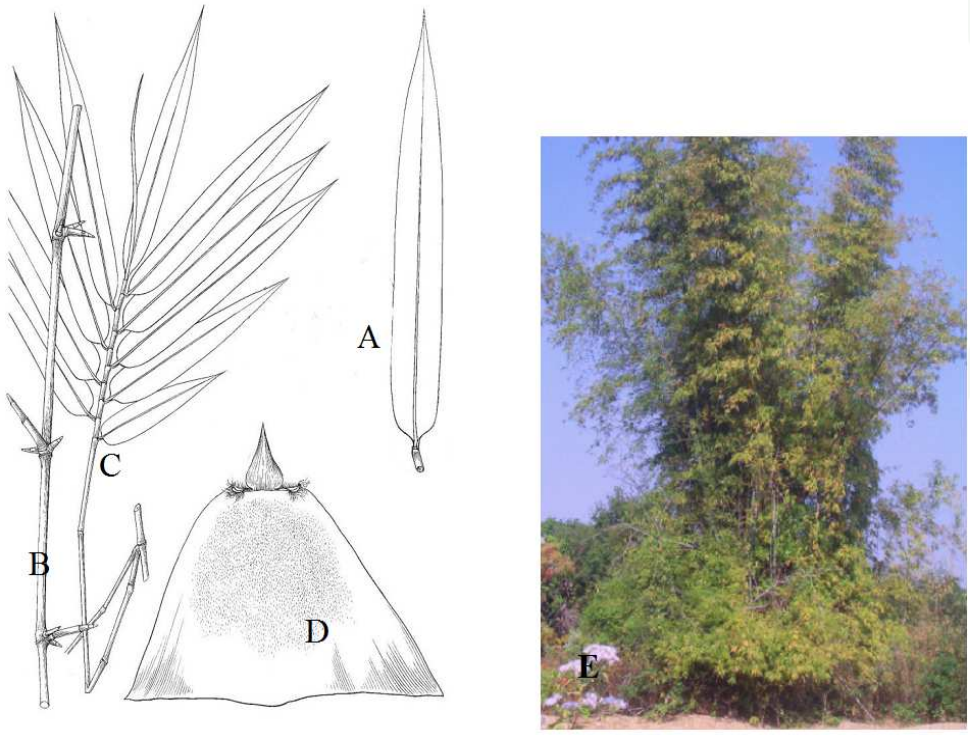


Figure 19 *Bambusa blumeana*: A. leaf-blade; B. portion of branchlet and spines; C. leafy branchlet; D. culm sheath; E. clump habit.

Source: A-D adapted from Li *et al*. (2006); E from Sangthong district, Vientiane capital in Central Region.

Species 2

Specimens examined: LAO PDR: *Chaiyalad P-3* (from wild), sterile, Champasak province, 2009 (KUFF, FRC); THAILAND: *Maxwell 740*, fertile, Phayao province, 1998 (BKF).

Scientific name: ***Bambusa polymorpha* Munro**, Trans. Linn. Soc. London. 26: 98. 1868; Gamble, Ann. Roy. Bot. Gard. Calc. 7: 36-37. *pl.34*. 1896; S. Dransfield and E.A. Widjaja, Pl. Resources S. E. Asia 7: 67. *illustration on page 67*. 1995; S. Ketphanh *et al.*, A Manual of the Bamboos of the Lao PDR: 23. *illustration on page 24*. 1994a; D.Z. Li *et al.*, Flora of China 22: 19, 20. *illustration on page 10*. 2006. (Figure 20).

Vernacular name: Mai poung.

Species description: Rhizomes pachymorph. Culms straight, densely tufted, curving outward, 15-18 m high, *ca.* 10-12 cm in diameter (mid-culm portion); internodes 40-60 cm long; walls 1.2-1.5 cm thick; nodes prominent; buds cordate. Culm sheaths deciduous, 18-19 cm long, 21-25 cm wide, covered with densely stiffly dark brown hairs; auricles long ciliate, when young embracing the culm; ligule irregularly dentate, ciliate; blade ovate-triangular, erect, covered with deciduous hairs. Branches arising from upper half of the culm, curved and densely interwoven. Leaf-blades linear-lanceolate, 20-28 cm long, 3-4.5 cm wide, usually hairy both sides, margins scabrous; auricles small, ciliate; ligule short. Inflorescences consisting of pseudospikelets, brownish, enclosed in a long curved glabrous bracts. Spikelets embraced by sheathlike bracts 1-1.5 cm long; florets 2 or 3, apical one sterile; rachilla segments flat, glabrous; glumes 3, ovate, apex mucronate; lemma ovate, many veined, apex mucronate; palea lanceolate, as long as or slightly longer than lemma, keels glabrous, apex acute; lodicules 3, 3-5 veined, margins ciliolate.

Ecology and Distribution: This species can be found in the mixed forest, deciduous forest and evergreen forest, particularly in the Southern Region of Lao PDR.

Utilization: The culms can be used for steaming sticky rice, making sticky rice containers, trays, winnowing-trays. The shoots are edible and usually harvested in June-August.

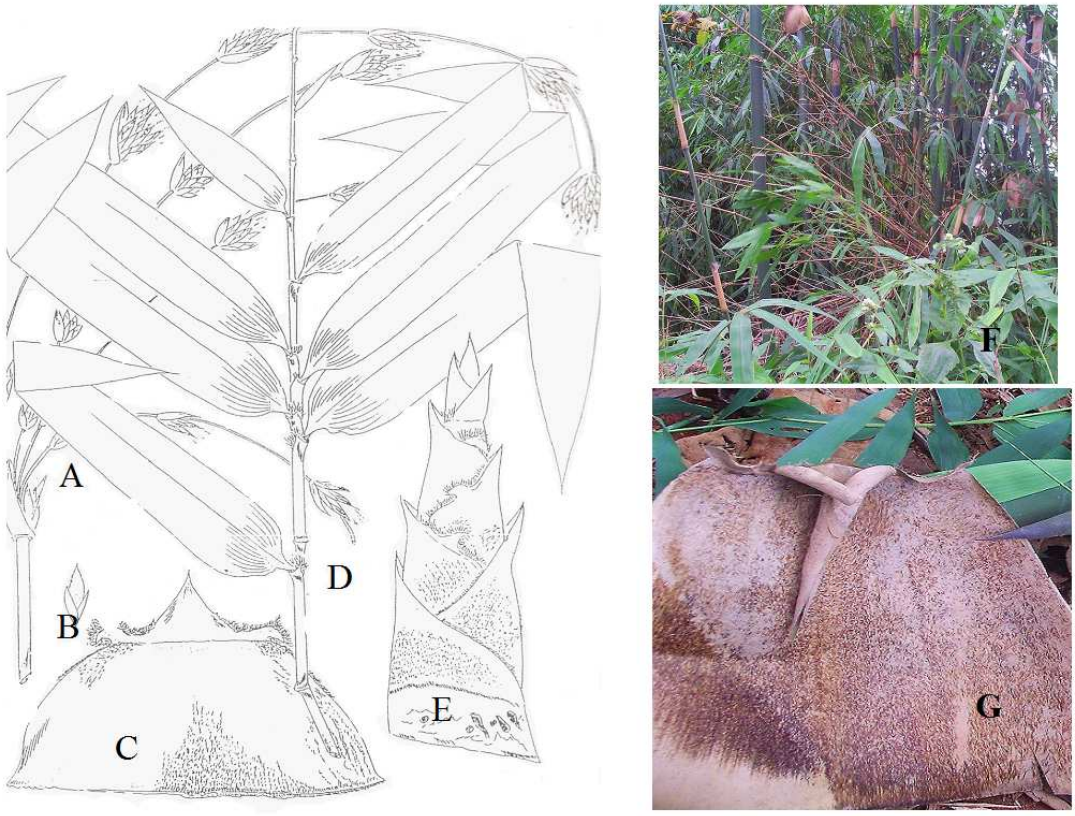


Figure 20 *Bambusa polymorpha*: A. flowering branchlet; B. spikelet; C. culm sheath; D. leafy branchlet; E. shoot; F. clump habit; G. culm sheath.

Source: A-E adapted from Ketphanh *et al*. (1994a); E-G from Pakse district, Champasak province in Southern Region.

Species 3

Specimens examined: LAO PDR: *Chaiyalad V-7* (from the wild), sterile, Vientiane capital, 2009 (KUFF, FRC); THAILAND: *Kerr 8754*, fertile, Loei province, 1879 (BK); *Jonganurar* and *Puudjaa 1479*, sterile, Loei province, 1997 (BKF); *Kokkamheang* 7, fertile, Lampang province, 1962 (BKF); *Larsen 9337*, fertile, Krabi province, 1962 (BKF); *Maxwell 93-721*, fertile, Lampool province, 1993 (BKF); *Phloenchit 1261*, sterile, Phetchaburi province, 1959 (BKF); *Smitinand* 535, fertile, Lampang province, 1961 (BKF); *Sorensen et al. 1121*, sterile, Chiang Mai province, 1958 (BKF).

Scientific name: ***Bambusa tulda* Roxb.**, Hort. Bengal. 25. Fl. Ind. ii: 193. 1814; Gamble, Ann. Roy. Bot. Gard. Calc. 7: 30. *pl. 71*. 1896; S. Dransfield and E.A. Widjaja, Pl. Resources S. E. Asia 7: 69. *illustration on page 70*. 1995; S. Ketphanh *et al.*, A Manual of the Bamboos of the Lao PDR: 21. *illustration on page 22*. 1994a; D.Z. Li *et al.*, Flora of China 22: 17, 21, 24. *illustration on page 7*. 2006. (Figure 21).

Vernacular name: Mai bong.

Species description: Rhizomes pachymorph. Culms usually bent, loosely tufted, 10-12 m high, *ca.* 3-5 cm in diameter (mid-culm portion); internodes 30-35 cm long, green to grey-green; walls 1.2-1.5 cm thick, with scurfy when young; nodes prominent, lower ones with aerial roots; buds cordate. Culm sheaths tardily deciduous, coriaceous, 13-15 cm long, 16-17 cm wide, often covered with appressed brown hairs; auricles large, unequal continuous with the blade, margins ciliate; ligule narrow, entire, minutely ciliolate; blades broadly triangular, coriaceous, erect. Branches dominant, slender. Leaf-blades linear-lanceolate to oblong, 17-18 cm long, 1.5-2.5 cm wide, covered with hairs, puberulent; auricles fringed with long white hairs; ligule very small. Inflorescences consisting of pseudospikelets 2-5 cm long, supported by chaffy bracts. Spikelets pale purple-green, linear, 2-3 cm long, 0.3-0.4 cm wide; florets 4-10, central 2-5 perfect; glumes 2-4; lemma ovate-oblong, 5-7 mm long, 2-3 mm wide, 8-10-veined, margins glabrous, apex acute; palea *ca.* 5 mm long, 1.5 mm wide, 3-veined.

Ecology and Distribution: This species can be found on hills, in mixed forest, and along watercourses in all regions of Lao PDR.

Utilization: The culms can be used for sticky rice containers, fence, fishing tools. The shoots are edible and usually harvested in May-August.

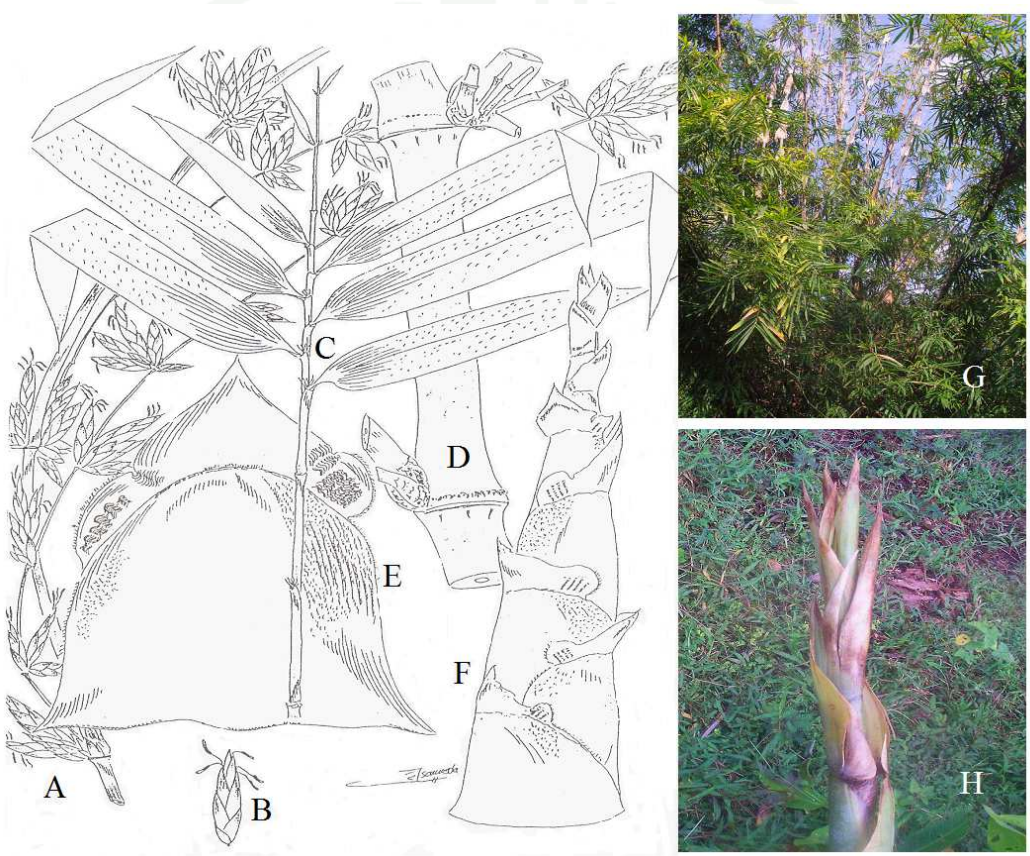


Figure 21 *Bambusa tulda*: A. flowering branchlet; B. spikelet; C. leafy branchlet; D. culm; E. culm sheath; F. shoot; G. clump habit; H. shoot.

Source: A-F adapted from Ketphanh *et al*. (1994a); G-H from Sangthong district, Vientiane capital in Central Region.

Species 4

Specimens examined: LAO PDR: *Chaiyalad O-2* (from wild), sterile, Oudomxay province, 2009 (KUFF, FRC); THAILAND: *Kerr 2213*, fertile, Loei province, 1879 (BK); *Larsen 9565*, fertile, Kanchanaburi province, 1962 (BKF); *Smitinand 5997*, fertile, Tak province, 1959 (BKF); *Smitinand 7015*, fertile, Tak province, 1960 (BKF); *Sorensen et al. 1805*, fertile, Chiang Mai province, 1958 (BKF).

Scientific name: ***Dendrocalamus brandisii* (Munro) Kurz**, Prelim. Rep. For. Veg. Pegu. App. B. 94. 1875, Forest Fl. Burma ii: 560. 1877; Gamble, Ann. Bot. Gard. Calc. 7: 90. 1896; S. Dransfield and E.A. Widjaja, Pl. Resources S. E. Asia 7: 83. *illustration on page 83*. 1995; D.Z. Li *et al.*, Flora of China 22: 40, 43. *illustration on page 41*. 2006; S. Sungkaew, Taxonomy and Systematics of *Dendrocalamus*: 179. *illustration on page 212, 213*. 2008. (Figure 22).

Vernacular name: Mai hok.

Species description: Rhizomes pachymorph. Culms erect with pendulous tip, greenish-grey to dull green, loosely tufted, without spines, 18-25 m high, *ca*. 13-17 cm in diameter (mid-culm portion); internodes 30-40 cm long; walls 1.3-2.4 cm thick; nodes slightly swelled, lower ones with aerial roots; buds cordate. Culm sheaths deciduous, 32-35 cm long, 21-22 cm wide, early deciduous, covered with brown hairs; auricles readily deciduous; ligule continuous with the sheath top, margin broadly lacerate; blades lanceolate, reflexed, sometime erect, covered with densely hairs. Branches arising from upper mid-culm part, primary branche dominant, secondary branches slender. Leaf-blades oblong-lanceolate, 22-30 cm long, 3-5 cm wide; auricles absent or as inconspicuous ridges; ligule margin dentate to sub-entire at the middle, lacerate outwards. Inflorescences consisting of pseudospikelets 5-20 per node. Spikelets ovate-orbicular, 6-9 mm long, 3-5 mm wide; florets 2-4; glumes 1 or 2, apex acute; lemma 5-6 mm; palea 2-keeled, ciliate, 3-veined between keels.

Notes: This species was often misidentified as *Dendrocalamus hamiltonii* due to both species have the same vernacular name called “Mai hok”.

Ecology and Distribution: This species can be found in mixed forest, dry evergreen forest, and evergreen forest in the Northern and Central Regions of Lao PDR.

Utilization: The culms can be used for house constructions. The shoots are edible, preserved by drying, salting, and canning and usually harvested in July-August.

Figure 22 *Dendrocalamus brandisii*: A. shoot; B. culm sheath; C. leafy branchlet; D. young culms with sheaths; E. shoots.

Source: A-C from Sungkaew (2008); D from Namor district, Oudomxay province in Northern Region; E from Vangvieng district, Vientiane province in Central Region.

Species 5

Specimens examined: LAO PDR: *Chaiyalad V-9* (from the wild), sterile, Vientiane capital, 2009 (KUFF, FRC); THAILAND: *Kerr 2213*, sterile, Loei province, 1879 (BK); *Dransfield 1438*, fertile, Chiang Mai province, 1997 (BKF); *Maxwell 15*, fertile, Chiang Mai province, 1996 (BKF); *Smitinand 2120*, fertile, Loei province, 1954 (BKF).

Scientific name: ***Dendrocalamus membranaceus*** **Munro**, Trans. Linn. Soc. London. 26: 149. 1868; Gamble, Ann. Bot. Gard. Calc. 7: 81. *pl. 71*. 1896; S. Dransfield and E.A. Widjaja, Pl. Resources S. E. Asia 7: 90. *illustration on page 91*. 1995; D.Z. Li *et al.*, Flora of China 22: 40. *illustration on page 35*. 2006; S. Sungkaew, Taxonomy and Systematics of *Dendrocalamus*: 170. *illustration on page 208, 209.* 2008. (Figure 23).

Vernacular name: Mai sang.

Species description: Rhizomes pachymorph. Culms erect, loosely tufted, without spines, 20-25 m high, *ca.* 10-15 cm in diameter (mid-culm portion); internodes 30-45 cm long; walls relatively thin, about 1.1-2 cm thick, when young covered with white powdery deciduous scurf; nodes prominent; buds cordate. Culm sheaths deciduous, 38-40 cm long, 17-18 cm wide, covered with dark brown to black hairs; auricles wavy or pleated, margins fringed with bristles; ligule margin divided into broad lacerations; blades linear-lanceolate, reflexed, and covered with brown hairs. Branches arising nearly all nodes, the primary one dominant, lower ones usually curved. Leaf-blades linear, 12-13 cm long, 1.2-2 cm wide, thin, hispid above; auricles falcate lobes, purplish ciliate; ligule very short. Inflorescences consisting of pseudospikelets, slightly compressed, 10-13 mm long, 2-5 mm wide. Spikelets 6-12 mm long; fertile florets 2-5; glumes usually 2 or more; lemma 9-11 mm long, apex long mucronate; palea 6-7 mm long.

Ecology and Distribution: This species can be found in mixed forest, base of the hills in all regions of Lao PDR.

Utilization: The culms can be used for construction of farm cottages, producing toothpick, chopsticks, sticks for roasting meat and vegetables, baskets, chicken cages, *etc.* The culm length of 5-7 m was at prices between US$ 0.4-0.8 in Vientiane. The shoots are edible, preserved by drying, salting, and usually harvested in June-August.

Figure 23 *Dendrocalamus membranaceus*: A. flying shoot; B. culm sheath; C. leafy branchlet; D. flowering branchlet; E. culm sheath; F. clump habit.

Source: A-D from Sungkaew (2008); E-F from Sangthong district, Vientiane capital in Central Region.

Species 6

Specimens examined: LAO PDR: *Chaiyalad V-8* (from the wild), sterile, Vientiane capital, 2009 (KUFF, FRC); THAILAND: *Kerr 17723*, fertile, Loei province, 1879 (BK); *Dransfield 1460*, sterile, Ubon Ratchathani province, 1997 (BKF); *Dransfield 1465*, sterile, Sakonnakhon province, 1997 (BKF); *Niyomdham 6463*, fertile, Lampang province, 2001 (BKF); *Smitinand* and *Thongzorn 1436*, sterile, Chiang Mai province, 1879 (BKF); *Smitinand et al. 7597*, fertile, Chiang Mai province, 1967 (BKF); *Sukkri 23*, fertile, Lampang province, 1879 (BKF).

Scientific name: ***Gigantochloa albociliata* (Munro) Kurz**, Prelim. Rep. Forest, Pegu App. A. 136, B. 93, in clavi. 1875, Forest Fl. Burma 2: 555. 1877; S. Dransfield and E.A. Widjaja, Pl. Resources S. E. Asia 7: 98. *illustration on page 98*. 1995; S. Ketphanh *et al.*, A Manual of the Bamboos of the Lao PDR: 36. *illustration on page 38*. 1994a; D.Z. Li *et al.*, Flora of China 22:46, 47. *illustration on page 46*. 2006. (Figure 24).

Vernacular name: Mai lai.

Species description: Rhizomes pachymorph. Culms elongate arcuate-decurved, densely tufted, 8-13 m high, *ca.* 2-4 cm in diameter (mid-culm portion); internodes 25-30 cm long, hispid when young; walls 1-1.5 cm thick; nodes prominent; buds cordate. Culm sheaths folded and coriaceous, 12-14 cm long, 7-10 cm wide, apex truncate and narrow, covered with dense dark hairs; auricles small; ligule ciliate, margin divided into broad lacerations; blades oblong-lanceolate, reflexed, acuminate. Branches arising from all nodes or nearly so, almost as strong as the culm. Leaf-blades linear-lanceolate, 18-19 cm long, 2-5 cm wide, apex subulate-acuminate, glabrous; ligule long, hairy; margin irregularly; auricles indistinct. Inflorescences consisting of pseudosoikelets, with white ciliate bracts. Spikelets elongate-linear, curved, and rarely straight, 1.5-2.3 cm long; florets 1 or 2; glumes 2 or 3, ovate; lemma margins white ciliate; palea shorter than lemma.

Ecology and Distribution: This species can be found along the river banks, and mixed forest in the Central and Southern Regions of Lao PDR.

Utilization: The culms can be used for steaming sticky rice and making sticky rice containers. The shoots are edible and usually harvested in July-September or October.

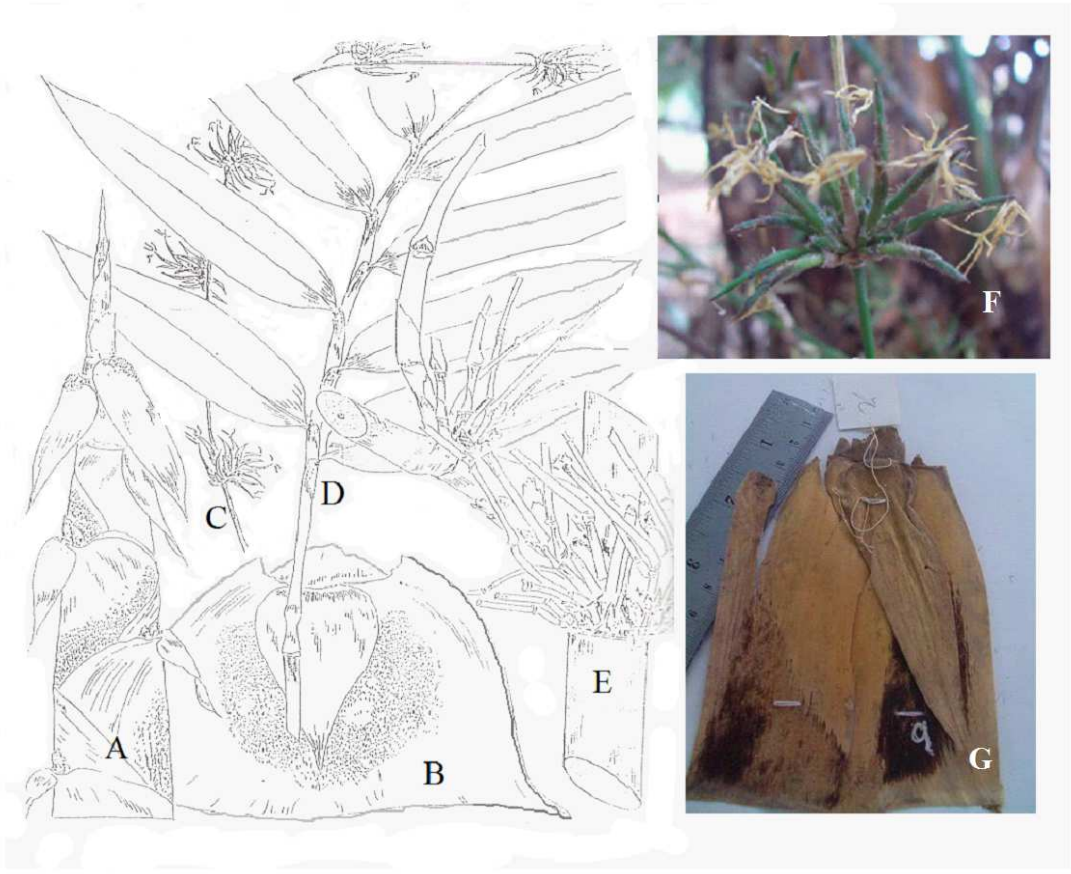


Figure 24 *Gigantochloa albociliata*: A. shoot; B. culm sheath; C. flowering branchlet; D. leafy branchlet; E. branches; F. spikelets; G. culm sheath.

Source: A-E adapted from Ketphanh *et al*. (1994a); F-G from Sangthong district, Vientiane capital in Central Region.

Species 7

Specimens examined: LAO PDR: *Chaiyalad O-1* (from the wild), sterile, Oudomxay province, 2009 (KUFF, FRC).

Scientific name: ***Indosasa sinica*** **C.D. Chou and C.S. Chao**, Acta Phytotax. Sin. 21: 65. 1983; D.Z. Li *et al.*, Flora of China 22: 144, 145. *illustration on page 189.* 2006. (Figure 25).

Vernacular name: Noh khome.

Species description: Rhizomes leptomorph. Culms straight, 8-12 m high, *ca.* 3-5 cm in diameter (mid-culm portion); internodes 22-30 cm long, flexuose; walls 0.7-1.2 cm thick; nodes very prominent; buds cordate. Culm sheaths tardily deciduous, coriaceus, 19-20 cm long, 9-10 cm wide, covred with densely stiffly brown hairs; auricles usually reflexed, covered with deciduous dark brown hairs; ligule early deciduous; blade narrowly lanceolate, margin incurved. Branches arising from mid-culm to top, in three to several. Leaf-blades linear-lanceolate, 10-15 cm long, 3-4 cm wide, usually hairy both sides, margins scabrous; sheath striate; auricles small, bearing a few bristles; ligule truncate, fimbriate, margin irregularly dentate to lacerate. Inflorescences consisting of pseudospikelets, rachilla articulate, glabrous; lemma 1.2-1.5 cm, glaucous, glabrous; palea shorter than lemma; lodicules membranous.

Ecology and Distribution: This species can be found in evergreen forest, dry evergreen forest, and in the mixed forest in the Northern Region of Lao PDR.

Utilization: The shoots are edible. In Nampheng village, Oudomxay province, the villagers harvested its shoots and sold to traders at prices US$ 0.15-0.25 per kg, and the harvest time is in November-April.

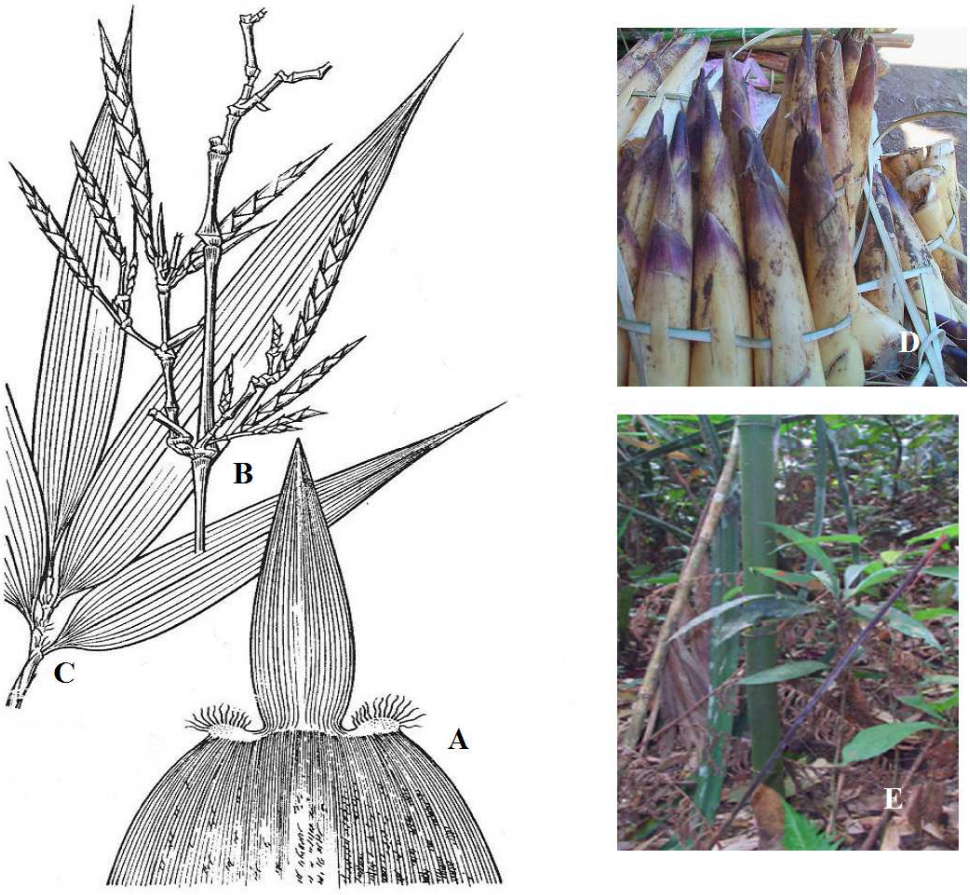


Figure 25 *Indosasa sinica*: A. culm sheath; B. flowering branchlet; C. leafy branchlet; D.shoots; E.culm.

Source: A-C adapted from Li *et al*. (2006); D-E from Namor district, Oudomxay province in Northern Region.

Species 8

Specimens examined: LAO PDR: *Chaiyalad V-10* (from the wild), sterile, Vientiane capital, 2009 (KUFF, FRC).

Scientific name: ***Schizostachyum* sp.** (Figure 26).

Vernacular name: Mai sod.

Species description: Rhizomes pachymorph. Culms erect with long pendulous tip, densely tufted, 8-12 m high, *ca*. 2-6 cm in diameter (mid-culm portion); internodes 35-45 cm long, covered with white hairs; walls 0.5-0.8 cm thick; nodes not prominent, oblique; buds cordate. Branches arising from mid-culm upward, curved. Culm sheaths hard, 13-14 cm long, 11-12 cm wide, covered with black and pale yellow hairs; auricles tiny or absent; ligule droopy or tiny; blades narrowly, linear-lanceolate, tapering, covered with densely hairs. Leaf-blades linear-lanceolate, 20-25 cm long, 2-4 cm wide; auricles small but prominent; ligule short. Inflorescences unknown.

Ecology and Distribution: This species can be found in mixed forest, flat land, deforested areas in the Central and Southern Regions of Lao PDR.

Utilization: The culms can be used for making mats (wall) size 1.5 m x 2 m which are sold at prices between US$ 0.4-1.2 per piece, grass broom handles, traditional music instrument (Khène) which is sold at prices up to US$ 8 (depends on design). The shoots are edible and usually harvested in July to October.

Figure 26 *Schizostachyum* sp: A. clump habit; B. shoot; C. culm sheath; D. leafy branchlet.

Source: All from Sangthong district, Vientiane capital in Central Region.

Species 9

Specimens examined: LAO PDR: *Chaiyalad P-6* (from the wild), sterile, Champasak province, 2009 (KUFF, FRC); THAILAND: *Dransfield 1468*, sterile, Ubon Ratchathani province, 1997 (BKF); *Dransfield 1473*, sterile, Sakonnakhon province, 1997 (BKF).

Scientific name: ***Schizostachyum virgatum* (Munro) H.B Naithani and Bennet**, Indian Forest 117 (1): 68. 1991. (Figure 27).

Vernacular name: Mai hia.

Species description: Rhizomes pachymorph. Culms straight with long pendulous tip, loosely tufted, 8-12 m high, *ca*. 2-4 cm in diameter (mid-culm portion); internodes 30-40 cm long, covered with appressed white hairs, glabrous later; walls 0.4-1 cm thick; nodes not prominent, smooth; buds cordate. Culm sheaths hard, outside covered with dark brown hairs, 23-24 cm long, 9-10 cm wide, margins revolute, covered with short rigid hairs; auricles bristle; ligule irregularly dentate, bristles; blades narrowly lanceolate, tapering, usually erect, covered with densely hairs. Branches from mid-culm upward. Leaf-blades linear-lanceolate, acuminate, 30-35 cm long, 3-4 cm wide; auricles small with bristles; ligule short. Inflorescences consisting of densely tufted of pseudospikelets at the nodes. Spikelets 15-17 mm long, only one perfect floret.

Ecology and Distribution: This species can be found along the river banks, in deciduous forest, evergreen forest, and mix forest in the Central and Southern Regions of Lao PDR.

Utilization: The culms can be used for making mats (panel) for house, flooring, ceilings, and any wall constructions or panel. The mat sized 2 m x 3 m is sold at prices US$ 1.5-1.6. The traditional music instrument (Khène and flute *etc.*) is sold at price US$ 5-8, depending on design.

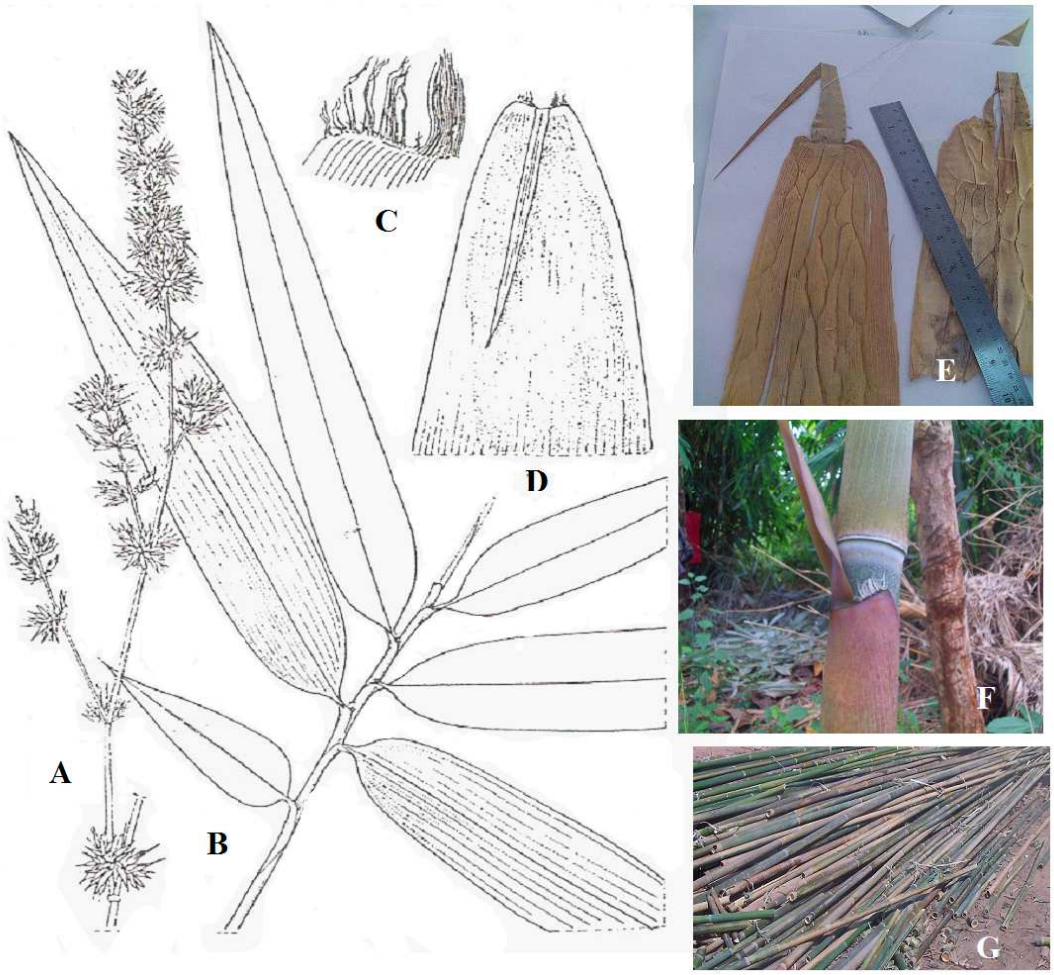


Figure 27 *Schizostachyum virgatum*: A. flowering branchlet; B. leafy branchlet; C. auricle; D. culm sheath; E. culm sheath; F. auricle; G. culms.

Source: A-D from Dransfield and Widjaja (1995); E-G from Pakse district, Champasak province in Southern Region.

Species 10

Specimens examined: LAO PDR: *Chaiyalad V-11* (from the wild), sterile, Vientiane capital, 2009 (KUFF, FRC); THAILAND: *Kerr 470*, fertile, Loei province, 1879 (BK); *Smitinand 8663*, sterile, Saraburi province, 1963 (BKF); *Phengklai et al. 12138*, sterile, Satun province, 1999 (BKF); *Phengklai et al. 12204*, sterile, Kanchanaburi province, 2000 (BKF); *Phengklai et al. 13019*, sterile, Trat province, 2000 (BKF); *Puudjaa 2002*, sterile, Phetchaburi province, 2002 (BKF).

Scientific name: ***Thyrsostachys siamensis*** **Gamble**, Ann. Roy. Bot. Gard. (Calcutta) vii. (1897) 59; S. Dransfield and E.A. Widjaja, Pl. Resources S. E. Asia 7: 145, 146, 147. *illustration on page 146*. 1995; D.Z. Li *et al.*, Flora of China 22: 38, 39. *illustration on page 34*. 2006. (Figure 28).

Vernacular name: Mai huak.

Species description: Rhizomes pachymorph. Culms straight with arching tip, densely tufted, 10-15 m high, *ca.* 3-5 cm in diameter (mid-culm portion), smooth, grayish-green; internodes 25-30 cm long; walls very thick, about 2-2.5 cm thick; nodes not swollen; buds cordate. Culm sheaths tardily deciduous, narrow, 25-28 cm long, 8-10 cm wide, pale to purplish-green turning and thin, covered with scattered hairs; auricles absent; ligule very short; blades narrowly-lanceolate, erected, 6.8-7 cm long, about 1.4-1.6 cm wide. Branches arising from mid-culm upwards, the primary branch from lower nodes usually dominant. Leaf-blades narrowly linear, 8-9 cm long, 0.8-1 cm wide, thin, secondary veins 3-5, hispid above, margins scabrous; sheath striate, cleft nearly to the base; auricles absent; ligule very short, ciliate, margin irregularly dentate to lacerate. Inflorescences consisting of pseudospikelets, many thin branchlets with bracteates. Spikelet 1.2-1.4 cm long; gemmiferous bracts 2 or 3; glumes 2 or 3; fertile florets 1-3; lemma 1-1.5 cm long; palea slightly longer than lemma.

Ecology and Distribution: This species can be found in mixed forest, deciduous forest, particularly in the Central Region of Lao PDR.

Utilization: The culms can be used for construction of farm houses, bamboo supports. The shoots are edible. The boiled shoots in plastic bag can be sold at prices US$ 0.15-0.25 per kg.

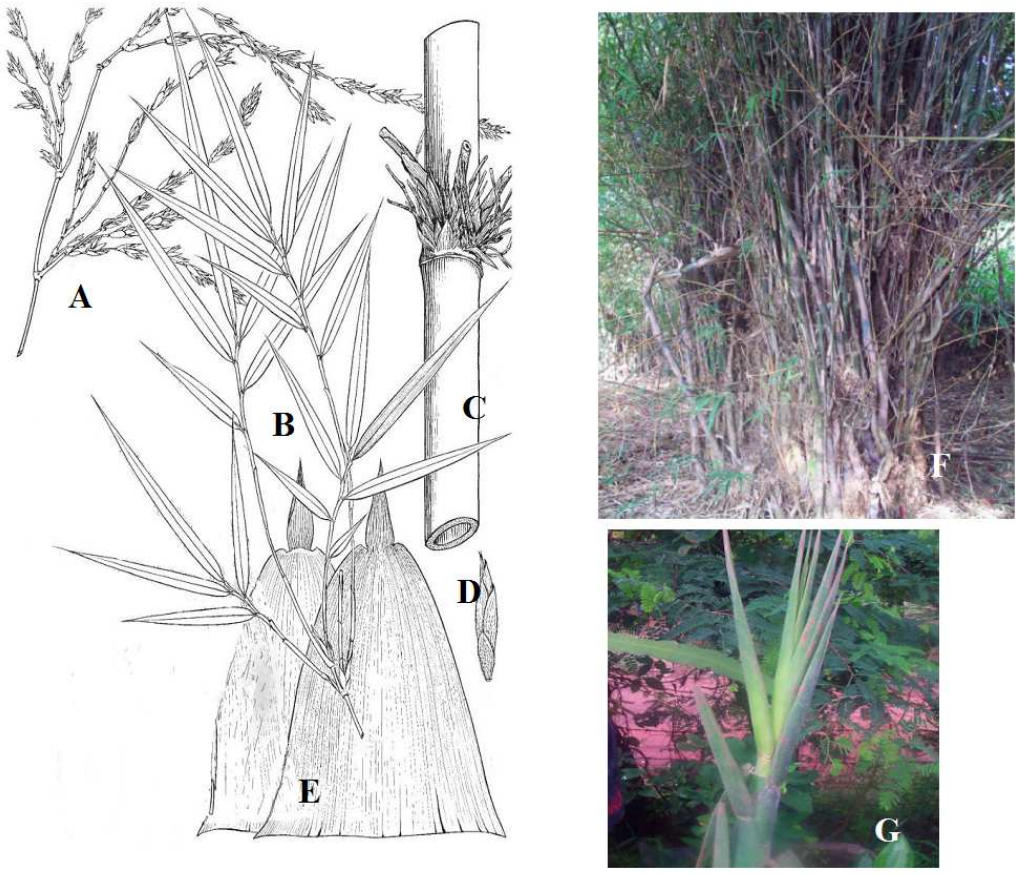


Figure 28 *Thyrsostachys siamensis*: A. flowering branchlet; B. leafy branchlet; C. portion of culm; D. spikelet; E. both sides of culm sheath; F.clump habit; G. shoot.

Source: A-J adapted from Li *et al*. (2006); K-L from Sangthong district, Vientiane capital in Central Region.

1.2 Rattan

Seven species from two genera of rattan commonly used in Lao PDR were found. These includes six species of *Calamus* (*C. palustris*, *C. poilanei*, *C. rhabdocladus*, *C. tenuis*, *C. solitarius*, *and C. tetradactylus*) and one species of *Plectocomiopsis* (*P. geminiflorus*). Species descriptions have been given here.

Species 1

Specimens examined: LAO PDR: *Chaiyalad P-9* (from material), sterile, Vientiane capital, 2009 (KUFF, FRC); *Evans et al. 214*, fertile, Bolikamxay province, 1999 (FRC); THAILAND: *Niyomdham* and *Ueachirakan 1771*, fertile, Krabi province, 1988 (BKF); *Santisuk 1861*, fertile, Chiang Mai province, 1988 (BKF).

Scientific name: ***Calamus palustris* Griff.,** Calcutta J. Nat. Hist. v. (60). 1845; Ann. Roy. Gard. Calcutta 11: 405. 1908; Dransfield and Manokaran, Pl. Resources S. E. Asia 6: 63. *illustration on page 63-64*. 1994; T. Evans *et al.*, A Field Guide Rattans of Lao PDR. 60-61. *pl. 60*. 2001. (Figure 29).

Vernacular name: Wai hang nou.

Species description: Clustered stem rattan, climbing, up to 30 m long or more. Stems *ca.* 2.5-3.5 cm in diameter; spines many, slender, up to 2 cm long. Canes *ca.* 1.5-2.5 cm in diameter; internodes to 30-35 cm long. Leaves 2-2.5 m long including the cirrus, with scattered brown yellow-based spines up to 3 cm long, usually less; knee conspicuous; ocrea to 3 mm long; petiole short, about 10-15 cm long; leaflets arranged in groups of 2-4, spathulate, to about 35-50 cm long, 3-4 cm wide. Inflorescences about 1 m long; rachilla 2-2.2 cm long in male, 5-7 cm in female; bracts sparsely armed. Fruit globular, about 9-12 mm diameter, covered with 12 vertical rows of straw-coloured scales with brown margins. Seed deeply pitted, the pits penetrating the endosperm.

Ecology and Distribution: This species grows in evergreen forest in Southern Region of Lao PDR.

Utilization: This species can be used for handicrafts (*e.g.* furniture, baskets, trays, rattan balls, winnowing trays, fish traps) of high quality. The semi-processed canes were exported at prices US$ 0.3-0.4 per cane (5 m long, 1-2 cm diameter).

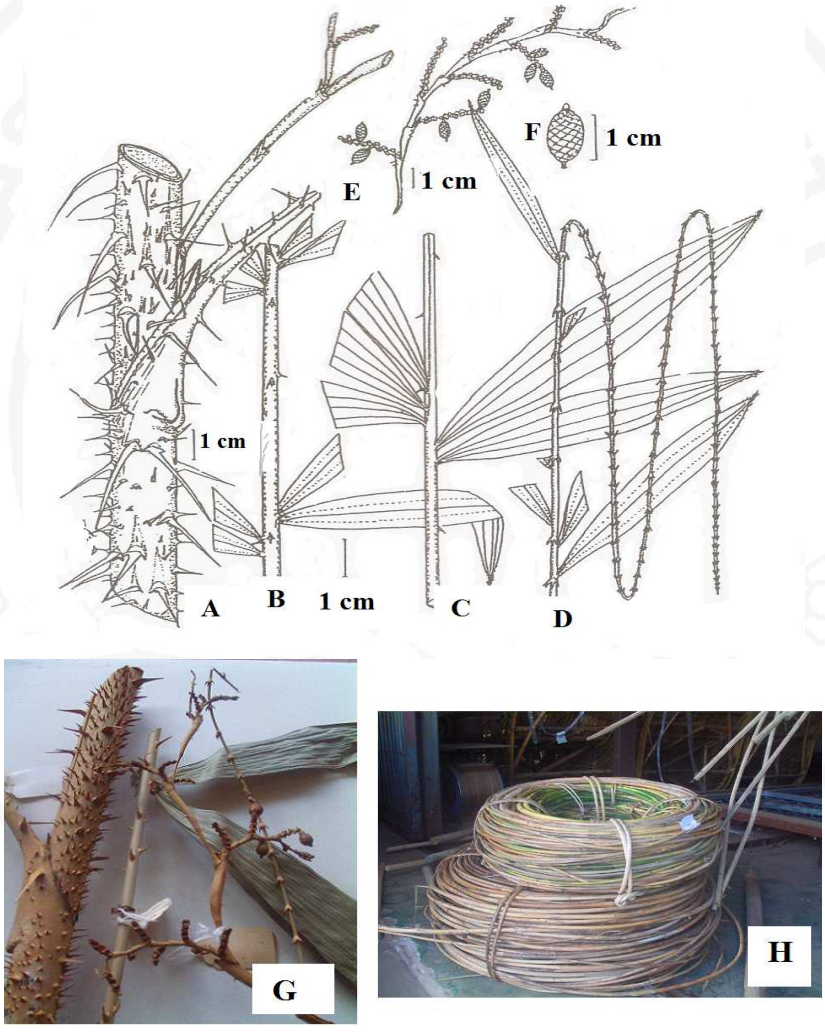


Figure 29 *Calamus palustris*: A. stem; B. petiole; C. rachilla; D. cirrus; E. fruit branchlet; F. fruit; G. specimen; H. canes.

Source: A-F adapted from Jintana, (1988); G from the specimen of *Evans et al.*, 214; H from Thapho village, Sisattanak District, Vientiane capital in Central Region.

Species 2

Specimens examined: LAO PDR: *Chaiyalad V-1* (from material), sterile, Vientiane capital, 2009 (KUFF, FRC); *Evans et al. 127*, fertile, Oudomxay province, 1999 (FRC).

Scientific name: ***Calamus poilanei* Conrard**, Fl. Indo-Chine [P. H. Lecomte *et al.*] 6: 1927, gallice; in Humbert, Not. Syst. vii. 28, latine. 1937; S. Ketphanh *et al.*, A Manual of the Rattans of the Lao PDR: 20. *illustration on page 22*. 1994b; T. Evans *et al.*, A Field Guide Rattans of Lao PDR. 32-33. *pl. 32*. 2001. (Figure 30).

Vernacular name: Wai thoun.

Species description: Solitary stem rattan, climbing up to 60 m long or more. Stems *ca.* 5-7 cm in diameter; spines many, slender, up to 4 cm long. Canes *ca.* 3-5 cm in diameter with upper internodes up to 30-40 cm long. Leaves 2-3.5 m long; with scattered brown yellow-based spines to 1-3 cm long; knee conspicuous; ocrea tiny, dry, bristly; petiole about 35-50 cm long, margins usually have spines in paire pointing in different directions; leaflets 50-80 cm long, 2-3 cm wide, arranged in pair. Flagellum about 1-3 m long, with spines. Inflorescences about 1-3 m long, usually 3 branched, flower cups not on stalks in female; bracts quite tightly sheathing, armed with stout claws and some short stout spines. Fruit globular, about 2-3 cm long, 1.2-2 cm wide, covered with 12 vertical rows of straw-coloured scales with brown margins. Seed deeply pitted, the pits penetrating the endosperm.

Ecology and Distribution: This species grows in evergreen forest in all regions of Lao PDR.

Utilization: This species provides very robust cane and can be used for funiture. The semi-processed canes were exported with a good price between US$ 1.5-2 per cane (5 m long, 3-5 cm in diameter).

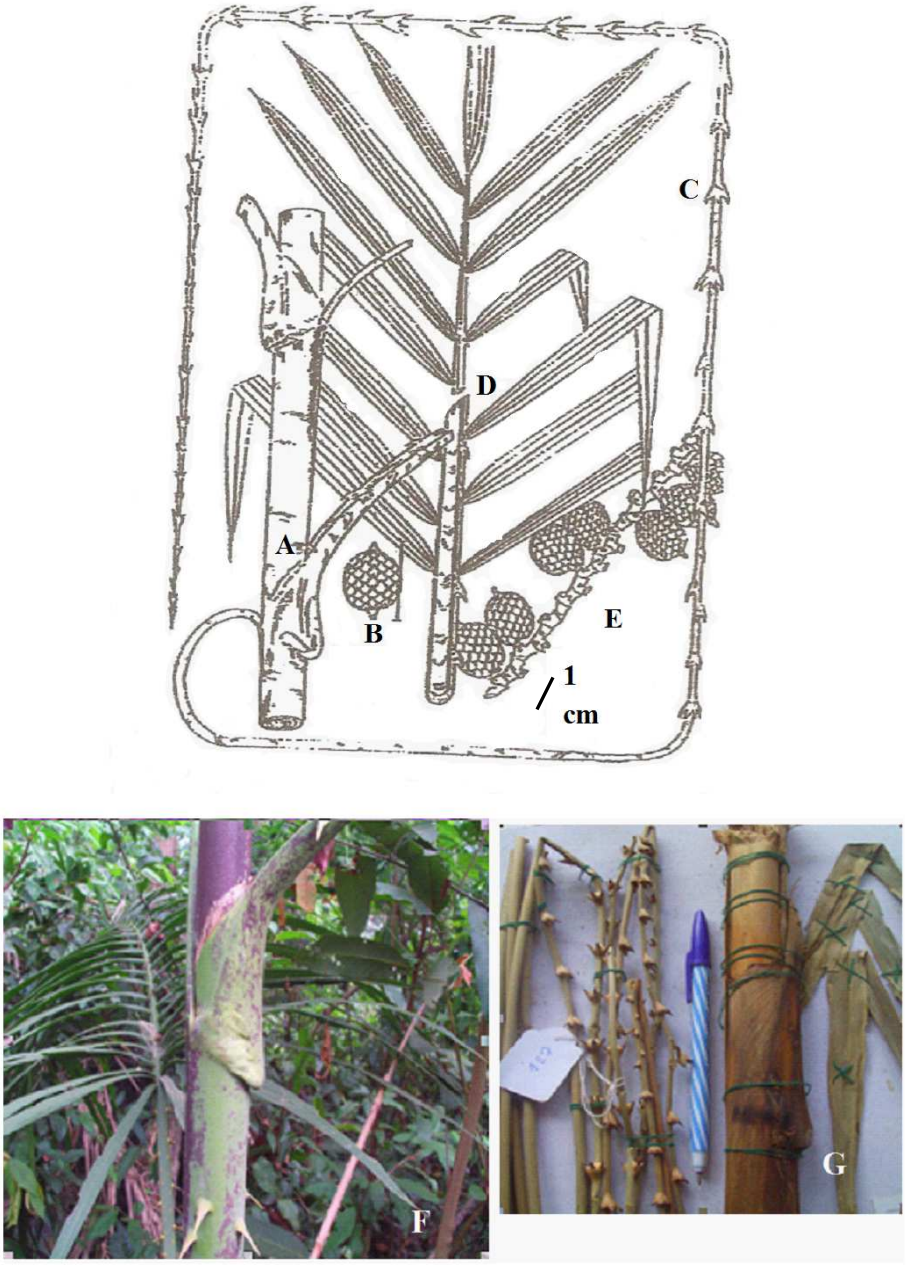


Figure 30 *Calamus poilanei*: A. stem; B. fruit; C. flagellum; D. rachilla; E. fruit branchlet; F. stem; G. specimen.

Source: A-E adapted from Ketphanh *et al*. (1994b); F from Nasaythong district, Vientiane capital in Central Region; G from the specimen of *Evans et al., 127*.

Species 3

Specimens examined: LAO PDR: *Chaiyalad O-3* (from the wild), sterile, Oudomxay province, 1999 (KUFF, FRC); *Evans et al. 20*, fertile, Oudomxay province, 1999 (FRC).

Scientific name: ***Calamus rhabdocladus* Burret**, Notizbl. Bot. Gart. Berlin-Dahlem 10: 884. 1930; S. Ketphanh *et al.*, A Manual of the Rattans of the Lao PDR: 25. *illustration on page 26*. 1994b; T. Evans *et al.*, A Field Guide Rattan of Lao PDR 57. *pl. 56*. 2001. (Figure 31).

Vernacular name: Wai faad.

Species description: Clustered stem rattan, climbing up to 15 m long or more. Stems *ca*. 1.5-2 cm in diameter. Canes *ca*. 1-2.5 cm in diameter with internodes 15-20 cm long. Spines slender up to 2 cm long, flat with dark tip. Leaves 2-2.5 m long; knee apparent; ocrea tiny, dry; petiole about 20-30 cm long, margins usually have spines in paire pointing in different directions; leaflets 45-50 cm long and 2-3 cm wide, arranged regularly; vein with bristles. Flagellum about 1-5 m long with short spines. Inflorescences about 1-5 m long, pendulous branchlet; armed with claws and long thin spines, male and female superficially similar. Fruit globular, about 1.8-2 cm long, and 1.6-2 cm wide, covered with 21 vertical rows of straw-coloured scales with reddish margins.

Ecology and Distribution: This species grows in evergreen forest in Northern Region of Lao PDR.

Utilization: The shoot/tip is edible.

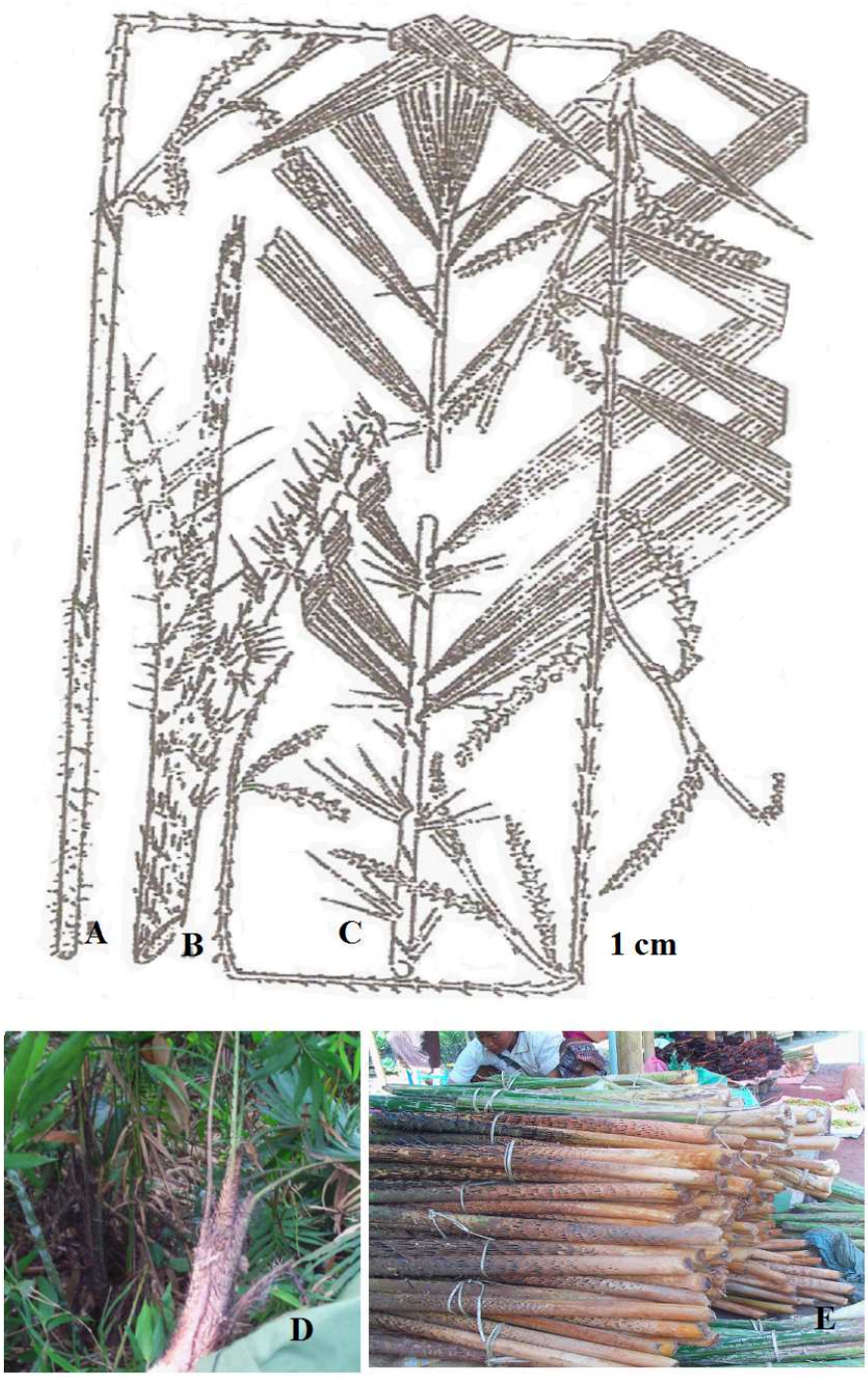


Figure 31 *Calamus rhabdocladus*: A. Inflorescences; B. stem; C. rachilla; D. stem; E. shoots.

Source: A-C adapted from Ketphanh *et al*. (1994b); D-E from Namor district, Oudomxay province in Northern Region.

Species 4

Specimens examined: LAO PDR: *Chaiyalad V-2* (from the wild), sterile, Vientiane capital, 2009 (KUFF, FRC); *Evans et al. 313*, fertile, Khammuan province, 1999 (FRC).

Scientific name: ***Calamus solitarius* T. Evans, Sengdala, Viengkham, Thamm. And J. Dransf.**, Kew Bull. 55(4): 932 (2000); S. Ketphanh *et al.*, A Manual of the Rattans of the Lao PDR: 28. *illustration on page 29*. 1994b; T. Evans *et al.*, A Field Guide Rattans of Lao PDR 40-41. *pl. 40*. 2001. (Figure 32).

Vernacular name: Wai thork.

Species description: Solitary stem rattan, climbing, up to 30 m long or more. Stems *ca*. 1.5-2 cm diameter; Canes *ca.* 1-1.5 cm in diameter with internodes 30- 40 cm long. Spines many, slender, up to 2 cm long. Leaves 0.8-1.3 m long; knee apparent; ocrea tiny; petiole margins usually have spines in paire pointing in different directions, about 5-10 cm long; leaflets about 15-30 cm long and 2.5-4 cm wide; vein with bristles, arranged strongly in groups of 4-6. Flagellum about 1-5 m long with reflexed spines. Inflorescences about 1-5 m long, pendulous branchlet, armed with claws and some long thin spines. Fruit globular, about 0.8-1.2 cm long and 0.6-1 cm wide, and covered with 12 vertical rows of straw-coloured scales with reddish margins.

Ecology and Distribution: This species grows in evergreen forest, dry evergreen forest in Central Region of Lao PDR, especially in Borikhamxay province.

Utilization: The canes can be used for baskets, trays. The semi-processed canes were exported at prices US$ 0.5-0.6 per cane (5 m long, 1-2 cm diameter).

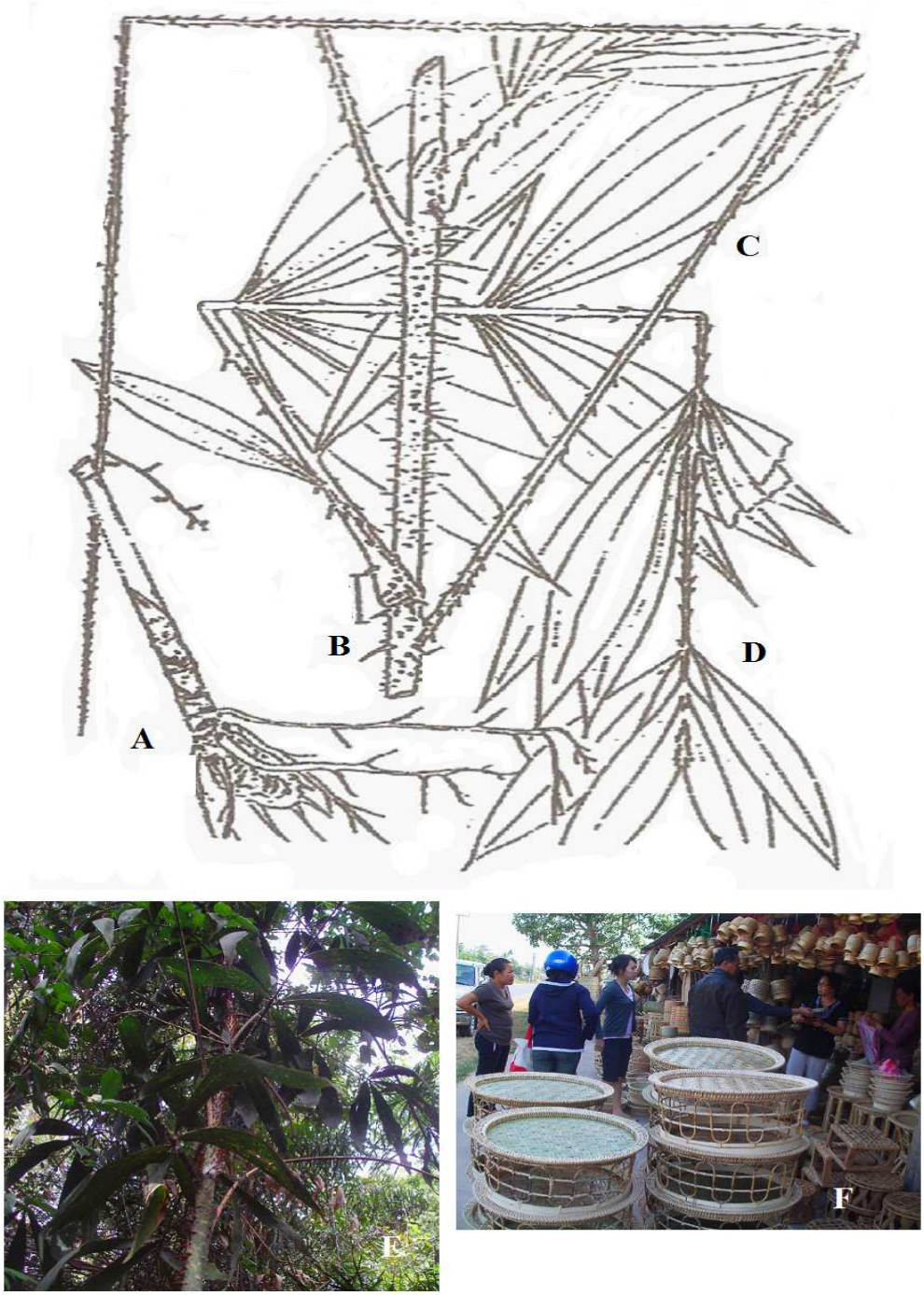


Figure 32 *Calamus solitarius*: A. stem with roots; B. stem; C. flagellum; D. rachilla; E. stem; F. trays made primarily from *C. solitarius*.

Source: A-D adapted from Ketphanh *et al*. (1994b); E-F from Nasaythong district, Vientiane capital in Central Region.

Species 5

Specimens examined: LAO PDR: *Chaiyalad V-12* (from the wild), sterile, Vientiane capital, 2009 (KUFF, FRC); *Evans et al. 36*, fertile, Vientiane, 1999 (FRC); THAILAND: *Maxwell 88-925*, fertile, Chiang Rai province, 1988 (BKF).

Scientific name: ***Calamus tenuis* Roxb.**, Hort. Bengal. 73; Fl. Ind. iii. 780; S. Ketphanh *et al.*, A Manual of the Rattans of the Lao PDR: 32. *illustration on page 34*. 1994b; T. Evans *et al.*, A Field Guide Rattan of Lao PDR 28-29. *Pl. 28*. 2001. (Figure 33).

Vernacular name: Wai nyeh.

Species description: Clustering stem rattan, climbing, up to 20 m long or more. Stems *ca.* 1.5-2.5 cm in diameter. Canes *ca.* 1-1.5 cm in diameter with internodes up to 20 cm long. Spines many, slender up to 2 cm long thin with black tip, bases form downswept crescents. Leaves about 1-1.4 m long; knee conspicuous; ocrea tiny; petiole about 8-10 cm long, margins usually have spines in pairs pointing in different directions; leaflets about 15-35 cm long and 1-1.6 cm wide, arranged in pairs regular; vein with bristles. Flagellum about 1.5-2.5 m long with reflexed spines. Inflorescences about 1.5-2.5 m long, pendulous branchlet, armed with claws and some long thin spines. Fruit globular, about 1.4-1.8 cm long and 0.8-1 cm wide, covered with 12 vertical rows of straw-coloured scales with pale yellow.

Ecology and Distribution: This species grows in dry evergreen forest, scrub with flooded areas in Central Region of Lao PDR.

Utilization: The shoot/tip is edible.

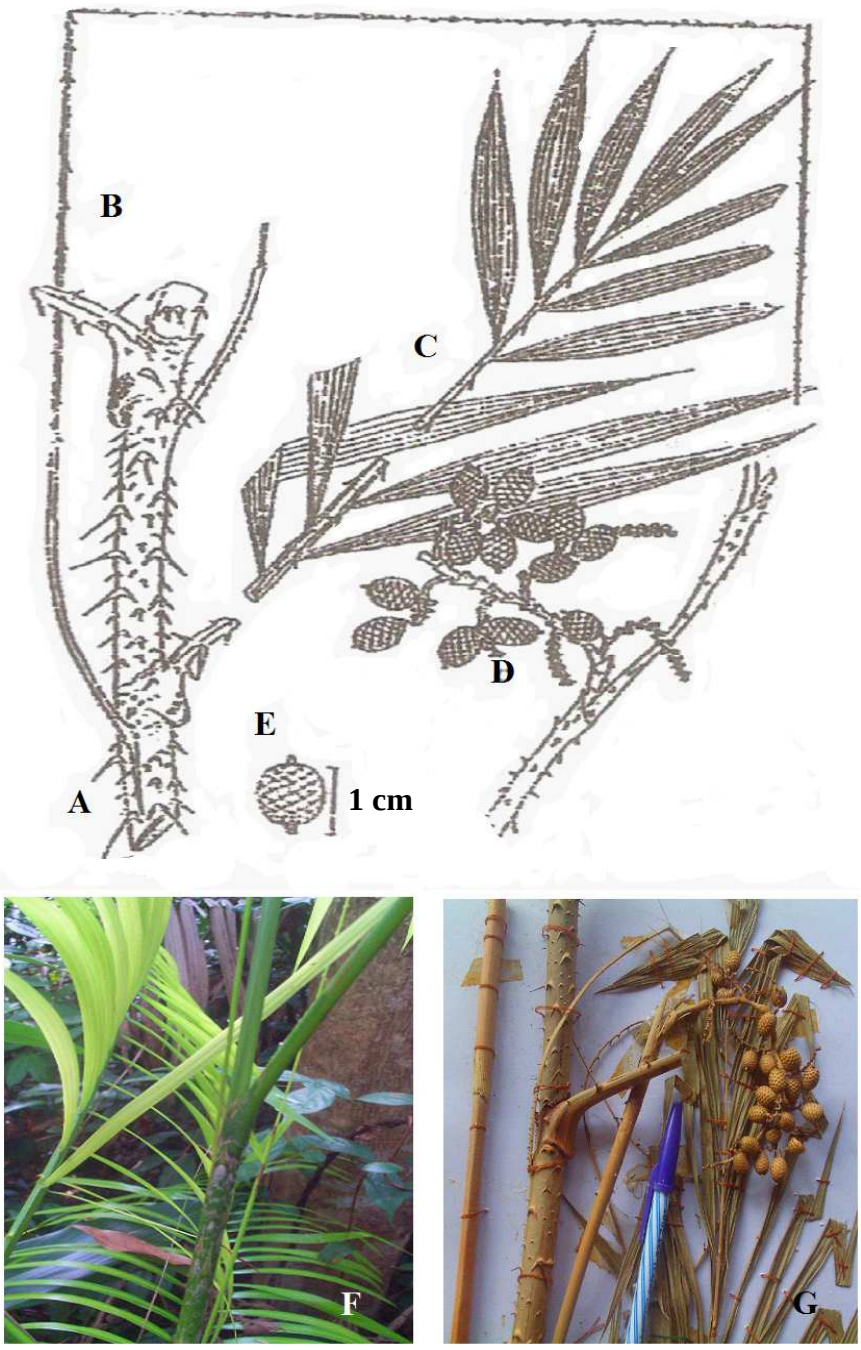


Figure 33 *Calamus tenuis*: A. stem; B. flagellum; C. rachilla; D. fruit branch; E. fruit; F. tip; G. specimen.

Source: A-E adapted from Ketphanh *et al*. (1994b); F from Phon Ngam village, Nasaythong district, Vientiane capital in Central Region; G from *Evans et al., 36.*

Species 6

Specimens examined: LAO PDR: *Chaiyalad P-8* (from material), sterile, Champasak province, 2009 (KUFF, FRC); *Evans et al. 214*, fertile, Champasak province, 1999 (FRC).

Scientific name: ***Calamus tetradactylus* Hance**, Journ. Bot. 13: 289. 1875; S. Ketphanh *et al.*, A Manual of the Rattans of the Lao PDR: 16. *illustration on page 17*. 1994b; T. Evans *et al.*, A Field Guide Rattans of Lao PDR. 44-45. *pl. 44*. 2001; S. Dransfield and N. Manokaran, Pl. Resources S. E. Asia 6: 72-73. *illustration on page 73*. 1994. (Figure 34).

Vernacular name: Wai savang.

Species description: Clustering stem rattan, climbing, up to 30 m long or more. Stems *ca.* 2-2.5 cm in diameter. Canes *ca.* 1-2 cm in diameter with internodes 15-20 cm long. Spines slender up to 2 cm long and thin. Leaves about 1-1.5 m long; knee apparent; ocrea tiny; petiole about 5-10 cm long, margins usually have spines in paire pointing in different directions; leaflets about 15-20 cm long, 2-3 cm wide, arranged in groups of 4-6; vein with bristles. Flagellum about 1-5 m long, with short reflexed spines. Inflorescences about 1-5 m long plus flagellum, pendulous branchlet, armed with claws and some long thin spines, male and female superficially similar. Fruit globular, about 0.8-1 cm long and 0.6-1 cm wide, and covered with 21 vertical rows of straw-coloured scales with reddish margins.

Ecology and Distribution: This species grows in evergreen forest in Southern Region of Lao PDR.

Utilization: The canes can be used for woven in sofa, baskets, trays, and other handicrafts. The canes at prices between US$ 0.2-0.3 (5 m long, 1-2 cm diameter).

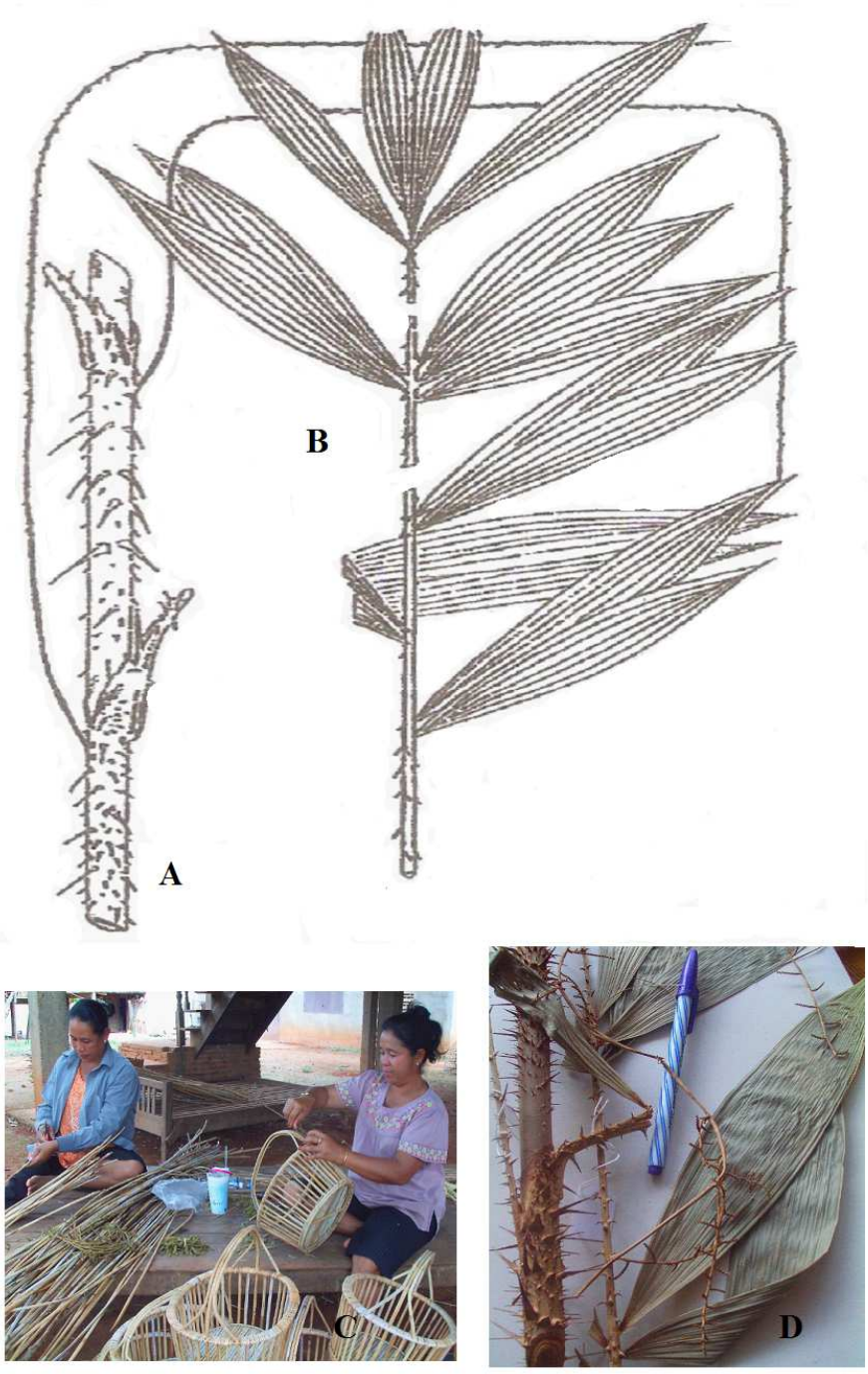


Figure 34 *Calamus tetradactylus*: A. stem with flagellum; B. rachilla; C. baskets; D. specimen.

Source: A-B adapted from Ketphanh *et al*. (1994b); C from Sanamxi village, Pakse district, Champasak province in Southern Region; D from the specimen of *Evans et al., 214*.

Species 7

Specimens examined: LAO PDR: *Chaiyalad P-10* (from the wild), sterile, Champasak province, 2009 (KUFF, FRC); *Evans et al. 409*, fertile, Champasak province, 1999 (FRC); THAILAND: *Dransfield* and *Bhoonab 5428*, sterile, Trang province, 1979 (BKF); *Larsen et al. 42736*, fertile, Surat Thani province, 1992 (BKF).

Scientific name: ***Plectocomiopsis geminiflorus*** **Becc.**, Fl. Brit. India [J. D. Hooker] vi. (479). 1893; S. Ketphanh *et al.*, A Manual of the Rattans of the Lao PDR: 46. *illustration on page 47*. 1994b; T. Evans *et al.*, A Field Guide Rattans of Lao PDR. 74-75. *pl. 74*. 2001. (Figure 35).

Vernacular name: Wai deng.

Species description: Clustered stem rattan, climbing, up to 30 m long or more. Stems *ca.* 3-6 cm in diameter. Canes *ca.* 2-3 cm in diameter with internodes 20- 25 cm long. Spines scattered, golden, slender up to 1 cm long. Leaves about 1-2 m long; knee absent; ocrea papery, 5-10 cm long, tattered quickly; petiole about 3-6 cm long, margins usually have spines in paire, plus cirrus of up to 1 m; leaflets about 30-45 cm long and 1.5-3 cm wide, arranged regularly; vein with bristles. Inflorescences about 0.5-1 m long, with thin spines, male usually 3 branched with many rachillas, and female usually 2 branched. Fruit globular, about 2.8-3 cm long and 2.6-3 cm wide.

Ecology and Distribution: This species grows in scrub and evergreen forests in Southern Region of Lao PDR.

Utilization: The cane can be sold at prices between US$ 0.1-0.2 (5 m long, 1-2 cm diameter), which is used for handicrafts, striped for made small rattan balls (for showing), trays, *etc*.

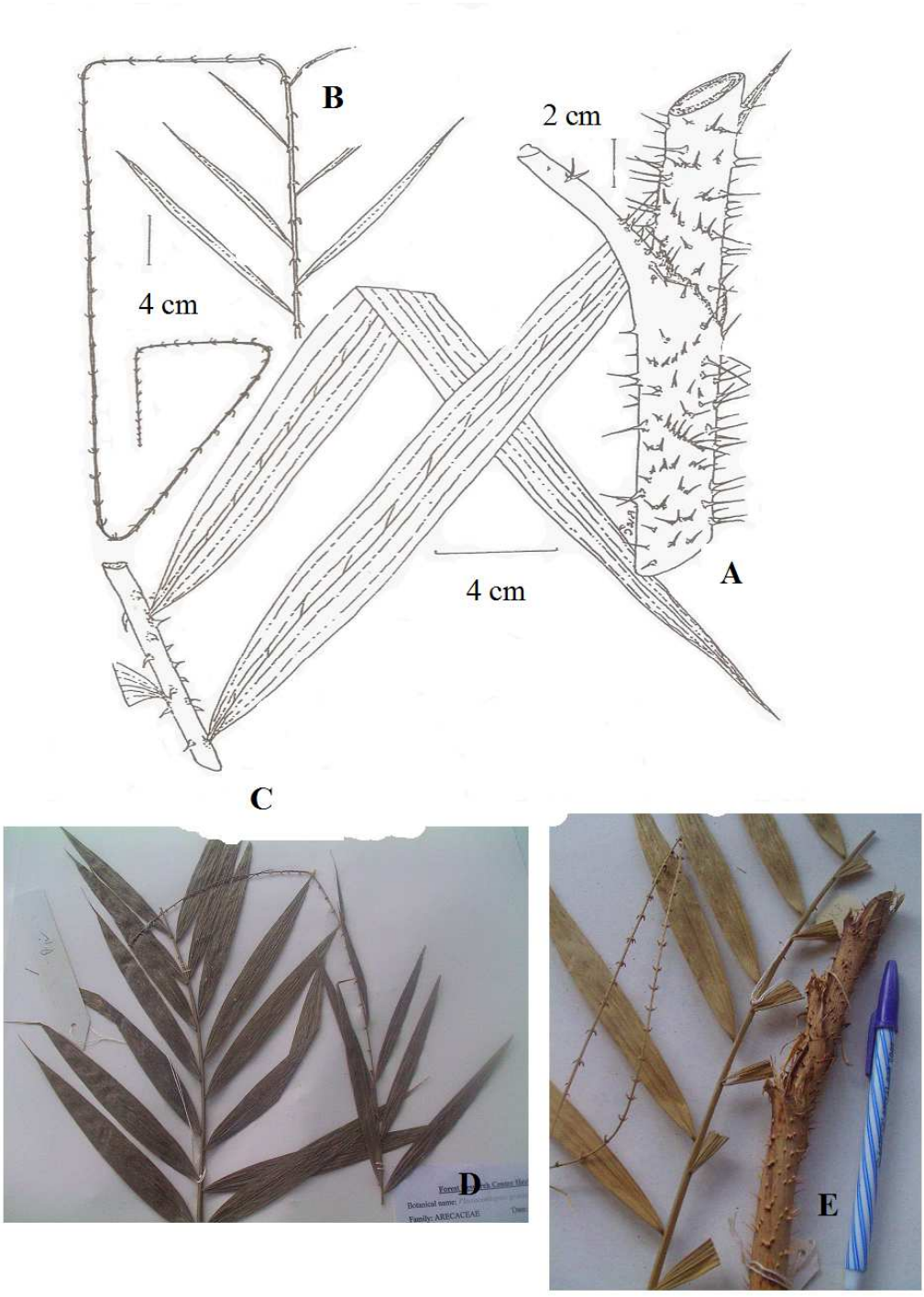


Figure 35 *Plectocomiopsis geminiflorus*: A. stem; B. cirrus; C. leaf; D. leaf with cirrus; E. stem and leaf.

Source: A-C adapted from Jintana (1988); D-E from Pakse district, Champasak province in Southern Region.

2. Anatomy of Bamboo Culm and Rattan Cane

2.1 Bamboo Culm Anatomy

The microscopic characteristics of the culms of ten bamboo species fall into three (out of four) types described by Wong (1995). Noh khome (*Indosasa sinica*) is the Type I, while the Type II was not found in this study, Mai phai banh (*Bambusa blumeana*), Mai poung (*B. polymorpha*), Mai bong (*B. tulda*), Mai sang (*Dendrocalamus membranaceus*), Mai lai (*Gigantochloa albociliata*), Mai sod (*Schizostachyum* sp.), Mai hia (*Schizostachyum virgatum*), and Mai huak (*Thyrsostachys siamensis*) are the Type III, and Mai hok (*Dendrocalamus brandisii*) is the Type IV.

Vascular bundles of the same bamboo genera are not necessary to be in the same type, such as *Dendrocalamus brandisii* is in Type IV, but *D. membranaceus* belongs to Type III. On the other hand, that from different genera can fall into the same type as found in three species of *Bambusa* (*B. blumeana*, *B. polymorpha*, *B. tulda*) and one species of *Dendrocalamus* (*D. membranaceus*), one species of *Gigantochloa* (*G. albociliata*), two species of *Schizostachyum* (*S. virgatum*, *Schizostachyum* sp.), and one species of *Thyrsostachys* (*T. siamensis*), they all fall into the same type, the Types III. Therefore, additional anatomical characteristics including the metavessels, protovessel, sclerenchyma sheaths, fiber strand, and parenchyma and also the bundles that characterize the bamboo culm (Figure 46) are necessary to be investigated in order to identify these bamboos at the species level.

This is more or less in agreement with an observation of Wong (1995), the sections of culm internodes of *Bambusa* sp. and *Dendrocalamus pendulus* examined showed a mixture of Type III and Type IV. These types occur mostly at the culm internodes which may need the extra support provided by three parts: basal, middle, and the top.

Species 1

Specimens examined: LAO PDR: *Chaiyalad P-4* (from material), fertile, Vientiane capital, 2009 (KUFF, FRC); *Chaiyalad P-5* (from wild), fertile, Vientiane capital, 2009 (KUFF, FRC).

Scientific name: ***Bambusa blumeana* Schultes**

Culm size *ca.* 10-15 cm in diameter (mid-culm portion); wall 1.5-2 cm thick. Vascular bundles sectioned at the middle of culm internodes are the Type III. Each vascular bundle consists of four discrete bundles (Figure 36). Two large round shape metavessels are about 240-265 μm wide. One phloem strand located between two metavessels at upper level. One small protovessel lacuna, about 32-40 μm wide, located between two metavessels at the under level. Sclerenchyma sheaths (fiber) are C-shape bundle of thick wall fiber cells attached in the outside part of the metavessels, phloem, and protovessel. Fiber strand at the inner part of culm wall appeared close to the protovessel at the lower level composes of two types of cells, small size thick wall fiber cells with small lumens surrounded outside and larger size but thin wall fiber cells with larger lumens inside the strand. The strand is elliptic to kidney shape embedded in the thick wall rounded to elliptic shape parenchymatous ground tissue.

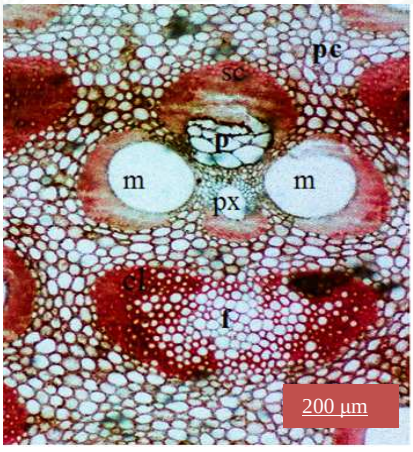


Figure 36 Vascular bundle from the inner part of the wall of *Bambusa blumeana* : (f=fiber strand; m=metavessel; p=phloem; pc=parenchyma; px=protovessel; sc=sclerenchyma sheath; cl=clump of thick wall fiber).

Species 2

Specimens examined: LAO PDR: *Chaiyalad P-2* (from material), fertile, Champasak province, 2009 (KUFF, FRC); *Chaiyalad P-3* (from wild), fertile, Champasak province, 2009 (KUFF, FRC).

Scientific name: ***Bambusa polymorpha* Munro**

Culm size *ca.* 10-12 cm in diameter (mid-culm portion); wall 1.2-1.5 cm thick. Vascular bundles sectioned at the middle of culm internodes are the Type III. Each vascular bundle consists of four discrete bundles (Figure 37). Two large round shape metavessels are about 212-228 μm wide. One phloem strand located between two metavessels on upper level. One small protovessel lacuna, about 18-26 μm wide, located between two metavessels at the under level. Sclerenchyma sheaths (fiber) are C-shape bundle of thick wall fiber cells attached at the outside part of the metavessels, phloem, and protovessel. Fiber strand at the inner part of culm wall appeared close to the protovessel at the lower level is a bean seed shape. It composes of two types of cells, a clump of small size thick wall fiber cells with small lumens at both end, and the remain is larger size but thin wall fiber with larger lumens the strand. The strand is elliptic to kidney shape embedded in the thin wall oval to elliptic shape parenchymatous ground tissue.

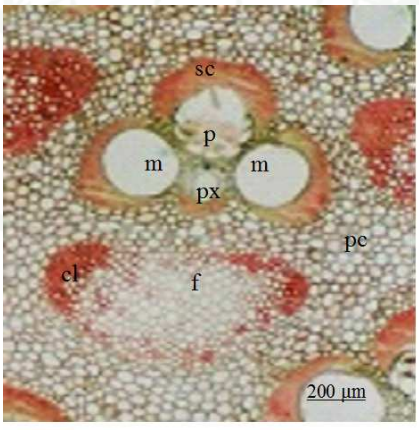


Figure 37 Vascular bundle from the inner part of the wall of *Bambusa polymorpha*: (f=fiber strand; m=metavessel; p=phloem; pc=parenchyma; px=protovessel; sc=sclerenchyma sheath; cl=clump of thick wall fiber).

Species 3

Specimens examined: LAO PDR: *Chaiyalad V-7* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC).

Scientific name: ***Bambusa tulda* Roxb.**

Culm size *ca.* 3-5 cm in diameter (mid-culm portion); wall 1.2-1.5 cm thick. Vascular bundles sectioned at the middle of culm internodes are the Type III. Its vascular bundles similar to *Bambusa blumeana.* Each vascular bundle consists of four discrete bundles (Figure 38). Two large round shape metavessels are about 174-185 μm wide. One phloem strand located between two metavessels at upper level. One small protovessel lacuna, about 30-38 μm wide, located between two metavessels at the under level. Sclerenchyma sheaths (fiber) are C-shape bundle of thick wall fiber cells attached at the outside part of the metavessels, phloem, and protovessel. Fiber strand at the inner part of culm wall appeared close to the protovessel at the lower level composes of two types of cells, small size very thick wall fiber cells with very small lumens surrounded outside and larger size with thin wall fiber cells and larger lumens inside the strand. The strand is elliptic to oval shape embedded in the thick wall rounded to elliptic shape parenchymatous ground tissue.

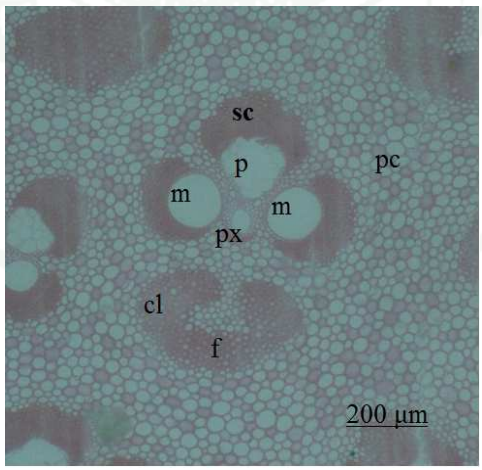


Figure 38 Vascular bundle from the inner part of the wall of *Bambusa tulda*: (f=fiber strand; m=metavessel; p=phloem; pc=parenchyma; px=protovessel; sc=sclerenchyma sheath; cl=clump of thick wall fiber).

Species 4

Specimens examined: LAO PDR: *Chaiyalad O-2* (from wild), fertile, Oudomxay province, 2009 (KUFF, FRC).

Scientific name: ***Dendrocalamus brandisii* (Munro) Kurz**

Culm size *ca*. 10-17 cm in diameter (mid-culm portion); wall 1.3-2.4 cm thick. Vascular bundles sectioned at the middle of culm internodes are the Type IV. Each vascular bundle consists of four discrete bundles (Figure 39). Two large round shape metavessels are about 120-135 μm wide. One phloem strand located between two metavessels at upper level. One small protovessel lacuna, about 26-34 μm wide, located between two metavessels at the under level. Sclerenchyma sheaths (fiber) are thin C-shape bundle of thick wall fiber cells attached at the outside part of the metavessels, phloem, and protovessel. The thicker of the sheath at metavessel, and phloem are similar. Two small vessels found between phloem and protovessel. At the inner part of culm wall two fiber strands are kidney shape embedded in the thin wall elliptic to rounded shape parenchymatous ground tissue, the fiber strand at the phloem side is smaller than at the protovessel side. Fiber cells of the strand are thicker wall at periphery and thin wall in the inner core.

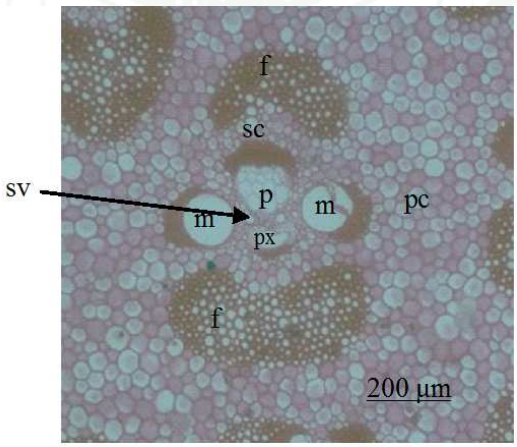


Figure 39 Vascular bundle from the inner part of the wall of *Dendrocalamus brandisii*: (f=fiber strand; m=metavessel; p=phloem; pc=parenchyma; px=protovessel; sc=sclerenchyma sheath; sv=small vessel).

Species 5

Specimens examined: LAO PDR: *Chaiyalad V-9* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC); *Chaiyalad V-6* (from material), fertile, Vientiane capital, 2009 (KUFF, FRC).

Scientific name: ***Dendrocalamus membranaceus*** **Munro**

Culm size *ca.* 9-12 cm in diameter (mid-culm portion); wall about 1.1-2 cm thick. Vascular bundles sectioned at the middle of culm internodes are the Type III. Each vascular bundle consists of four discrete bundles (Figure 40). Two large round shape metavessels are about 162-178 μm wide. One phloem strand located between two metavessels at upper level. One small protovessel lacuna, about 10-22 μm wide, located between two metavessels at the under level. Sclerenchyma sheaths (fiber) are bundle composes of two types of cells, small size thick wall fiber cells with small lumens are inside and larger size but thin wall fiber with larger lumens are outside, the sheath at the phloem is thicker than the others. Two small vessels found between phloem and protovessel. Fiber strand at the inner part of culm wall appeared close to the protovessel at the lower level composes of large size very thin wall fiber cells. The strand is heart shape embedded in the thin wall elliptic to oval shape parenchymatous ground tissue.

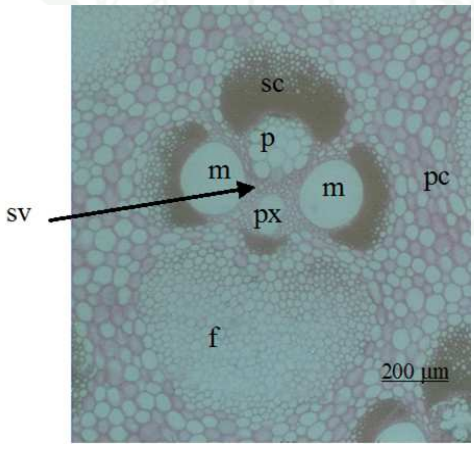


Figure 40 Vascular bundle from the inner part of the wall of *D. membranaceus*: (f=fiber strand; m=metavessel; p=phloem; pc= parenchyma; px=protovessel; sc=sclerenchyma sheath; sv=small vessel).

Species 6

Specimens examined: LAO PDR: *Chaiyalad V-8* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC).

Scientific name: ***Gigantochloa albociliata* (Munro) Kurz**

Culm size *ca.* 3-4 cm in diameter (mid-culm portion); wall 1-1.5 cm thick. Vascular bundles sectioned at the middle of culm internodes are the Type III. Each vascular bundle consists of four discrete bundles (Figure 41). Two large round shape metavessels are about 164-176 μm wide. One phloem strand located between two metavessels at upper level. One small protovessel lacuna, about 21-30 μm wide, located between two metavessels at the under level. Sclerenchyma sheaths (fiber) are C-shape bundle of thick wall fiber cells attached at the outside part of the metavessels, phloem, and protovessel. The sheath is similar thick or a little thicker at the phloem. Fiber strand at the inner part of culm wall appeared close to the protovessel at the lower level composes of large size thin wall cells. The strand is a heart to half round shape embedded in the thick wall oval to rounded shape parenchymatous ground tissue.

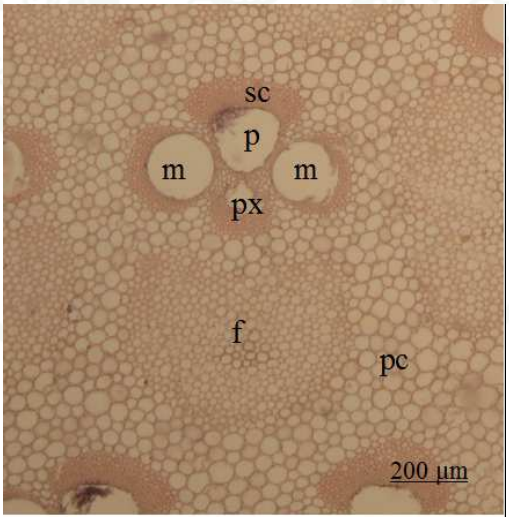


Figure 41 Vascular bundle from the inner part of the wall of *Gigantochloa albociliata*: (f=fiber strand; m=metavessel; p=phloem; pc=parenchyma; px=protovessel; sc=sclerenchyma sheath).

Species 7

Specimens examined: LAO PDR: *Chaiyalad O-1* (from the wild), fertile, Oudomxay province, 2009 (KUFF, FRC).

Scientific name: ***Indosasa sinica*** **C.D. Chou and C.S. Chao**

Culm size *ca.* 5-7 cm in diameter (mid-culm portion); wall 0.7-1.2 cm thick. Vascular bundles sectioned at the middle of culm internodes are the Type I. Each vascular bundle consists of four discrete bundles (Figure 42). Two large round shape metavessels are about 105-117 μm wide. One phloem strand located between two metavessels at upper level. One small protovessel lacuna, about 24-36 μm wide, located between two metavessels at the under level. Sclerenchyma sheaths (fiber) are thick C-shape bundle are similar thickness. They composes of two types of cells, small size very thick wall fiber cells with very small lumens as a layer inside and larger size but thin wall fiber cells with larger lumens at outside layer at the sheath. Ground tissue is large round thin wall irregular size parenchymatous calls.

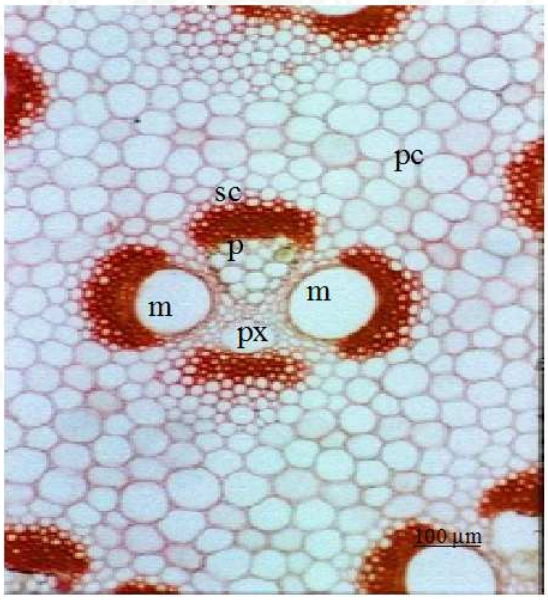


Figure 42 Vascular bundle from the inner part of the wall of *Indosasa sinica*: (m=metavessel; p=phloem; pc=parenchyma; px=protovessel; sc=sclerenchyma sheath).

Species 8

Specimens examined: LAO PDR: *Chaiyalad V-10* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC); *Chaiyalad V-5* (from product), fertile, Vientiane capital, 2009 (KUFF, FRC).

Scientific name: ***Schizostachyum* sp.**

Culm size *ca*. 2-6 cm in diameter (mid-culm portion); wall 0.5-1.2 cm thick. Vascular bundles sectioned at the middle of culm internodes are the Type III. Each vascular bundle consists of four discrete bundles (Figure 43). Two large round shape metavessels are about 121-132 μm wide. One phloem strand located between two metavessels at upper level. One small protovessel lacuna, about 32-46 μm wide, located between two metavessels at the under level. Sclerenchyma sheaths (fiber) compose of very thick wall fiber cells attached at the outside part of the metavessels, phloem, and protovessel. Only at the phloem sheath is thicker and composes of two layers where the outer layer is large size and thinner wall fiber. Fiber strand at the inner part of culm wall appeared close to the protovessel at the lower level composes of large size thin wall fiber cells. The strand is high heart shape embedded in the thin wall elliptic to oval shape parenchymatous ground tissue.

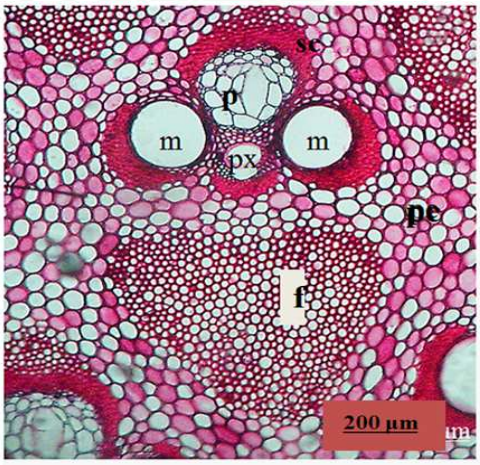


Figure 43 Vascular bundle from the inner part of the wall of *Schizostachyum* sp.: (f=fiber strand; m=metavessel; p=phloem; pc=parenchyma; px=protovessel; sc=sclerenchyma sheath).

Species 9

Specimens examined: LAO PDR: *Chaiyalad P-6* (from the wild), fertile, Champasak province, 2009 (KUFF, FRC); *Chaiyalad P-1* (from material), fertile, Champasak province, 2009 (KUFF, FRC).

Scientific name: ***Schizostachyum virgatum*** **(Munro) H.B Naithani and Bennet**

Culm size *ca*. 3-5 cm in diameter (mid-culm portion); very thin wall about 0.4-1 cm thick. Vascular bundles sectioned at the middle of culm internodes are the Type III. Each vascular bundle consists of four discrete bundles (Figure 44). Two large round shape metavessels are about 132-148 μm wide. One phloem strand located between two metavessels at upper level. One small protovessel lacuna, about 35-44 μm wide, located between two metavessels at the under level. Sclerenchyma sheaths (fiber) are thick and thicker at the metavessels. They composes of two types cells, a thin layer of small size very thick wall fiber cells with small lumens at inside and a thick layer of larger size but thin wall fiber cells with larger lumens outside the sheath. Fiber strand is narrow elliptical shape sometimes appeared close to the sheath of protovessel cause missing identification of the vascular bundles type. The strand composes of thin wall fiber similar to the outside layer of the sheath. Ground tissue is oval shape thin wall parenchymatous cells.

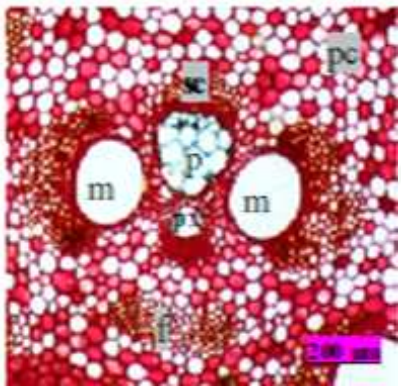


Figure 44 Vascular bundle from the inner part of the wall of *Schizostachyum virgatum*: (f=fiber strand; m=metavessel; p=phloem; pc=parenchyma; px=protovessel; sc=sclerenchyma sheath).

Species 10

Specimens examined: LAO PDR: *Chaiyalad V-11* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC).

Culm size *ca.* 4-7cm in diameter (mid-culm portion); wall about 2-2.5 cm thick. Vascular bundles sectioned at the middle of culm internodes are the Type III. Each vascular bundle consists of four discrete bundles (Figure 45). Two large round shape metavessels are about 182-198 μm wide. One phloem strand located between two metavessels at upper level. One small protovessel lacuna, about 25-34 μm wide, located between two metavessels at the under level. Two small vascular between phloem and protovessel. Sclerenchyma sheaths (fiber) very thick wall fiber cells attached at the outside part of the metavessels, phloem, and protovessel. The sheath at the phloem is much thicker than the others. Fiber strand at the inner part of culm wall appeared close to the protovessel at the lower level composes of large size very thick wall fiber cells. The strand is high heart shape embedded in the thin wall elliptic to oval shape parenchymatous ground tissue.

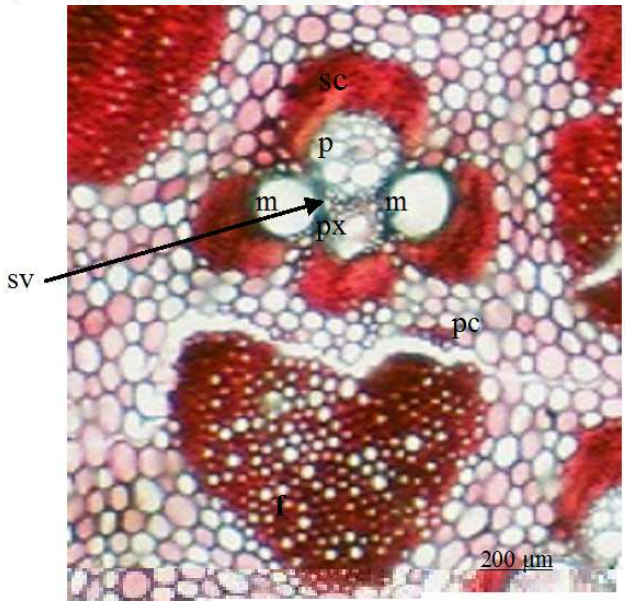


Figure 45 Vascular bundle from the inner part of the wall of *Thyrsostachys siamensis*: (f=fiber strand; m=metavessel; p=phloem; pc=parenchyma; px=protovessel; sc=sclerenchyma sheath; sv=small vascular).

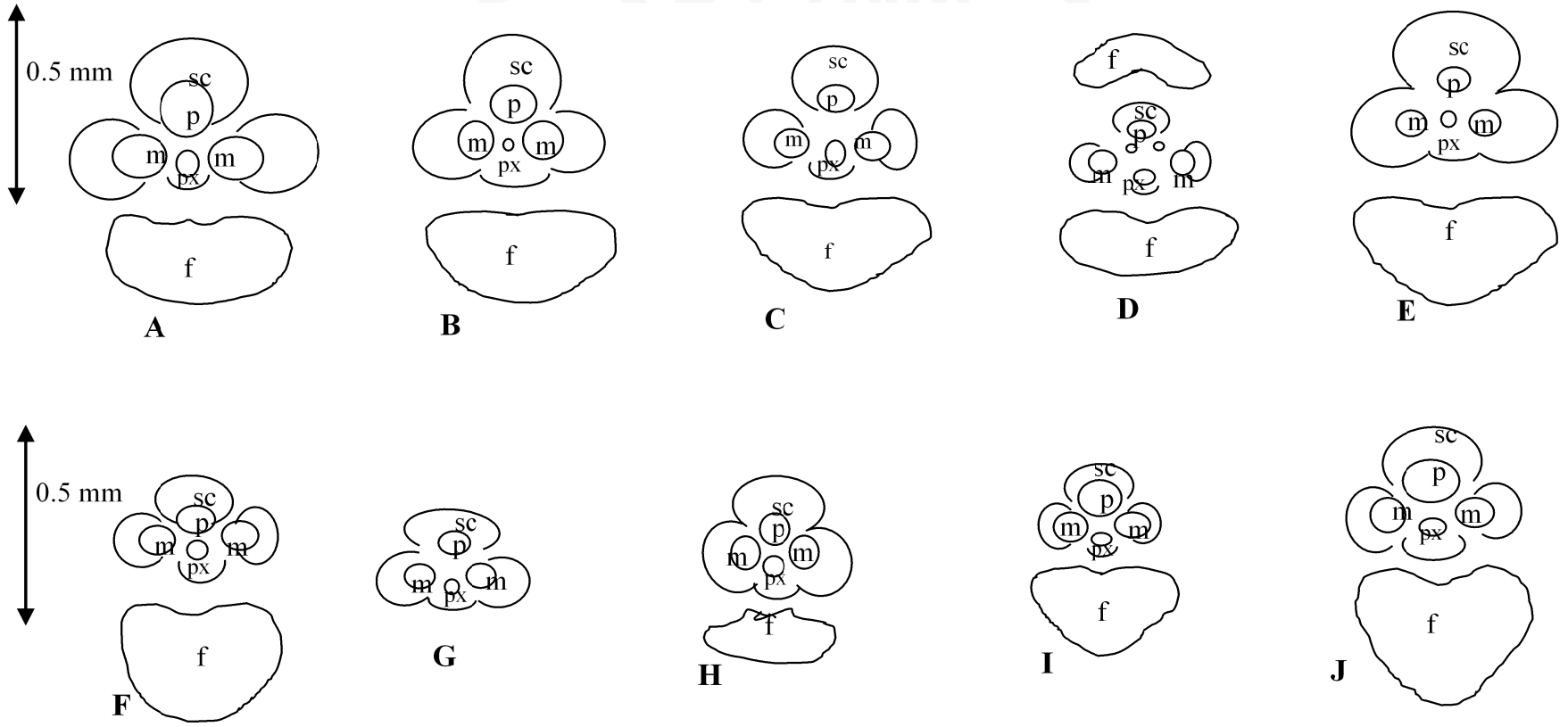


Figure 46 The bundles characterize of bamboo culm anatomy. A. *Bambusa blumeana*; B. *Bambusa polymorpha*; C. *Bambusa tulda*; D. *Dendrocalamus brandisii*; E. *Dendrocalamus membranaceus*; F. *Gigantochloa albociliata*; G. *Indosasa sinica*; H. *Schizostachyum virgatum*; I. *Schizostachyum* sp.; J. *Thyrsostachys siamensis.* (sc=sclerenchyma sheath; p=phloem; m=metavessel; px=protovessel; f=fiber strand).

2.2 Rattan Cane Anatomy

Vascular bundles of the canes sectioned at the middle of internode of rattans species in this study fall into two, of the total three types, as reported by Siripatanadilok (1986). Six species of the genus *Calamus* (*C. palustris, C. poilanei, C. rhabdocladus, C. tenuis, C. solitarius, and C. tetradactylus*) fall into the Type I and one species of genus *Plectocomiopsis* (*P. geminiflorus*) is in the Type III. The Type II was not found in this study. This type can be found only in the genus *Plectocomia* (Siripatanadilok, 1986) which is not present in this study. Similar to that of bamboos, details of the following parts: metavassel, protovassel, fiber cap, phloem strands, and ground tissue, are also important (Figure 54).

Siripatanadilok (1974) suggested that the Type I is not only found in the genus *Calamus* but alos in the genus *Daemonorops* and *Korthalsia*. Therefore, it must be careful when use only the vascular bundle type to identify a rattan. It is appears that the anatomical characters of epidermis, cortex, vascular bundles, fiber cap, and ground parenchyma are significantly important for physical and mechanical properties of the rattan canes.

Species 1

Specimens examined: LAO PDR: *Chaiyalad P-9* (from material), fertile, Vientiane capital, 2009 (KUFF, FRC).

Scientific name: ***Calamus palustris* Griff.**

Cane size *ca.* 2-3 cm in diameter. Vascular bundles sectioned at the middle of cane internodes are The type I. Epidermal cells are rectangular, about 20-22 μm wide, 45-48 μm high, lumens are at the base, ovate shape about 1/3-1/2 of epidermal high (Figure 47A). Cortex consists of 3-4 layers of rectangular to elliptical shape and thin. One row of small fiber bundle alternately with small vascular bundles are scattered within the cortex. The vascular bundles consist of one large metavessel flanked with two phloem strands (Figure 47B). At the center core of the cane the metavessel is oval shapes, diameter about 192-198 μm, two phloem strands are at the upper part of metavessel in reverse bowl shape. Sieve tube members mostly 3-5 cells closely arranged in single row. Strongly lignified fiber cap cover outside next to phloem strands. The fiber cap is thin wall fiber cells, the wall thickness of the fiber cap cells are almost uniform from the periphery vascular bundles through the center vascular bundles. The ground tissue consists of large generally thin wall (except as thin layer near cortex is thicker wall) irregular shape parenchyma cells, intercellular spaces are large and numerous. Stegmata is not distinct.

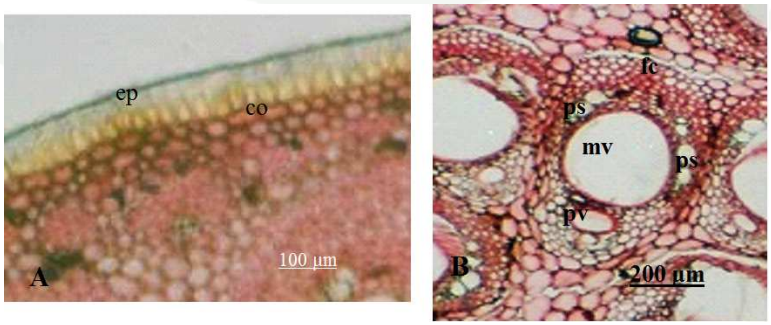


Figure 47 Microscopic pictures from the middle cane internodes of *Calamus palustris*: A. showing epidermal layer and cortex; B. vascular bundles at the central core of the cane. (ep=epidermis; co=cortex; fc=fiber cap; ps=phloem strand; mv=metavessel; pv=protovessel).

Species 2

Specimens examined: LAO PDR: *Chaiyalad V-1* (from material), fertile, Vientiane capital, 2009 (KUFF, FRC).

Scientific name: ***Calamus poilanei* Conrard**

Cane size *ca.* 3-5 cm in diameter. Vascular bundles sectioned at the middle of cane internodes are The type I. Epidermal cells are broad rectangular, about 13-16 µm wide, 28-34 µm high, lumens are at the base, small oval shape about 1/3-1/2 of epidermal high (Figure 48A). Cortex 3-5 layers are round to elliptical shape thin cells. One row of small fiber bundle alternately with small vascular bundles are scattered within the cortex. The vascular bundles consist of one large metavessel flanked with two phloem strands (Figure 48B). At the center core of the cane the metavessel is oval shapes, diameter about 394-410 µm, two phloem strands are at the upper part of metavessel in reverse bowl shape. Sieve tube members mostly 4-6 cells tightly arranged in single row often one sieve tube at the upper part isolated. Strongly lignified fiber cap cover outside next to phloem strands. The fiber cap is thick wall fiber cells, the wall thickness of the fiber cap cells are almost uniform from the periphery vascular bundles through the center vascular bundles. The ground tissue consists of large generally thick wall irregular shape parenchyma cells, intercellular spaces are large and numerous. Small vascular bundles and few fiber bundles are found scattering in ground tissue.

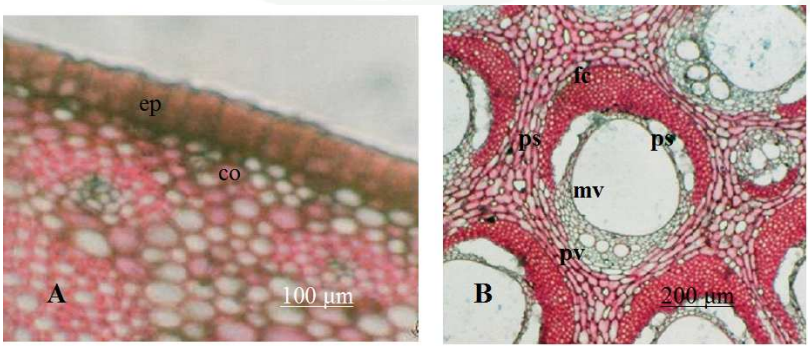


Figure 48 Microscopic pictures from the middle cane internodes of *Calamus poilanei*: A. showing epidermal layer and cortex; B. vascular bundles at the central core of the cane. (ep=epidermis; co=cortex; fc=fiber cap; ps=phloem strand; mv=metavessel; pv=protovessel).

Species 3

Specimens examined: LAO PDR: *Chaiyalad O-3* (from the wild), fertile, Oudomxay province, 1999 (KUFF, FRC).

Scientific name: ***Calamus rhabdocladus*** **Burret**

Cane size *ca.* 1-2.5 cm in diameter. Vascular bundles sectioned at the middle of cane internodes are The type I. Epidermal cells are narrow rectangular, about 9-11 μm wide, 37-41 μm high, lumens are similar to the shape of epidermal about 2/3-3/4 of epidermal high (Figure 49A). Cortex 18-20 layers are oval to elliptical shape thin wall cells. Two or three rows of small and large fiber bundles are scattered within the cortex. The vascular bundles consist of one large metavessel with two phloem strands (Figure 49B). At the center core of the cane the metavessel is round to oval shapes, diameter about 191-196 μm, two phloem strands are almost at the upper part of metavessel in reverse tray shape. Sieve tube members mostly 3-4 cells tightly arranged in single row. Strongly lignified fiber cap cover outside next to phloem strands. The fiber cap is thick wall fiber cells, the wall thickness of the fiber cap cells are almost uniform from the periphery vascular bundles through the center vascular bundles. The ground tissue consists of large generally thin wall (except as thin layer near cortex is thicker wall) irregular shape parenchyma cells, intercellular spaces are large and numerous. Small vascular bundles are in ground tissue. Stegmata (silica bodies) are frequent at the boundary of fiber bundles and of fiber cap from cortex to the center.

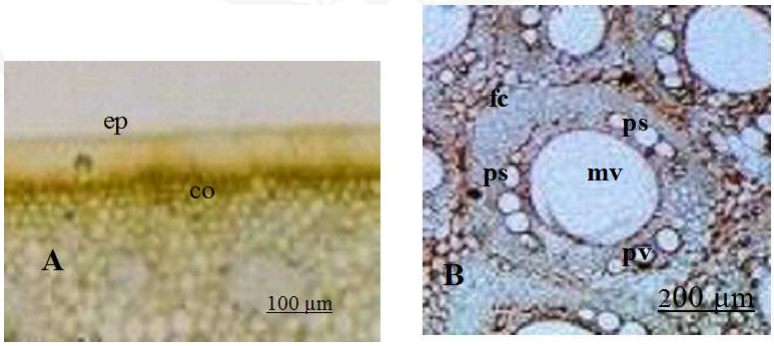


Figure 49 Microscopic pictures from the middle cane internodes of *Calamus rhabdocladus*: A. showing epidermal layer and cortex; B. vascular bundles at the central core of the cane. (ep=epidermis; co=cortex; fc=fiber cap; ps=phloem strand; mv=metavessel; pv=protovessel).

Species 4

Specimens examined: LAO PDR: *Chaiyalad V-2* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC); *Chaiyalad V-13* (from material), fertile, Vientiane capital, 2009 (KUFF, FRC).

Scientific name: ***Calamus solitarius*** **T. Evans, Sengdala, Viengkham, Thamm. And J. Dransf.**

Cane size *ca.* 1-2 cm in diameter. Vascular bundles sectioned at the middle of cane internodes are The type I. Cuticle is wavy or seriate, epidermal cells are broad rectangular, about 11-18 μm wide, 22-28 μm high, lumens are at the base, small oval shape about 1/3-1/2 of epidermal high (Figure 50A). Cortex 6-10 layers are ovate to elliptical shape thick wall cells. One row of small fiber bundle alternately with small vascular bundles are scattered within the cortex. The vascular bundles consist of one large metavessel flanked with two phloem strands (Figure 50B). At the center core of the cane the metavessel is round to oval shapes, diameter about 240-249 μm, two phloem strands are at the upper part of metavessel in reverse V-or bowl shape. Sieve tube members mostly 3-4 cells normally separately arranged in single row. Strongly lignified fiber cap cover outside next to phloem strands. The fiber cap is thick wall fiber cells, the wall thickness of the fiber cap cells are almost uniform from the periphery vascular bundles through the center vascular bundles. Small vascular bundles are seldom found large in ground tissue. Stegmata is not distinct.

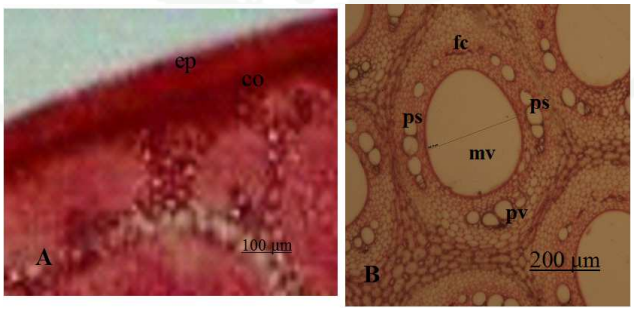


Figure 50 Microscopic pictures from the middle cane internodes of *Calamus solitarius*: A. showing epidermal layer and cortex; B. vascular bundles at the central core of the cane. (ep=epidermis; co=cortex; fc=fiber cap; ps=phloem strand; mv=metavessel; pv=protovessel).

Species 5

Specimens examined: LAO PDR: *Chaiyalad V-12* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC).

Scientific name: ***Calamus tenuis* Roxb.**

Cane size *ca.* 1-1.5 cm in diameter. Vascular bundles sectioned at the middle of cane internodes are The type I. Epidermal cells are broad rectangular, about 13-20 μm wide, 23-31 μm high, lumens are at the base, small oval shape about 1/2-3/4 of epidermal high (Figure 51A). Cortex 5-7 layers of round to elliptical shape sclerified thick wall cells. One row of small fiber bundle alternately with small vascular bundles are scattered within the cortex of which there fibers are very thick wall. The vascular bundles consist of one large metavessel flanked with two phloem strands (Figure 51B). At the center core of the cane the metavessel is round to oval shapes, diameter about 138-150 μm, two phloem strands are flanked of metavessel in reverse bowl shape. Sieve tube members mostly 3-4 cells tightly arranged in single row. Strongly lignified fiber cap cover outside next to phloem strands. The fiber cap is thick wall fiber cells, the wall thickness of the fiber cap cells are almost uniform from the periphery vascular bundles through the center vascular bundles. The ground tissue consists of large generally thin wall (except as thin layer near cortex is thicker wall) irregular shape parenchyma cells, intercellular spaces are large and numerous. Small vascular bundles and fiber bundles are frequent found in ground tissue.

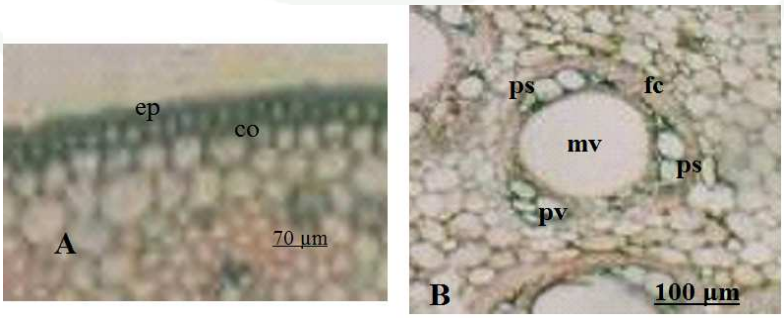


Figure 51 Microscopic pictures from the middle cane internodes of *Calamus tenuis*: A. showing epidermal layer and cortex; B. vascular bundles at the central core of the cane. (ep=epidermis; co=cortex; fc=fiber cap; ps=phloem strand; mv=metavessels; pv=protovessel).

Species 6

Specimens examined: LAO PDR: *Chaiyalad P-8* (from material), fertile, Champasak province, 2009 (KUFF, FRC).

Scientific name: ***Calamus tetradactylus* Hance**

Cane size *ca.* 1-2 cm in diameter. Vascular bundles sectioned at the middle of cane internodes are The type I. Epidermal cells are rectangular, about 12-19 μm wide, 30-37 μm high, lumens are at the base, small oval shape about 1/4-1/3 of epidermal high (Figure 52A). Cortex 4-5 layers are round to elliptical shape thick wall cells. Only one row of small fiber bundle alternately with small vascular bundles are scattered within the cortex. The vascular bundles consist of one large metavessel flanked with two phloem strands (Figure 52B). At the center core of the cane the metavessel is round to oval shapes, diameter about 238-247 μm, two phloem strands are flanked of metavessel almost in parallel rows. Sieve tube members mostly 4-7 cells but only 3-4 cells are large arranged in single row. Strongly lignified fiber cap cover outside next to phloem strands. The fiber cap is very thin wall fiber cells, the wall thickness of the fiber cap cells are almost uniform from the periphery vascular bundles through the center vascular bundles. The ground tissue consists of large generally thin wall irregular shape parenchyma cells, intercellular spaces are large and numerous. Small vascular bundles are found scattering in ground tissue. Stegmata is not distinct.

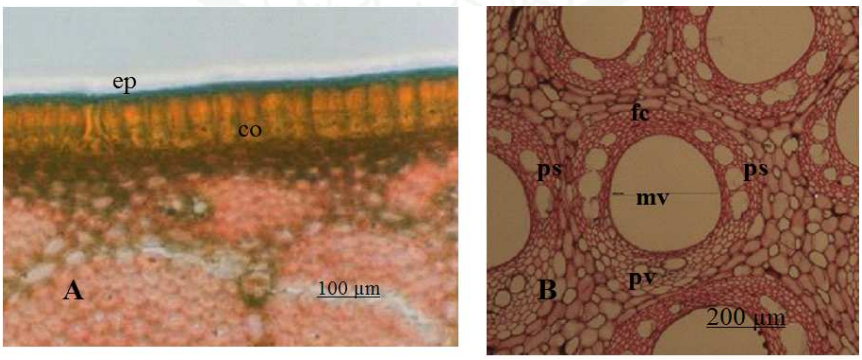


Figure 52 Microscopic pictures from the middle cane internodes of *Calamus tetradactylus*: A. showing epidermal layer and cortex; B. vascular bundles at the central core of the cane. (ep=epidermis; co=cortex; fc=fiber cap; ps=phloem strand; mv=metavessel; pv=protovessel).

Species 7

Specimens examined: LAO PDR: *Chaiyalad P-10* (from the wild), fertile, Champasak province, 2009 (KUFF, FRC); *Chaiyalad P-7* (from material), fertile, Champasak province, 2009 (KUFF, FRC).

Scientific name: ***Plectocomiopsis geminiflorus* Becc.**

Cane size *ca.* 1.5-3 cm in diameter. Vascular bundles sectioned at the middle of cane internodes are The type III. Since the specimens preparation was not perfect because damaging epidermis, therefore there is no epidermal description. Cortexes about 10 layers are elliptical shape thin wall cells. One row of small fiber bundle alternately with small vascular bundles are scattered within the cortex (Figure 53A). The vascular bundles consist of two large metavessels with one phloem strand on the upper (Figure 53B). At the center core of the cane two metavessels are round to oval shapes, diameter about 85-98 μm, one phloem strand are at the upper part of metavessels, sieve tube members are more than 20 cells tightly arranged in 3-4 layers. Strongly lignified fiber cap cover outside next to phloem strands. Thick wall fiber cap cells appeared only at the outer most vascular bundle. The fibers of the caps are mainly thin wall fibers. Small fiber bundles are found scattering in ground tissue. Stegmata is not distinct and frequent at the boundary of the cap through out the cane.

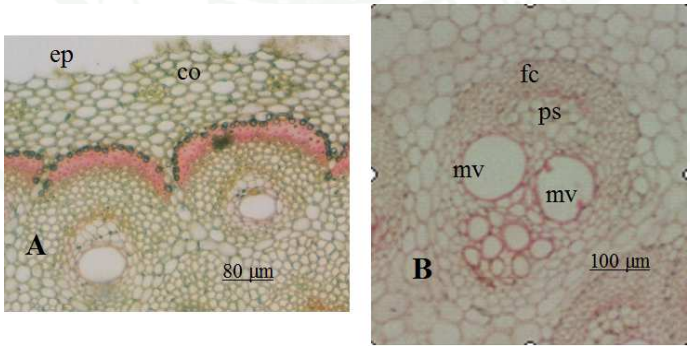


Figure 53 Microscoppic pictures from the middle cane internodes of *Plectocomiopsis geminiflorus*: A. showing epidermal layer, cortex and periphery vascular bundles; B. vascular bundles at the central core of the cane. (ep=epidermis; co=cortex; fc=fiber cap; ps=phloem strand; mv=metavessels; pv=protovessel).

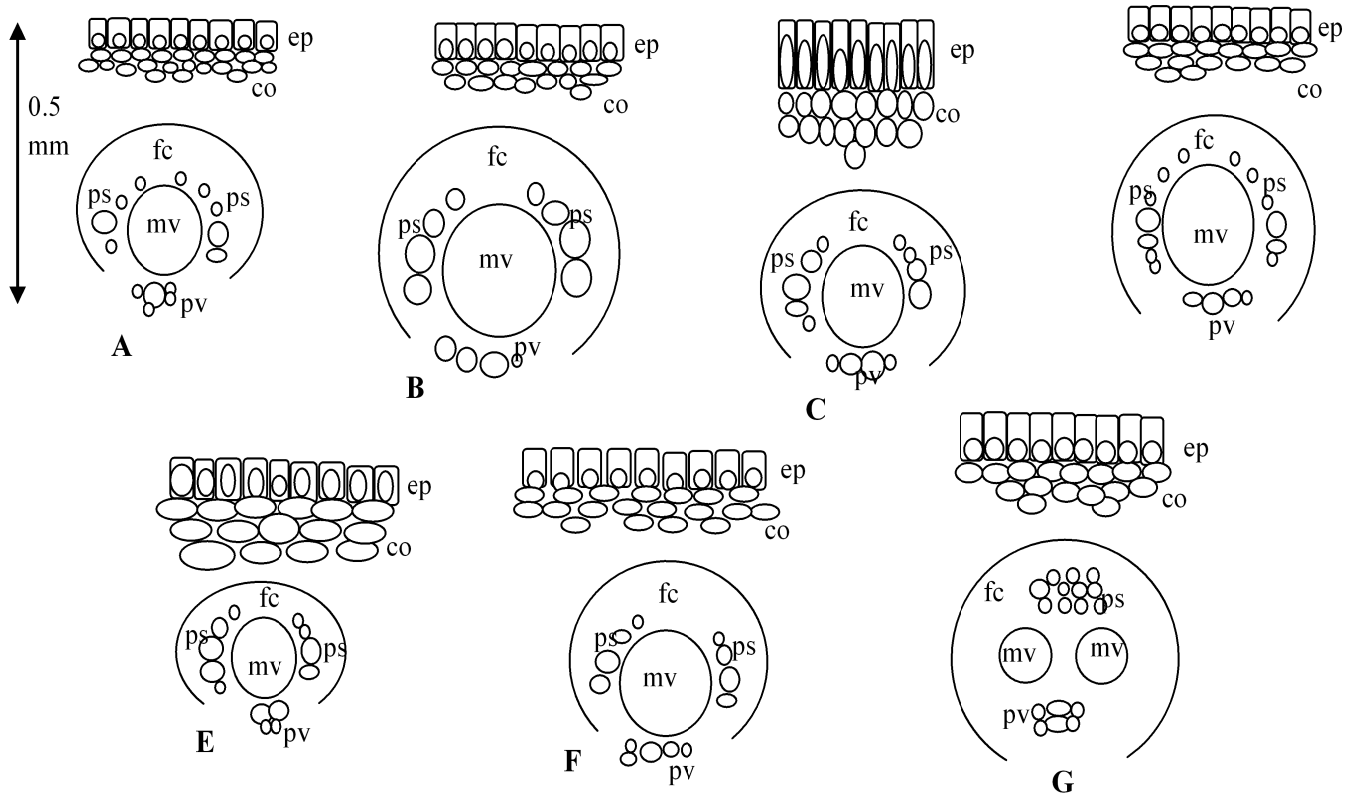


Figure 54 Comparative of exterior cells and vascular bundles structure size of cane anatomy. A. *Calamus palustris*; B. *Calamus poilanei*; C. *Calamus rhabdocladus*; D. *Calamus solitarius*;E. *Calamus tenuis*; F. *Calamus tetradactylus*; G. *Plectocomiopsis geminiflorus*. (ep=epidermis; co=cortex; fc=fiber cap; ps=phloem strands; mv=metavessel; pvprotovessel).

CONCLUSIONS

Morphological and anatomical descriptions, together with their utilization of bamboos and rattans commonly used in Lao PDR are presented. Ten species from six genera of the bamboos and seven species from two genera of the rattans have been taxonomically identified. The utilization of these species in each region is summarized in Table 2 for the bamboos and Table 3 for the rattans. The conclusions here are based primarily on the species that are commonly used in the particular region. Some species can be found naturally in all regions but it is not necessary that the species occuring in the wilds of that region will always be commonly or popularly used too.

In the Northern Region, two species of bamboos and one species of rattan were commonly used; they are Noh khome (*Indosasa sinica*), Mai hok (*Dendrocalamus brandisii*), and Wai faad (*Calamus rhabdocladus*), respectively. In the Northern Region and there is a preference for the consumption of 'Noh khome' the shoots of which are also sold in the Vientiane markets, and are also exported to China. The species 'Mai hok' is also consumed in the Central Region, but not in the Southern Region. Other culm products were found in the Northern Region include chopsticks, toothpicks, roasting sticks, bamboo supports, mats, baskets, sticky rice containers, *etc*. However, these products were generally imported from other regions, rather than being processed in the Northern Region. Rattan shoots/tips of 'Wai faad' are also collected for consumption and for sale to the traders from roadside stalls.

In the Central Region, six species of bamboos and three species of rattans were commonly used; these include Mai lai (*Gigantochloa albociliata*), Mai huak (*Thyrsostachys siamensis*), Mai bong (*Bambusa tulda*), Mai sod (*Schizostachyum* sp.), Mai sang (*Dendrocalamus membranaceus*), Mai phai banh (*Bambusa blumeana*), Wai thoun (*Calamus poilanei*) Wai thork (*Calamus solitarius*), and Wai nyeh (*Calamus tenuis*) respectively. The most popular species for consumption are Mai lai and Mai hauk. These species are collected in the region for sale, as well as being brought from other regions. In Vientiane, there are many traders selling the bamboo products made

from culm of Mai sang, Mai sod and Mai phai banh. These products are bamboo beds, mats, cages, baskets, bamboo supports, chopsticks, toothpicks, roasting sticks, sticky rice containers, *etc.* Many products produced in the Central Region are taken by traders to other regions for sale. Rattan products such as furniture, trays, baskets, *etc*. were found in the Central Region, but the raw materials or these products were brought from other provinces.

In the Southern Region, two species of bamboos and three species of rattans were commonly used; they are Mai poung (*Bambusa polymorpha*), Mai hia (*Schizostachyum virgatum*), Wai savang (*Calamus tetradactylus*), Wai hang nou (*Calamus palustris*) and Wai deng (*Plectocomiopsis geminiflorus*), respectively. Culm mats made from Mai hia are widely available, while Mai poung is widely used for the production of sticky rice containers and lams. The rattan products found in this region, which were made from 'Wai savang, Wai hang nou and Wai deng' included furniture, trays, baskets, rattan sates, rattan balls, cages, *etc*.

In the anatomy study, photographs of the culm and cane sections show the different types identified. The anatomical characteristics of all samples collected from the wild and raw material for bamboo Appendix 3 and rattan Appendix 4 show consistency in types of vascular bundles that can be used as standards for the identification of bamboos and rattans commonly used in Lao PDR. It can be also used for the matching of products with the raw materials.

The bamboo culms cross-section fall into three types, out of four, described by Wong (1995) as follows: Type I, is found in *Indosasa sinica*; the Type II was not found in this study; Type III is found in *Bambusa blumeana, B. polymorpha, B. tulda*, *Dendrocalamus membranaceus*, *Gigantochloa albociliata*, *Schizostachyum* sp., *Schizostachyum virgatum*, and *Thyrsostachys siamensis*; and Type IV is found in *Dendrocalamus brandisii*. The rattan canes cross-section fall into two types, of the total of three, described by Siripatanadilok (1986) as follows: Type I can be found in all six species of *Calamus*; while the Type II was not found in this study; and Type III is only found in one species of *Plectocomiopsis, P. geminiflorus*.

Table 2 Bamboos commonlyused in Lao PDR and their utilizations based on observations and interviews: O-1. *I. sinica*; O-2.*D. brandisii*; V-6. *S. virgatum*; V-7. *B. tulda*; V-8. *G. albociliata*; V-9. *D. membranaceus*; V-10. *Schizostachyum* sp.; V-11. *Thyrsostachys siamensis*; P-3. *B. polymorpha*; P-5. *B. blumeana*.

No.	Utilization	Northern Lao PDR							Central Lao PDR								Southern Lao PDR					
		Culm	Shoot	O-1	O-2	V-9	V-7	V-10	V-8	V-10	P-5	V-6	V-9	V-7	V-8	V-11	O-2	P-3	V-10	P-5	V-6	V-7	V-8
1	House wall	√				√		√		√	√		√					√	√	√			
2	House	√			√	√		√		√	√		√			√	√			√			
3	Column for farm house	√			√	√				√	√		√				√	√		√			
4	Beam for farm house	√		√		√	√			√	√	√	√	√		√					√		
5	KanhYaa (for roof house)	√		√		√					√		√					√		√			
6	Stake	√		√	√						√		√				√	√		√			
7	Fence	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
8	Strip	√			√	√	√		√		√		√	√	√		√	√		√		√	√
9	Basket	√				√				√	√		√	√				√		√			
10	Mat	√				√		√		√	√	√	√	√				√	√	√	√	√	
11	Chicken	√				√	√	√		√	√	√	√	√		√	√	√	√	√	√	√	
12	Bird cage	√			√	√	√				√	√	√	√		√	√	√		√	√	√	

Table 2 (Cont.)

No.	Utilization	Northern Lao PDR								Central Lao PDR								Southern Lao PDR					
		Culm	Shoot	O-1	O-2	V-9	V-7	V-10	V-8	V-10	P-5	V-6	V-9	V-7	V-8	V-11	O-2	P-3	V-10	P-5	V-6	V-7	V-8
13	Bamboo stair/staircase	√				√					√		√			√		√		√		√	
14	Cradle	√				√				√	√							√		√			
15	Trap (for rats)	√		√	√	√	√		√		√	√	√	√	√	√	√	√		√	√	√	√
16	Lee/xail	√									√		√					√	√	√			
17	Grass	√		√								√		√							√		
18	Handle (fishhook, hoe, and *etc* .)	√		√		√	√			√	√	√	√	√		√		√			√		√
19	Chopstick	√				√					√		√					√		√			
20	Pha Khao	√				√	√				√		√			√	√	√		√		√	
21	Sticky rice	√		√	√	√	√		√		√		√	√	√		√	√		√		√	√
22	Sticky rice	√		√		√	√		√	√		√		√	√	√		√		√		√	
23	Farmer's	√			√	√	√					√		√	√	√		√		√		√	
24	Smoking	√							√							√							
25	Winnowing	√		√	√	√	√		√			√	√	√	√	√	√	√		√		√	√
26	Bamboo stick	√				√				√				√			√					√	

Table 2 (Cont.)

No.	Utilization	Northern Lao PDR								Central Lao PDR								Southern Lao PDR					
		Culm	Shoot	O-1	O-2	V-9	V-7	V-10	V-8	V-10	P-5	V-6	V-9	V-7	V-8	V-11	O-2	P-3	V-10	P-5	V-6	V-7	V-8
27	Stick for grill	√		√		√	√			√		√	√	√	√	√	√	√		√		√	
28	Stick for	√				√				√				√						√		√	
29	Bed	√			√	√						√	√	√						√		√	
30	Toothpicks	√				√						√		√						√		√	
31	Raft	√				√					√		√	√			√			√		√	
32	Boiled		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
33	Fermented bamboo		√		√	√	√		√		√	√	√	√	√	√	√	√	√	√		√	√
34	Sun dry		√		√	√	√	√	√	√	√	√	√	√	√	√	√	√		√		√	√
35	Boiled shoots in a plastic bag		√			√		√		√			√	√	√	√	√		√			√	√
36	Khean (a kind of instrument)	√						√			√		√						√		√		
37	Bell/cowbe	√			√	√	√					√		√	√					√		√	
38	Furniture	√		√	√	√	√			√		√	√	√			√	√		√		√	
39	Furniture	√			√	√						√		√						√		√	
40	Support	√			√	√	√					√		√				√		√		√	

Table 3 Rattans commonly used in Lao PDR and their utilizations based on observations and interviews: O-3. *Calamus rhabdocladus*; V-1. *C. poilanei*; V-2. *C. solitarius*; V-12. *C. tenuis*; P-8. *C. tetradactylus*; P-9. *C. palustris*; P-10. *P. geminiflorus.*

No.	Utilization	Cane	Tip	Northern Lao PDR			Central Lao PDR					Southern Lao PDR				
				O-3	V-12	V-1	V-1	V-12	V-2	P-8	O-3	P-9	P-8	P-10	V-1	V-12
1	Furniture frame	√			√	√	√	√				√			√	√
2	Furniture consists	√			√	√	√		√	√		√		√	√	√
3	Match (together)	√			√				√	√		√		√		
4	Strip	√											√			
5	Rattan sat	√				√	√		√			√			√	
6	Knife cover	√				√	√		√	√			√	√		
7	Exported as semi-processed products	√			√	√		√	√	√		√	√	√	√	
8	Exported for dried tips		√		√			√								√
9	Fruit (sell)				√	√	√	√	√	√		√	√	√	√	√
10	Animals trap	√			√											
11	Rattan ball	√		√	√			√	√	√	√		√	√		√
12	Edible (tip)		√	√	√	√	√	√	√	√	√	√	√	√	√	√

Remark: O=Oudomxay province, P=Pakse (Champasuk province), V=Vientian capital.

RECOMMENDATIONS

The descriptions of the species of the bamboos and the rattans described in this thesis have been based on information gathered from a range of sources, relating the characteristics of both bamboos and rattans. The information collated includes the correct scientific names of specimens, as well as the local names. The identification of species has been based on the use of both morphological and anatomical characteristics. The combination of these two techniques are very useful for the identification of the species of bamboos and rattans, particulary in the case of the lack of reproductive parts which are the most important parts to key out the species using morphological technique alone.

Ideally, all species of the bamboos and rattans should be collected from the natural 'wild'conditions to compare with what that used as materials in any products made from them using both morphological and anatomical approaches. Anatomical sections of culms and canes should be kept for use as standard for future reference. It is acknowledged that some locally well known species were not covered by this study, and it is recommended that any future study to include samples of those not covered by the current study.

Bamboos and rattans have an impotant role in the rural economy of rural Lao PDR, not only in providing products for local use but also for income generation. There are opportunities for increased utilization of locally available bamboos and rattans, particularly for use in the production of handicrafts. It is recommended that an inventory of natural bamboo and rattan resources be established and maintained, for the management of these important resources on a sustainable basis.

The government of the Lao PDR, and especially the Department of Forestry within the Ministry of Agriculture and Forestry, should also focus on providing technical and marketing assistance through survey and reporting on the availability, status, and use of bamboo and rattan resources. Forest offices should provide training programs for villagers on techniques of production, development and improvement, relating to bamboos and rattans, as well as the sustainable management of these resources.

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APPENDIX

Appendix 1 List of bamboos from nine provinces, Lao PDR.

Local name	Scientific name
Mai loi	*Arundinaria petelotii* Camus
Mai phai pa	*Bambusa arundiaria* var. *spinosa* Rez
Mai pa or	*Bambusa bacooa* Roxb.
Mai phai ban	*Bambusa blumeana* Schult. & Schuit.f.
Mai pong khiou	*Bambusa burmanica* Gamble
Mai ka sa	*Bambusa chunii* Chai & Fung
Mai bong varn	*Bambusa nutans* Wall. ex Munro
Mai kern	*Bambusa polymorpha* Munro
Mai sang kham	*Bambusa striata* Lodd. ex Lundl. (*B. vulgaris*)
Mai hang	*Bambusa* sp.
Mai kok	*Bambusa thorelii* Roxb.
Mai bong khome	*Bambusa tuda* Roxb.
Mai poo	*Bambusa tuldoides* Munro
Mai khao lam	*Cephalostachyum pergracile* Munro
Mai dai	*Cephalostachyum* sp.
Mai san	*Chimonobambusa purpurea* Hsueh & Yi
Mai hok varn/ phai tong	*Dendrocalamus asper* Backer
Mai hor hak	*Dendrocalamus barbatus* Hsuch & D. Zli
Mai sang phai/ hang sang	*Dendrocalamus brandisii* (Munro) Kurz
Mai dam khouane	*Dendrocalamus giganteus* Wall. ex Munro
Mai hok kiou	*Dendrocalamus hamiltonii* Nees & Arn. ex Munro
Mai ving	*Dendrocalamus latifolus* Munro
Mai phang	*Dendrocalamus longifimbriatus* Gamble
Mai sang	*Dendrocalamus membranaceus* Nees
Mai lo	*Dendrocalamus pendulus* Ridley
Mai bong khai	*Dendrocalamus sciens* Munro
Mai bor/pouak	*Dendrocalamus sinicus f. aequotus* K.L.Wang
Mai hia	*Dinochloa scandense* Buse

Appendix 1 (Continued)

Local name	Scientific name
Mai viet	Unidentified
Mai lai khome	*Gigantochloa albociliata* Munro & Kurz
Mai sa not	*Gigantochloa apus* Schytle & Kurz
Mai ngan varn	*Gigantochloa atter* (Hask) Kurz
Mai luoang mouk	*Gigantochloa haskarliana* Kurz, Backer & Hayne
?	*Gigantochloa latifolia* Ridley
Mai noh khome	*Indosasa sinica* C.D. Chou & C.S. Chao
Mai kong pi	*Indosasa* sp.
Mai ka sean	*Neohouzeana mekongensis* Buse
Mai sod	*Oxytenanthera albociliata* or *Gigantochloa albociliata* Munro & Kurz
Mai ka sa	*Phyllostachys* sp.
Mai noh varn	*Phyllostachys* sp.
Mai lan varn	*Semiarundinaria* sp.
Mai lan khome	*Semiarundinaria microphylla* Munro & Chao
Mai cha deng	*Semiarundinaria* sp. (*Arundinaria maling*)
Mai san ta lom	*Semiarundinaria griftithiana* Munro, Chao & Renv
Mai cha fhat	*Semiarundinaria* sp.
Mai hia	*Schizostachyum blumei* (*C. virgatum* Munro & Kurz)
Mai hok nam	*Schizostachyum branchycladum* Kurz
Mai phoung chine	*Schizostachyum grande* Kurz
Mai Chod	*Vietnamosasa ciliata* (A. Camus) Nguyen
Phai Phek	*Vietnamosasa pusilla* (Chevalier & A. Camus) Nguyen
Mai louang khao khouay	Unidentified

Source: Ketphanh *et al*. (1994a).

Appendix 2 List of rattans in Lao PDR.

Local name	Scientific name
Wai nang/tia	*Calamus acanthophyllus* Becc.
Wai hom/ blong eur	*Calamus acanthospathus* Griff.
Wai hang nou/khee kai	*Calamus bimaniferus* T. Evans
?	*Calamus bousigonii* Becc.
?	*Calamus ceratophorus* Conrard
?	*Calamus dioicus* Lour.
?	*Calamus dongnaiensis* Becc.
Wai nam xai	*Calamus erectus* Roxb.
Wai nam louang/lao	*Calamus flagellum* Griff.
?	*Calamus godefroyi* Becc.
Wai home/soum	*Calamus gracilis* Roxb.
Wai deng	*Calamus guruba* Ham.
Wai sueay	*Calamus harmandii* Pierre ex Becc.
Wai hang nou/nam lee	*Calamus henryanus* Becc.
Wai deng/kuae lao	*Calamus hypoleucus* (Kurz) Kurz
Wai luem	*Calamus kingianus* Becc.
Wai luem/ka tok	*Calamus laoensis* T. Evans
?	*Calamus longisetus* Griff.
Wai nuey/nok khor	*Calamus nambariensis* Becc.
?	*Calamus obovoideus* S.J. Pei & S.Y. Chen
Wai ka ting	*Calamus oligostachys* T. Evans
?	*Calamus oxycarpus* Becc.
Wai hang nou/nam louang	*Calamus palustris* Griff.
Wai louang	*Calamus platyacanthus* Warb. ex Becc.
Wai thoun	*Calamus poilanei* Conrard
Boun varn	*Calamus rhabdocladus* Burret
Wai kabong/boun dam	*Calamus rudentum* Roxb.
?	*Calamus salicifolius* Becc.
Wai khome/nuae	*Calamus siamensis* Becc.

Appendix 2 (continued)

Local name	Scientific name
Wai thok/yong	*Calamus solitarius* T. Evans *et al.*
?	*Calamus* sp. A
?	*Calamus* sp. B
Wai nyeh	*Calamus tenuis* Roxb
Wai sa vang/hang nou	*Calamus tetradactylus* Hance
?	*Calamus thysanolepis* Hance.
Wai ton/khome/na	*Calamus viminalis* Willd.
Wai lai	*Calamus wailing* Pei and Chen
?	*Calamus walkerii* Hance.
Boun fhat	*Daemonorops jenkinsiana* (Griff.) Mart
?	*Daemonorops* sp. A
?	*Daemonorops* sp. B
?	*Korthalsia bejaudii* Gagnepain ex Humbert
Wai ta luek	*Korthalsia laciniosa* (Griffith) Martius
?	*Korthalsia* sp.
Wai nam xai/ lao	*Myrialepis paradoxa* (Griff.) Mart
?	*Plectocomia elongate* Mart. ex Blume
?	*Plectocomia himalayana* Griffith
?	*Plectocomia kerrana* Becc.
?	*Plectocomia pierreama* Burret
Wai deng	*Plectocomiopsis geminiflora* (Griff.) Becc.

Source: Evans *et al.* (2001)**.**

Appendix 3 Voucher bamboo specimens for anatomical study. All specimens from the wild were taken from mid-culm portion.

Species	Specimen examined
Bambusa blumeana	*Chaiyalad P-4* (from material), fertile, Vientiane capital, 2009 (KUFF, FRC); *Chaiyalad P-5* (from wild), fertile, Vientiane capital, 2009 (KUFF, FRC).
Bambusa polymorpha	*Chaiyalad P-2* (from material), fertile, Champasak province, 2009 (KUFF, FRC); *Chaiyalad P-3* (from wild), fertile, Champasak province, 2009 (KUFF, FRC).
Bambusa tulda	*Chaiyalad V-7* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC).
D. brandisii	*Chaiyalad O-2* (from wild), fertile, Oudomxay province, 2009 (KUFF, FRC).
D. membranaceus	*Chaiyalad V-9* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC); *Chaiyalad V-6* (from material), fertile, Vientiane capital, 2009 (KUFF, FRC).
Gigantochloa albociliata	*Chaiyalad V-8* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC).
Indosasa sinica	*Chaiyalad O-1* (from the wild), fertile, Oudomxay province, 2009 (KUFF, FRC).
Schizostachyum sp.	*Chaiyalad V-10* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC); *Chaiyalad V-5* (from product), fertile, Vientiane capital, 2009 (KUFF, FRC).
Schizostachyum virgatum	*Chaiyalad P-6* (from the wild), fertile, Champasak province, 2009 (KUFF, FRC); *Chaiyalad P-1* (from material), fertile, Champasak province, 2009 (KUFF, FRC).
Thyrsostachys siamensis	*Chaiyalad V-11* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC).

Appendix 4 Voucher rattan specimens for anatomical study. All specimens from the wild were taken from mid-culm portion.

Species	Specimens examined
Calamus palustris	*Chaiyalad P-9* (from material), fertile, Vientiane capital, 2009 (KUFF, FRC).
Calamus poilanei	*Chaiyalad V-1* (from material), fertile, Vientiane capital, 2009 (KUFF, FRC).
Calamus rhabdocladus	*Chaiyalad O-3* (from the wild), fertile, Oudomxay province, 1999 (KUFF, FRC).
Calamus solitarius	*Chaiyalad V-2* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC); *Chaiyalad V-13* (from material), fertile, Vientiane capital, 2009 (KUFF, FRC).
Calamus tenuis	*Chaiyalad V-12* (from the wild), fertile, Vientiane capital, 2009 (KUFF, FRC).
Calamus tetradactylus	*Chaiyalad P-8* (from material), fertile, Champasak province, 2009 (KUFF, FRC).
Plectocomiopsis geminiflorus	*Chaiyalad P-10* (from the wild), sterile, Champasak province, 2009 (KUFF, FRC); *Chaiyalad P-7* (from material), fertile, Champasak province, 2009 (KUFF, FRC).

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