การทบทวนอนุกรมวิธานของพืชวงศ์หญ้าเผ่าย่อยข้าวฟ่างในประเทศไทย

นางสาวอรทัย เนียมสุวรรณ

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TAXONOMIC REVISION OF SUBTRIBE SORGHINAE (POACEAE) IN THAILAND

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อรทัย เนียมสุวรรณ : การทบทวนอนุกรมวิธานของพืชวงศ์หญ้าเผ่าย่อยข้าวฟ่างในประเทศไทย. (TAXONOMIC REVISION OF SUBTRIBE SORGHINAE (POACEAE) IN THAILAND) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร. ต่อศักดิ์ สีลานันท์, อ. ที่ปรึกษาวิทยานิพนธ์ร่วม: Jan Frederik Veldkamp, Ph.D., 176 หน้า.

ถึงแม้ว่าพืชวงศ์หญ้าเผ่าย่อยข้าวฟ่างในประเทศไทยจะได้มีการศึกษาไปบ้างแล้ว แต่ยังไม่ครบถ้วนสมบูรณ์ ดังนั้นการศึกษาทบทวนทางอนุกรมวิธานครั้งนี้จึงมีวัตถุประสงค์ 3 ประการ คือ (1) ศึกษาสายสัมพันธ์ทางวิวัฒนาการโดยอาศัยหลักฐานด้านโมเลกุลของพืช 2 สกุลที่มีความสัมพันธ์กันอย่างใกล้ชิด ได้แก่ *Chrysopogon* และ *Vetiveria* โดยใช้ข้อมูลจากยีน *ITS* ในนิวเคลียส และ *trnL-F* ในคลอโรพลาสต์ ผลการศึกษาชี้แนะว่าควรรวม 2 สกุลเป็นสกุลเดียวภายใต้ชื่อสกุล *Chrysopogon* (2) ศึกษาลักษณะกายวิภาคของแผ่นใบและลำต้นของหญ้าเผ่าย่อยข้าวฟ่างในประเทศไทยเพื่อนำมาใช้ในการจำแนกกลุ่มทางอนุกรมวิธาน โดยผลการศึกษาพบว่าลักษณะทางกายวิภาคสามารถใช้ในการจำแนกในระดับชนิดและสกุลของเผ่าย่อยข้าวฟ่างได้ ซึ่งลักษณะในแผ่นใบ ได้แก่ เซลล์สั้น, ผลึกซิลิกา, ขนขนาดใหญ่, ขนขนาดเล็ก, หนามเกิดจากผิว, ปุ่มเล็ก, ปากใบ และรูปร่างของสเกลอเรงคิมาที่ขอบแผ่นใบ และการเรียงตัวของมัดท่อลำเลียงในลำต้น (3) ศึกษาทบทวนทางอนุกรมวิธานโดยอาศัยข้อมูลด้านสัณฐานวิทยา กายวิภาคศาสตร์ของแผ่นใบและลำต้น และข้อมูลด้านสายสัมพันธ์ทางวิวัฒนาการโดยหลักฐานด้านโมเลกุล ผลการศึกษาพบว่ามีพืชเผ่าย่อยข้าวฟ่างในประเทศไทยทั้งหมด 29 ชนิด ใน 7 สกุล ในจำนวนนี้มีพืชที่มีรายงานครั้งแรกของประเทศไทย 1 ชนิด คือ *Chrysopogon gryllus* (L.) Trin. subsp. *gryllus* และพืชที่คาดว่าจะเป็นชนิดใหม่ของโลก 2 ชนิด ในสกุล *Capillipedium* นอกจากนี้ยังได้กำหนดตัวอย่างต้นแบบ (Lectotype) ให้กับ *Andropogon capilliflorus* Steud (ชื่อพ้องของ *Capillipedium parviflorum* (R. Br.) Stapf) และ *Hemisorghum mekongense* (A. Camus) C. E. Hubb. ในขณะเดียวกันได้กำหนดให้ *Andropogon laguroides* DC. (*Bothriochloa laguroides* (DC.) Herter) เป็น type species ของ *Andropogon* sect. *Amphilophis* (ชื่อพ้องของสกุล *Bothriochloa*) ซึ่งผลการศึกษาครั้งนี้จะเป็นส่วนหนึ่งของ Flora of Thailand (Poaceae) ซึ่งมีเป้าหมายที่จะเสร็จสิ้นโครงการในปี 2552

สาขาวิชา......วิทยาศาสตร์ชีวภาพ....ลายมือชื่อนิสิต...อรทัย เนียมสุวรรณ...
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ORATAI NEAMSUVAN : TAXONOMIC REVISION OF SUBTRIBE SORGHINAE (POACEAE) IN THAILAND. ADVISOR: ASST. PROF. TOSAK SEELANAN, Ph.D., CO-ADVISOR: JAN FREDERIK VELDKAMP, Ph.D., 176 pp.

In Thailand, although the grasses subtribe Sorghinae have previously been revision studied, it is still not completed. Hence, the aims of this study were to conduct the taxonomic revision of Sorghinae in three topics. Firstly, molecular phylogeny of closely related genera *Chrysopogon* and *Vetiveria* based on nuclear *ITS* and chloroplast *trnL-F* genes to clarify taxonomic delimitation of these two genera, the results suggested strongly to include *Vetiveria* in *Chrysopogon*. Secondly, anatomical utilization of leaf and culm in classification of genera and species in Sorghinae, the results revealed that micro-structures such as short cells, silica-bodies, macro-hairs, micro-hairs, prickle-hairs, papillae, stomata, shape of sclerenchyma at leaf margin, and vascular bundle arrangement in culm could be used both at generic and specific levels. Finally, taxonomic revision employing morphological character, anatomy and molecular phylogeny, which indicated that as many as 29 species in 7 genera were enumerated in Thailand. Among those, *Chrysopogon gryllus* (L.) Trin. subsp. *gryllus* was a new record to Thailand, while 2 new species of *Capillipedium* were found. In addition, the lectotypification of *Andropogon capilliflorus* Steud (synonym of *Capillipedium parviflorum* (R. Br.) Stapf), and *Hemisorghum mekongense* (A. Camus) C. E. Hubb. was established. Moreover, *Andropogon laguroides* DC. (*Bothriochloa laguroides* (DC.) Herter) was selected to be a type species of *Andropogon* sect. *Amphilophis* (synonym of *Bothriochloa*). The outcome from this study will be submitted to Flora of Thailand (Poaceae) targeting to complete in 2009.

Field of Study:.....Biological Science....Student's Signature:...Oratai Neamsuvan....
Academic Year:...2008.....................Advisor's Signature:..............................
Co-Advisor's Signature:...J.F. Veldkamp....

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CHAPTER I

GENERAL INTRODUCTION

1.1 Rational

The grasses subtribe Sorghinae belongs to the family Poaceae. The most familiar genus of this subtribe is *Sorghum* which is known as animal and human food. It is estimated that approximately 8 genera, namely *Bothriochloa, Capillipedium, Chrysopogon, Dichanthium, Hemisorghum, Pseudosorghum, Sorghum* and *Vetiveria* can be found in Thailand (Nanakorn and Norsangsri, 2001).

Taxonomically, although some genera in Sorghinae previously have been studied, they still are not complete. For example, the genus *Bothriochloa* and *Dichanthium* studied by Sathagul (1990) were found 6 and 4 species, respectively, while 5 and 7 species, respectively, were found by Nanakorn and Norsangsri (2001).

For anatomical study, leaf epidermis, leaf in transverse section and culm in transverse section have been carried out in some species of *Bothriochloa*, *Capillipedium*, *Chrysopogon*, *Dichanthium* and *Sorghum* (Metcalfe, 1960). However, those represented the specimens and some species occurring outside Thailand.

Yet, molecular study (Adams et al., 1998) on 4 species of *Vetiveria* and 2 species of *Chrysopogon* had found that these two genera were very closely related, and based on the priority rule, *Vetiveria* was subsequently merged into *Chrysopogon* (Veldkamp, 1999). However, more in-depth molecular studies on the *Chrysopogon-Vetiveria* issue should be carried out to assess the validity of this conclusion as previous molecular analysis included only few sampled taxa; therefore it may be more reliable to include more taxa sampling and to examine phylogenetic relationships among species in these two genera.

With aforementioned aspects, coupled with no revisional study in the remaining genera (i.e., *Capillipedium, Hemisorghum, Sorghum* and *Pseudosorghum*) in Thailand, it is appropriate to conduct the taxonomic revision of subtribe Sorghinae.

1.2 Objectives

1) To accomplish a taxonomic revision of the subtribe Sorghinae in Thailand.
2) To examine the anatomical character of subtribe Sorghinae in Thailand.
3) To construct a phylogeny of the *Chrysopogon-Vetiveria* complex based on molecular data.

1.3 Scopes of study

This study was focused on Poaceae, subtribe Sorghinae in 3 views: 1) molecular phylogeny of *Chrysopogon* and *Vetiveria* based on worldwide specimens, 2) leaf and culm anatomy based on Thai specimens and 3) taxonomic study based on Thai specimens deposited in Thai and abroad herbaria. This research was carried out from June 2004 to December 2008.

1.4 Anticipated benefits

The outcome from this research will be beneficial to the Flora of Thailand project. Also, the finding will be served as the basis for further study in Poaceae.

CHAPTER II

LITERATURE REVIEW

The Poaceae or the grass family is the fifth largest family of flowering plants in terms of species and genera, after Compositae, Leguminosae, Orchidaceae and Rubiaceae. Phytogeographically, however, it occupies a third of the land's surface (Schantz, 1954, cited in Clayton and Renvoize, 1986) and grows on all continents and in all habitats. Moreover, the grasses are certainly the most important as far as humans are concerned. Among 10,000 species in this diverse family are all of the major cereals such as wheat, rice, barley and corn, as well as other widely used plants like bamboos and sugarcane. In addition, they supply directly, or indirectly, as animal feed. Grasses are of major economic importance as weeds and as horticultural plants in amenity horticulture, namely playing field, parks and lawns. Therefore, Poaceae is now in need of major studies and conservation to guarantee their continued existence (Jacobs and Everett, 2000).

2.1 Taxonomic study in subtribe Sorghinae

Subtribe Sorghinae is in tribe Andropogoneae of subfamily Panicoideae. Globally, there are approximately 151 species in 14 genera: *Asthenochloa, Bothriochloa, Capillipedium, Cleistachne, Chrysopogon, Dichanthium, Euclasta, Hemisorghum, Pseudodichanthium, Pseudosorghum, Spathia, Sorghastrum, Sorghum,* and *Vetiveria* (Clayton and Renvoiz, 1986).

Camus and Camus (1912) found 16 species of Sorghinae comprising *Capillipedium* 3 species, *Chrysopogon* 3 species, *Dichanthium* 2 species, *Pseudosorghum* 2 species, *Sorghum* 4 species and *Vetiveria* 2 species, from Indo-china.

Bor (1960) studied grasses of Burma, Ceylon, India and Pakistan and found 83 species of Sorghinae composed of *Bothriochloa* 17 species, *Capillipedium* 7 species, *Chrysopogon* 16 species, *Cleistachne* 2 species, *Dichanthium* 9 species, *Euclasta* 1 species, *Hemisorghum* 1 species, *Pseudodichanthium* 1 species, *Pseudosorghum* 1 species, *Sorghastrum* 1 species, *Sorghum* 25 species and *Vetiveria* 2 species.

Clayton et al. (1994) studied grasses of Ceylon and recorded 16 species of Sorghinae, namely *Bothriochloa* 3 species, *Chrysopogon* 5 species, *Dichanthium* 2 species, *Hemisorghum* 1 species, *Sorghum* 3 species and *Vetiveria* 2 species.

Gilliland (1971) described 13 species of Sorghinae from Malaya including *Bothriochloa* 2 species, *Capillipedium* 1 species, *Chrysopogon* 3 species, *Dichanthium* 3 species, *Sorghum* 2 species and *Vetiveria* 2 species.

Liu (2000) described 14 species of Sorghinae from Taiwan including *Bothriochloa* 3 species, *Capillipedium* 3 species, *Chrysopogon* 1 species, *Dichanthium* 2 species, *Sorghum* 4 species and *Vetiveria* 1 species.

Chen and Phillips (2006) studied grasses of China and discovered 21 species of Sorghinae, namely *Bothriochloa* 3 species, *Capillipedium* 5 species, *Chrysopogon* 4 species, *Dichanthium* 3 species, *Pseudosorghum* 1 species and *Sorghum* 5 species

As mentioned above, Poaceae subtribe Sorghinae was completely studied and already published as a flora for neighbor countries around Thailand, while scanty and scattering researches have been done in Thailand. For example, the only 2 species of *Bothriochloa*, 1 species of *Capillipedium*, 2 species of *Chrysopogon*, 1 species of

Dichanthium, 1 species of *Pseudosorghum* and 1 species of *Vetiveria* were recorded for studies in the flora of Thailand by Bor (1965).

Sathagul (1990), in her master thesis, studied *Bothriochloa* and *Dichanthium* and found 6 and 4 species respectively. Unfortunately, the research was not published in any accepted taxonomic journals.

Veldkamp (1999) revised *Chrysopogon* and *Vetiveria* in Thailand, then proposed to include these 2 genera under *Chrysopogon* and recorded 8 species of this genus from Thailand.

Nanakorn and Norsangsri (2000) listed 39 species of Sorghinae from Thailand including *Bothriochloa* 5 species, *Capillipedium* 5 species, *Chrysopogon* 6 species, *Dichanthium* 7 species, *Hemisorghum* 1 species, *Pseudosorghum* 2 species, *Sorghum* 11 species and *Vetiveria* 2 species. However, since this was a mere checklist for Thai grasses, there was neither key nor a description.

Accordingly, it shows that taxonomic study of Sorghinae in Thailand still is not complete.

2.2 Anatomical study in subtribe Sorghinae

Metcalfe (1960) conducted the anatomical investigation in Poaceae (Gramineae), then proposed anatomical method and described leaf and culm anatomical characters of many grasses. Among them, some species of Sorghinae including *Bothriochloa caucasica*, *B. pertusa*, *Capillipedium venustum*, *Chrysopogon zeylanicus*, *Cleistachne sorghoides, Dichanthium aristatum, D. polyptychum, D. sericeum* and *Sorghum halepense* were included. This is the first work that various species of grasses were conducted for anatomical study. In addition, it is the basic for the later anatomical research in Poaceae.

Renvoize (1982) examined the species in the Andropogoneae of which *Asthenochloa tenera, Bothriochloa insculpta, Capillipedium parviflorum, Cleistachne sorghoides, Chrysopogon plumulosus, Dichanthium annulatum, Euclasta condylotricha, Hemisorghum venustum, Pseudodichanthium serrafalcoides, Pseudosorghum fasciculare, Sorghum arundinaceum, Sorghastrum stipoides, Spathia neurosa, Vetiveria nigritana* were included. However, he considered the leaf anatomical character as a uniform within the tribe, consequently he described them in a single generalized description.

Dávila and Clark (1990) surveyed leaf epidermis of 17 species of *Sorghastrum* by SEM. It was found that papillar morphology was variable but taxonomically informative in distinguishing among the species. Based on the absence or presence of papillae, and differences in papillar morphology, three informal groups within *Sorghastrum* are recognized.

Watson and Dallwitz (1992) studied the grass genera of the world; leaf anatomy of some genera in Sorghinae: *Asthenochloa, Bothriochloa, Capillipedium, Chrysopogon, Dichanthium*, *Spathia, Sorghastrum, Sorghum* and *Vetiveria*, was also examined. However, those were given with the description representing generic characters.

Chaudhary, Mumtaz and Khan (2001) studied leaf epidermis of *Vetiveria zizanioides* and described seven epidermal characters, namely short-cell, silica body, macro-hair, micro-hair, prickle-hair, stoma and long cell. Moreover, Meffei (2002) examined leaf anatomy of *Vetiveria zizanioides* as representative of the genus *Vetiveria* and described characters of abaxial and adaxial epidermis as well as cross section of the blade, which corresponds to those by previous authors.

As mentioned above, it is pointed out that some species studied for anatomy occur outside Thailand, whereas all specimens were obtained outside Thailand as well. Moreover, only description was given, while a key to any taxonomic levels based on anatomical character has never been tried.

2.3 History of molecular phylogeny in subtribe Sorghinae

Interests in the evolution of grasses began early in this century and empirical approaches to phylogenetic reconstruction of the Poaceae starting with cladistic analyses of morphological and anatomical characters. Recently, molecular data have provided the grounds for phylogenetic studies in grasses at the subfamilial and tribal levels (Hilu, Alice and Liang, 1999). These studies were based on information from chloroplast DNA (cpDNA) restriction sites and DNA sequencing of the *rbcL*, *ndhF, rps4*, *rpoC2*, *matK*, nuclear ribosomal DNA (nrDNA) 18s and 26S, phytochrome, and granule-bound starch synthase genes, as well as the noncoding nrDNA Internal Transcribed Spacer (ITS) region (Hamby and Zimmer, 1988; Doebley et al., 1990; Davis and Soreng, 1993; Cummings, King, and Kellogg, 1994; Hsiao et al., 1994; Nadot, Bajon, and Lejeune, 1994; Barker, Linder, and Harley, 1995, 1999; Clark, Zhang, and Wendel, 1995; Duvall and Morton, 1996; Liang and Hilu, 1996; Mathews and Sharrock, 1996; Mason-Gamer, Weil and Kellogg, 1998; Soreng and Davis, 1998 and Hsiao et al., 1999). Although these studies have refined our understanding of grass evolution at the subfamilial level and, to a certain degree, at the tribal level, major questions remain to be resolved. Within minor clades of tribe, namely subtribe and genera, relative placement and taxonomic status are debatable. For example in Andropogonae, a tribe bearing economic grasses of corn, sugarcane and sorghum, though Andropogoneae is monophyletic tribe, but many of subtribes, namely Andropogoninae, Anthistiriinae, Rottboelliinae, Saccharinae, and Sorghinae are not monophyly (Mathews et al., 2002). However, the effort to clarify the relationship within subtribes and treat systematic following phylogeny is scanty. But the concentration is mostly to clarify at generic level, such as *Miscanthus*-*Saccharum* complex in Saccharinae (Hodkinson et al., 2002).

For Sorghinae, the phylogeny was started to study in 2000 by Spangler. The study included 12 species of *Sorghum*, 2 species of *Chrysopogon* and 1 species from each of *Bothriochloa*, *Capillipedium*, *Cleistachne*, *Dichanthium* and *Sorghastrum*. The results revealed that this subtribe is not monophyletic group. However, this study was mainly focused on *Sorghum*, it occurred that the genus was not monophyletic group. Hence, the author proposed to revise the generic limit for the group. Later, Dillon, Lawrence and Henry (2001) constructed a phylogenetic tree of *Sorghum* based on ITS1 region, and found 5 clades in this genus. Moreover, the identical DNA sequences were seen from *Sorghum bicolor*, *S.* x *almum*, *S. arundinaceum*, *S. angustum*, *S. drummondii* and *S. propinquum*. In addition, *S. bulbosum* was identical to *S. plumosum*, and *S. interjectum* was identical to *S. stipoideum*. Then, they suggested that further study of species boundaries in Sorghum should be considered. Therefore, Spangler (2003) based on molecular study, proposed distinct 3 genera separated from the traditional *Sorghum*, namely *Sorghum*, *Sarga* and *Vacoparis*. However, Dillon et al. (2007) studied phylogeny of *Sorghum* based on molecular data obtaining from *Adh1*, *ITS1* and *ndhF* genes, and found that *Sorghum* is a distinct monophyletic genus against Spangler's (2003) study.

As mentioned above, it occurs that only the genus *Sorghum* from subtribe Sorghinae was largely studied for molecular phylogeny, while the rest genera seemed to be ignored.

With aforementioned literature reviews of 3 historical studies, it can be seen that revision of Sorghinae in Thailand has never been completed and some never been done. Therefore, it is advisable to revise grass subtribe Sorghinae in Thailand.

CHAPTER III

PHYLOGENY OF *Chrysopogon-Vetiveria* COMPLEX

3.1 Introduction

Traditionally, *Chrysopogon* Trin. and *Vetiveria* Bory have been regarded as distinct entities. However, the close relationship between the two genera was already observed by Hackel (1889), who said that the two were hardly distinct, as they were united by intermediary species, and suggested that *Chrysopogon* might be derived from *Vetiveria.*

Previously, *Chrysopogon* was composed of 26 species (Clayton and Renvoize, 1986) distributed in tropical region of old world and 1 species in Cuba and Florida. It was recognized by a traid of one sessile spikelet and two pedicelled spikelets. *Vetiveria* was composed of 10 species (Clayton and Renvoize, 1986) distributed in old world tropics. It was recognized by many pairs of sessile and pedicelled spikelets below a terminal triad.

Clayton and Renvoize (1986) noted that *Chrysopogon* intergrades with *Vetiveria* via *C. sylvaticus* (usually 2 sessile spikelets per raceme) and *Vetiveria* links to *Chrysopogon* by *V. pauciflora* (2 or 3 sessile spikelets per raceme)

Recently, Adams et al. (1998) studied RAPDs of *Vetiveria* 4 species and *Chrysopogon* 2 species and revealed that *C. fulvus* was most similar to *V. elongata*, whereas *C. gryllus* was most similar to *V. zizanioides*. It was noted that two *Chrysopogon* species were each more similar to *Vetiveria* taxa than to each other. Therefore, they suggested that some taxonomic revision was warranted between these two genera.

Based on intermediate form of morphological characters and RAPDs' result, Veldkamp (1999) proposed to include these two genera under *Chrysopogon*. Hence, 45 species of *Chrysopogon* are now recorded following his study.

Thus far, this issue is accepted by many recent workers, namely Chen and Phillips (2006) in Flora of China, Clayton, Harman and Williamson (2008) in GrassBase of Royal Botanic Gardens, Kew. However, the validation of that conclusion has never been assessed by any molecular phylogenies. Therefore, the present study was aimed to clarify taxonomic status of *Chrysopogon* and *Vetiveria* using molecular data and to examine phylogenetic relationships among species in these two genera.

3.2 Materials and Methods

3.2.1 Taxon sampling and outgroup selection

Voucher specimens of *Chrysopogon* and *Vetiveria* species deposited in National Herbarium Naderland, Leiden University, Herbarium of the University of Aarhus, Denmark, and Herbarium of Department of Botany, Chulalongkorn University, Thailand, were sampled (Table 3.1). The duplicates of some species were selected to represent geographical distribution. Outgroup was obtained from 2 species of *Sorghum*: *S. bicolor* and *S. nitidum*, as well as 2 species of *Pseudosorghum*: *P. fasciculare* and *P. zollingerii*.

3.2.2 DNA Extraction

Total genomic DNA was extracted with DNAeasy Plant Mini Kit (Qiagen) according to manufacturer's instructions.

3.2.3 Amplification, purification and sequencing

The ribosomal ITS region was amplified from 39 individuals representing 28 species of *Chrysopogon*, 11 individuals representing 8 species of *Vetiveria* and 5 individuals representing 4 species of outgroup (Table 3.1). Primers for amplifying followed White et al. (1990) including pairs of ITS5/ ITS4 or ITS5/ITS2 and ITS3/ITS4.

The chloroplast *trn*L intron and *trnL-F* intergenic spacer were amplified from 19 individuals representing 14 species of *Chrysopogon*, 5 species of *Vetiveria* and 1 species of outgroup (Table 3.1). Primers c and f (Taberlet et al., 1991) were used for amplifying.

Table 3.1 Specimens selected for DNA study (/ = successful amplification, - = not successful amplification)

Species	Locallity	Voucher specimens (Herbarium)	ITS	*trnL-F*
C. aciculatus	Thailand	O. Neamsuvan 161 (PSU)	/	/
C. aucheri	Iran	K.H. et F. Rechinger 3712 (AAU)	/	/
C. castaneus	India	S.R. Yadav 8678 (L)	/	/
C. fallax	Australia	S.T.Blake 17938 (L)	/	/
C. fulvus 1	Thailand	M. Lazarides 7420 (L)	/	/
C. fulvus 2	Ceylon	G. Davidse 7505 (L)	/	/
C. gryllus subsp. *gryllus*	Romania	Th. Solacolu et G.h. Bujorean 335 (L)	/	/
C. gryllus subsp. *echinulatus*	India	Mare Siugh 378 (L)	/	/
C. gryllus	Thailand	O. Neamsuvan 165 (BCU)	/	/
C. latifolius	Australia	I.B. Wilson 30 (L)	/	/
C. micrantherus	New Guinea	L.J.Brass 8579 (L)	/	/
C. orientalis 1	Laos	JBH 1267 (L)	/	/
C. orientalis 2	Thailand	C.F. van Beusekom et al. 3816 (L)	/	/
C. orientalis 3	India	Hohenacker 1285 (L)	/	/
C. pallidus	Australia	Adams 816 (L)	/	/
C. pauciflorus	USA	George R. Cooley 9039 (L)	/	/
C. perlaxus	Thailand	K. Larsen 8015 (L)	/	/
C. plumulosus	Africa	A. Pappi 4743 (L)	/	/
C. serrulatus 1	Thailand	Ch. Charoenphol, K. Larsen & E. Warncke 5036 (L)	/	/
C. serrulatus 2	Indonesia	W.C. Verboom 24 (L)	/	/
C. serrulatus 3	Nepal	T. Hoshino et al. 9670178 (L)	/	-
C. serrulatus 4	USA	Jansen en Wachter 41100 (L)	/	-
C. setifolius	Australia	R.L. Specht 1242 (L)	/	-
C. sylvaticus	Australia	C.E.Hubbard 8587 (L)	/	-
C. subtilis	Indonesia	C.A. Backer 36550 (L)	/	-
C. tenuiculmis	Indonesia	Fr. E. Schmutz SVD 5756 (L)	/	/
C. verticillatus	India	H.J.Luooney 3664 (L)	/	/
C. zeylanicus	Ceylon	F. Ballard 1164 (L)	/	-
V. elongata	Australia	R. Story 8351 (L)	/	/
V. festucoides 1	Philippines	Species Blancoanae 383 (L)	/	-
V. festucoides 2	Thailand	K. Larsen, T. Smitinand and E. Warncke 1113 (AAU)	/	-
V. festucoides 3	Vietnam	J.B. Hacker 1559 (L)	/	-
V. filipes	Australia	Story & Yapp 163 (L)	/	/

Table 3.1 (Continued)

Species	Locality	Voucher specimens (Herbarium)	ITS	*trnL-F*
V. fulvibarbis	Burkina Faso	S. Lægaard et al. 18194 (L)	/	/
V. nemoralis	Vietnam	Hb. B. Balansa L. 0281424 (L)	/	-
V. nigritana 1	Congo	J. Brynaert 620 (L)	/	-
V. nigritana 2	Africa	Herbier de Ch. d'Alle Zei (L)	/	-
V. pauciflora S.T.Blake	Australia	L.A.Crawen 4619 (L)	/	/
V. zizanioides	Thailand	O. Neamsuvan 273 (BCU)	/	/
Outgroup				
S. bicolor	USA	Derral Herbst & Glen Spence 5622 (L)	/	/
S. nitidum	Papua New Guinea	Robert Höft 3065 (L)	/	-
P. fasciculare	Vietnam	B. Balansa 1770 (L)	/	-
P. Zollingerii 1	Indonesia	F 48 (L)	/	-
P. Zollingerii 2	Vietnam	J.D. Wogch 35030 (L)	/	-

PCR amplification was performed in a 25 µl volume containing 2.5 mM MgCl2, 200 µM of each dNTP, 5 pM of each primer, and 1.5 U of *Taq* DNA polymerase, 10x PCR Buffer, and approximately 25 ng DNA template.

The PCR procedure included an initial 5 min denaturation at 95ºC, 40 cycles of 30 s denaturation at 95ºC, 30 s annealing at 55-60ºC, and 2 min extension at 72ºC, and then followed by 8 min at 72ºC for the final extension.

PCR products were purified by the Promega PCR cleaning kit following manufacturer's instruction. Then, purified products were sequenced by Macrogen (Korea).

3.2.4 Phylogenetic analysis

DNA sequences were edited with sequencher 4.1 (Gene Codes Corporation, Ann Arbor, Michigan, USA). Multiple alignments of DNA sequences were made using CLUSTAL X 1.81 (Thompson et al., 1997), and then output was manually adjusted in BioEdit (Hall, 2007). Gaps were treated as a missing state. Some indels were recoded as separate characters (0, 1, & 2) appended in the matrix. Phylogenetic analysis was performed with the maximum parsimony method using PUAP* version 4.0b10 (Swofford, 2002). Most parsimonious trees were searched using a heuristic strategy with 1,000 replications of random addition sequence, starting trees were obtained via stepwise addition for TBR branch swapping, one tree was held at each step during stepwise addition. Support for the nodes resolved in the strict consensus of the most parsimonious trees was evaluated with bootstrap analysis with TBR branch-swapping on 1,000 replications. The following categories modified from Kress et al. (2005) were used to describe levels of bootstrap support: poor < 50%; weak = 50-70%; moderate = 71-84%; and strong = 85-100% (Kress et al, 2002).

3.3 Results

Analysis of ITS (full data: 39 ingroup + 5 outgroup)

The length of unaligned ITS region ranged from 649 bp in *C. zeylanicus* and *C. pauciflorus* to 654 bp in *C. subtilis*. A total aligned length for ITS of 44 specimens (39 ingroup and 5 outgroup specimens) was 689 characters, of which 22 characters were excluded and recoded with 0, 1, or 2 at the last 11 characters. When gaps were treated as missing state, 491 characters were constant, 54 variable characters were parsimony-uninformative, and 122 characters were parsimony-informative. The heuristic search with ITS data produced 73 trees with the tree length of 366 steps, a consistency index (CI) excluding uninformative characters = 0.5748, a retension index (RI) = 0.8166 and a scaled consistency index (RC) = 0.5310. The strict consensus tree of all most parsimonious trees is shown in Figure 3.1.

From phylogenetic tree, outgroup and ingroup were separated with poor bootstrap support. Among ingroup, 8 major clades were recognized: A, B, C, D_1, D_2, E, F, and G.

Resolution was moderate to high, except clade A and C, for the internal branches of the tree depicted in Fig. 3.1. Although the strict consensus tree suggested clade A and B were sister taxa, while D_1-D_2 formed sister taxon to clade E and these latter clades form a sister taxon to clade C, the relationships among clades A through E were ambiguous due to low bootstrap supports.

Exception for clade A and C, major clades were supported with moderate to high bootstrap value. It was found that clade G was shown as a basal clade, followed by clade F. Clade A-B formed a sister to C-D_1-D_2-E clade. Clade A formed a sister to clade B. Similarly, clade C formed a sister to D_1-D_2-E clade. Moreover, D_1 and D_2 formed a sister with poor bootstrap support to each other. Also D_1-D_2 clade formed a sister clade to E with poor bootstrap support.

Analysis of *trnL-F* region

The length of unaligned *trnL-F* region ranged from 784 bp in *C. pauciflorus* to 834 bp in *V. zizanioides*. A total aligned length for *trnL-F* of 27 specimens (26 ingroup and 1 outgroup specimens) was 908 characters, of which 131 characters were excluded and recoded with 0, 1, or 2 at the last 20 characters. When gaps were treated as missing state, 740 characters were constant, 15 variable characters were parsimony-uninformative, and 22 characters were parsimony-informative. Hence, it is shown that *trnL-F* region is less variable than the nuclear ITS region for the studied samples. Analysis of this *trnL-F* region matrix resulted in 899 equally parsimonious cladograms with a tree length of 62 steps, a consistency index (CI) excluding uninformative characters = 0.7778, a retension index (RI) = 0.9180 and a scaled consistency index (RC) = 0.7700. The strict consensus tree of all most parsimonious trees is shown in Figure 3.2.

From phylogenetic tree, outgroup and ingroup were separated with poor bootstrap support. Among ingroup in order to be in line with the ITS tree, 6 major clades were recognized: A, B, C, D_1+F, E and G. Clade D_2 is not presented here because the specimens were not included.

The result showed that relationship or position of major clades were different from those in ITS tree. Clade B was placed as a basal in this tree, instead of clade G in the ITS tree. Within the remaining taxa, clade G formed as a sister to the rest with weak bootstrap support (64%). Beyond this, only clade A and E were formed with weak and strong bootstrap support, respectively. Interestingly, *V. fulvibarbis* (A-clade) and *V. zizanioides* (C-clade) were also included in E-clade. The rest were formed as D_1+F but with low bootstrap support. Coupled with clade G, clade D_1+F plus clade A form a sister to clade *V. fulvibarbis*-C-E with poor bootstrap support as well. In addition, clade D_1+F forms a sister to A with poor bootstrap support too.

Not only position but bootstrap support value is also different when comparing *trnL-F* analysis to ITS. Clade A excluding *C. zeylanicus* in the ITS tree is 95% bootstrap support, while it is only 67% bootstrap support in the *trnL-F* tree. Clade B show 100% bootstrap support in the ITS tree, but it is only 93% bootstrap support in the *trnL-F* tree.

In addition, the *trnL-F* analysis resulted in less resolved topology in all clades comparing with the ITS tree may be due to lower phylogenetic informative characters.

Analysis of combined data

Because of the two regions investigated produced a few different results, therefore, the sequence data of ITS and *trnL-F* were subjected to ILD test before combining data for additional analysis. The resulting *p* value was 0.4300. This suggested that the nuclear and chloroplast data sets were not statistically incongruent. Thus, both data matrices could be combined to a single dataset and used for simultaneous analysis.

The combined data matrix was 1,591 characters, of which 163 characters were excluded and recoded with 0, 1, or 2 at the last 31 characters. When gaps were treated as missing state, 1241 characters were constant, 72 variable characters were parsimony-uninformative, and 115 characters were parsimony-informative. Analysis of this combined matrix resulted in 11 equally parsimonious cladograms with a tree length of 337 steps, a consistency index (CI) excluding uninformative characters = 0.6109, RI = 0.8092 and RC = 0.5691. The strict consensus tree of all most parsimonious trees is shown in Figure 3.3.

From phylogenetic tree, outgroup and ingroup were separated with poor bootstrap support. Among ingroup, 7 major clades present: A, B, C, D_1, E, F, and G. Moreover, it shows that combined data has better resolution and more well-supported nodes than the results of either data set alone.

Clade A is similar to those in ITS tree and *V. fulvibarbis* is included although its bootstrap support (91%) is less than that in the ITS analysis (95%; without *C. zeylanicus*).

Clade B corresponds to those in the ITS and *the trnL-F* analyses in term of species found in both trees. However, it is more similar to the ITS tree as shown in complete resolution and similar to the *trnL-F* tree as shown in basal position in the tree.

Clade C separated only 1 taxon-*V. zizanioides*- is sister to clade A with poor bootstrap support. The position is not corresponding to either the ITS or the *trnL-F* analyses. It forms the clade with *V. fulvibarbis* and *C. gryllus* subsp. *gryllus* in the *trnL-F* analysis, while it forms a sister with the D_1-D_2-E clade in the ITS tree.

Clade D_1 and F which formed as a polytomy due to insufficient phylogenetic information in *trnL-F* analysis are completely resolved here with fully supported (100% for each clades). The placement of these 2 clades is sister group to each other.

Clade E and G are resolved as distinct clades with high bootstrap support. Placement of E and G in the ITS and *trnL-F* trees are not strongly bootstrap supported but in the combined analysis, their placements are strongly supported. Similar to the *trnL-F* tree, the G clade is placed as the second basal most from the root with 88% bootstrap support and the E clade is sistered to A-C clade with weak support.

Overall, the topology of the combined analysis is similar to most of the *trnL-F* tree with higher bootstrap supports in many more resolved clades, A through G, possibly from the ITS tree.

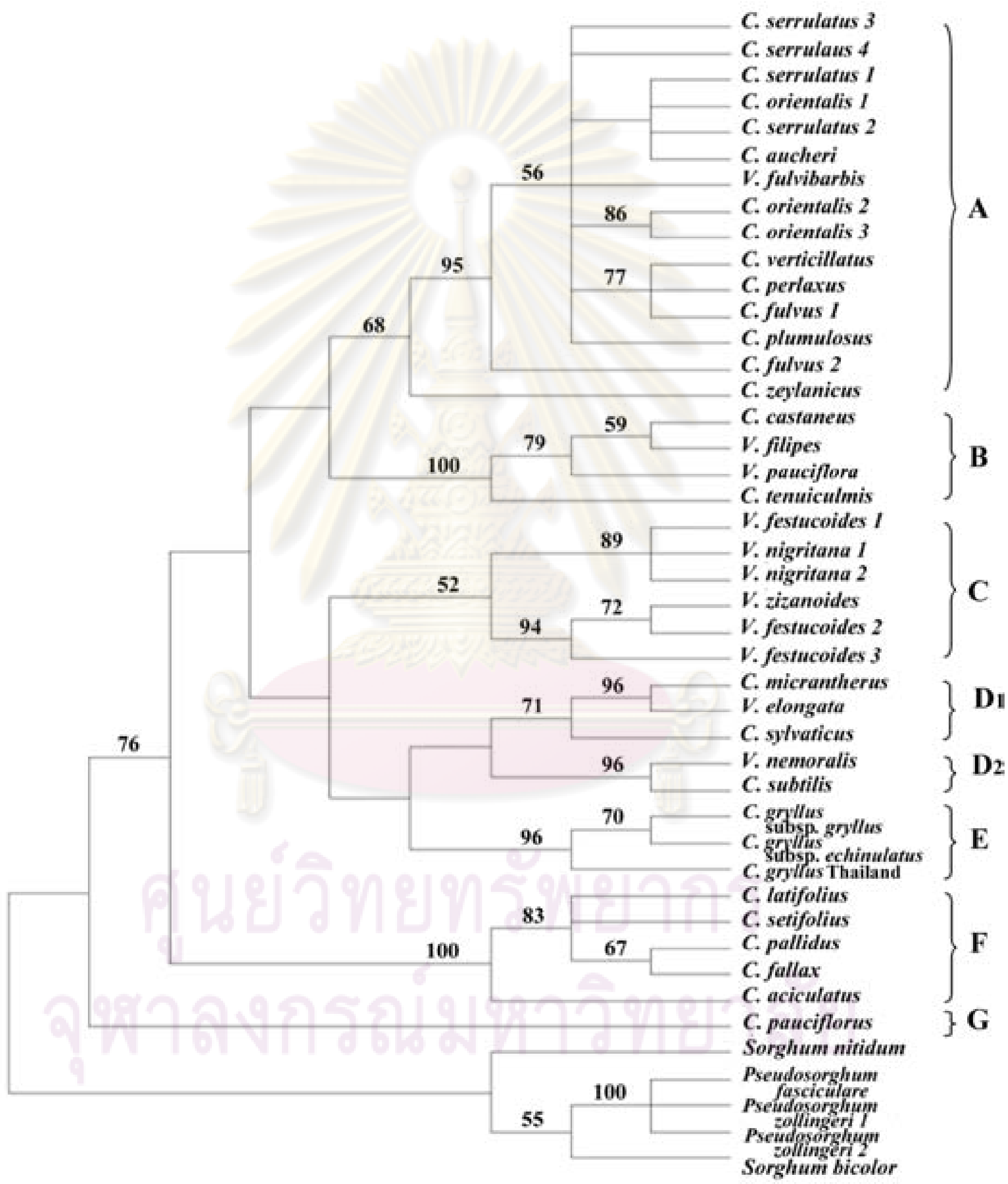

Figure 3.1 The strict consensus of 73 equally parsimonious trees of the ITS sequence data (length = 366, CI excluding uninformative characters = 0.5748, RI = 0.8166) showing bootstrap value (above the branch if ≥ 50%).

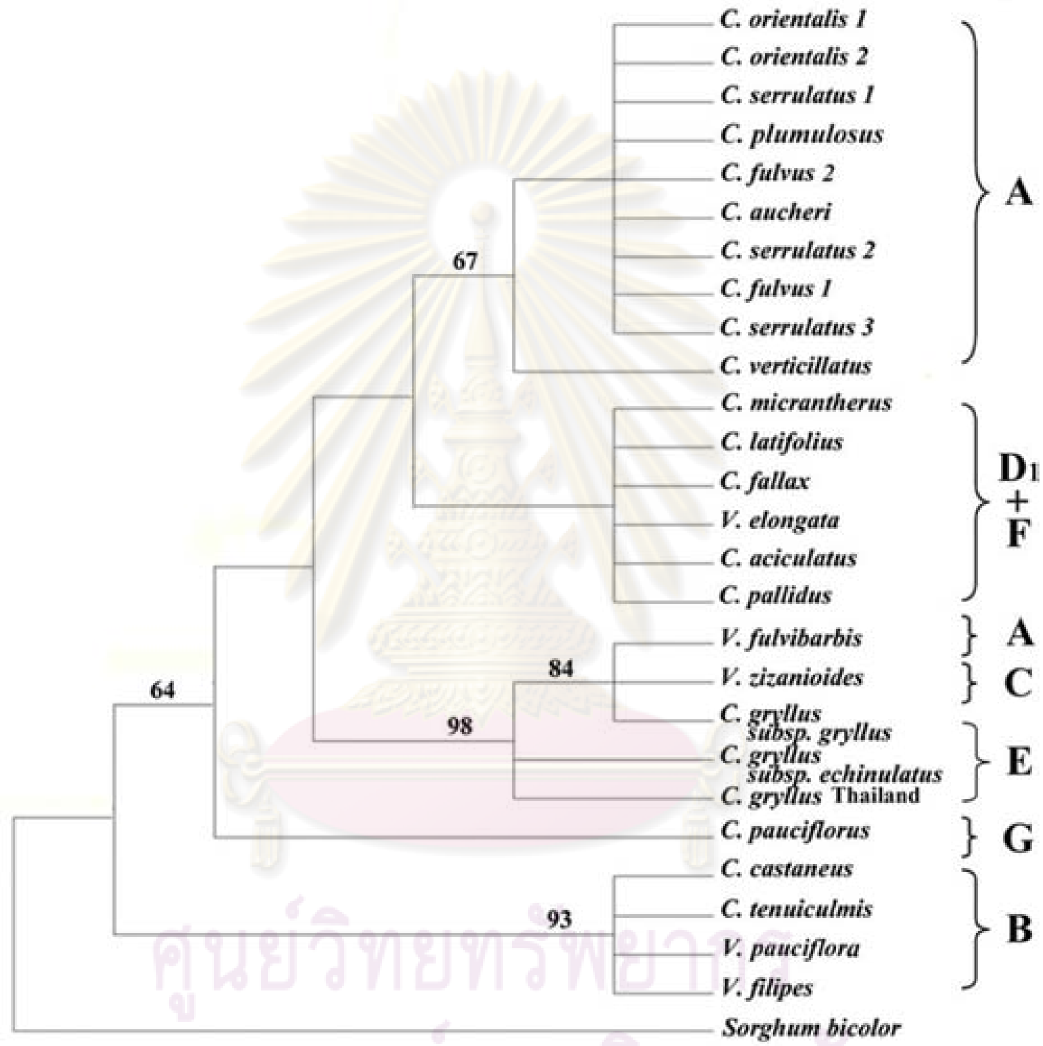

Figure 3.2 The strict consensus of 899 equally parsimonious trees of the *trnL-F* sequence data (length = 62, CI excluding uninformative characters = 0.7778, RI = 0.9180) showing bootstrap value (above the branch if ≥ 50%).

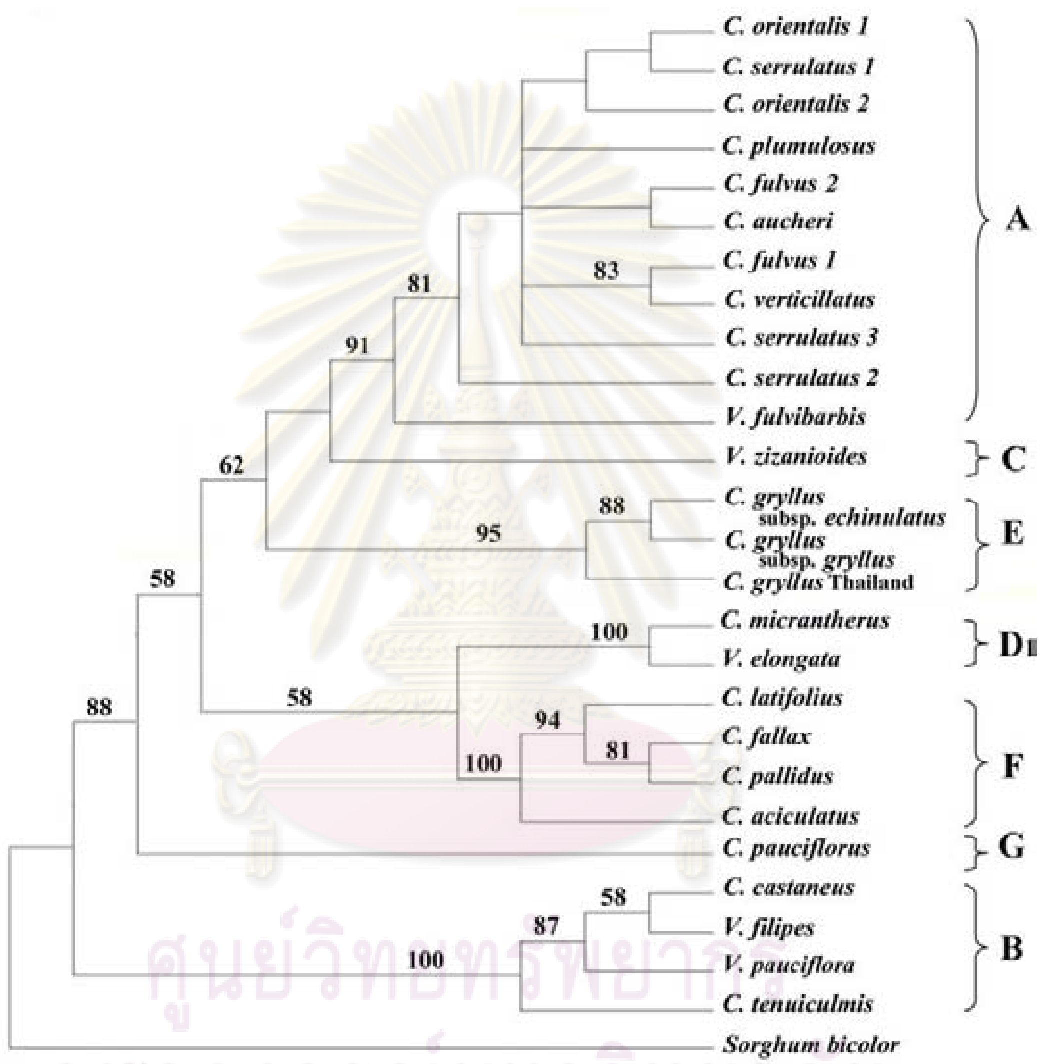

Figure 3.3 The strict consensus of 11 equally parsimonious trees for the combined data matrix of ITS and the *trnL-F* intron and spacer regions (length = 337, CI excluding uninformative characters = 0.6109, RI = 0.8092) showing bootstrap value (above the branch if ≥ 50%).

3.4 Discussion

This study is the first molecular phylogenetic hypothesis of the relationships among species and genera of *Chrysopogon* and *Vetiveria*. The data set of DNA sequence of ITS and *trnL-F* were analyzed separately before being combined into a single data set. The analysis shows that the combined tree exhibits the best phylogenetic reconstruction. However, the study reveals that ITS data provides evidence for phylogenetic investigation of closely related species, whilst *trnL-F* region is useful at higher level such as infragerneric group.

Phylogenetic relationship of *Chrysopogon* and *Vetiveria*

The results from ITS, *trnL-F* and combined analyses are concordant, showing that *Vetiveria* is not monophyletic and its member were dispersed within *Chrysopogon*.

Thus, the molecular phylogenetic analysis is congruent with morphological data (Veldkamp, 1999) in including *Vetiveria* to *Chrysopogon*.

By submerging *Vetiveria* into *Chrysopogon*, some characters become synapomorphies for the genus *Chrysopogon*. All species of *Chrysopogon* have laterally compressed lower glume of sessile spikelet, while other genera in Sorghinae have dorsally compressed lower glume. In addition, by leaf anatomy, short cells at costal zones in *Chrysopogon* are alternately arranged with long cells, while they are in rows in the rest of genera. Moreover, poorly developed bulliform cells present in *Chrysopogon* and *Vetiveria*, while they are well developed in the rest genera.

Morphologically, Clayton and Renvoize (1986) regarded *Vetiveria* as a basal group of *Chrysopogon* as well as Celarier (1959) considered *V. zizanioides* as the most primitive and possibly the ancestral form of *Chrysopogon*. However, this result from molecular data disagrees with those suggestions since taxa in *Vetiveria* are dispersed among *Chrysopogon* species. Hence, the *Vetiveria* names of taxa used in this study could be changed followed Veldkamp (1999) for subsequent referals:

Vetiveria elongata (R. Br.) Stapf ex C.E. Hubb. = *Chrysopogon elongatus* (R. Br.) Benth.

Vetiveria festucoides (Presl) Ohwi = *Chrysopogon festucoides* (Presl) Veldk.

Vetiveria filipes (Benth.) C.E. Hubb. = *Chrysopogon filipes* (Benth.) Reeder

Vetiveria fulvibarbis (Trin.) Stapf = *Chrysopogon fulvibarbis* (Trin.) Veldk.

Vetiveria nemoralis (Balansa) A. Camus = *Chrysopogon nemoralis* (Balansa) Holtt.

Vetiveria nigritana (Benth.) Stapf = *Chrysopogon nigritanus* (Benth.) Veldk.

Vetiveria pauciflora S.T.Blake = *Chrysopogon oliganthus* Veldk.

Vetiveria zizanioides (L.) Nash = *Chrysopogon zizanioides* (L.) Roberty

The eight clades of *Chrysopogon*

Since combined tree shows more reliable and much better resolution, thus the infrageneric relationship or relationships among groups of species are mainly based on combined analysis. However, some from ITS analysis may be referred to since full data were done in the ITS analysis.

From phylogenetic tree, eight independent clades were formed; however, no good characters can be recognized to define some clades as a whole.

Clade A is presented with strong bootstrap support (91% in combined analysis). Thus, this clade should be real. From combined tree, two subclades are recovered. The first one is *C. fulvibarbis* clade which is resolved as a basal lineage of this group. Its characters are many sessile spikelets per raceme and glabrous pedicel at pedicelled spikelet. The second one which is sister to *C. fulvibarbis* is composed of the species that shared characters of one sessile spikelet per raceme and hairy pedicel at pedicelled spikelet.

After considering *C. zizanioides*, a sister taxon to Clade A, and *C. fulvibarbis*, a basal lineage of clade A, it seems that the most recent ancestor of clade A had a character of many sessile spikelets per raceme and glabrous pedicel as found in *C. zizanioides* and *C. fulvibarbis*. And later the ancestor was diverged to be 2 subclades of *C. fulvibarbis* clade which still retains many sessile spikelets per raceme as well as glabrous pedicel and of the clade containing the rest taxa of clade A which bears derivative characters of one sessile spikelet per raceme as well as hairy pedicel.

Veldkamp (1999) considered *C. fulvibarbis* as an intermediate taxon between *Chrysopogon* and *Vetiveria* by its many characters belonging to *Chrysopogon* such as long geniculated awn as well as oblique and pungent hairy callus. This suggestion is congruent with our combined data analysis that shows *C. fulvibarbis* as intermediate clade between *C. zizanioides* clade and the rest taxa in clade A.

Geographically, the members in this clade distribute from Malesia to South-East Asia, India, Eastern Europe, Arabia to Africa, and India is currently the center of species diversity for this clade (Cope, 1982, 1995; Phillips, 1995; Veldkamp, 1999).

Although this clade is formed with strong bootstrap support, the species in this clade are resolved as a polytomy. Moreover, the accessions of some species are not grouped together. The disparate position of one species is somewhat problematic and may be due to the widespread distribution of each species with significant local differentiation (Kress et al., 2005).

According to previous study, *C. fulvus* and *C. perlaxus* were closely related species (Larsen, 1965) due to their peculiar tuft of hairs on the back of the upper glume of the sessile spikelet. In the ITS analysis, both species referred from *C. fulvus* 1 and *C. perlaxus* from Thailand show as a sister group with 77% bootstrap support, whereas it is 83% in combined data. This agrees with Larsen’s suggestion. However, the relationship between these 2 species is not well defined because, in the ITS tree, *C. verticillatus* is arranged as a trichotomy in this subclade, while *C. fulvus 2* from Ceylon is placed outside this subclade.

Bor (1960) pointed out that *C. fulvus* presented some difficulties for the taxonomists owing to its variability not only in the vegetative parts but also in the size of the spikelets and anthers. This is confirmed by our study because the spikelet size of *C. fulvus* 2 from Ceylon is much smaller than *C. fulvus* 1 from Thailand. One reason for variation in *C. fulvus* may be different strains within species which octoploid (n=40) and diploid (n=10) were found (Mehra, 1955).

Other studies concerning relationship in this group include Cope (1982) who stated that *C. aucheri*, *C. fulvus*, and *C. serrulatus* were a cluster of closely related species. Veldkamp (1999) stated that *C. serrulatus* is very similar to *C. orientalis* and is perhaps only a form of that species. Also, Phillips (1995) suggested that *C. serrulatus* belongs to the same group of species as *C. plumulosus.* These suggestions are supported by this study that all species are placed in the same clade A with strong bootstrap support in the ITS and combined analyses. However, the exactly relationship among these species still is not resolved. Thus, further studies, with other genes are needed to clarify relationships within this clade.

Clade B which comprises *C. castaneus, C. filipes, C. oliganthus* and *C. tenuiculmis* expresses as a basal clade by the *trnL-F* and combined analyses. Due to fully supported clade, thus this basal clade should be true. Yet, despite this statistical support for the molecular results, it is difficult to find any morphological synapomorphies of the whole B clade. However, three species interior to *C. tenuiculmis* have synapomorphic character of straight awn, instead of geniculate in *C. tenuiculmis*. Given that *S. bicolor*, an ougroup taxon, was both straight and geniculate awn whereas genus *Pseudosorghum*, the other outgroup taxon in ITS analysis, was only geniculate awn, therefore, it may be suggested that geniculate awn is found in ancestor of *Chrysopogon,* i.e. plesiomorphic. Biogeographically, most species distribute from Sunda Islands, New Guinea to Australia, except *C. castaneus* which endemic to India (Veldkamp, 1999 and 2000).

C. filipes and *C. oliganthus* are purposed as closely related taxa by Veldkamp (1999). This study agrees with that suggestion because these two species are sister in the same clade.

C. tenuiculmis was noticed by Veldkamp (1999) that it was very close to *C. subtilis*. These two species are morphologically quite similar and quite distinct from other SE Asian and Australian species. Their synapomorphy is a peculiar sessile spikelet with an abruptly contracted apex of the gibbose lower glume, which in some cases may become 2-awned. However, the result from our ITS analysis does not agree with that notice since these two species are placed in separate clade, *C. tenuiculmis* in clade B and *C. subtilis* in clade D_2. Biogeographically, these 2 species are distributed in East Java and Lesser Sunda Islands (Veldkamp, 1999). Also, they grow in very dry area. Then, it is possible that they adapt to survive in the similar circumstance.

Clade C, from the ITS data, comprises 3 species: *C. zizanioides, C. festucoides* and *C. nigritanus*. Synapomorphic characters of this group are many sessile spikelets (up to 14) per raceme and square shape of callus (Clayton, Harman and Williamson, 2008). From full data of the ITS analysis, 2 subclades are resolved with weak bootstrap support (52%). *C. nigritanus* and *C. zizanioides* are separated in different subclades, while *C. festucoides* accessions are dispersed on both subclades. Biogeographically, *C. festucoides* and *C. zizanioides* distribute in Indian subcontinent to Indo-China, while *C. nigritanus* native to Africa (Veldkamp, 1999). It is noted that, if excluding *C. festucoides* 1, their distribution and placement in the ITS tree are concordant. The position of *C. festucoides* 1, a type specimen from Philippines, clustered with African clade of *C. nigritanus* is unexpected by distribution. However, morphologically, it is not surprised because these 2 species are very close taxa (Veldkamp, 1999). The disparate position of accessions in one species may be due to the widespread distribution of each species with significant local differentiation.

Not only *C. nigritanus*, but *C. festucoides* is also considered to be close to *C. zizanioides.* Zuloaga et al. (2003) treated *C. festucoides* as a synonym of *C. zizanioides*. Because of the resolution of *C. festucoides* is unclear by this phylogenetic analysis, then, it is better to keep them separately. However, more specimens represent all distribution and other gene regions should be studied to clarify its exact position in phylogeny.

Clade D_1 and D_2 were resolved as a sister clade to each other with poor bootstrap support. Shared character of these 2 subclades is few sessile spikelets per raceme. However, high bootstrap supports are found in both separated clades.

Clade D_1 comprises 3 species in ITS analysis: *C. sylvaticus, C. elongatus* and *C. micrantherus* with moderate bootstrap support (71%). Then, this clade may be real. Biogeographically, this clade distributes from Papua New Guinea to Australia.

Clade D_2 comprises 2 species in ITS analysis: *C. nemoralis* and *C. subtilis* with strong bootstrap support (96%). Then this clade should be reliable. Biogeographically, this clade distributes from Indo-China to Australia.

As mentioned by Velkamp (1999), *C. micrantherus* was proposed as the most similar taxa to *C. filipes*. However, present study does not agree with that suggestion because both species are placed in different clades. Conversely, this study shows that *C. elongatus* is close to *C. micrantherus* because they form a sister species to each other with high bootstrap support (96% in ITS and 100% in combined data). In addition, only 1 base pair from ITS sequence and 1 base pair from *trnL-F* are different between these 2 species. Therefore, it is suitable to include them into one species under the name *Chrysopogon elongatus* (R. Br.) Benth by this study.

Clade E comprises 3 specimens from *C. gryllus*: *C. gryllus* subsp. *gryllus*, *C. gryllus* subsp. *echinulatus* and *C. gryllus* from Thailand. It is formed with strong bootstrap support both in ITS (96%) and combined (95%) analyses. Then, this clade should be reliable. Morphologically, *C. gryllus* subsp. *gryllus* has one sessile spikelet per raceme, while there are 2-3(-5) sessile spikelets per raceme in *C. gryllus* subsp. *echinulatus*. For specimen from Thailand, it is resolved as a basal lineage. It mostly has one sessile spikelet, rarely 2 sessile spikelets per raceme. Therefore, Thai specimen should be identified as *C. gryllus* subsp. *gryllus* and may be regarded as an intermediate form of *C. gryllus* subsp. *gryllus* and *C. gryllus* subsp. *echinulatus*.

Biogeographically, *C. gryllus* subsp. *gryllus* is a species with a remarkably disjunct distribution. In the west part of its range it is centered mainly on the Mediterranean region and southeast Europe, extending eastwards to northern Iraq and the Caucasus Moutains. There is then a gap of nearly 5000 km before an eastern, morphologically indistinguishable population is found in Assam, with a few plants having been collected further west in Nepal and Simla region (Cope, 1980). Later, extended distribution in eastern part is reported from Yunnan, China (United States Department of Agriculture, 2003) and Thailand by This study. The distribution pattern shows that dispersal must have happened at least before the Miocene, after which the Himalaya Mountains would have been a barrier to migration.

For *C. gryllus* subsp. *echinulatus*, its distribution range is in between of those two centers of *C. gryllus* subsp. *gryllus*. It occurs from north eastern part of Afghanistan eastwards through northern Pakistan and Kashmir, and along the Himalayas to central Nepal. From combined analysis, *C. gryllys* subsp. *gryllus* is resolved as a basal lineage, and then, *C. gryllus* subsp. *echinulatus* is descendant from *C. gryllys* subsp. *gryllus*. As biogeography mentioned above, it reveals that *C. gryllus* subsp. *echinulatus* originate at Himalaya range after Himalaya formation.

Clade F comprises *C. aciculatus, C. latifolius, C. setifolius, C. fallax and C. pallidus* for full data in the ITS analysis and excluding *C. setifolius* in the combined data. Because of fully supported clade, so this clade should be real. *C. aciculatus* is resolved as a basal lineage with distinct characters of creeping rhizome and straight awn, while rhizome short and geniculate awn in the rest taxa of clade F. It is possible that the most recent ancestor of this clade is diverged into 2 directions of different lineages as mentioned. Geographically, as suggested by previous documents, the origin of *C. aciculatus* was uncertain. Drakensteijn (1693) stated as South India, while Rumphius (1750) mentioned for Ambon, Indonesia, whereas Jansen, Westphal and Kartasubrata (1992) expressed as tropical Asia, Australia and Polynesia. However, from the ITS tree, *C. aciculatus* is grouped with other four species: *C. latifolius, C. setifolius, C. fallax and C. fallidus*, which endemic to Australia with 100% bootstrap support. This is suggested that origin of *C. aciculatus* should be in Australia. It can be hypothesized that the wide spread of *C. aciculatus* now because of its callus which can hook with feather or hairs and then promote it to long disperse.

C. fallax and *C. pallidus* were closely related taxa as proposed by Black (1943). This suggestion is confirmed here by sister taxa of relationship, although it is not resolved with strong bootstrap support.

Clade G comprises only one species of *C. pauciflorus*. Morphologically, it has different characters from the rest in the genus including annual, very long awn, and much reduced pedicelled spikelet. Geographically, this species is endemic to Cuba and Florida, whereas the rest distribute in Africa, Asia and Australia. Then these reasons may cause it to be unique and construct a separate clade.

This species was established in 1878 by Chapman as *Sorghum pauciflorum* Chapm. It means this species has some characters close to *Sorghum*. However, present study confirms that this species is grouped in *Chrysopogon* by combined analysis.

Unstable taxa. Causes of conflict between topology

Mostly, topologies recovered from the separate ITS and *trnL-F* analyses are congruent. If considering in composition of each clade, the members which found in the ITS tree also are found in the same clade of the *trnL-F* tree. However, this is except for *C. fulvibarbis* which its placement in the ITS and the *trnL-F* trees is different. In the ITS tree, *C. fulvibarbis* is placed in clade A with 95% bootstrap support (without *C. zeylanicus*), while it is resolved as a trichotomy to *C. zizanioides* and *C. gryllus* subsp. *gryllus* with 98% bootstrap support in the *trnL-F* tree. One explanation could be that this species is of hybrid origin. From *trnL-F* analysis, *C. gryllus* subsp. *gryllus* is expressed as a maternal donor for *C. fulvibarbis*, while a species in clade A, from ITS analysis, is expressed as a paternal donor. Because *C. gryllus* subsp. *gryllus* and a species of clade A contain only one sessile spikelet per raceme, then *C. fulvibarbis* should bear only one sessile spikelet as well. However, this does not agree with morphology of *C. fulvibarbis* because it contains many sessile spikelets per raceme. The *C. fulvibarbis* character is similar to those in *C. zizanioides* or even *C. nigritanus* which endemic to Africa. It may further explain that hybrid ancestor of *C. fulvibarbis* maybe adapted their form to survive in the same habitat with *C. zizanioides* or either closely related species *C. nigritanus* because these 3 species inhabit by river bank. Interestingly, *C. gryllus* subsp. *gryllus*, now, distributes from southeast Europe, extending eastwards to northern Iraq, the Caucasus Moutains, Himalayas to China and Thailand, but it is not present in Africa. This is likely that *C. gryllus* subsp. *gryllus* was present in Africa in the past, but it was later extinct.

Biogeographical considerations

Some insights about biogeographical patterns shown by the studied group can be concluded from combined analysis. Considering to distribution, major areas of distribution are Australia, Malesia, Indochina, South Asia, Africa and America. This pattern suggests that widespread distribution of *Chrysopogon* is due to long-distance dispersal.

Regarding to the basal B clade, *C. oliganthus* and *C. filipes* are endemic to Australian continent (Papua New Guinea and Australia), while *C. tenuiculmis* is endemic to Lesser Sunda Island as well as *C. castaneus* is endemic to India. In addition, the clade D_1 is endemic to Australian continent and the clade F distributes from Australia to Asia. While clades A, C, D_2 and E distribute in South-East Asia to South China, India, East Europe to Africa, of which, Asia is center of diversity for the genus. This suggests the origin of *Chrysopogon* might be Australian continent and then disperses to other parts of Asia, east of Europe and extending to Africa and America.

CHAPTER IV

ANATOMICAL STUDY

4.1 Introduction

The anatomical characters of grass leaves have been studied and used as the systematiclly informative for more than a century by various investigators. Duval-Jouve (1875), from his work on bulliform cells of various tribes, first suggested the value of leaf anatomy as an aid to grass classification.

Later, anatomical investigations reveal that the leaf epidermis and internal structure of grass roots, stems and leaves as well as the anatomy structure of embryo are useful in characterizing the major taxa within the family. For example, Prat (1936, 1948, and 1960) used silica cells and epidermal hairs to divide the grasses into three groups: panicoids, with dumbbell or cross-shaped silica cells and long bicellular hairs; chloridoids, with saddle-shaped silica cells and short bicellular hairs; and festucoids, with round cilica cells and no bicellular or cushion hairs. Brown (1958) reviewed the works of others on grass leaf anatomy and also his own studies on the mestome, parenchyma sheath, and chlorenchyma, and established six sub-groups in Poaceae including bambusoids, festucoids, arundoids, panicoids, aristidoids, and chloridoids. Significantly, the delimitation of subfamily is now firmly based upon differences in leaf anatomy. According to Clayton and Renvoize (1986), Poaceae was divided into 6 subfamilies: Arundinoideae, Bambusoideae, Centothecoideae, Chloridoideae, Panicoideae and Pooideae, based on cross section of leaf blade.

Besides major taxa, the anatomical studies of leaves can elucidate relationships among members of lower taxa of grasses. Morrone et al. (2001) investigated leaf anatomy of the genus *Arthropogon* Nees and found that a new genus, *Canastra* Morrone, Zuloaga, Davidse & Filgueiras, can be segregated from the old *Arthropogon*. Ma, Peng and Li (2005) stated that leaf anatomy is taxonomic significance as evidence to support the genus *Aniselytron* against *Calamagrostis* s.l. Moreover, Silva and Alquini (2003) could distinguish between the species *Axonopus scoparius* (Flügge) Kuhlm. and *A. fissifolius* (Raddi) Kuhlm. by leaf anatomy. Herrera-Arrieta and Grant (1994) studied leaf anatomy of *Muhlenbergia Montana* complex and recognized a close relationship between the two taxa, *M. virescens* and *M. quadridentata*. Consequently, a change of rank was suggested in which *M. quadridentata* (H.B.K.) Kunth was proposed as *M. virescens* (H.B.K.) Kunth ssp. *quadridentata* (H.B.K.) Herrera (comb. nov.)

As mentioned above, it is shown that leaf anatomy has proved to be a good tool for grass systematics. In the contrary, culm anatomy of grasses has been little explored for classification. In *Dasyochoa*, *Blepharidachne* and *Munroa*, however, culm anatomy has shown usefulness to distinguish groups at subfamilial or tribal rank (Sánchez, 1983a, 1983b, 1984, cited in Siqueiros-Delgado, 2007). Siqueiros-Delgado (2007) examined culm anatomy of subtribe Boutelouineae and pointed out that some culm anatomical characters are useful for inferring relationships at generic level. So, it is evident that anatomical approach can be used for grass classification at all taxonomic ranks.

So far, in subtribe Sorghinae, 8 species in 5 genera were studied in leave and culm cross section as well as abaxial epidermis by Metcalfe (1960). Moreover, study in leaf epidermis of *Vetiveria zizanioides* was performed by Chaudhary, Mumtaz and Khan (2001). However, the remaining taxa found in Thailand have never been done.

Therefore, it is of interest to investigate anatomical characters of leaves and culms of subtribe Sorghinae in Thailand.

4.2 Materials and Methods

Plant Materials: living plants and herbarium specimens used in anatomical studies were listed in Table 4.1. In total, 21 species in 7 genera were examined.

Methods: For leaf epidermal study, abaxial and adaxial epidermal peels of leaf blades were prepared by applying nail polish on epidermis, then, allowed nail polish to be dry. Then, leaf tissue beneath nail-polish painted epidermis was removed using a scalpel. Leaf tissue was mounted for temporary slides. Light microscope was used to photograph. Leaf epidermis in some taxa were studied by scanning electron microscope (SEM), especially adaxial epidermis since it was difficult to obtain epidermis replica by applying nail polish.

For leaf cross section, middle points of mature leaves were cut by Automatic MT-3 microtome (Toyozumi Dengenkiki Co., Ltd.) at 6 µm thickness. Then the sections were stained by safranin-O and mounted for temporary slides. Light microscope was used to photograph.

For culm cross section, middle points of internode were cut by Automatic MT-3 microtome (Toyozumi Dengenkiki Co., Ltd.) at 7 µm thickness. Then the sections were stained in safranin-O and mounted on slide. Light microscope was used to photograph.

Anatomical description was mainly followed those of Metcalfe (1960) and some to those of Ellis (1976).

Table 4.1 Taxa of Subtribe Sorghinae used in anatomical investigation.

Species	Collector	Locallity	Herbarium
Bothriochloa bladhii (Retz.) S. T. Blake	O. Neamsuvan 251	Nam Nao National Park, Petchabun	BCU
	O. Neamsuvan 206	Chumphon	BCU
	O. Neamsuvan 257	Phuluang National Park, Loei	BCU
Bothriochloa pertusa (L.) A. Camus	O. Neamsuvan 235	Kasetsart University, Nakhon Pathom	BCU
	O. Neamsuvan 172	Chumphon	BCU
Capillipedium assimile (Steud.) A. Camus	O. Neamsuvan 255	Phukradueng National Park, Loei	BCU
	O. Neamsuvan 242	Phu Chi Fa, Chiang Rai	BCU
Capillipedium laoticum A. Camus	O. Neamsuvan 269	Huay Kha Kheng, Uthai Thani	BCU
Capillipedium parviflorum (R. Br.) Stapf	O. Neamsuvan 222	Doi Chang, Chiang Mai	BCU
	O. Neamsuvan 249	Nam Nao National Park, Petchabun	BCU
Capillipedium sulcatum Bor	O. Neamsuvan 192	Phukradueng National Park, Loei	BCU
Chrysopogon aciculatus (Retz.) Trin.	O. Neamsuvan 161	Chumphon	BCU
	O. Neamsuvan 211	Phu Phan National Park, Sakon Nakhon	BCU
Chrysopogon fulvus Spreng) Choiv.	O. Neamsuvan 241	Huay Kha Kheng, Uthai Thani	BCU

Table 4.1 (Continued)

Species	Collector	Locallity	Herbarium
Chrysopogon gryllus (L.) Trin. subsp. *gryllus*	O. Neamsuvan 165	Phu Chi Fa, Chiang Rai	BCU
	O. Neamsuvan 261	Phu Luang National Park, Loei	BCU
	O. Petrmitr 331	Doi Luang National Park, Lampang	CMU
Chrysopogon lawsonii (Hook.f.) Veldk.	C. Phengklai and T. Smitinand 6085	Inthanon, Chiang Mai	BKF
	Noi Mao s.n.	Chiang Mai	BKF
Chrysopogon orientalis (Desv.) A. Camus	O. Neamsuvan 213	Phu Khiew, Chaiyaphum	BCU
	O. Neamsuvan 252	Nam Nao National Park, Petchabun	BCU
	O. Neamsuvan 238	Sichang, Chon Buri	BCU
Chrysopogon serrulatus Trin.	O. Neamsuvan 243	Sa Med island, Rayong	BCU
	O. Neamsuvan 244	Pha Taem National Park, Ubon Ratchathani	BCU
	J.F. Maxwell 04-751	Lamphun	CMU
Chrysopogon zizanioides (L.) Roberty	O. Neamsuvan 247	Sam Lan Waterfall, Saraburi	BCU
Dichanthium annulatum (Forssk.) Stapf	O. Neamsuvan 233	Kasetsart University, Nakhon Pathom	BCU
	O. Neamsuvan 188	Chiang Dao, Chiang Mai	BCU
Dichanthium aristatum (Poir.) C.E. Hubb.	O. Neamsuvan 265	Khao Yai National Park, Nakhon Ratchasima	BCU
Dichanthium caricosum (L.) A. Camus 1	O. Neamsuvan 253	Nam Nao National Park, Petchabun	BCU
Dichanthium caricosum (L.) A. Camus	O. Neamsuvan 234	Kasetsart University, Nakhon Pathom	BCU
	O. Neamsuvan 267	Chiang Rai	BCU
Hemisorghum mekongense (A. Camus) C. E. Hubb.	O. Neamsuvan 262	by Me Khong river, Nong Khai	BCU
Pseudosorghum fasciculare (Roxb.) A. Camus	O. Neamsuvan 271	Lom Kao, Petchabun	BCU
	S. Gardner G22	Doi Chiang Dao, Chiang Mai	CMU
Sorghum bicolor (L.) Moench	O. Neamsuvan 246	Bo Ploi, Kanchanaburi	BCU
Sorghum nitidum (Vahl) pers.	O. Neamsuvan 259	Phu Luang, Loei	BCU
	O. Neamsuvan 245	Bo Ploi, Kanchanaburi	BCU
	O. Neamsuvan 250	Nam Nao National Park, Petchabun	BCU
Sorghum propinqumm (Kunth) Hitchc. var. *siamense* (Piper) Snowden	O. Neamsuvan 239	Yommaratch, Bangkok	BCU

Remarks: BCU = Kasin Suvatabhandhu Herbarium, Department of Botany, Chulalongkorn University; BKF = The Forest Herbarium, Royal Forest Department; CMU = The herbarium, Department of Biology, Chiang Mai University.

4.3 Results

The leaf anatomy of 7 genera and 21 species representing subtribe Sorghinae in Thailand was investigated. The variation of the leaf structures in the upper epidemis, lower epidermis and transverse sections as well as culm in transverse section are described as follows:

KEY TO THE GENERA

1. Short-cells over costal zones solitary or paired, alternate with long-cells, bulliform cells not clearly developed where far from midrib ………………... **3. *Chrysopogon***
1. Short-cells over costal zones in 1-3 rows, bulliform cells clearly developed
  2. Prickle-hairs absent ……………………………...…………… **5. *Hemisorghum***
  2. Prickle-hairs present on either upper or lower surface
    3. Stomata at upper epidermis absent
      4. Papillae consist of 2 types: small globose and slightly large oblique ………… …………………………………………………….………….. ***2. Capillipedium***
      4. Papillae consist of 1 types: various-sized globose …..….. **6. *Pseudosorghum***
    3. Stomata at upper epidermis present
      5. Vascular bundle scattered throughout the culm ………………… **7. *Sorghum***
      5. Vascular bundle in 3 more or less distinct circles near epidermis of culm
        6. Micro-hairs with short basal cells at upper epidermis ……. **1. *Bothriochloa***
        6. Micro-hairs with equal or long basal cells at upper epidermis …………… ……………………………………………………………. **4. *Dichanthium***

1. BOTHRIOCHLOA

Leaf epidermis: upper and lower epidermis mostly similar, except bulliform cells present at upper epidermis. Short-cells, mostly in rows over the veins. Silica-bodies intermediate between cross and dumb-bell shaped, or nodular over the veins. Micro-hairs present, the distal cell tapering to a pointed apex. Papillae present or absent. Stomata with triangular or low dome-shaped subsidiary cells. **Leaf in transverse section**: Mesophyll with chlorenchyma markedly radiate. Vascular bundles: 3 types: first-ordered vascular bundle, second-ordered vascular bundle and third order-vascular bundle. Bundle sheaths single. Leaf margin accompanied by sclerenchyma. **Culm in transverse section**: round, flattened to concave on one side.

Key to the species

1. Papillae absent at adaxial epidermis, 3 first-ordered vascular bundles in keel .... **1) *B. bladhii***
1. Papillae present at adaxial epidermis, 1 first-ordered vascular bundle in keel .... **2) *B. pertusa***

1) *Bothriochloa bladhii* (Retz.) S.T.Blake

Leaf epidermis

Adaxial epidermis (Figure 4.1 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-5 cell rows. Long-cells rectangular, thin and sinuous wall, 32.5-112.5 by 17.5-25 µm. Short-cells abundant, in 1-3 rows but mostly 1 row, some solitary or paired alternate with costal long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shaped, few nodular. Prickle-hairs common, prickle, 50-67.5 µm long. **Intercostal zone**: 13-27 cell rows. Long-cells rectangular, thick and sinuous wall, 50-100 by 22.5-25 µm. Interstomatal cells 35-87.5 by 25-32.5 µm, concave ends. Bulliform cells thin wall, 2-5 rows, 22.5-100 by 17.5-30 µm. Short-cells sparsely, solitary or paired, alternate with long-cells. Silica-bodies cross-shaped and tall, narrow and crenate shape. Macro-hairs rarely, c. 1400 µm long. Micro-hairs sparsely, length 27.5-62.5 µm, basal cells 20-27.5 µm, distal cells 25-37.5 µm. Prickle-hairs common, hook, 17.5-22.5 µm. Stomata 3-5 rows, 25-27.5 µm long, subsidiary cells triangular.

Abaxial epidermis (Figure 4.1 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-5 cell rows. Long-cells rectangular, thin and sinuous wall, 25-142.5 by 10-17.5 µm. Short-cells abundant, 1-3 rows but mostly 1 row. Silica-bodies mostly intermediate between cross and dumb-bell shape. Papillae sparsely to common; many, globose, small cuticular papillae on each long-cell. **Intercostal zone**: 7-15 cell rows. Long-cells rectangular, thick and sinuous wall, 425.-137.5 by 10-15 µm, Interstomatal cells 20-37.5 by 37.5-60 µm, concave ends, Short-cells common, solitary or paired, alternate with long-cells, Silica-bodies mostly cross-shaped, few tall, narrow and crenate shape. Micro-hairs common, length 55-67.5 µm, basal cells 30-37.5 µm, distal cells 25-32.5 µm; Prickle-hairs sparsely, small prickle, 22.5-32.5 µm long. Papillae sparsely to common; globose, small cuticular papillae on each long-cell; also an oblique, slightly large papillae on each interstomatal cell. Stomata 2-4 rows, 22.5-27.5 µm long, subsidiary cells triangular.

Leaf in transverse section (Figure 4.1 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth; bulliform cells mostly in irregular group, few in fan-shaped group, associated with round or inflated medium size of colourless cells. **Abaxial epidermis** smooth, associated with few and small colourless cells. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, second and third-ordered vascular bundles with completely radiate. **Keel** conspicuous, rounded, containing 3 first-ordered vascular bundles accompanied among them by 2-4 third-ordered vascular bundles which centered by 1 second-ordered vascular bundle, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 16-18 in entire blade; second-ordered vascular bundles medium, round or elliptic, usually 3 between each pair of first-ordered vascular bundles; third-ordered vascular bundles small, angular, at least pentagonal in outline, mostly 1 rarely 2-3 between each pair of second-ordered vascular bundles. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially, second and third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 4-12 cells wide and 2-4 cells high; second-ordered vascular bundle with small abaxial strand or both adaxial and abaxial strands or girdes, the strands or girders sometime consisting of only a few cells; third-ordered vascular bundle not accompanied by sclerenchyma; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 10-30 cells wide and 8-10 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 2-3 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in transverse section (Figure 4.1 H.)

Outline round, concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of about 10 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** mostly round, some elliptic; in 3 more or less distinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

2) *Bothriochloa pertusa* (L.) A. Camus

Leaf epidermis

Adaxial epidermis (Figure 4.2 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-9 cell rows. Long-cells rectangular, thin and sinuous wall, 50-192.5 by 7.5-12.5 µm. Short-cells abundant, in 1-3 rows but mostly 1 row. Silica-bodies mostly dumb-bell shaped, some nodular. Prickle-hairs common, prickle, 45-75 µm long. **Intercostal zone**: 6-18 cell rows. Long-cells rectangular, thick and sinuous wall, 60-92.5 by 10-12.5 µm. interstomatal cells 67.5-107.5 by 20-22.5 µm, concave ends. Bulliform cells thin wall, 1-3 rows, 25-50 by 12.5-22.5 µm. Short-cells sparsely, some solitary and few paired, alternate with long-cells. Silica-bodies mostly cross-shaped and few tall, narrow and crenate shape. Macro-hairs common, 125-462 µm long. Micro-hairs common, length 42.5-75 µm, basal cells 17.5-20 µm, distal cells 25-27.5 µm. Prickle-hairs common, hook, 22.5-32.5 µm long. Stomata 1-3 rows, mostly 1 row, 22.5-25 µm long, subsidiary cells low dome-shaped.

Abaxial epidermis (Figure 4.2 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-6 cell rows. Long-cells rectangular, thin and sinuous wall, 67.5-190 by 7.5-15 µm. Short-cells abundant, 1-2 rows. Silica-bodies dumb-bell shaped and nodular. Papillae densely; many, globose, small cuticular papillae on each long-cell. **Intercostal zone**: 6-7 cell rows. Long-cells rectangular, thick and sinuous wall, 45-112.5 by 7.5-17.5 µm. Interstomatal cells 55-82.5 by 20-25 µm, concave ends. Short-cells some solitary and sparsely paired, alternate with intercostal long-cells. Silica-bodies mostly cross-shaped, few tall and narrow and crenate shape. Macro-hairs sparsely, 200-437 µm long. Micro-hairs common, length 37.5-47.5 µm, basal cells 17.5-20 µm, distal cells 22.5-27.5 µm. Prickle-hairs common, hook, 17.5-30 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell; also an oblique, slightly large papillae on each interstomatal cell. Stomata 1-6 rows, mostly 2 rows, 25-27.5 µm long, subsidiary cells low dome-shaped.

Leaf in transverse section (Figure 4.2 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth; bulliform cells mostly in irregular group, few in fan-shaped group, associated with few and small colourless cells **Abaxial epidermis** smooth, papillose, associated with few and small colourless cells. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, second and third-ordered vascular bundles with completely radiate. **Keel** conspicuous, rounded, containing 1 median first-ordered vascular bundle accompanied on either side by 4-7 second-and third-ordered vascular bundles, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, c. 9 in entire blade; second-ordered vascular bundles medium, round, usually 3 between each pair of first-ordered vascular bundles; third-ordered vascular bundle small, angular, at least tetragonal in outline, 1 rarely 2 between each pair of second-ordered vascular bundles. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially, second and third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 3-10 cells wide and 2-3 cells high; second-ordered vascular bundles with small abaxial or both adaxial and abaxial strands, the strands sometime consisting of only a few cells; third-ordered vascular bundles not accompanied by sclerenchyma; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 6-25 cells wide and 5-6 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 2-3 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in transverse section (Figure 4.2 H.)

Outline round, flattened to slightly concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre tending to break down, outer ground tissue composed of about 7-8 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** mostly round, some elliptic; in 3 more or less distinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

2. CAPILLIPEDIUM

Leaf epidermis: upper and lower epidermis mostly similar, except bulliform cells present and stomata absent at upper epidermis. Short-cells solitary, paired or in rows. Silica-bodies distinct on costal zone, silicified or not silicified on intercostal zone; intermediate between cross and dumb-bell shaped, nodular. Micro-hairs present. **Leaf in transverse section**: Mesophyll with radiate chlorenchyma. Vascular bundles: 3 types: first-ordered vascular bundle, second-ordered vascular bundle and third order-vascular bundle. Bundle sheath single. Leaf margin accompanied by sclerechyma. **Culm in transverse section**: round, flattened or concave on one side.

Key to the species

1. Vascular bundle in culm scaterred ……………………………..…...……. **1)** ***C. assimile***
1. Vascular bundle in culm 3 more or less indistinct circles near epidermis
    2. Sclerenchyma at leaf margin relatively small, crescent-shaped cap …………………………………………..………………..……….. **2)** ***C. laoticum***
    2. Sclerenchyma at leaf margin well-developed and pointed cap
        3. Interstomatal cells 22.5-35 µm; bearing an oblique, slightly large papillae on each interstomatal cell …………………………….………….... **3)** ***C. parviflorum***
        3. Interstomatal cells 37.5-62.5 µm; bearing mostly 2-3, rarely 1, globose or oblique papillaeon each interstomatal cell …………………… **4)** ***C. sulcatum***

1) ***Capillipedium assimile*** **(Steud.) A. Camus**

Leaf epidermis

Adaxial epidermis (Figure 4.3 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3 cell rows. Long-cells rectangular, thin and sinuous wall, 87.5-132.5 by 10-15 µm. Short-cells abundant, in a row on all costal zones. Silica-bodies mostly intermediate between cross and dumb-bell shaped, some nodular. Prickle-hairs common, large prickle, 112.5-125 µm long. Macro-hairs abundant, 220-300 µm long, swollen base. Papillae densely; many, globose, small cuticular papillae on each long-cell. **Intercostal zone**: 5-7 cell rows. Long-cells rectangular, thick and sinuous wall, 62.5-112.5 by 17.5-20 µm. Bulliform cells thin wall, 1-5 rows, 50-107.5 by 10-25 µm. Short-cells sparsely, paired, alternate with intercostal long-cell. Silica-bodies cross-shaped. Micro-hairs scanty, length 35-45 µm, basal cells 22.5-27.5 µm, distal cells 17.5-20 µm, distal cell tapering to a pointed apex. Prickle-hairs common, hook, 20-30 µm long. Papillae common to densely; many, globose, small, cuticular papillae on each long-cell.

Abaxial epidermis (Figure 4.3 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3 cell rows. Long-cells rectangular, thin and sinuous wall, 100-152.5 by 10-15 µm. Short-cells abundant in a row and few, solitary, alternate with long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shaped, some nodular. Macro-hairs abundant, 70-1100 µm, swollen base. Papillae densely; many, globose, small cuticular papillae on each long-cell. **Intercostal zone**: 3-9 cell rows. Long-cells rectangular, thick and sinuous wall, 75-157.5 by 10-15 µm. Interstomatal cells 37.5-102.5 by 15-17.5 µm, concave ends. Short-cells sparsely, solitary, alternate with intercostal long-cell. Silica-bodies nodular, tall and narrow. Micro-hairs common, length 50-60 µm, basal cells 27.5-32.5 µm, distal cells 22.5-27.5 µm, distal cell tapering to a pointed apex. Prickle-hairs common, hook, 22.5-32.5 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell; also 1-2 oblique, slightly large papillae on each interstomatal cell. Stomata 25-32.5 µm long, 1-2 rows, subsidiary cells low dome-shaped.

Leaf in Transverse section (Figure 4.3 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth with slight rib on first-ordered vascular bundle near keel; bulliform cells some in irregular groups, others in fan-shaped group, associated with round and small size of colourless cells. **Abaxial epidermis** smooth, papillose. **Mesophyll**: chlorenchyma radiate, first-orderedand second-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, third-ordered vascular bundles with completely radiate or interrupted abaxially. **Keel** conspicuous, triangular, containing 1 median first-ordered vascular bundle accompanied on either side by 3-6 second and third-ordered vascular bundles which alternately arranged, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 9-14 entire blade; second-ordered vascular bundles medium, round, 3-5 between each pair of first-ordered vascular bundles; third-ordered vascular bundles small, angular, at least tetragonal in outline; usually 1 alternately arranged with second-ordered vascular bundle. **Bundle sheaths** single; first-ordered vascular bundles with sheaths interrupted abaxially; most second-ordered vascular bundles with complete sheaths; rarely interrupted abaxially; third-ordered vascular bundle with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 3-5 cells wide and 1-2 cells high; almost second-ordered vascular bundles abaxially and adaxially accompanied by small girders, the girders consisting of 3-5 cells wide and 2 cells high; third-ordered vascular bundles mostly abaxially accompanied by small strands or girders, rarely abaxially and adaxially accompanied by small strands or girders, strands or girders consisting of 2-6 cells wide and 1-2 cells high; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 5-50 cells wide and 5-7 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1-2 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap relatively small and crescent-shaped.

Culm in transverse section (Figure 4.3 H.)

Outline round, flattened on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of about 13-15 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, scattered, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

2) *Capillipedium laoticum* A. Camus

Leaf epidermis

Adaxial epidermis (Figure 4.4 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-5 cell rows. Long-cells rectangular, thin and sinuous wall, 75-100 by 7.5-10 µm. Short-cells abundant in a row, few solitary or paired. Silica-bodies mostly intermediate between cross and dumb-bell shaped, few cross-shaped. Macro-hairs abundant, 110-300 µm. Papillae densely; many, globose, small cuticular papillae on each long-cell. **Intercostal zone**: 4-7 cell rows. Long-cells rectangular, thick and sinuous wall, 87.5-137.5 by 12.5-17.5 µm. Bulliform cells smooth and thin wall, 50-112.5 by 12.5-17.5 µm. Short-cells sparsely, solitary, alternate with long-cells. Silica-bodies not silicified over intercostal zone. Micro-hairs few, length 35-53 µm, basal cells 24-28 µm, distal cells 11-25 µm, distal cell tapering to a pointed apex. Prickle-hairs common**,** 25-50 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell.

Abaxial epidermis (Figure 4.4 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-5 cell rows. Long-cells rectangular, thin and sinuous wall, 62.5-100 by 7.5-12.5 µm. Short-cells abundant in a row. Silica-bodies mostly intermediate between cross and dumb-bell shape, few nodular or cross- shaped. Macro-hairs abundant, 75-200 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell. **Intercostal zone**: 3-5 cell rows. Long-cells rectangular, thick and sinuous wall, 70-100 by 12.5-17.5 µm. Interstomatal cells 75-112.5 by 12.5-15 µm, concave ends. Short-cells rarely, solitary, alternate with long-cells. Silica-bodies intermediate between cross and dumb-bell shaped. Macro-hairs sparsely, 50-112.5 µm long. Micro-hairs sparsely, length 28-46 µm, basal cells 14-26.5 µm, distal cells 14-19.5 µm, distal cell tapering to a pointed apex. Prickle-hairs sparsely, hook, 25-30 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell; also 1-2 oblique, slightly large papillae on each interstomatal cell. Stomata c. 24 µm long, 1-2 rows, subsidiary cells low dome-shaped.

Leaf in transverse section (Figure 4.4 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth, slightly round rib on first-ordered vascular bundle, shallow to moderate furrow over bulliform cells; bulliform cells mostly in fan-shaped group, few in irregular groups, few associated with round and small size of colourless cells. **Abaxial epidermis** smooth, papillose. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, second-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially or abaxially only, third-ordered vascular bundles with completely radiate or few interrupted abaxially. **Keel** conspicuous, triangular, containing 1 median first-ordered vascular bundle accompanied on either side by 2-3 third-ordered vascular bundles, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, c. 6 in entire blade; second-ordered vascular bundles medium, round, 4-5 between each pair of first-ordered vascular bundles; third-ordered vascular bundles small, angular, at least tetragonal in outline, usually 1 between each pair of second-ordered vascular bundles. **Bundle sheaths** single; first-ordered vascular bundles with sheaths interrupted abaxially; second-and third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 3-9 cells wide and 2-3 cells high; second-ordered vascular bundles abaxially and adaxially accompanied by small girders, the girders consisting of 5-6 cells wide and c. 2 cells high; third-ordered vascular bundles abaxially accompanied by small strands, strands consisting of 3-4 cells wide and 1 cells high; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 25-45 cells wide and c. 3 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1-2 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap relatively small and crescent-shaped.

Culm in Transverse section (Figure 4.4 H.)

Outline round, concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre tending to break down, outer ground tissue composed of about 4-6 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** elliptic to round, in 3 more or less indistinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

3) *Capillipedium parviflorum* (R. Br.) Stapf

Leaf epidermis

Adaxial epidermis (Figure 4.5 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3 cell rows. Long-cells rectangular, thin and sinuous wall, 92.5-130 by 20-22.5 µm. Short-cells abundant in 1 row, rarely in 2 rows; few, solitary and paired alternate with long-cell. Silica-bodies mostly intermediate between cross and dumb-bell shaped, some cross-shaped. Macro-hairs common, 60-140 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell. Prickle-hairs abundant, prickle, 25-50 µm long. **Intercostal zone**: 5-7 cell rows. Long-cells rectangular, thick and sinuous wall, 40-107.5 by 17.5-22.5 µm. Bulliform cells smooth and thin wall, 25-100 by 12.5-22.5 µm. Micro-hairs few, length ca. 42.5-50 µm, basal cells 25-30 µm, distal cells 17.5-20 µm, distal cell tapering to a pointed apex. Prickle-hairs abundant, hook, 25-32.5 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell.

Abaxial epidermis (Figure 4.5 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-5 cell rows. Long-cells rectangular, thin and sinuous wall, 25-52.5 by 12.5-17.5 µm. Short-cells abundant, in a row; few, solitary, alternate with long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shaped, some cross-shaped, few long and narrow shape. Macro-hairs abundant, 45-100 µm long, swollen base. **Intercostal zone**: 3-7 cell rows. Long-cells rectangular, thick and sinuous wall, 35-80 by 10-22.5 µm. Interstomatal cells 22.5-35 by 22.5-20 µm, concave ends. Short-cells few, solitary, alternate with long-cell. Silica-bodies cross-shaped. Macro-hairs rarely, 45-52.5 µm long, swollen base. Micro-hairs sparsely, length 35-45 µm, basal cells 22.5-27.5 µm, distal cells 17.5-20 µm, distal cell tapering to a pointed apex. Prickle-hairs sparsely, hook, 27.5-35 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell; also an oblique, slightly large papillae on each interstomatal cell. Stomata 22.5-27.5 µm long, 1 row, subsidiary cells low dome-shaped.

Leaf in transverse section (Figure 4.5 E.-G.)

Outline V-shaped. **Adaxial epidermis** moderately pronounced and round ribs on first-ordered vascular bundle, slight ribs on larger second-ordered vascular bundles; bulliform cells some in irregular groups, others in fan-shaped group, associated with round and small size of colourless cells. **Abaxial epidermis** smooth, papillose. **Mesophyll**: chlorenchyma radiate, first-orderedand most second-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, third-ordered vascular bundles with completely radiate or interrupted abaxially. **Keel** conspicuous, triangular, containing 1 median first-ordered vascular bundle accompanied on either side by 1-3 second and third-ordered vascular bundles which alternately arranged, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 8-12 in entire blade; second-ordered vascular bundles medium, round, 3-4 between each pair of first-ordered vascular bundles; third-ordered vascular bundles small, angular, at least pentagonal in outline, 1-2 between each pair of second-ordered vascular bundles. **Bundle sheaths** single; first-ordered vascular bundles with sheaths interrupted abaxially; most second-ordered vascular bundles with complete sheaths, rarely interrupted abaxially; third-ordered vascular bundle with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 4-8 cells wide and 2-3 cells high; second-ordered vascular bundles abaxially and adaxially accompanied by small girders, the girders consisting of 2-7 cells wide and 2-4 cells high; third-ordered vascular bundles abaxially accompanied by small strands or girders, strands or girders consisting of 2-6 cells wide and 2 cells high; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 6-25 cells wide and 5-7 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1-2 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in Transverse section (Figure 4.5 H.)

Outline round, concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, center solid, outer ground tissue composed of about 10-12 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** elliptic to round, in 3 more or less indistinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

4) *Capillipedium sulcatum* Bor

Leaf epidermis

Adaxial epidermis (Figure 4.6 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-5 cell rows. Long-cells rectangular, thin and sinuous wall, 62.5-150 by 7.5-15 µm. Short-cells abundant, in a row. Silica-bodies mostly intermediate between cross and dumb-bell shaped, rarely cross-shaped. Macro-hairs common, 17-35 µm. Prickle-hairs common, prickle, 47.5-60 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell. **Intercostal zone**: 6-9 cell rows. Long-cells rectangular, thick and sinuous wall, 75-112.5 by 10-15 µm. Bulliform cells smooth and thin wall, 37.5-87.5 by 12.5-25 µm. Short-cells few, solitary, alternate with long-cell. Silica-bodies not silicified. Micro-hairs few, length 40-54 µm, basal cells 21-31 µm, distal cells 19-23 µm, distal cell tapering to a pointed apex. Prickle-hairs common, hook, 22.5-32.5 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell.

Abaxial epidermis (Figure 4.6 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3 cell rows. Long-cells rectangular, thin and sinuous wall, 55-100 by 5-10 µm. Short-cells abundant, in a row, rarely in 2 rows, rarely solitary. Silica-bodies mostly dumb-bell shaped, rarely nodular shape. Macro-hairs abundant, 70-170 µm, swollen base. **Intercostal zone**: 3-8 cell rows. Long-cells rectangular, thick and sinuous wall, 57.5-87.5 by 10-12.5 µm. Interstomatal cells 37.5-62.5 by 12.5-5 µm, concave ends. Short-cells rarely. Micro-hairs scanty, length 36-44 µm, basal cells 19-22 µm, distal cells 17-22 µm, distal cell tapering to a pointed apex. Prickle-hairs scanty, hook, 20-30 µm long. Papillae densely; many, globose, small cuticular papillae on each long-cell; also 2-3, rarely 1, larger, globose or oblique papillae on each interstomatal cell. Stomata c. 20 µm long, 1 row, subsidiary cells low dome-shaped.

Leaf in transverse section (Figure 4.6 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth; bulliform cells mostly in fan-shaped groups, few in irregular groups, associated with round and small size of colourless cells. **Abaxial epidermis** smooth, papillose. **Mesophyll**: chlorenchyma radiate, first-orderedand most second-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, third-ordered vascular bundles with completely radiate or interrupted abaxially. **Keel** conspicuous, triangular, containing 1 median first-ordered vascular bundle accompanied on either side by 1 second- and 1 third-ordered vascular bundles, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, c. 9 in entire blade; second-ordered vascular bundles medium, round, 8-9 between each pair of first-ordered vascular bundles; third-ordered vascular bundles small, angular, at least tetragonal in outline, usually 1 between each pair of second-ordered vascular bundles. **Bundle sheaths** single; first-ordered vascular bundles with sheaths interrupted abaxially; second- and third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 4-5 cells wide and c. 2 cells high; second-ordered vascular bundles abaxially and adaxially accompanied by small girders, the girders consisting of 2-5 cells wide and c. 2 cells high; third-ordered vascular bundles abaxially accompanied by small strands or girders, strands or girders consisting of 2-4 cells wide and 1 cells high; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 32-46 cells wide and 5-6 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 2-3 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in Transverse section (Figure 4.6 H.)

Outline round, concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of about 5-7 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, in 3 more or less indistinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

3. CHRYSOPOGON

Leaf epidermis: lower and upper epidermis mostly similar. Short-cells, over the vein, mostly single. Silica-bodies, over the veins, mostly cross-shaped. Micro-hairs present, the distal cell tapering to a rounded or pointed apex. Stomata with triangular or low dome-shaped subsidiary cells. **Leaf in transverse section**: Mesophyll with radiate chlorenchyma. Vascular bundles: 3 types: first-ordered vascular bundle, second-ordered vascular bundle and third order-vascular bundle. Bundle sheaths single. Leaf margin accompanied by sclerechyma. **Culm in transverse section**: round, or elliptic, flattened or concave on one side.

Key to the species

1\. Keel round, silica-bodies mostly intermediate between cross and dumb-bell shaped at costal zones .... **1)** ***C. aciculatus***
1\. Keel triangular, silica-bodies cross-shaped at costal zones
  2. First-ordered vascular bundle in keel 1
    3. Mesophyll containing air cavity ……………………….……… **7) *C. zizanioides***
    3. Mesophyll solid
      4. Macro-hairs at adaxial surface absent …………………….. **6) *C. serrulatus***
      4. Macro-hairs at adaxial surface present
        5. sclerenchyma at leaf margin well-developed ……….…. **4) *C. lawsonii***
        5. sclerenchyma at leaf margin relatively small ………….. **5) *C. orientalis***
  2. First-ordered vascular bundle in keel 3-5
      6. First-ordered vascular bundle in keel 3, vascular bundle in 3 more or less indistinct circles near epidermis ………………………………. **2) *C. fulvus***
      6. First-ordered vascular bundle in keel 5, vascular bundle scattered throughout the culm ………………………….. **3) *C. gryllus* subsp. *gryllus***

1) *Chrysopogon aciculatus* (Retz.) Trin.

Leaf epidermis

Adaxial epidermis (Figure 4.7 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-9 cell rows. Long-cells rectangular, thin and sinuous walls, 35-80 by 7.5 µm. Short-cells common, solitary, alternate with long-cells. Silica-bodies cross-shaped. **Intercostal zone**: 16-20 cell rows. Long-cells rectangular, thick and sinuous walls. Interstomatal cells with concave ends. Bulliform cells thin and smooth wall, 2-3 rows, 25-55 µm long. Silica-bodies mostly intermediate between cross and dumb-bell shaped, few cross-shaped. Micro-hairs common, length 40-55 µm, basal cell 10-17.5 µm, distal cell 30-37.5 µm, distal cell tapering to a rounded apex. Prickle-hairs common, hook, 12.5-22 µm long. Stomata in 1-2 rows, with low dome-shaped subsidiary cells.

Abaxial epidermis (Figure 4.7 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-7 cell rows. Long-cells rectangular, thin and sinuous wall, 30-100 by 7.5-12.5 µm. Short-cells abundant, solitary or paired, alternate with long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shaped, few cross-shaped. **Intercostal zone**: 31-37 cell rows. Long-cells rectangular, thick and sinuous walls, 75-150 by 12.5-20 µm. Interstomatal cells concave ends. Short-cells common, solitary or paired, alternate with long-cells. Silica-bodies cross-shaped. Micro-hairs common, length 41.25-47.5 µm, basal cell 10-12.5 µm long, distal cell 31.25-35 µm long, distal cell tapering to a rounded or pointed apex. Prickle-hairs common, hook, c. 17.5 µm long. Stomata in a single row, subsidiary cells low dome-shaped.

Leaf in Transverse section (Figure 4.7 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth; bulliform cells mostly in irregular groups, few in fan-shaped group, associated with round or inflated small or large size of colourless cells, bulliform cells not developed near margin. **Abaxial epidermis** smooth, associated with round and small size of colourless cells. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, a few second-ordered vascular bundles with chlorenchyma interrupted abaxially; third-ordered vascular bundles with completely radiate. **Keel** conspicuous, round, containing 1 median first-ordered vascular bundle accompanied on either side by 1 second-ordered vascular bundle and 3-4 third-ordered vascular bundles, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, elliptic or round, 9-10 in entire blade; second-ordered vascular bundles not clearly developed, rarely 1 between each pair of first-ordered vascular bundles; third-ordered vascular bundle small, angular, at least tetragonal in outline, 7-10 between each pair of first-ordered vascular bundles. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially and adaxially, second-or third-ordered vascular bundles with complete sheaths, a few second-ordered vascular bundle with sheaths interrupted abaxially. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 7-13 cells wide and 3-4 cells high, second-or third-ordered vascular bundle not accompanied by sclerenchyma cells; midrib: keel bundles with well-marked abaxially girders or strands only, median first-ordered vascular bundles abaxially accompanied by large girders of 7-20 cells wide and 8 cells high sclerenchyma, few third-ordered vascular bundles abaxially accompanied by small strands or girders of few cells; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in Transverse section (Figure 4.7 H.)

Outline round, concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre tending to break down, outer ground tissue composed of about 7-9 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, in 3 more or less indistinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

2) *Chrysopogon fulvus* (Spreng) Choiv.

Leaf epidermis

Adaxial epidermis (Figure 4.8 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 2-5 cell rows. Long-cells rectangular, thin and sinuous wall, 100-187.5 µm by 22.5-27.5 µm. Short-cells abundant, mostly solitary, few paired, alternate with long-cells. Silica-bodies cross-shaped. Prickle-hairs common, hook, 32.5-40 µm long. **Intercostal zone**: 12-15 cell rows. Long-cells rectangular, thick and sinuous walls, 125-275 by 25-30 µm. Bulliform cells thin and smooth wall, 2-6 rows, 37.5-112.5 by 20-37.5 µm. Short-cells abundant, mostly solitary, few paired, alternate with long-cells. Silica-bodies cross-shaped. Micro-hairs common, length 75-85 µm, basal cells 37.5-42.5 µm long, distal cells 37.5-40 µm long, distortion, distal cell tapering to a rounded or pointed apex. Prickle-hairs abundant, hook, 30-37.5 µm long. Stomata 1-2 rows near margin, subsidiary cells low dome-shaped.

Abaxial epidermis (Figure 4.8 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 2-5 cell rows. Long-cells rectangular, thin and sinuous wall, 25-65 by 15-17.5 µm. Short-cells abundant, mostly solitary, scanty in paired, alternate with long-cells. Silica-bodies cross-shaped. Prickle-hairs common, hook, 37.5-50 µm long. **Intercostal zone**: 24-38 cell rows. Long-cells rectangular, thick and sinuous walls, 45-67.5 by 20-27.5 µm. Interstomatal cells 50-92.5 by 20-25 µm, concave ends. Short-cells abundant, mostly solitary, scanty in paired, alternate with long-cells. Silica-bodies cross-shaped. Micro-hairs abundant, length 67.5-77.5 µm, basal cell 30-40 µm long, distal cell 32.5-37.5 µm long, distal cell tapering to a rounded apex. Prickle-hairs abundant, hook, 32.5-30 µm long. Stomata 30-32.5 µm long, 11-12 rows, subsidiary cells low dome-shaped.

Leaf in Transverse section (Figure 4.8 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth, associated with few, round and small size of colourless cells; bulliform cells not well-developed, 2-3 fan-shaped groups on either sides of midrib. **Abaxial epidermis** smooth. **Mesophyll**: chlorenchyma radiate, first-orderedand second-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially. **Keel** conspicuous, triangular, containing 3 median first-ordered vascular bundles accompanied among them by 3-4 third-ordered vascular bundles which centered by 1 second-ordered vascular bundle, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 11-14 in entire blade; second-ordered vascular bundles medium, round, usually 1 between each pair of first-ordered vascular bundle; third-ordered vascular bundle small, angular, at least pentagonal in outline, 3-4 on either side of second-ordered vascular bundle. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially and adaxially, second-ordered vascular bundles with sheaths interrupted abaxially, third-ordered vascular bundle with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 4-7 cells wide and 2-4 cells high; second-ordered vascular bundles with small abaxial girders, consisting of only a few cells; third-ordered vascular bundles not accompanied by sclerenchyma; midrib: keel bundles with well-marked abaxially girders or strands only, first-ordered vascular bundles abaxially accompanied by large girders of 6-17 cells wide and 4-5 cells high sclerenchyma, second-ordered vascular bundles abaxially accompanied by small strands or girders of 2-8 cells wide and 1-5cells high; leaf margin with cap of sclerenchyma, cap relatively small and pointed.

Culm in Transverse section (Figure 4.8 H.)

Outline elliptic to oblong, flattened on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of about 6-7 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, in 3 more or less distinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

3) *Chrysopogon gryllus* (L.) Trin. subsp. *gryllus*

Leaf epidermis

Adaxial epidermis (Figure 4.9 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 5-9 cell rows. Long-cells rectangular, thin and sinuous wall, 62.5-107.5 µm long. Short-cells abundant, mostly solitary, few paired, alternate with long-cells. Silica-bodies cross-shaped. Prickle-hairs abundant, prickle, 50-130 µm long. **Intercostal zone**: 25-36 cell rows. Long-cells rectangular, thick and sinuous walls, 80-150 µm long. Interstomatal cells 87.5-100 µm long, concave ends. Bulliform cells thin and smooth wall, 5-6 rows, 17.5-50 µm long. Short-cells abundant, solitary, alternate with long-cells. Silica-bodies cross-shaped. Macro-hairs common, 125-300 µm long. Micro-hairs abundant; length 52.5-60 µm, basal cell 17.5-30 µm long, distal cell 27.5-37.5 µm long; distal cell tapering to a pointed apex. Stomata 5-7 rows, 27.5-37.5 µm long, subsidiary cells low dome-shaped.

Abaxial epidermis (Figure 4.9 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 5-10 cell rows. Long-zone thin and sinuous wall, 250-430 µm. Short-cells abundant, solitary, alternate with long-cells. Silica-bodies cross-shaped. Prickle-hairs common at costal zone, small size, 60-80 µm long. **Intercostal zone**: 32 cell rows. Long-cells rectangular, thick and sinuous walls, 300-500 µm long. Interstomatal cells 350-400 µm, concave ends. Short-cells abundant, solitary, alternate with long-cells. Silica-bodies cross-shaped. Macro-hairs sparsely, 400-700 µm. Micro-hairs abundant, length 210 µm-300 µm, basal cell 80-120 µm long, distal cell 130-180 µm long, distal cell tapering to a rounded or pointed apex. Prickle-hairs rarely, small prickle, 17.5-20 µm long. Stomata 120-130 µm, 6-10 rows, subsidiary cells low dome-shaped.

Leaf in Transverse section (Figure 4.9 E.-G.)

Outline V-shaped. **Adaxial epidermis** moderately pronounced and round ribs on first-ordered vascular bundles, shallow and wide furrows; bulliform cells most in fan-shaped groups, not developed near margin, associated with 1-2 rows of round and medium size of colourless cells. **Abaxial epidermis** smooth except slightly ribbed on keel. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, most second-ordered vascular bundles with completely radiate, a few second-ordered vascular bundles with chlorenchyma interrupted adaxially, third-ordered vascular bundles with chlorenchyma completely radiate. **Keel** conspicuous, triangular, containing 5 median first-ordered vascular bundle accompanied among them by 1-3 third-ordered vascular bundles which centered by 1 second-ordered vascular bundle, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 11-13 in entire blade; second-ordered vascular bundles medium, round, 1 between each pair of first-ordered vascular bundle; third-ordered vascular bundles small, angular, at least pentagonal in outline, 3-6 on either side of second-ordered vascular bundle. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially and adaxially, second and third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: larmina: first-ordered vascular bundles with adaxial and abaxial girders, usually 7-18 cells wide and 3-7 cells high; second-ordered vascular bundles with small adaxial girders, the girders consisting of only a few cells; midrib: keel bundles with well-marked abaxially girders only, first-ordered vascular bundles abaxially accompanied by 10-32 cells wide and 6-9 cells high sclerenchyma, second-ordered vascular bundles abaxially accompanied by 5-14 cells wide and 7-8 cells high, some third-ordered vascular bundles abaxially accompanied by a few cells sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1-2 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in Transverse section (Figure 4.9 H.)

Outline elliptic, concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of usually 4-6 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round or elliptic, scattered throughout the culm, outermost circle of smallest size bundles embedded in sclerenchyma.

4) ***Chrysopogon lawsonii* (Hook.f.) Veldk.**

Leaf epidermis

Adaxial epidermis (Figure 4.10 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 6-7 cell rows. Long-cells rectangular, thin and sinuous wall, 37.5-125 by 17.5-22.5 µm. Short-cells solitary, alternate with long-cells. Silica-bodies cross-shaped. Prickle-hairs abundant, hook, 25-30 µm long. **Intercostal zone**: 8-20 cell rows. Long-cells rectangular, thick and sinuous walls, 32.5-87.5 by 20-22.5 µm. Interstomatal cells 72.5-117.5 by 20-27.5 µm, concave ends. Bulliform cells thin and smooth wall, 3-4 rows, 17.5-37.5 by 15-20 µm. Short-cells solitary, alternate with long-cells. Silica-bodies cross-shaped. Micro-hairs common, present both over costal and intercostal zones, length 50-57.5 µm, basal cells 20-22.5 µm, distal cells 27.5-37.5 µm, distal cell tapering to a pointed apex. Prickle-hairs abundant, hook, 30-50 µm long. Stomata c. 37.5 µm long, 5-7 rows, subsidiary cells triangular.

Abaxial epidermis (Figure 4.10 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 6-8 cell rows. Long-cells rectangular, thin and sinuous wall, 32-5-92.5 by 10-12.5 µm. Short-cells abundant, solitary, alternate with long-cells. Silica-bodies cross-shaped. Prickle-hairs rarely, c. 12.5 µm. **Intercostal zone**: 4-8 cell rows. Long-cells rectangular, thick and sinuous walls, 50-112.5 by 12.5-15 µm. Interstomatal cells 60-110 by 15-22.5 µm, concave ends. Short-cells abundant, solitary, alternate with long-cells. Silica-bodies cross-shaped. Micro-hairs sparsely, present both costal and intercostal zones, length 40-45 µm, basal cells 15-25 µm, distal cells 20-25 µm, distal cell tapering to a pointed apex. Stomata 32.5-37.5 µm long, 5-9 rows, subsidiary cells triangular.

Leaf in Transverse section (Figure 4.10 E.-H.)

Outline V-shaped. **Adaxial epidermis** moderately pronounced and round ribs over first-ordered vascular bundle, shallow and wide furrows over second-and third-ordered vascular bundles; bulliform cells in fan-shaped groups, not developed near margin, associated with 1-2 rows of round and medium size of colourless cells. **Abaxial epidermis** moderately pronounced and round ribs over first-ordered vascular bundle. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, second-ordered vascular bundles with chlorenchyma interrupted abaxially, third-ordered vascular bundles with completely radiate. **Keel** conspicuous, triangular, containing 1 median first-ordered vascular bundle accompanied among them by 3 third-ordered vascular bundles, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 11-13 in entire blade; second-ordered vascular bundles medium, round, 1 between each pair of vascular bundles; third-ordered vascular bundles small, angular, at least pentagonal in outline, usually 3 on either side of second-ordered vascular bundles. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially and adaxially, second- and third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 3-12 cells wide and 2-4 cells high; some third-ordered vascular bundles accompanied by small adaxial or abaxial strands, the strands consisting of only a few cells; midrib: keel bundles with well-marked abaxially girders or strands only, first-ordered vascular bundles abaxially accompanied by 6-24 cells wide and 4-5 cells high girder sclerenchyma, third-ordered vascular bundles abaxially accompanied by 2-5 cells wide and 1 cell high of strand or girder sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

5) *Chrysopogon orientalis* (Desv.) A. Camus

Leaf epidermis

Adaxial epidermis (Figure 4.11 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-4 cell rows. Long-cells rectangular, thin and sinuous walls, 75-125 by 22.5-27.5 µm. Short-cells mostly solitary, rarely paired. Silica-bodies cross-shaped. Macro-hairs common, 100-210 µm long. Prickle-hairs common, hook, 30-60 µm long. **Intercostal zone**: 6-12 cell rows. Long-cells rectangular, thick and sinuous walls, 50-132.5 by 20-27.5 µm. Interstomatal cells 65-105 by 15-20 µm, concave ends. Bulliform cells both sides of mid-vein, 3-6 cell rows, 32.5-62.5 by 20-30 µm. Short-cells mostly solitary, rarely paired. Silica-bodies cross-shaped. Macro-hairs abundant, 60-180 µm long. Micro-hairs length 65-80 µm, basal cells 25-30 µm, distal cells 40-50 µm, distortion, distal cell tapering to a rounded apex. Prickle-hairs abundant, hook, 40-100 µm. Stomata 2 rows near margins, 25-32.5µm, subsidiary cells low dome-shaped.

Abaxial epidermis (Figure 4.11 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 4-7 cell rows. Long-cells rectangular, thin and sinuous wall, 40-87.5 by 12.5-17.5 µm. Short-cells abundant, solitary, alternate with long-cells. Silica-bodies cross-shaped. Prickle-hairs common, prickle, 40-80 µm long. **Intercostal zone**: 12-28 cell rows. Long-cells rectangular, thick and sinuous walls, 50-125 by 15-20 µm. Interstomatal cells 57.5-95 by 17.5-22.5 µm, concave ends. Short-cells abundant, mostly solitary, rarely paired, alternate with long-cells. Silica-bodies cross-shaped. Micro-hairs length 65-72.5 µm, basal cells 27.5-32.5 µm, distal cells 37.5-40 µm, distal cell tapering to a rounded or pointed apex. Prickle-hairs common, hook, 30-50 µm long. Stomata 32.5-40 µm, 5-8 rows, subsidiary cells low dome-shaped.

Leaf in transverse section (Figure 4.11 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth except a moderately pronounced and round rib over first-ordered vascular bundles on either side of keel, deep and wide furrows; bulliform cells not clearly developed except for a group of fan shape on either side of the midrib, associated with 1 layer of round and medium size of colourless cells. **Abaxial epidermis** slightly ribbed on first-ordered vascular bundles. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially; few second-ordered vascular bundles with chlorenchyma interrupted abaxially; most of second-ordered vascular bundle and third-ordered vascular bundles with chlorenchyma completely radiate. **Keel** conspicuous, triangular, containing 1 median first-ordered vascular bundle accompanied on either side by 4-6 second and third-ordered vascular bundles, of which 1-2 third-ordered vascular bundles adjacent to first-ordered vascular bundle, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 9-11 in entire blade; second-ordered vascular bundles medium, round, 3-4 between each pair of first-ordered vascular bundle; third-ordered vascular bundles small, angular, at least pentagonal in outline, 1-3 between each pair of first-ordered vascular bundles, irregularly arrange: usually next to first-ordered vascular bundle and flanking second-ordered vascular bundles. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially and adaxially, a few second-ordered vascular bundles with sheaths interrupted abaxially, most of second- and third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 2-12 cells wide and 2-3 cells high; few second-ordered vascular bundles with small abaxial strands or girders, the strands or girders consisting of only a few cells; midrib: keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 9-20 cells wide and 4-5 cells high sclerenchyma, few second-ordered vascular bundles abaxially accompanied by a few cells sclerenchyma; leaf margin with cap of sclerenchyma, cap relatively small and pointed.

Culm in transverse section (Figure 4.11 H.)

Outline round, concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of usually 6-7 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, in 3 more or less distinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

6) *Chrysopogon serrulatus* Trin.

Leaf epidermis

Adaxial epidermis (Figure 4.12 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 4 cell rows. Long-cells rectangular, thin and sinuous wall, 55-105 by 17.5-20 µm. Short-cells abundant, solitary, alternate with long-cells. Silica-bodies mostly cross-shaped, some irregular cross-shaped. Prickle-hairs common, hook, 30-40 µm long. **Intercostal zone**: 10-12 cell rows. Long-cells rectangular, thick and sinuous walls, 50-112.5 by 22.5-27.5 µm. Interstomatal cell thick and sinuous walls, 137.5-175 by 32.5-40 µm, concave end. Bulliform cells thin and smooth wall, 2-3 cell rows, 25-62.5 by 25-32.5 µm. Short-cells abundant, mostly solitary, rarely paired, alternate with long-cells. Silica-bodies mostly cross-shaped, some irregular cross-shaped. Micro-hairs very sparsely, length 50-80 µm, basal cells 21-30 µm, distal cells 30-50 µm, distortion, distal cell tapering to a rounded or pointed apex. Prickle-hairs abundant, hook, 30-50 µm long. Stomata rarely, near margin, ca. 30-40 µm, subsidiary cells low dome-shaped.

Abaxial epidermis (Figure 4.12 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 2-4 cell rows. Long-cells rectangular, thin and sinuous wall, 20-92.5 by 10-12.5 µm. Short-cells abundant, solitary, alternate with long-cells. Silica-bodies mostly cross-shaped, some irregular cross-shaped. **Intercostal zone**: 6-17 cell rows. Long-cells rectangular, thick and sinuous walls, 37.5-117.5 by 12.5-17.5 µm. Interstomatal cells 62.5-95 by 15-20 µm, concave ends. Short-cells abundant, solitary, alternate with long-cells. Silica-bodies mostly cross-shaped, some irregular cross-shaped. Micro-hairs common, length 47.5-75 µm, basal cells 20-30 µm, distal cells 27.5-50 µm, distortion, distal cell tapering to a rounded apex. Prickle-hairs sparsely, prickle, 37.5-55 µm long. Stomata 37.5-45 µm long, 3-5 rows, subsidiary cells low dome-shaped.

Leaf in transverse section (Figure 4.12 E.-G.)

Outline V-shaped. **Adaxial epidermis** slight rib on first-ordered vascular bundles; bulliform cells not clearly developed except for few groups of fan shape on either side of the midrib, associated with few, round and medium size of colourless cells. **Abaxial epidermis** smooth. **Mesophyll**: chlorenchyma radiate; first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially; most of second and third-ordered vascular bundles with completely radiate, a few second-ordered vascular bundles with chlorenchyma interrupted abaxially. **Keel** conspicuous, triangular, containing 1 median first-ordered vascular bundle accompanied on either side by 3-5 second- and third vascular bundles, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 12-13 in entire blade; second-ordered vascular bundles medium, round, 3-5 between each pair of first-ordered vascular bundle; third-ordered vascular bundles small, angular, at least pentagonal in outline, 1-3 between each pair of first-ordered vascular bundles, irregularly arrange: usually next to first-ordered vascular bundle and flanking second-ordered vascular bundles. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially and adaxially, most of second and third-ordered vascular bundles with complete sheaths, a few second-ordered vascular bundles with sheaths interrupted abaxially. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 3-10 cells wide and 4-5 cells high; second-ordered vascular bundles with small abaxial or both abaxial and adaxial strands, the strands consisting of only a few cells; midrib: keel bundles with well-marked abaxially girders or strands only, median first-ordered vascular bundles abaxially accompanied by large girders of 8-24 cells wide and 4-5 cells high sclerenchyma, some third-ordered vascular bundles abaxially accompanied by small strands of 4-6 cells wide and 1-2 cells high, the adaxial surface above the keel being supported by a wide plate with 1 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap relatively small and crescent-shaped .

Culm in transverse section (Figure 4.12 H.)

Outline elliptic, concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of usually 6-7 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, in 3 more or less distinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

7) *Chrysopogon zizanioides* (L.) Roberty

Leaf epidermis

Adaxial epidermis (Figure 4.13 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-6 cell rows. Long-cells rectangular, thin and sinuous wall, 35-75 by 17.5-20 µm. Short-cells abundant, solitary, alternate with long-cells. Silica-bodies cross-shaped. **Intercostal zone**: 9-12 cell rows. Long-cells rectangular, thick and sinuous wall, 42.5-92.5 by 15-22.5 µm. Interstomatal cells 80-110 by 20-22.5 µm, concave ends. Bulliform cells 1-6 cell rows, 15-50 by 21-35 µm. Short-cells abundant, solitary; few, paired; alternate with long-cells. Silica-bodies cross-shaped. Micro-hairs common, present at intercostal zones, length 55-62.5 µm, basal cells 15-25 µm, distal cells 37.5-42.5 µm, distal cell tapering to a rounded apex. Prickle-hairs rarely, 40-45 µm. Stomata 2-3 rows, 30-37.5 µm, subsidiary cells low dome-shaped.

Abaxial epidermis (Figure 4.13 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 4-6 cell rows. Long-cells rectangular, thin and sinuous wall, 17-80 by 11.25-12.5 µm. Short-cells abundant, solitary, alternate with long-cells. **Intercostal zone**: 5-9 cell rows. Long-cells rectangular, thick and sinuous wall, 37.5-95 by 15 µm. Interstomatal cells 55-90 by 17.5-20 µm, concave ends. Short-cells abundant, solitary or paired, alternate with long-cells. Silica-bodies cross-shaped. Micro-hairs common, present at intercostal zones, length 50-60 µm, basal cells 17.5-22.5 µm, distal cells 32.5-37.5 µm, distal cell tapering to a rounded or pointed apex. Prickle-hairs sparsely, hook, 20-30 µm. Stomata 2 rows, 35-42.5 µm, subsidiary cells low dome-shaped.

Leaf in transverse section (Figure 4.13 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth; bulliform cells not clearly developed except for a single group of fan shape on the adaxial surface of the keel.

Abaxial epidermis smooth. **Mesophyll**: chlorenchyma radiate; first-, second-, and a few third-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially; most third-ordered vascular bundles with completely radiate, some third-ordered vascular bundles with chlorenchyma interrupted abaxially; 2 air-cavities between a pair of first-ordered vascular bundle. **Keel** conspicuous, triangular, containing 1 median first-ordered vascular bundle accompanied on either side by 1 second-ordered vascular bundle and 2 third-ordered vascular bundles which alternately arranged, bundles abaxially arranged; adaxial ground tissue consisting of colourless cells. **Vascular bundles**: first-ordered vascular bundles large, elliptic to round, 12-15 in entire blade; second-ordered vascular bundles, medium, round, 1 between each pair of first-ordered vascular bundle; third-ordered vascular bundle small, round, 2-3 alternately arranged with second-ordered vascular bundles. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially or adaxially and abaxially; second-ordered vascular bundles with complete sheaths or interrupted abaxially; third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 5-10 cells wide and 3-5 cells high; elliptic second-ordered vascular bundles abaxially and adaxially accompanied by girders, the girders consisting of 3-6 cells wide and 3-5 cells high; round second-ordered vascular bundles abaxially accompanied by small girders, girders consist of a few cells: keel bundles with abaxially and adaxially girders, median first-ordered vascular bundles abaxially accompanied by 7-20 cells wide and 5-7 cells high sclerenchyma with adaxially accompanied by small girders of few cells, second-ordered vascular bundles adaxially and abaxially accompanied by small girders of few cells; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Leaf in transverse section (Figure 4.13 H.)

Outline round, concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre tending to break down, outer ground tissue usuall 10 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** mostly round, some elliptic, scattered throughout the culm, outer circles composed of smallest and small bundles with embedded in sclerenchyma.

4. DICHANTHIUM

Leaf epidermis: upper and lower epidermis mostly similar, except bulliform cells present at upper epidermis. Short-cells, over the veins, in rows. Silica-bodies, over the veins, mostly intermediate between cross and dumb-bell shaped. Micro-hairs present; the distal cell tapering to a rounded or a pointed apex. Stomata mostly with triangular, but some with low dome-shaped subsidiary cells. **Leaf in transverse section**: Mesophyll with distinctly radiate chlorenchyma. Vascular bundles: 3 types: first-ordered vascular bundle, second-ordered vascular bundle and third order-vascular bundle. Bundle sheaths single. Leaf margin accompanied by sclerechyma. **Culm in transverse section**: round, flattened or concave on one side.

Key to the species

1. Micro-hairs with long basal cell at adaxial epidermis ………….. **1)** ***D. annulatum***
1. Micro-hairs with nearly equal of basal and distal cells at adaxial epidermis
   2. Macro-hair absent at abaxial epidermis …………..…………… **2)** ***D. aristatum***
   2. Macro-hair present at abaxial epidermis ……….…………….. **3)** ***D. caricosum***

1) ***Dichanthium annulatum*** **(Forssk.) Stapf**

Leaf epidermis

Adaxial epidermis (Figure 4.14 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: in 3 cell rows. Long-cells rectangular, thin and sinuous walls, 80-150 by 12.5-20 µm. Short-cells abundant, in a row; some, solitary or paired, alternated long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shaped, some nodular, few cross-shaped, over costal zones; abundant, cross-shaped, over mid-vein. **Intercostal zone**: 4-10 cell rows. Long-cells rectangular, thick and sinuous walls, 75-200 by 15-20 µm. Interstomatal cells 60-80 by 17.5-25 µm, concave ends. Bulliform cells 45-117.5 by 17.5-32.5 µm. Short-cells sparsely, solitary or paired, alternate with long-cells. Silica-bodies sparsely, tall, narrow and crenate shape in single or couple with cross-shaped. Macro-hairs common, 360-1400 µm long. Micro-hairs sparsely, over intercostal zone and interstomatal zone, length 65-75 µm, basal cells 32.5-42.5 µm, distal cells 27.5-32.5 µm, distal cell tapering to a pointed apex. Prickle-hairs sparsely, 22.5-40 µm long. Stomata 1 row, 27.5-30 µm long, subsidiary cells low-dome shaped and triangular.

Abaxial epidermis (Figure 4.14 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-4 cell rows. Long-cells rectangular, thin and sinuous walls, 92.5-175 by 7.5-20 µm. Short-cells abundant, in 1-2 rows but mostly 1 row, over costal zones; abundant, alternate with long-cell over mid-vein. Silica-bodies mostly intermediate between cross and dumb-bell shaped, some nodular. Prickle-hairs common, prickle, 32.5-60 µm long. **Intercostal zone**: 4-8 cell rows. Long-cells rectangular, thick and sinuous walls, 50-170 by 12.5-17.5 µm. Interstomatal cells 42.5-75 by 25-30 µm, concave ends. Short-cells common solitary or sparsely paired, alternate with long-cells or interstomatal cells. Silica-bodies sparsely, tall, narrow and crenate shape, or cross shape. Macro-hairs sparsely, 150-500 µm. Micro-hairs sparsely, over intercostal zone, length 65-82.5 µm, basal cells 30-50 µm, distal cells 32.5-37.5 µm, distal cell tapering to a pointed apex. Papillae abundant, 2-4, small, globose, cuticular papillae over intercostal long-cells; also an oblique, slightly large papillae over each interstomatal long-cell. Stomata 1-2 rows, 25-30 µm long, subsidiary cells triangular and low-dome shape.

Leaf in transverse section (Figure 4.14 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth, slightly, narrow ribs, and shallow, rounded furrows; bulliform cells some in irregular groups, others in fan-shaped group, associated with colourless cells. **Abaxial epidermis** smooth, papillose. **Mesophyll**: chlorenchyma radiate; first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially; second-ordered vascular bundles with completely radiate, sometimes with interupted adaxially, rarely interrupted adaxially and abaxially; third-ordered vascular bundles with completely radiate. **Keel** conspicuous, rounded, containing 1 median first-ordered vascular bundle accompanied on either side by 6-7 third-ordered vascular bundles, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 8-10 in entire blade; second-ordered vascular bundles medium, round, 2-3 between each pair of first-ordered vascular bundles; third-ordered vascular bundles small, angular, at least pentagonal in outline, 1-3 alternately arranged with second-ordered vascular bundles. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially, second and third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 3-9 cells wide and 1-3 cells high; almost second-ordered vascular bundle accompanied by small abaxial or both adaxial and abaxial strands or girders, the strands or girders sometime consisting of only a few cells; few third-ordered vascular bundles accompanied by small abaxial strands; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 6-25 cells wide and 4-5 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in transverse section (Figure 4.14 H.)

Outline round, flattened to slightly concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of 3-6 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, in 3 more or less distinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

2) *Dichanthium aristatum* (Poir.) C.E. Hubb.

Leaf epidermis

Adaxial epidermis (Figure 4.15 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-7 cell rows. Long-cells rectangular, thin and sinuous walls, 100-187.5 by 10-17.5 µm. Short-cells abundant, in 1-2 rows but mostly 1 row. Silica-bodies mostly intermediate between cross and dumb-bell shaped, few nodular. Prickle-hairs common, prickle, 40-57.5 µm long. **Intercostal zone**: 4-6 cell rows. Long-cells rectangular, thick and sinuous walls, 105-285 by 15-22.5 µm. Interstomatal cells 155-175 by 20-35 µm, concave ends. Bulliform cells 3-4 rows, 55-125 by 20-37.5 µm. Short-cells some solitary, few paired, alternate with long-cells. Silica-bodies tall, narrow and crenate shape and cross-shaped. Macro-hairs scanty, c. 650 µm. Micro-hairs sparsely, over intercostal zone, length 50-55.56 µm, basal cells 25.56-27.78 µm, distal cells 24.44-27.78 µm, distal cell tapering to a pointed apex. Prickle-hairs sparsely, hook, 18.75-27.5 µm long. Stomata 1 row, 27.5-30 µm long, subsidiary cells triangular.

Abaxial epidermis (Figure 4.15 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-7 cell rows. Long-cells rectangular, thin and sinuous walls, 100-200 by 7.5-15 µm; Short-cells abundant, in 1-3 rows but mostly 1 row. Silica-bodies mostly nodular, some intermediate between cross and dumb-bell shaped. Prickle-hairs common, prickle, 35-50 µm long. Papillae sparsely, small globose cuticular papillae over costal long-cells. **Intercostal zone**: 3-6 cell rows. Long-cells rectangular, thick and sinuous walls, 65-

212.5 by 10-15 µm. Interstomatal-cells 70-90 by 25-30 µm, concave ends. Short-cells common solitary, few paired, alternate with long-cells. Silica-bodies some cross-shaped, few tall, narrow and crenate shape. Micro-hairs sparsely, length 47.5-70 µm, basal cells 25-40 µm, distal cells 22.5-30 µm, distal cell tapering to a pointed apex. Papillae abundant; 1-4 small, globose, cuticular papillae over intercostal long-cells; also an oblique, slightly large papillae, over interstomatal long-cell. Stomata 1-2 rows, 27.5-30 µm long, subsidiary cells low-dome shaped and triangular.

Leaf in transverse section (Figure 4.15 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth with slight rib on first-ordered vascular bundle; bulliform cells some in irregular groups, others in fan-shaped group, associated with colourless cells. **Abaxial epidermis** smooth, papillose. **Mesophyll**: chlorenchyma radiate; first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially; most second-ordered vascular bundles with completely radiate, a few with chlorenchyma interrupted abaxially, third-ordered vascular bundle with completely radiate. **Keel** conspicuous, rounded, containing 1 median first-ordered vascular bundle accompanied on either side by 3 second-ordered vascular bundles and ending with 1 second-ordered vascular bundle, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, c. 9 in entire blade; second-ordered vascular bundles medium, round, usually 3 between each pair of first-ordered vascular bundle; third-ordered vascular bundle small, angular, at least pentagonal in outline, usually 1, alternately arrange with second-ordered vascular bundles. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially, most of second- and all third-ordered vascular bundles with complete sheaths, a few second-ordered vascular bundles with sheaths interrupted abaxially. **Sclerenchyma**: laminar: first-ordered vascular bundles with adaxial and abaxial girders, rarely with abaxial girder only, usually 3-8 cells wide and 1-3 cells high; second-ordered vascular bundle accompanied by small adaxial and abaxial strands, the strands usually composed of only a few cells; third-ordered vascular bundle accompanied by small abaxial strands; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 9-27 cells wide and 4-5 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1-2 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in transverse section (Figure 4.15 H.)

Outline round, flattened on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of about 6-10 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round to elliptic, in 3 more or less distinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

3) ***Dichanthium caricosum*** **(L.) A. Camus**

Leaf epidermis

Adaxial epidermis (Figure 4.16 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-5 cell rows. Long-cells rectangular, thin and sinuous walls, 37.5-200 by 20-27.5 µm. Short-cells abundant, in a row; sparsely, solitary, alternate with long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shaped, some cross-shaped and nodular. Prickle-hairs common, prickle, 40-57.5 µm long. **Intercostal zone**: 4-8 cell rows. Long-cells rectangular, thick and sinuous walls, 75-250 by 12.5-20 µm. Interstomatal cell 67.5-137.5 by 17.5-22.5 µm. Bulliform cells smooth and thin wall, 2-4 rows, 37.5-100 by 25-37.5 µm. Short-cells scanty, solitary, alternate with long-cells. Silica-bodies tall, narrow and crenate shape. Macro-hairs common, 730-1040 µm. Micro-hairs sparsely, length 52.5-62.5 µm, basal cells 27.5-32.5 µm, distal cells 25-30 µm, distal cell tapering to a pointed apex. Prickle-hairs common, hook, 20-27.5 µm long. Stomata 1-2 rows, 27.5-35 µm long, subsidiary cells triangular.

Abaxial epidermis (Figure 4.16 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-5 cell rows. Long-cells rectangular, thin and sinuous walls, 30-125 by 10-12.5 µm. Short-cells abundant, 1-3 rows; common, solitary, alternate with long-cells over mid-vein. Silica-bodies mostly intermediate between cross and dumb-shaped shape; cross-shaped over mid-vein. Prickle-hairs common, prickle, 20-52.5 µm long. Papillae abundant; 1-4, small, globose cuticle papillae over costal long-cells. **Intercostal zone**: 1-13 cell rows. Long-cells rectangular, thick and sinuous walls, 57.5-112.5 by 7.5-17.5 µm. Interstomatal cells 57.5-92.5 by 27.5-32.5 µm, concave ends. Short-cells sparsely, paired, alternate with long-cells. Silica-bodies paired of tall, narrow and crenate shape with cross-shaped. Macro-hairs common, 225-287.5 µm. Micro-hairs sparsely, over intercostal zone, length 55-67.5 µm, basal cells 32.5-37.5 µm, distal cells 25-32.5 µm, distal cell tapering to a pointed apex. Papillae abundant; 1-3, small, globose cuticle papillae over intercostal long-cells; also an obliquely, slightly large papillae over each interstomatal long-cell. Stomata 1-2 row, 30-37.5 µm long, subsidiary cells low-dome shaped and triangular.

Leaf in transverse section (Figure 4.16 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth with slight rib on first-ordered vascular bundle; bulliform cells some in irregular groups, others in fan-shaped group, associated with colourless cellss. **Abaxial epidermis** smooth, papillose. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, most second- and all third-ordered vascular bundles with completely radiate, few second-ordered vascular bundles with chlorenchyma interrupted abaxially. **Keel** conspicuous, round, containing 1 median first-ordered vascular bundle accompanied on either side by 5-8 third-ordered vascular bundles, sometimes second-ordered vascular bundles present alternately with third-ordered vascular bundle; bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 9-11 in entire blade; second-ordered vascular bundles medium, round, usually 3 between each pair of vascular bundle; third-ordered vascular bundle small, angular, at least tetragonal in outline, 1-3 alternately arranged with second-ordered vascular bundle. **Bundle sheaths** single, first-ordered vascular bundles and a few second-ordered vascular bundles with sheaths interrupted abaxially, third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: almost third-ordered vascular bundles accompanied by small abaxial strands; almost second-ordered vascular bundle accompanied by small adaxial and abaxial strands, the strands sometime consisting of only a few cells; first-ordered vascular bundles with adaxial and abaxial girders, usually 4-8 cells wide and 1-3 cells high; most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 8-25 cells wide and 5 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1-2 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in transverse section (Figure 4.16 H.)

Outline round, concave on one side. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre tending to break down, outer ground tissue composed of about 4-10 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, in 3 more or less distinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

5. HEMISORGHUM

Leaf epidermis: upper and lower epidermis mostly similar, except bulliform cells present at upper epidermis. Short-cells, over the veins, mostly in rows. Silica-bodies, over the veins; intermediate between cross and dumb-bell shaped, cross-shaped or nodular. Macro-hairs absent. Micro-hairs present, the distal cell tapering to a rounded or pointed apex. Papillae absent. Stomata with triangular, or low dome-shaped subsidiary cells. **Leaf in transverse section**: Mesophyll with distinctly radiate chlorenchyma. Vascular bundles: 3 types: first-ordered vascular bundle, second-ordered vascular bundle and third order-vascular bundle. Bundle sheaths single. Leaf margin accompanied by sclerechyma. **Culm in transverse section**: round, flattened on one side.

***Hemisorghum mekongense* (A. Camus) C. E. Hubb.**

Leaf epidermis

Adaxial epidermis (Figure 4.17 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-6 cell rows. Long-cells rectangular, thin and sinuous walls, 45-170 by 7.5-12.5 µm. Short-cells abundant, in a row; some, solitary, alternate with long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shaped, some cross-shaped. **Intercostal zone**: 8-22 cell rows. Long-cells rectangular, thick and sinuous walls, 65-150 by 10-17.5 µm. Bulliform cells 1-3 rows, sinuous wall, 17.5-80 by 17.5-22.5 µm. Interstomatal cells thick and sinuous walls, 65-137.5 µm, concave end. Short-cells common solitary, few paired, alternate with long-cells. Silica-bodies crossed-shape, tall, narrow and crenate shape. Micro-hairs sparsely, over intercostal zone, length 30-37.5 µm, basal cells 10-15 µm, distal cells 20-22.5 µm, distal cell tapering to a rounded or pointed apex. Stomata 2-7 rows, 17.5-27.5, subsidiary cells low-dome shaped and triangular.

Abaxial epidermis (Figure 4.17 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-8 cell rows. Long-cells rectangular, thin and sinuous walls, 37.5-160 by 10-12.5 µm. Short-cells abundant, in 1-2 rows. Silica-bodies mostly intermediate between cross and dumb-bell shaped, few nodular. **Intercostal zone**: 10-32 cell rows. Long-cells rectangular, thick and sinuous walls, 55-150 by 12.5-15 µm. Interstomatal cells 50-82.5 by 15-22.5 µm, sinuous wall, concave ends. Short-cells common solitary, sparsely paired, alternate with long-cells. Silica-bodies cross shape and tall, narrow and crenate shape. Micro-hairs sparsely, length 32.5-37.5 µm, basal cells 15-17.5 µm, distal cells 17.5-22.5 µm, distal cell tapering to a pointed apex. Stomata 2-7 rows, 22.5-27.5 µm long, subsidiary cells triangular.

Leaf in transverse section (Figure 4.17 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth except a slight rib over first-ordered vascular bundle on either side of keel; bulliform cells some in irregular group, others in fan-shaped group, associated with round and medium size of colourless cells. **Abaxial epidermis** smooth. **Mesophyll**: chlorenchyma radiate; first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially; almost second-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, rarely with abaxially interrupted only; third-ordered vascular bundle with completely radiate. **Keel** conspicuous, rounded, containing 1 first-ordered vascular bundles accompanied on either side by 2-3 second-ordered vascular bundles which alternately arranged with 1 third-ordered vascular bundle, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round; second-ordered vascular bundles medium; second-ordered vascular bundle medium, round, usually 3 between each pair of first-ordered vascular bundle; third-ordered vascular bundle slightly small or nearly equal size to second-ordered vascular bundle, angular, at least pentagonal in outline; usually 3 alternately arrange with second-ordered vascular bundle. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted abaxially, some second-ordered vascular bundles with abaxially interrupted; third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 4-8 cells wide and 2 cells high; second-ordered vascular bundle accompanied by small adaxial and abaxial girders, consisting of 2-5 cells wide and 2 cells high; third-ordered vascular bundle not accompanied by sclerenchyma; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 13-38 cells wide and 5-7 cells high sclerenchyma, second-ordered vascular bundles abaxially accompanied by 2-8 cells wide and 2-6 cells high sclerenchyma, third-ordered vascular bundle abaxially accompanied by small strands; the adaxial surface above the keel being supported by a wide plate with 2 cells high of hypodermal sclerenchyma.

Culm in transverse section (Figure 4.17 H.)

Outline round, flattened on one side. **Epidermis** composed of round to square shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of about 10-12 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, scattered throughout the culm, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

6. PSEUDOSORGHUM

Leaf epidermis: upper and lower epidermis mostly similar, except bulliform cells present and stomata absent at upper epidermis. Short-cells, over the veins, mostly in rows. Silica-bodies mostly intermediate between cross and dumb-bell shaped, few nodular. Macro-hairs present. Micro-hairs present. Papillae present. Stomata with low dome-shaped subsidiary cells. **Leaf in transverse section**: Mesophyll with distinctly radiate chlorenchyma. Vascular bundles: 3 types: first-ordered vascular bundle, second-ordered vascular bundle and third order-vascular bundle. Bundle sheaths single. Leaf margin accompanied by sclerechyma. **Culm in transverse section**: round, concave on one side.

Pseudosorghum fasciculare **(Roxb.) A. Camus**

Leaf epidermis

Adaxial epidermis (Figure 4.18 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3 cell rows. Long-cells rectangular, thin and sinuous walls, 30-37 by 7.5-10 µm. Short-cells abundant, in a row. Silica-bodies mostly intermediate between cross and dumb-bell shape, few nodular. Prickle-hairs abundant, prickle, 30-125 µm. Papillae densely; many, small, globose, cuticular papillae on each long-cells. **Intercostal zone**: 5-13 cell rows. Long-cells rectangular, thick and sinuous walls, 67.5-87.5 by 15-17.5 µm. Bulliform cells 1-3 cell rows, 52.5-90 by 20-32.5. Short-cells sparsely, solitary and paired, alternate with long-cells. Silica-bodies acutely angled shape, paired of cross shape with acutely angled shape. Macro-hairs sparsely, 1600-2000 µm. Micro-hairs sparsely, at intercostal zone, length 45-55 µm, basal cells 35-40 µm, distal cells 15-20 µm, distal cell tapering to a pointed apex. Prickle-hairs sparsely, hook, 22.5-30 µm. Papillae densely; many, small, globose, cuticular papillae on each long-cells.

Abaxial epidermis (Figure 4.18 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-5 cell rows. Long-cells rectangular, thin and sinuous wall, 62.5-175 by 5-10 µm. Short-cells abundant, in 1-2 rows. Silica-bodies mostly intermediate between cross and dumb-bell shaped, few nodular. Prickle-hairs abundant, prickle, 35-50 µm. Papillae densely; many, small, globose cuticular papillae on each long-cells. **Intercostal zone**: 5-9 cell rows. Long-cells rectangular, thick and sinuous wall, 75-150 by 7.5-10 µm. Interstomatal cells 45-62.5 by 17.5-20 µm, concave ends. Short-cells sparsely, solitary, alternate with long-cells. Silica-bodies square shape. Micro-hairs sparsely, at intercostal zone, length 40-50 µm, basal cells 7.5-17.5 µm, distal cells 25-32.5 µm, distal cell tapering to a pointed apex. Papillae densely; many, small, globose cuticular papillae on each long-cells; also 2-3, slightly large, globose on each interstomatal cell. Stomata 2-3 rows, 22.5-27.5 µm long, subsidiary cells low-dome shaped.

Leaf in Transverse section (Figure 4.18 E.-G.)

Outline V-shaped, wide, open nearly 180º. **Adaxial epidermis** ribs and furrows; rib conspicuous, triangular, over all vascular bundles; furrows medium; bulliform cells some in irregular groups, others in fan-shaped group. **Abaxial epidermis** slightly ribs, over all vascular bundles; papillose. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles and some second-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially, second-ordered vascular bundle with chlorenchyma interrupted abaxially, third-ordered vascular bundles with completely radiate. **Keel** conspicuous, triangular, containing 1 median first-ordered vascular bundle accompanied on either side by 1-3 second- and third-ordered vascular bundles which alternately arranged, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round; second-ordered vascular bundles medium, round, 3-4 between each pair of first-ordered vascular bundles; third-ordered vascular bundles small, angular, at least pentagonal in outline; 1 alternately arranged with second-ordered vascular bundles. **Bundle sheaths** single; first-ordered vascular bundles with sheaths interrupted abaxially; most second-ordered vascular bundles with complete sheaths; rarely interrupted abaxially; third-ordered vascular bundle with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 3-6 cells wide and 1-3 cells high; second-ordered vascular bundles abaxially and adaxially accompanied by girders, the large girders at abaxial consisting of 6-9 cells wide and 3-4 cells high, the small strands or girders at adaxial consisting of 2-4 cells wide and 1 cell high; some third-ordered vascular bundles abaxially only or both abaxially and adaxially accompanied by small strands, strands consisting of 3-4 cells wide and 1-2 cells high; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by more or less 30 cells wide and 2-3 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1-2 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in transverse section (Figure 4.18 H.)

Outline elliptic to round, concave on one side. **Epidermis** composed of rectangular to square or round shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre solid, outer ground tissue composed of about 5-7 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** elliptic to round, in 3 more or less distinct circles near epidermis, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

Notes: This species was studied by herbarium specimen which more flaccid. Therefore, some characters such as ribs and furrows may be not exactly reliable.

7. SORGHUM

Leaf epidermis: upper and lower epidermis mostly similar, except bulliform cells present at upper epidermis. Short-cells, over the veins, mostly in rows, but sometimes solitary or paired. Silica-bodies, over the veins, usually intermediate between cross and dumb-bell shaped or nodular. Micro-hairs present; the distal cell tapering to a pointed apex. Stomata with triangular, low-dome or dumb-bell shaped subsidiary cells. **Leaf in transverse section**: Mesophyll with distinctly radiate chlorenchyma. Vascular bundles: 3 types: first-ordered vascular bundle, second-ordered vascular bundle and third order-vascular bundle. Bundle sheaths single. Leaf margin accompanied by sclerechyma. **Culm in transverse section**: round.

Key to the species

1. Macro-hairs present, papillae present at abaxial ………...………….. 2) ***S. nitidum***
1. Macro-hairs absent, papillae absent
   2. prickle-hair absent at abaxial epidermis ……………..…………… 1) ***S. bicolor***
   2. prickle-hair few at abaxial epidermis ……………..……… 3) ***S. propinquum***

1) Sorghum bicolor (L.) Moench

Leaf epidermis

Adaxial epidermis (Figure 4.19 A.-B.)

Zonation costal and intercostal zones distinguishable. Costal zone: 3-7 cell rows. Long-cells rectangular, thin and sinuous wall, 125-220 by 17.5-22 µm. Short-cells abundant, in 1-3 rows; sparsely, solitary or paired, alternate with long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shaped, few nodular, in rows; some, cross-shaped, tall and narrow or crenate, alternate with long-cells. Prickle-hairs common, prickle, 45-62.5 µm. **Intercostal zone**: 13-24 cell rows. Long-cells rectangular, thick and sinuous walls, 62.5-230 by 20-27.5 µm. Interstomatal cells thick and sinuous walls, 92.5-175 by 22.5-25 µm. Bulliform cells rectangular, thick and sinuous walls, 3-8 rows, 25-100 by 27.5-40. Short-cells common, solitary or paired, alternate with long-cells. Silica-bodies cross-shaped, tall and narrow or crenate. Micro-hairs common, at intercostal zone, length 37.5-50 µm, basal cells 12.5-17.5 µm, distal cells 25-32.5 µm. Prickle-hairs common, hook, 20-45 µm. Stomata 2-4 rows, 30-35 µm, subsidiary cells low-dome shaped or triangular.

Abaxial epidermis (Figure 4.19 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 4-9 cell rows. Long-cells rectangular, thin and sinuous wall, thin and sinuous wall, 37.5-220 by 15-17.5 µm. Short-cells abundant, in 1-3 rows; common, solitary and paired, alternate with long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shaped, few nodular, in rows; some, cross-shaped, tall, narrow and crenate, alternate with long-cells. **Intercostal zone**: 14-24 cell rows. Long-cells rectangular, thick and sinuous wall, 100-325 by 20-32.5 µm. Interstomatal cells thick and sinuous wall, 85-155 by 20-27.5 µm, concave ends. Short-cells common, solitary and paired, alternate with long-cells. Silica-bodies cross-shaped; tall, narrow and crenate; alternate with long-cells. Micro-hairs sparsely, at intercostal zone, length 45-50 µm, basal cells 15-20 µm, distal cells 25-35 µm. Stomata 2-6 rows, 22.5-47.5 µm long, subsidiary cells low-dome shaped.

Leaf in transverse section (Figure 4.19 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth; bulliform cells some in fan-shaped group, others in irregular group, associated with round or inflated medium size of colourless cells. **Abaxial epidermis** smooth, except slight ribs over first-orderedand some second-ordered vascular bundles on keel. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles and some second-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially; some second-ordered vascular bundles with chlorenchyma interrupted abaxially; third-ordered vascular bundles with completely radiate. **Keel** conspicuous, rounded, containing 3-6 first-ordered vascular bundles accompanied among them by 3-6 second- and third-ordered vascular bundles which alternately arranged, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, numerous; second-ordered vascular bundles medium, round, 3-4 between each pair of first-ordered vascular bundle; third-ordered vascular bundles small to nearly similar size to second-ordered vascular bundles, angular, at least pentagonal in outline, 3-8 alternately arranged with second-ordered vascular bundle. **Bundle sheaths** single, first-ordered vascular bundles with sheaths interrupted adaxially and abaxially, a few second-ordered vascular bundles with sheaths interrupted abaxially; third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 4-12 cells wide and 3-4 cells high; most second-ordered vascular bundle accompanied by small adaxial and abaxial strands or girders, strands or girders consisting of 3-4 cells wide and 2-4 cells high; third-ordered vascular bundle not accompanied by sclerenchyma; midrib: most keel bundles with well-marked abaxially girders only, median first-ordered vascular bundles abaxially accompanied by 9-36 cells wide and 8 cells high sclerenchyma, lateral 2 first-ordered vascular bundles and most third-ordered vascular bundles abaxially accompanied by 3-12 cells wide and 5-7 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1-2 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in transverse section (Figure 4.19 H.)

Outline round. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre tending to break down, outer ground tissue composed of about 1-2 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, scattered throughout the culm, the outermost circle composed of smallest bundles and embedded in sclerenchyma.

2) *Sorghum nitidum* (Vahl) Pers.

Leaf epidermis

Adaxial epidermis (Figure 4.20 A.-B.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-6 cell rows. Long-cells rectangular, thin and sinuous wall, 100-250 by 12.5-20 µm. Short-cells abundant, a row over all costal zones; common, solitary, alternate with long-cells. Silica-bodies intermediate between cross and dumb-bell shaped, and nodular. **Intercostal zone**: 11-16 cell rows. Long-cells rectangular, thick and sinuous wall, 107.5-175 by 12.5-22.5 µm. Interstomatal cells 80-152.5 by 17.5-22.5 µm. Bulliform cells 4-6 rows, 50-145 by 12.5-25. Short-cells common, solitary, alternate with long-cells. Silica-bodies cross-shaped, or intermediate between cross and dumb-bell shaped. Macro-hairs sparsely, 350-520 µm. Micro-hairs sparsely, over intercostal zone, length 50-65 µm, basal cells 20-37.5 µm, distal cells 25-35 µm. Prickle-hairs common, hook, 17.5-20 µm. Stomata 1-2 rows, 27.5-30 µm, subsidiary cells triangular.

Abaxial epidermis (Figure 4.20 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-6 cell rows. Long-cells rectangular, thin and sinuous wall, 100-270 by 10-12.5 µm. Short-cells abundant, in a row. Silica-bodies intermediate between cross and dumb-bell shaped, and nodular. Papillae densely, many, globose, small cuticular papillae on each long-cell. **Intercostal zone**: 4-13 cell rows. Long-cells rectangular, thick and sinuous wall, 137.5-250 by 7.5-25 µm. Interstomatal cells 42.5-95 by 12.5-30 µm, concave ends. Short-cells sparsely, solitary or paired, alternate with long-cells. Silica-bodies paired of intermediate between cross and dumb-bell shaped with cross-shaped, or paired of cross-shaped with nodular. Macro-hairs 600-1000 µm. Micro-hairs common, over intercostal zone, length 45-50 µm, basal cells 27.5-32.5 µm, distal cells 17.5-25 µm. Prickle-hairs sparsely, hook, 20-25 µm. Papillae densely, many, globose, small cuticular papillae on each long-cell; also 2-3 larger, globose or oblique papillae on each interstomatal cell. Stomata 1-2 rows, 30-35 µm long, subsidiary cells low-dome shaped.

Leaf in transverse section (Figure 4.20 E.-G.)

Outline V-shaped. **Adaxial epidermis** slightly ribbed on first-ordered vascular bundles; bulliform cells mostly in fan-shaped group, few in irregular group, associated with few, round and small colourless cells. **Abaxial epidermis** smooth except small rib over first-orderedand larger second-ordered vascular bundles on keel, papillose. **Mesophyll**: chlorenchyma radiate; first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially; second-ordered vascular bundles with chlorenchyma interrupted abaxially or both adaxially and abaxially; most third-ordered vascular bundles with completely radiate, a few third-ordered vascular bundles with chlorenchyma interrupted abaxially. **Keel** conspicuous, rounded, containing 3 first-ordered vascular bundles accompanied among them by 1-3 second-ordered vascular bundles which alternately arranged with 1 third-ordered vascular bundle, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, 9-12 in entire blade; second-ordered vascular bundle medium, rather less markedly angular to round, usually 3 between each pair of vascular bundle; third-ordered vascular bundles small, angular, at least tetragonal in outline, 1-2 alternately arranged with second-ordered vascular bundle. **Bundle sheaths** single; first-ordered vascular bundles with sheaths interrupted abaxially; most second-ordered vascular bundles with complete sheaths, a few with sheaths interrupted abaxially; third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 4-8 cells wide and 2-3 cells high; second-ordered vascular bundles accompanied by small adaxial and abaxial strands or girders, the strands sometime consisting of only a few cells; midrib: most keel bundles with well-marked abaxially girders only, first-ordered vascular bundles abaxially accompanied by 5-30 cells wide and 4-7 cells high sclerenchyma, second-ordered vascular bundles abaxially accompanied by 2-9 cells wide and 2-4 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 1-2 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in transverse section (Figure 4.20 H.)

Outline round. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre tending to break down, outer ground tissue composed of 7-9 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, scattered throughout the culm, outer circles composed of smallest and small bundles with embedded in sclerenchyma.

3) *Sorghum propinquum* (Kunth) Hitchc. var. *siamense* (Piper) Snowden

Leaf epidermis

Adaxial epidermis (Figure 4.21 A.-B.)

Zonation costal and intercostal zones distinguishable. Costal zone: 3-4 cell rows. Long-cells rectangular, thin and sinuous walls, 32.5-117.5 by 12.5-17.5 µm. Short-cells abundant, in 1-3 rows; common, solitary, alternate with long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shape, few nodular, in rows; scanty cross-shaped, alternate with long-cells. Prickle-hairs sparsely, prickle, 30-50 µm long. **Intercostal zone**: 5-13 cell rows. Long-cells rectangular, thick and sinuous walls; 42.5-137.5 by 17.5-22.5 µm. Interstomatal cells thick and sinuous walls, 62.5-100 by 17.5-20 µm. Bulliform cells 1-3 rows, 20-62.5 by 17.5-22.5 µm. Short-cells common solitary, few paired, alternate with long-cells. Silica-bodies cross-shaped. Micro-hairs sparsely, length 42.5-60 µm, basal cells 15-25 µm, distal cells 27.5-35 µm. Prickle-hairs common, hook, 17.5-25 µm long. Stomata 2-3 rows, 32.5-40 µm, subsidiary cells low-dome shaped or dumb-bell shape.

Abaxial epidermis (Figure 4.21 C.-D.)

Zonation costal and intercostal zones distinguishable. **Costal zone**: 3-7 cell rows. Long-cells rectangular, thin and sinuous wall, 87.5-150 by 10-12.5 µm. Short-cells abundant, in 1-3 rows; sparsely, solitary or paired, alternate with long-cells. Silica-bodies mostly intermediate between cross and dumb-bell shaped, some nodular. Prickle-hairs rarely, c. 25 µm long. **Intercostal zone**: 2-18 cell rows. Long-cells rectangular, thick and sinuous wall, 42.5-140 by 15-20 µm. Interstomatal cells thick and sinuous wall, 70-92.5 by 20-25 µm, concave ends. Short-cells abundant, solitary or paired, alternate with long-cells. Silica-bodies cross-shaped. Micro-hairs sparsely, length 27.5-50 µm, basal cells 12.5-20 µm, distal cells 15-30 µm. Stomata 2-6 rows, 30-37.5 µm long, subsidiary cells low-dome shaped.

Leaf in transverse section (Figure 4.21 E.-G.)

Outline V-shaped. **Adaxial epidermis** smooth; bulliform cells some in fan-shaped group, others in irregular group, associated with few, round and small colourless cells. **Abaxial epidermis** smooth, except large rib on median first-ordered vascular bundles. **Mesophyll**: chlorenchyma radiate, first-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially; second-ordered vascular bundles with chlorenchyma interrupted adaxially and abaxially; most third-ordered vascular bundles with completely radiate, a few with chlorenchyma interrupted abaxially. **Keel** conspicuous, rounded, containing 3 first-ordered vascular bundles accompanied among them by 1-2 second-ordered vascular bundles which alternately arranged with 1 third-ordered vascular bundles, bundles abaxially arranged. **Vascular bundles**: first-ordered vascular bundles large, round, c. 19 in entire blade; second-ordered vascular bundles medium, round, c. 3 between each pair of first-ordered vascular bundle; third-ordered vascular bundle small to nearly equal size to second-ordered vascular bundles, angular, at least pentagonal in outline, 3-4 alternately arranged with second-ordered vascular bundle. **Bundle sheaths** single; first-ordered vascular bundles with sheaths interrupted abaxially; most second-ordered vascular bundles with complete sheaths, a few with sheaths interrupted abaxially; third-ordered vascular bundles with complete sheaths. **Sclerenchyma**: lamina: first-ordered vascular bundles with adaxial and abaxial girders, usually 4-12 cells wide and 3-4 cells high; second-ordered vascular bundles with adaxial and abaxial girders, girders consisting of 2-6 cells wide and 2-4 cells high; few third-ordered vascular bundles with abaxial strands, strands composed of a few cell; midrib: most keel bundles with well-marked abaxially girders only, first-ordered vascular bundles abaxially accompanied by 7-44 cells wide and 6-8 cells high sclerenchyma, most second-ordered vascular bundles abaxially accompanied by 5-10 cells wide and 5-7 cells high sclerenchyma, the adaxial surface above the keel being supported by a wide plate with 2 cells high of hypodermal sclerenchyma; leaf margin with cap of sclerenchyma, cap well-developed and pointed.

Culm in transverse section (Figure 4.21 H.)

Outline round. **Epidermis** composed of rectangular shape cells. **Ground tissue** cells gradually becoming larger on passing inwards from the periphery to the centre of the culm, centre tending to break down, outer ground tissue composed of about 10-14 layers of sclerenchyma cells, inner ground tissue composed of parenchyma cells. **Vascular bundles** round, scattered throughout the culm, outer circles composed of smallest and small bundles with embedded in sclerenchyma.

4.4 Discussion and Conclusion

In Sorghinae, leaf epidermis in surface view is divided into 2 zones of costal and intercostal zones. These two main zones are distinguishable. In the species studied the epidermis is similarly organized, which agrees with Metcalfe's observations (1960). Generally, the epidermis of grass leaf is made up of 2 cell types: "long and short-cells" (Metcalfe, 1960). In this study, there are 4 types of long-cells, costal long-cells, intercostal long-cells, interstomatal cells and bulliform cells. In Sorghinae, costal and intercostal long-cells are similar in shape. Both are rectangular and sinuous walls, but costal long-cells are more narrower than the other. Interstomatal cells are found at intercostal zone situating between 2 stomata. Obviously, if stomata are absent, interstomatal cells are absent as well.

Short-cells are more frequent in the costal zone than the intercostal zone. In *Chrysopogon*, they occur in solitary or paired as alternating with long-cells both in costal and intercostal zones. On the other hand, the rest of genera contain 1-3 rows of short-cells with few solitary or paired of short-cells at costal zones, while they are solitary or paired alternating with long-cells at intercostal zones. This is concordant to Metcalfe (1960) who stated that short-cells occur in rows, in pairs, or solitary.

Short-cell has been generally called as silica-cell because it is filled with a single silica-body. The silica-bodies have various shapes and considerable value for diagnostic and taxonomic purposes. Silica-bodies observed are mostly cross-shaped, intermediate between cross and dumb-bell shape, some tall, narrow and crenate, or nodular. It is noticeable that silica-bodies can separate Sorghinae into 2 groups. The first is only cross-shaped silica-bodies found on the genus *Chrysopogon* (excepting *C. aciculatus* with mostly intermediate between cross and dumb-bell shaped present). The second is combination of silica-bodies of cross, intermediate between cross and dumb-bell shape, nodular or tall, narrow and crenate shapes found in the rest of genera.

Font Quer (1975, cited in Vieira et al., 2002) defines papillae as the simplest of trichomes, characterized by wall projection followed by the protoplast of cells. According to Ellis (1979), Poaceae papillae occur in long and short-cells, especially in intercostal zones, in numbers that may vary from one to many per cell. In subtribe Sorghinae, these structures are not observed in *Chrysopogon, Hemisorghum* and *Sorghum* (except *S. nitidum*), whereas papillae group occurs in all studied species of *Bothriochloa, Capillipedium*, *Dichanthium* and *Pseudosorghum*. Interestingly, there are papillae on lower epidermis of *Sorghum nitidum* while they are not present in other studied species of this genus; this is congruent with Dávila and Clark (1988, cited in Dávila and Clark, 1990) who revealed that *Sorghum* subg. *Parasorghum* (possessing *S. nitidum*) exhibits two to several small papillae per interstomatal and intercostal long-cell. From the study, two types of papillae are discovered. The first type is small globose papillae resulting from a cuticular projection not being followed by the wall and protoplast of the epidermis cell. This papillae type occurs in large number at costal and intercostal long-cell of *Bothriochloa, Capillipedium*, *Dichanthium*, and *Pseudosorghum*. The other type is larger and oblique papillae which occur at interstomatal cells of *Bothriochloa*, *Capillipedium*, *Dichanthium*, and *S. nitidum*. Both types of papillae are found together in *Bothriochloa, Capillipedium*, *Dichanthium* and *S. nitidum*, while only the first type is found in *Pseudosorghum*. Thus, the absence or presence of papillae as well as pattern of papillae arrangement can be interpreted as a taxonomic indicator for Sorghinae.

Prickles are unicellular, and they are distinguished by a dilated based and a pointed apex. They occur in the costal or intercostal zones of all studied species except *Hemisorghum mekongense*, i.e. prickle-hairs is absent. Therefore, the absence or presence of prickles can be used for classification at generic level.

Micro-hairs are made up of two cells, the apical cell presenting an extremely thin wall, sometimes caduceus (Tateoka, Inowe and Kawano, 1959). Although all studied species have micro-hairs, the character of short or long basal cells, however, can be informative for Sorghinae. For example, micro-hairs are short basal cell in *Bothriochloa*, whereas it is long basal cell in *Capillipedium*. Metcalfe (1960) stated that micro-hairs were not seen in *Capillipedium*. However, Faruqi (1961) revealed micro-hairs in *C. parviflorum* and *C. spicigerum*. This present study confirms Faruqi's investigation with micro-hairs in all specimens and species of *Capillipedium*, though, abundance may be varies.

According to Ellis (1979), the Poaceae stomata generally occur in well-defined bands in intercostal zones, and they may be classified according to the shape of subsidiary cells. Thus, there are low or high-domed or triangular shapes of subsidiary cells in Andropogoneae (Renvoize, 1982). For Sorghinae, it comprises low-domed and triangular shape, however both of stomata types can be found in single leaf. So, the shapes of stomata are not diagnostic character, but presence or absence is informative for classification.

Ellis (1976) defines bulliform cells as being an intrinsic part of the epidermis, differing from the other epidermal elements proper for being generally larger and more inflated. Besides, their occurrence and distribution may be valuable for diagnostic purpose. In the studied species, bulliform cells are in upper epidermis, which agrees with Renvoize (1982). Mostly, this structure is well developed, except in *Chrysopogon* which generally occurs in fewer groups on either side of midrib or some times are not distinct groups. Then, poor development of bulliform cells is diagnosis for *chrysopogon*. For bulliform cell group, two forms are found: fan-shaped form and irregular form. Unfortunately, both forms are observed in same specimen. Therefore, this character is uninformative for Sorghinae.

According to Metcalfe (1960), midrib or keel in Poaceae may conspicuously or may not present, and its shape is either round or triangular. For Sorghinae, the species show conspicuous keel with round or triangular shape. Moreover, this present study reveals the valuable shape of keel as diagnostic character within Sorghinae. In addition, it should be noted that number of first-ordered vascular bundle in keel, one or more, is useful to classify.

Renvoize (1982) studied Andropogoneae and found the chlorenchyma around all classes of vascular bundles, namely clearly radiate, obscurely radiate or non-radiate. Within Sorghinae, chlorenchyma is clearly radiate and its cell is long and narrow. This study also agrees with Metcalf (1960).

For culm anatomy, vascular bundle arrangement is diagnostic character. It divides Sorghinae into 2 groups; vascular bundle scattered throughout the culm and 3 more or less distinct circles of vascular bundle near epidermis. The first group is found in *Hemisorghum,* and *Sorghum.* The second group is found in *Bothriochloa*, *Dichanthium,* and *Pseudosorghum.* However, both patterns are present together in *Capillipedium* and *Chrysopogon*. It means the pattern of vascular bundle arrangement in culm useful to classification in both generic and specific levels.

Relationship in *Chrysopogon*

Chrysopogon is now composed of two old genera, *Chrysopogon* and *Vetiveria*. From the present study, the old genus of *Vetiveria* (*V. zizanioides* and *V. lawsonii*) contains solitary or paired of short-cells alternating with long-cells, which similar to those of the old *Chrysopogon*. Moreover, bulliform cells in *Vetiveria* are not clearly developed where far from the midrib, which similar to those in *Chrysopogon* as well.

Therefore, this finding confirms Velkamp's revision (1999) that included these two genera in one under *Chrysopogon*. Moreover, these 2 characters are considered as synapomorphies for congener of *Chrysopogon* and *Vetiveria*.

Relationship in *Bothriochloa, Capillipedium* and *Dichanthium*

Bothriochloa, Capillipedium and *Dichanthium* were treated as closely related genera. Morphologically, *Bothriochloa* is similar to *Capillipedium* due to translucent furrow at pedicell of pedicelled spikelet, while *Bothriochloa* is close to *Dichanthium* as an inflorescent form of digitate raceme. Moreover, hybridization among three genera can be found, namely, *B. bladhii* × *B. ischaemum*, *B. bladhii* × *D. annulatum* and *B. bladhii* × *C. parviflorum* (DeWet and Harlan, 1966). In addition, the data from phylogeny (Spangler, 2000) suggested that these 3 genera were grouped in the same clade with high bootstrap support (92%). From present anatomical study, shared characters of these genera are two types of papillae at lower epidermis which including small, globose cuticular papillae at intercostal long-cells, and an oblique, slightly large papillae over interstomatal cells.

Although each genus can be recognized, the boundary among them seems to be blurred as some characters probably are homoplasious or apomorphies, for example, absence of stomata at adaxial epidermis of *Capillipedium*, short basal cells of micro-hairs in *Bothriochloa*. In the other hand, "shared" characters of *Dichanthium* are also found in other genera as well, e.g., absence of papillae at adaxial epidermis of all *Dichanthium* and *Bothriochloa bladhii*, and long basal cells of micro-hairs in leaf epidermis of *Dichanthium* and *Capillipedium*. Therefore, anatomical characters support these three genera as closely relatives. However, certain anatomical differences were existed as revealed by this study and that of Faruqi (1962), which could be used in showing relationships between different species as well as their hybrids.

Due to morphological and cytological evidences, De Wit and Harlan (1966 and 1970) have advocated uniting them. However, other evidences about molecular phylogeny have never been fully studied. Then, further investigation to clarify taxonomic status of these three genera is still needed.

Relationship in *Hemisorghum* and *Sorghum*

Hemisorghum mekongense was firstly treated as a variety of *Sorghum halepense* by A. Camus in (1919), Later she treated it as a rank of species level: *Sorghum mekongense*. In addition, from morphological study in chapter 5, *H. mekongense* is similar to *Sorghum propinquum*, a close species of *S. halepense* as well.

Morphologically, vegetative part, form and color of inflorescence are similar to those in *Sorghum*. However, many characters of reproductive part, namely serrare rachis and pedicel, slender spikelet, 2-keeled at lower glume of sessile spikelet and scabrous keel, are different from those in *Sorghum*.

Anatomically, from this study, some characters, namely scattered vascular bundle throughout the culm, many second-and third-ordered vascular bundles in a pair of first-ordered vascular bundle, absent macro-hair, absent papillae and short basal cells of micro-hairs, are shared between *H. mekongense* and *S. propinquum*. These characters support to close relationship between these taxa. However, some other characters, namely absent prickle-hairs and one first-ordered vascular bundle in keel, distinguish *H. mekongense* from *S. propinquum.*

In general, anatomical characters are useful for classifying. The valuable characters include short-cell, silica-body, macro-hair, micro-hair, prickle-hair, papillae, presence or absece of stomata, bulliform cells development, number of first-ordered vascular bundle in keel, sclerenchyma shape at leaf margin, and vascular bundle arrangement in culm.

Hence, the present work suggests that anatomical characters can be used as another tool to classify grasses in subtribe Sorghinae into generic and specific level, but using both characters of leaf and stem combined together. Moreover, it provides some efficient anatomical characters for further anatomical study.

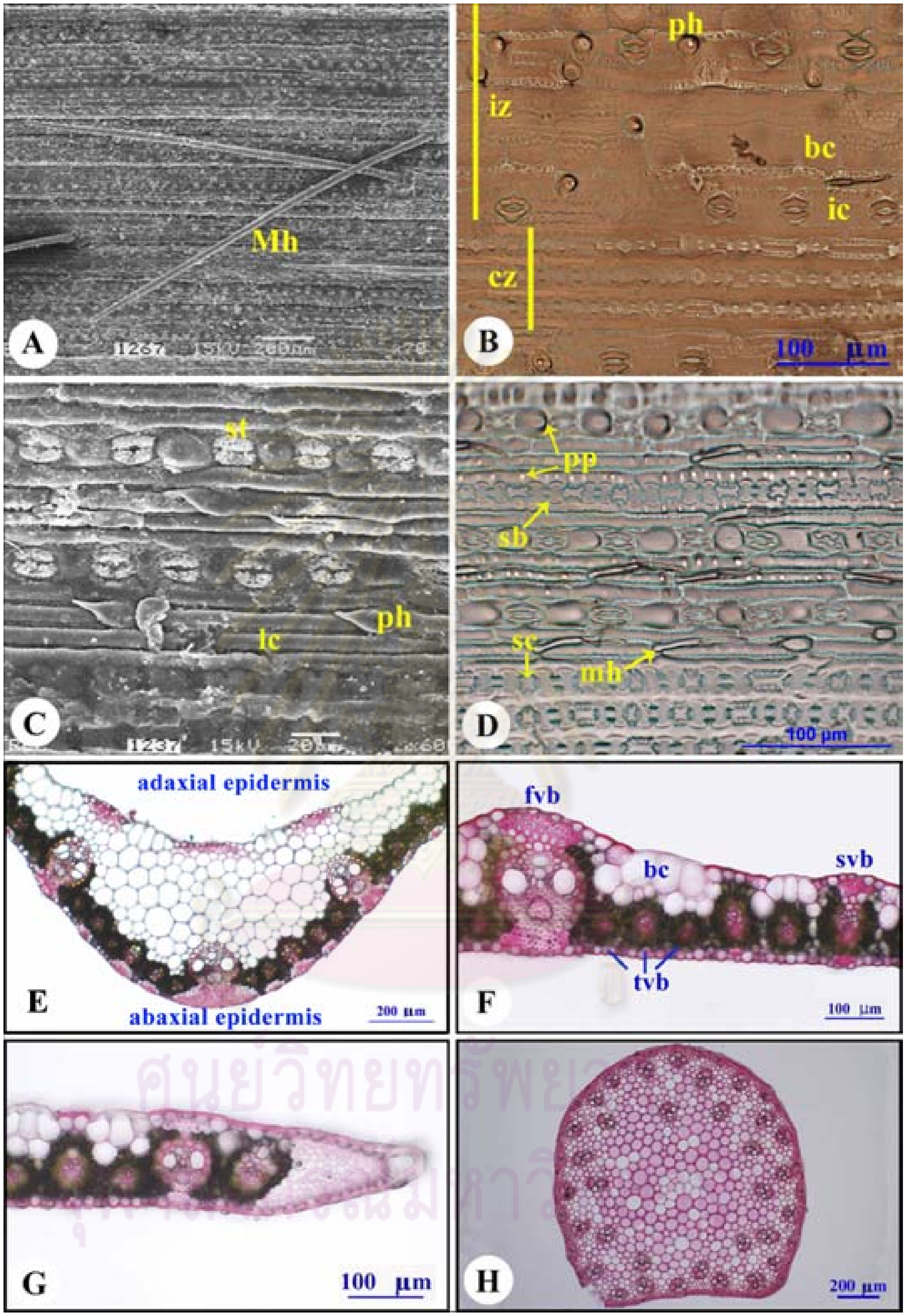

Figure 4.1 Leaf and culm anatomy of *Bothriochloa bladhii*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (bc=bulliform cell, cz=costal zone, ic=interstomatal cell, iz=intercostal zone, lc=long-cell, Mh=macro-hair, mh=micro-hair, ph=prickle-hair, pp=papillae, sb=silica body, sc=short-cell, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

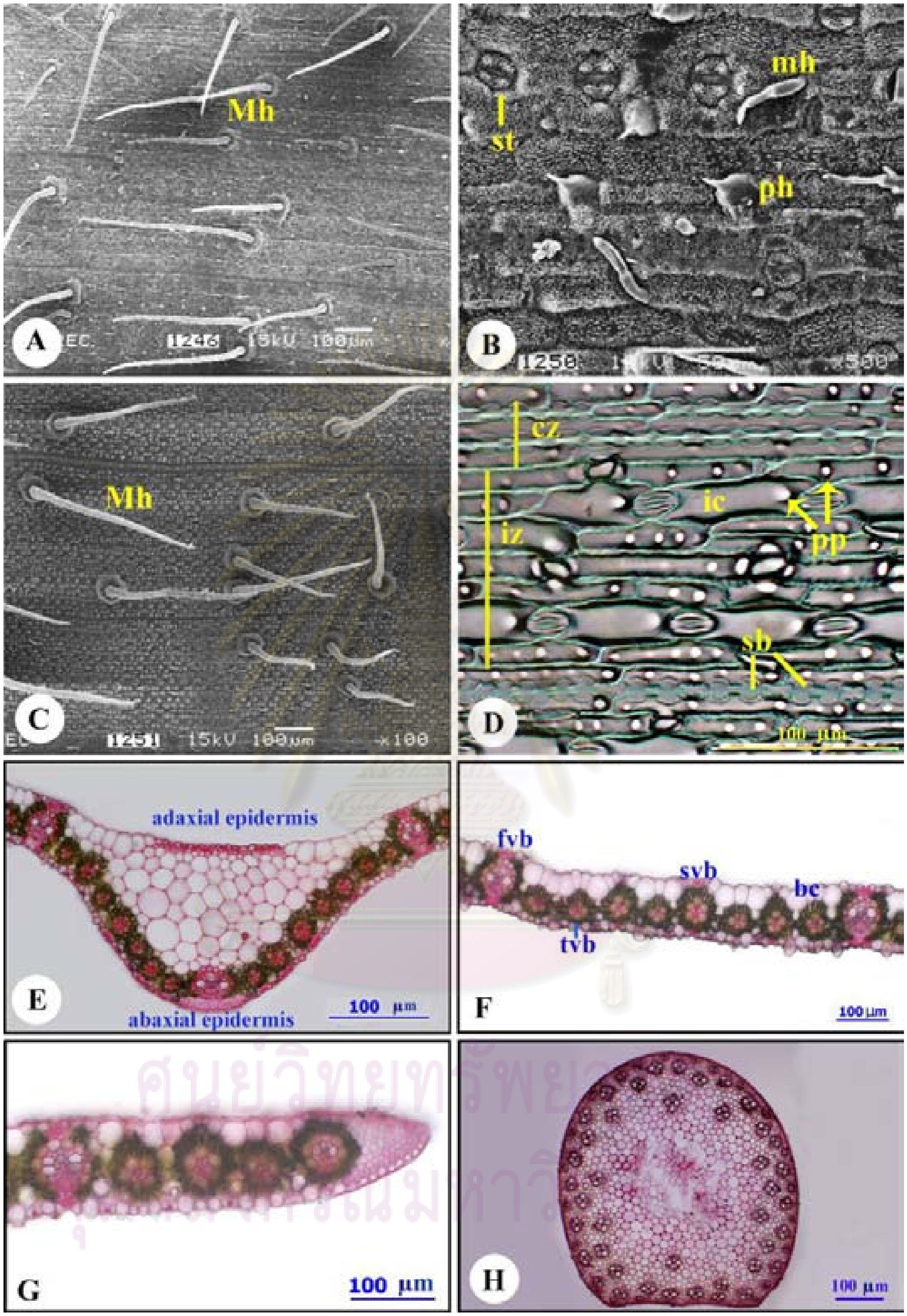

Figure 4.2 Leaf and culm anatomy of *Bothriochloa pertusa*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (bc=bulliform cell, cz=costal zone, ic= interstomatal cell, iz=intercostal zone, Mh=macro-hair, mh=micro-hair, ph=prickle-hair, pp=papillae, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

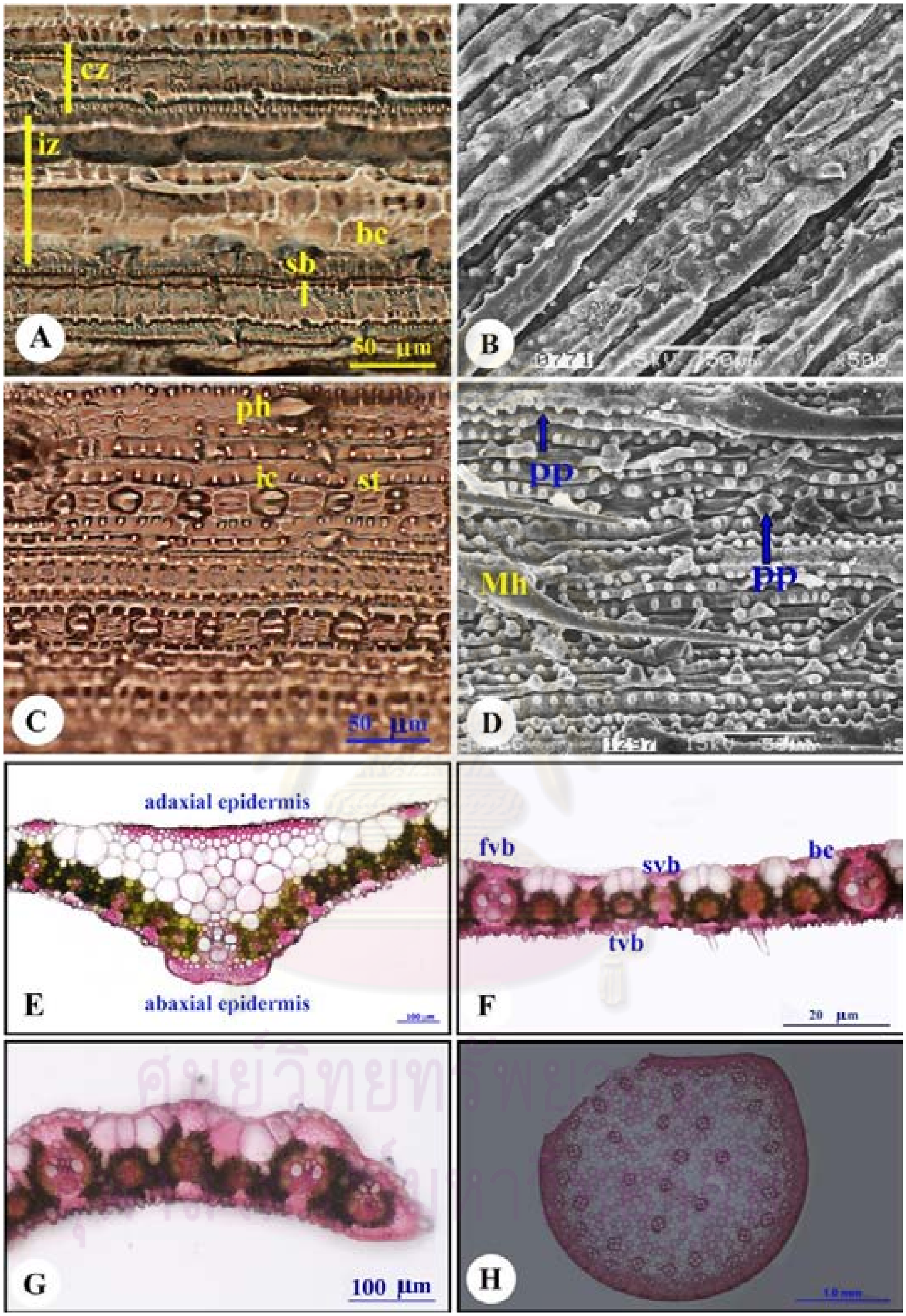

Figure 4.3 Leaf and culm anatomy of *Capillipedium assimile*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (bc=bulliform cell, cz=costal zone, ic= interstomatal cell, iz=intercostal zone, Mh=macro-hair, ph=prickle-hair, pp=papillae, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

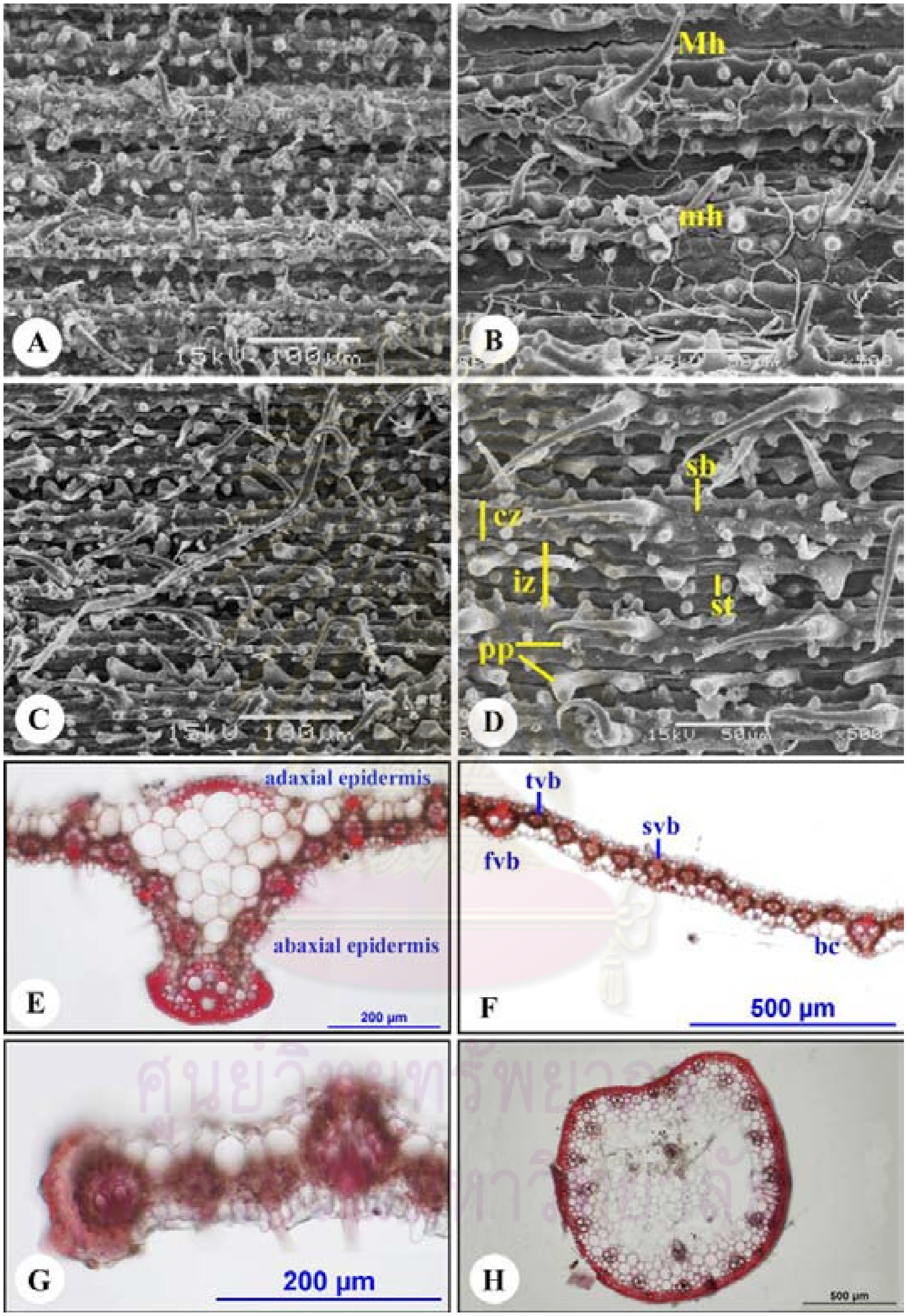

Figure 4.4 Leaf and culm anatomy of *Capillipedium laoticum*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (bc=bulliform cell, cz=costal zone, iz=intercostal zone, Mh=macro-hair, mh=micro-hair, ph=prickle-hair, pp=pipallae, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

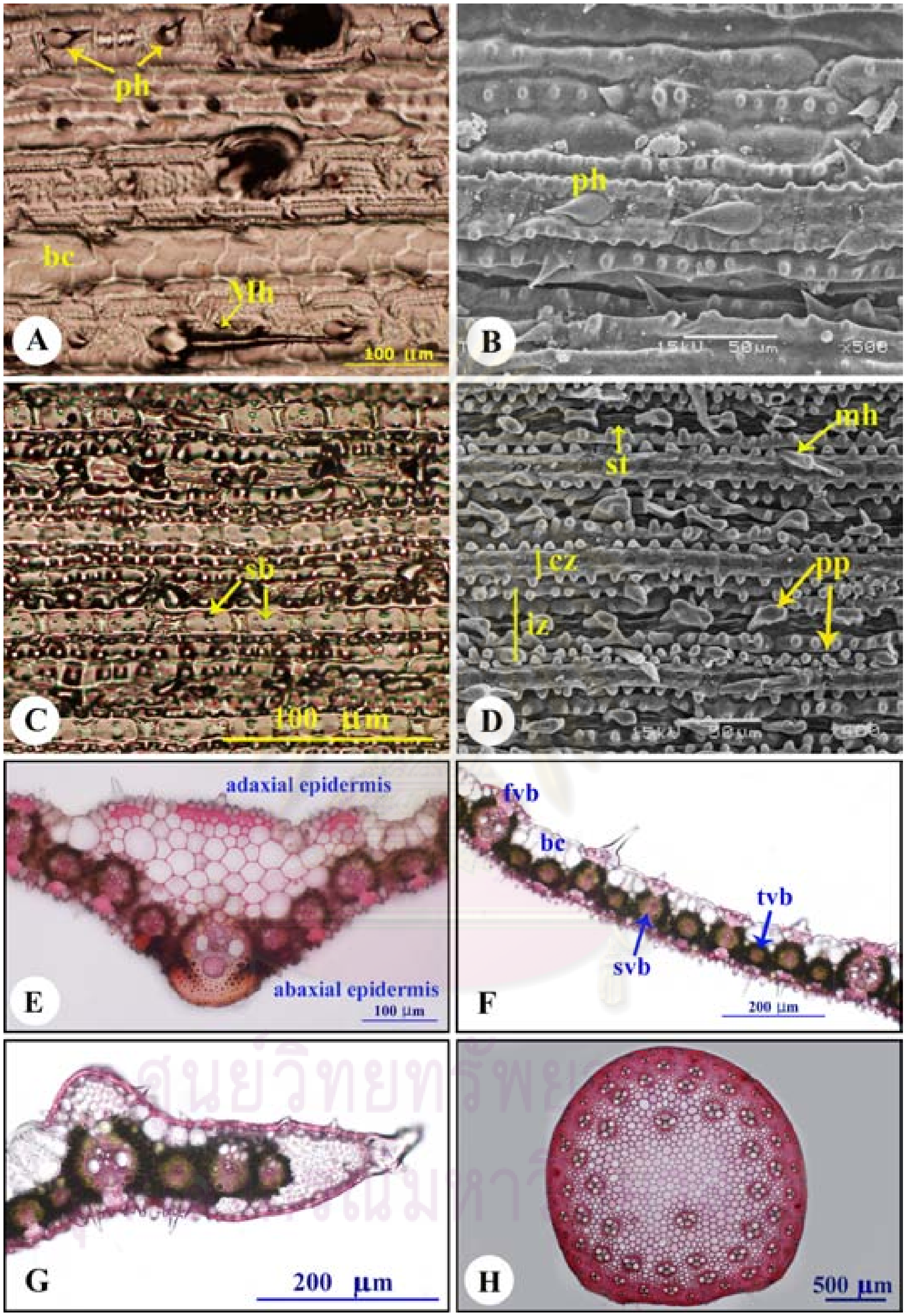

Figure 4.5 Leaf and culm anatomy of *Capillipedium parviflorum*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (bc=bulliform cell, cz=costal zone, iz=intercostal zone, Mh=macro-hair, mh=micro-hair, ph=prickle-hair, pp=papillae, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

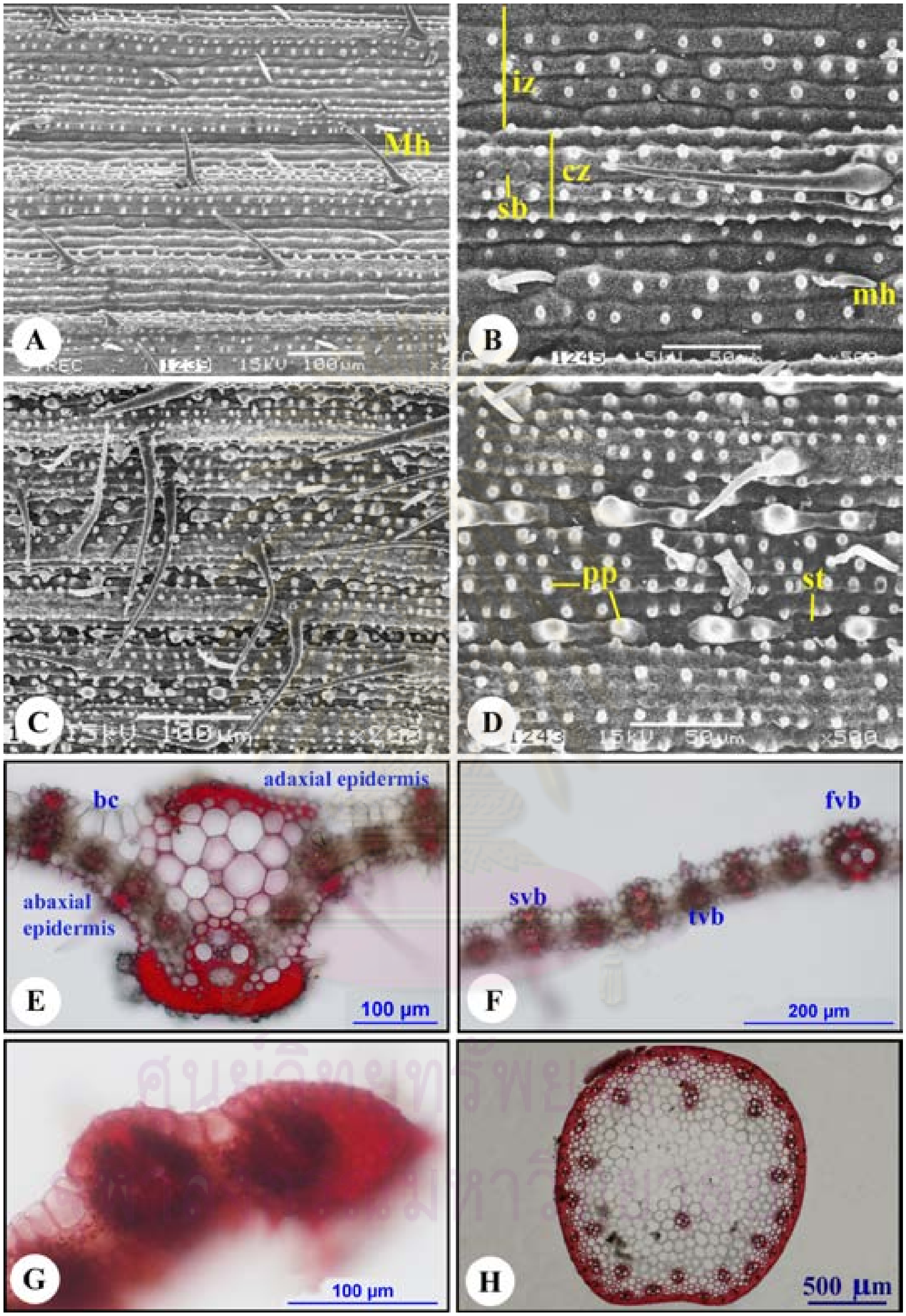

Figure 4.6 Leaf and culm anatomy of *Capillipedium sulcatum*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (bc=bulliform cell, cz=costal zone, iz=intercostal zone, Mh=macro-hair, mh=micro-hair, pp=papilae, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

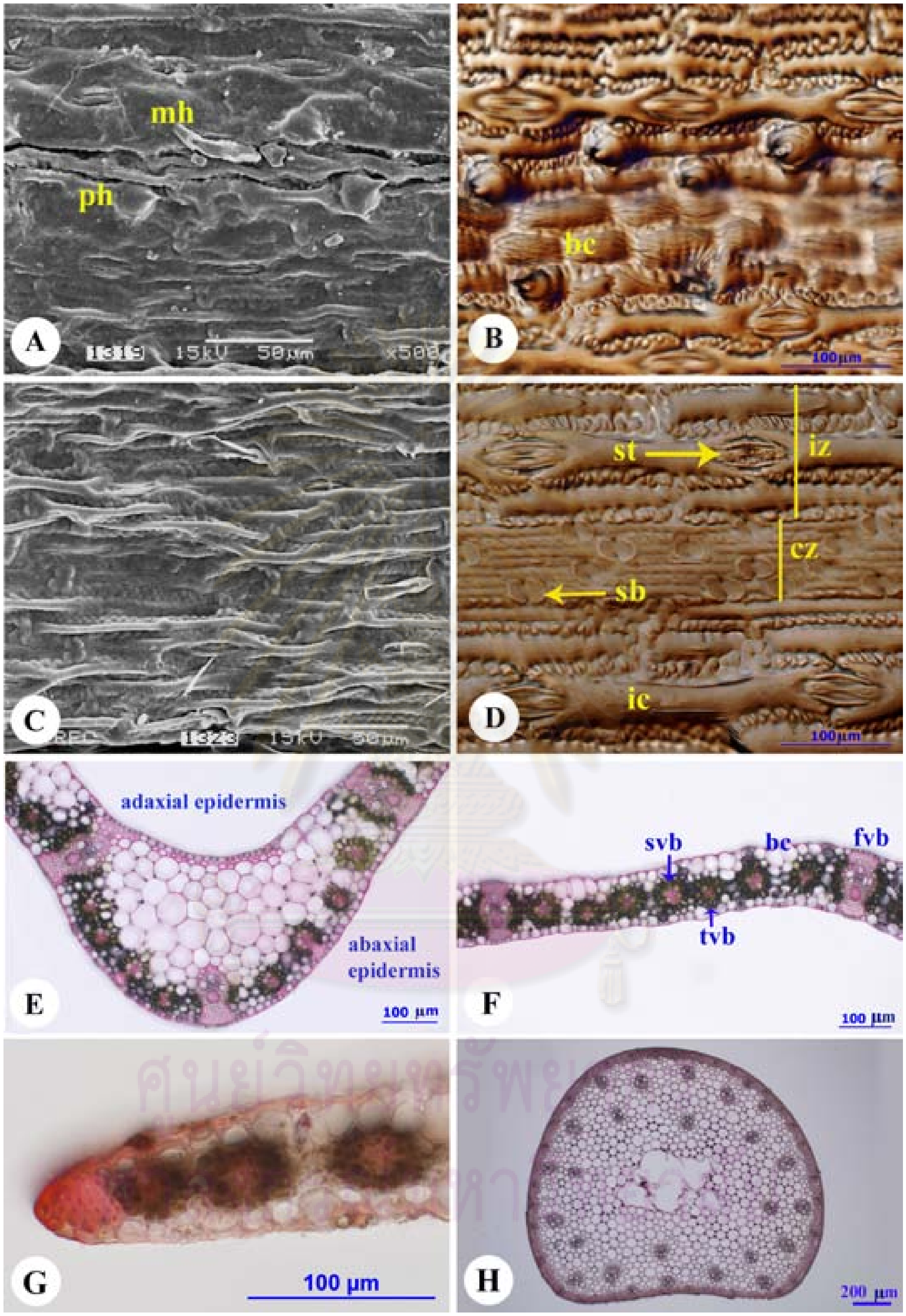

Figure 4.7 Leaf and culm anatomy of *Chrysopogon aciculatus*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (bc=bulliform cell, cz=costal zone, ic=interstomatal cell, iz=intercostal zone, mh=micro-hair, ph=prickle-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

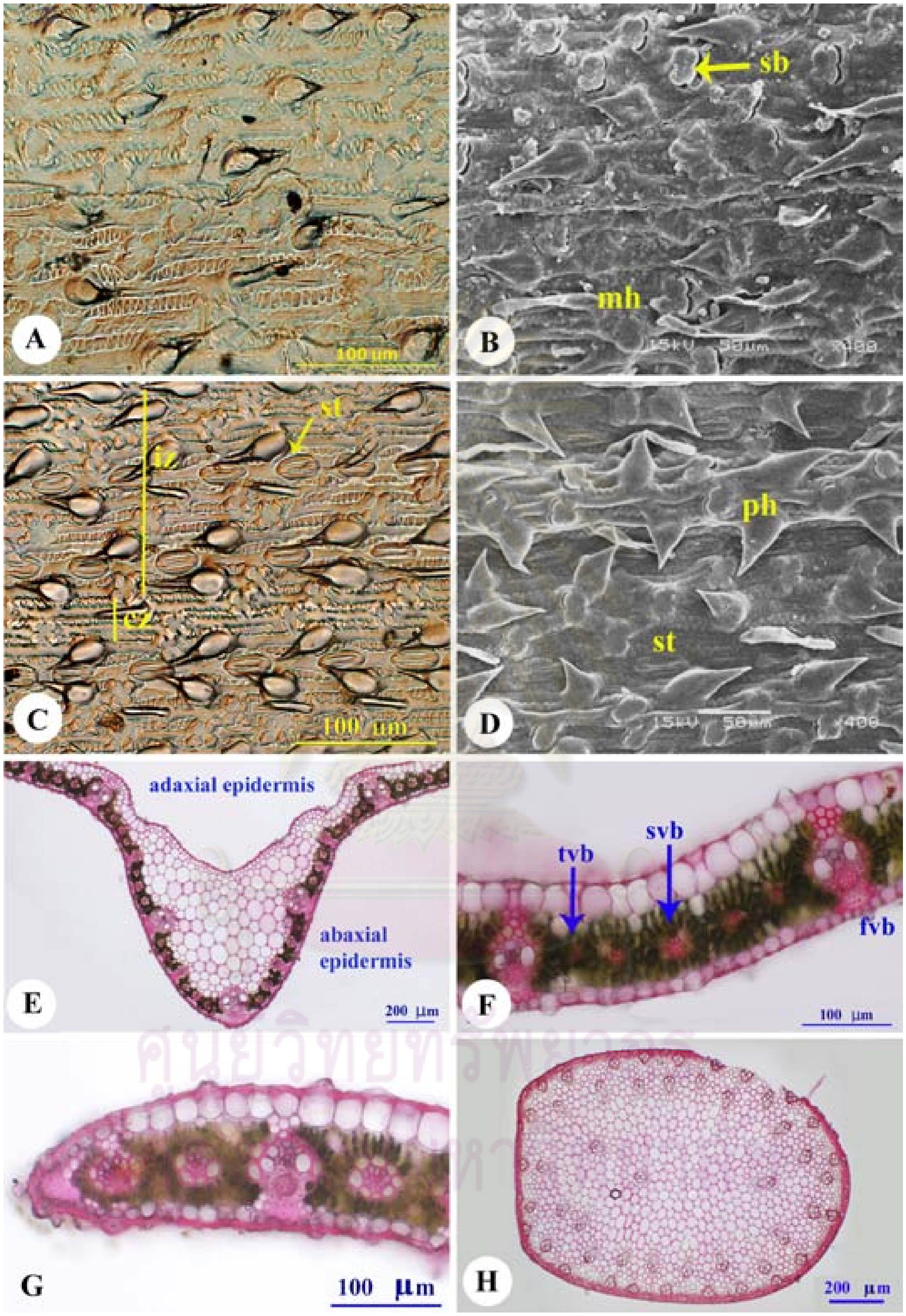

Figure 4.8 Leaf and culm anatomy of *Chrysopogon fulvus*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section.(cz=costal zone, iz=intercostal zone, mh=micro-hair, ph=prickle-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

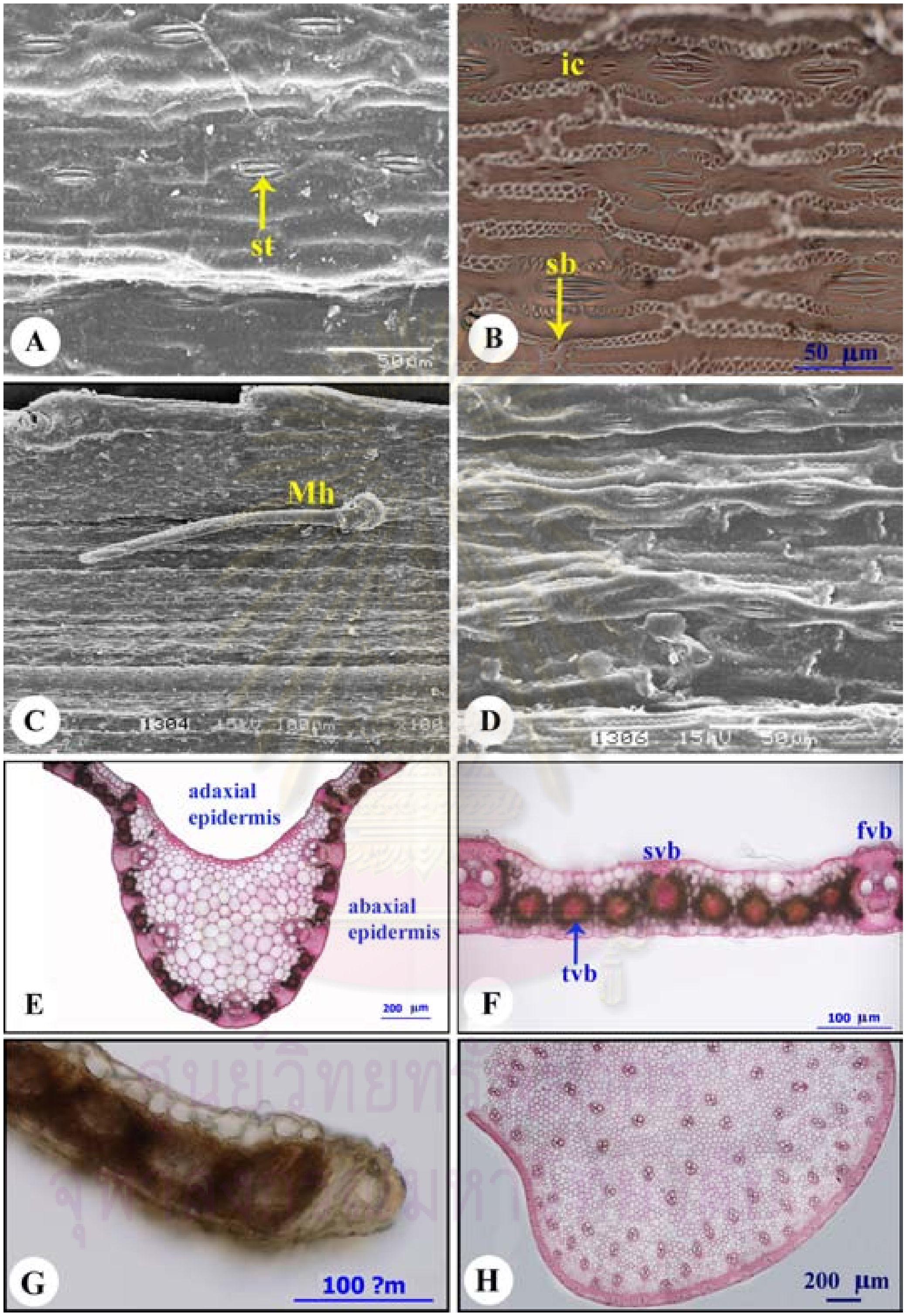

Figure 4.9 Leaf and culm anatomy of *Chrysopogon gryllus* subsp. gryllus: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (ic=interstomatal cell, Mh=macro-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

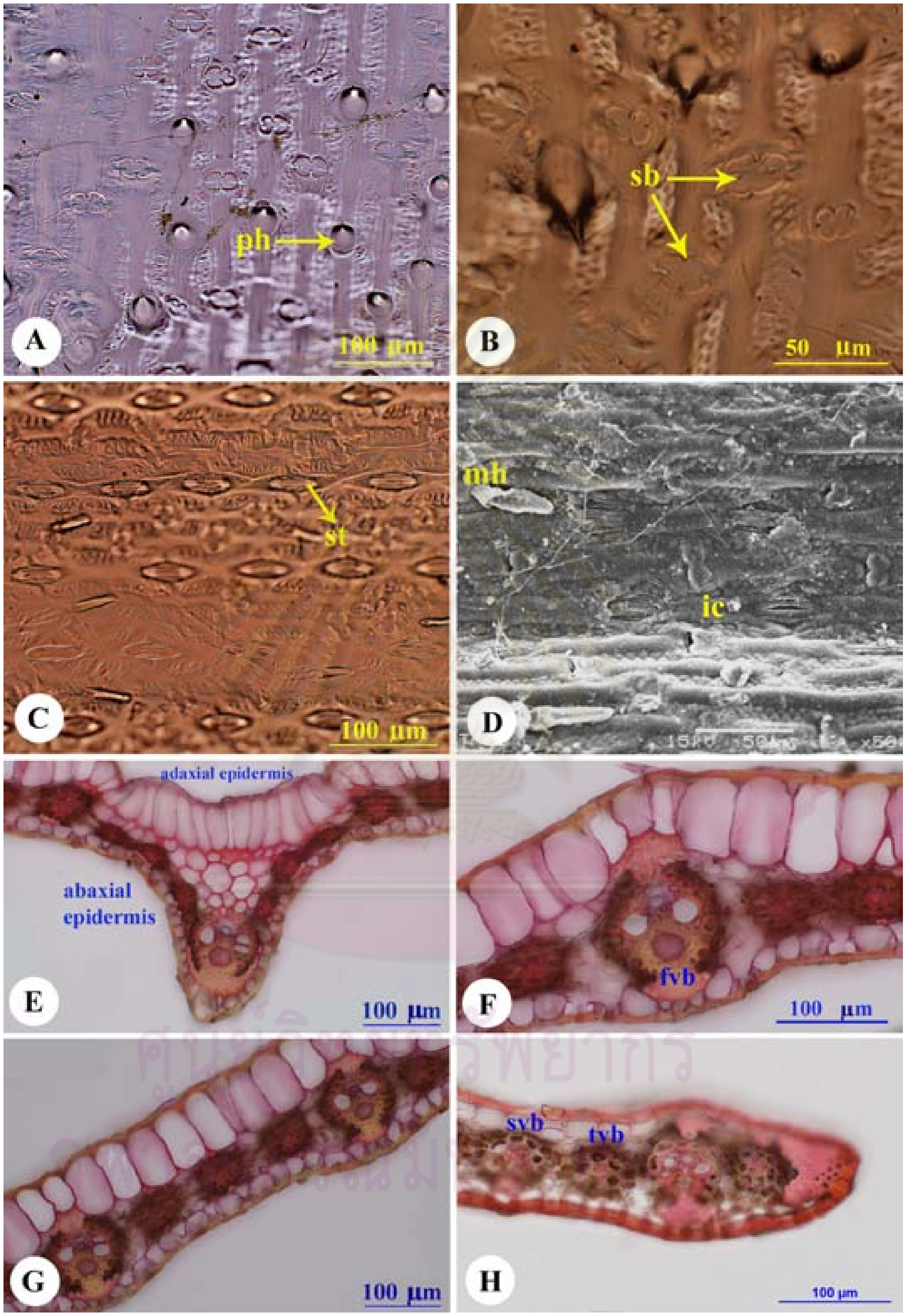

Figure 4.10 Leaf anatomy of *Chrysopogon lawsonii*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-H. leaf in transverse section. (ic=interstomatal cell, mh=micro-hair, ph=prickle-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

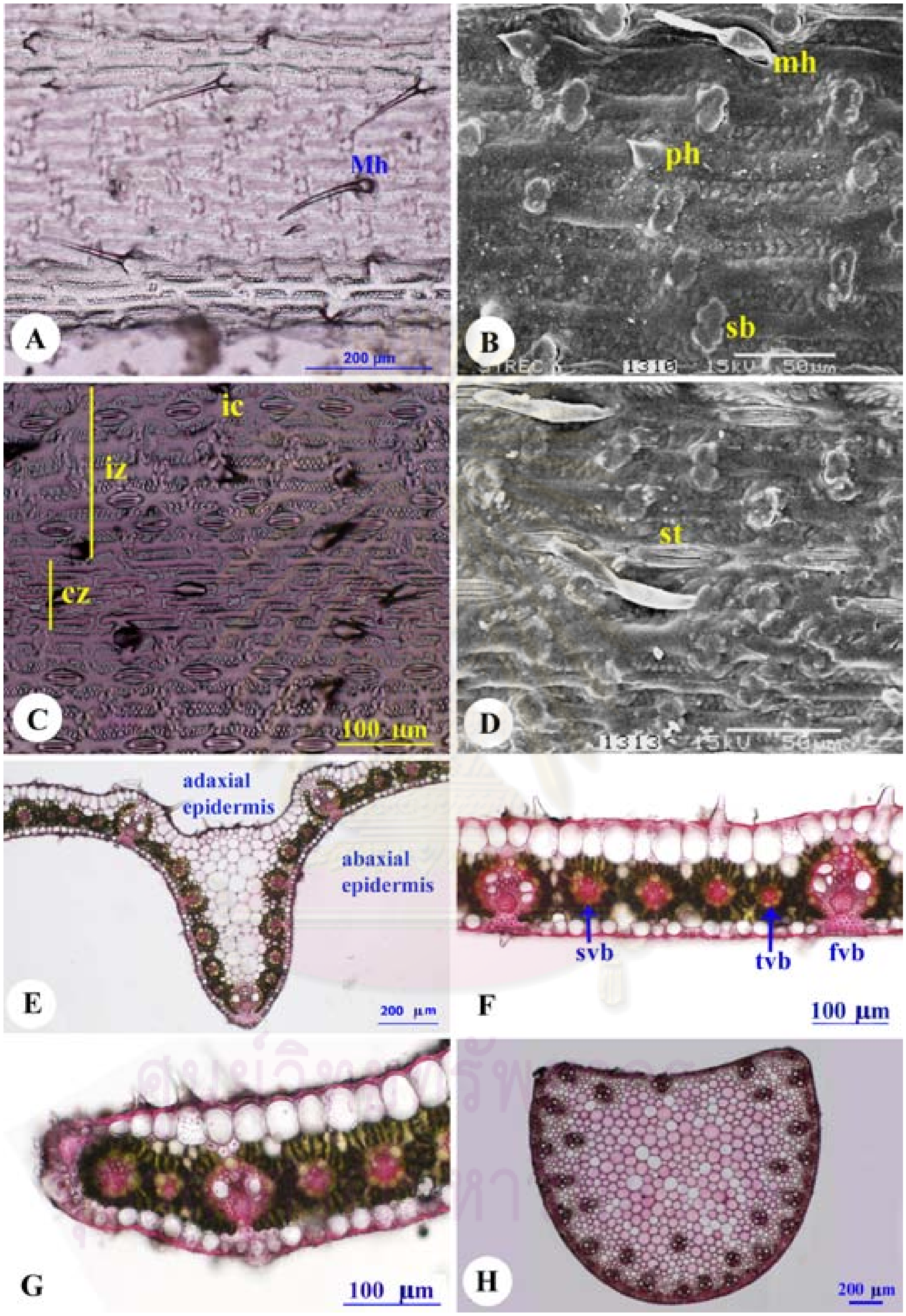

Figure 4.11 Leaf and culm anatomy of *Chrysopogon orientalis*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (cz=costal zone, ic=interstomatal cell, iz=intercostal zone, Mh= macro-hair, mh=micro-hair, ph=prickle-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

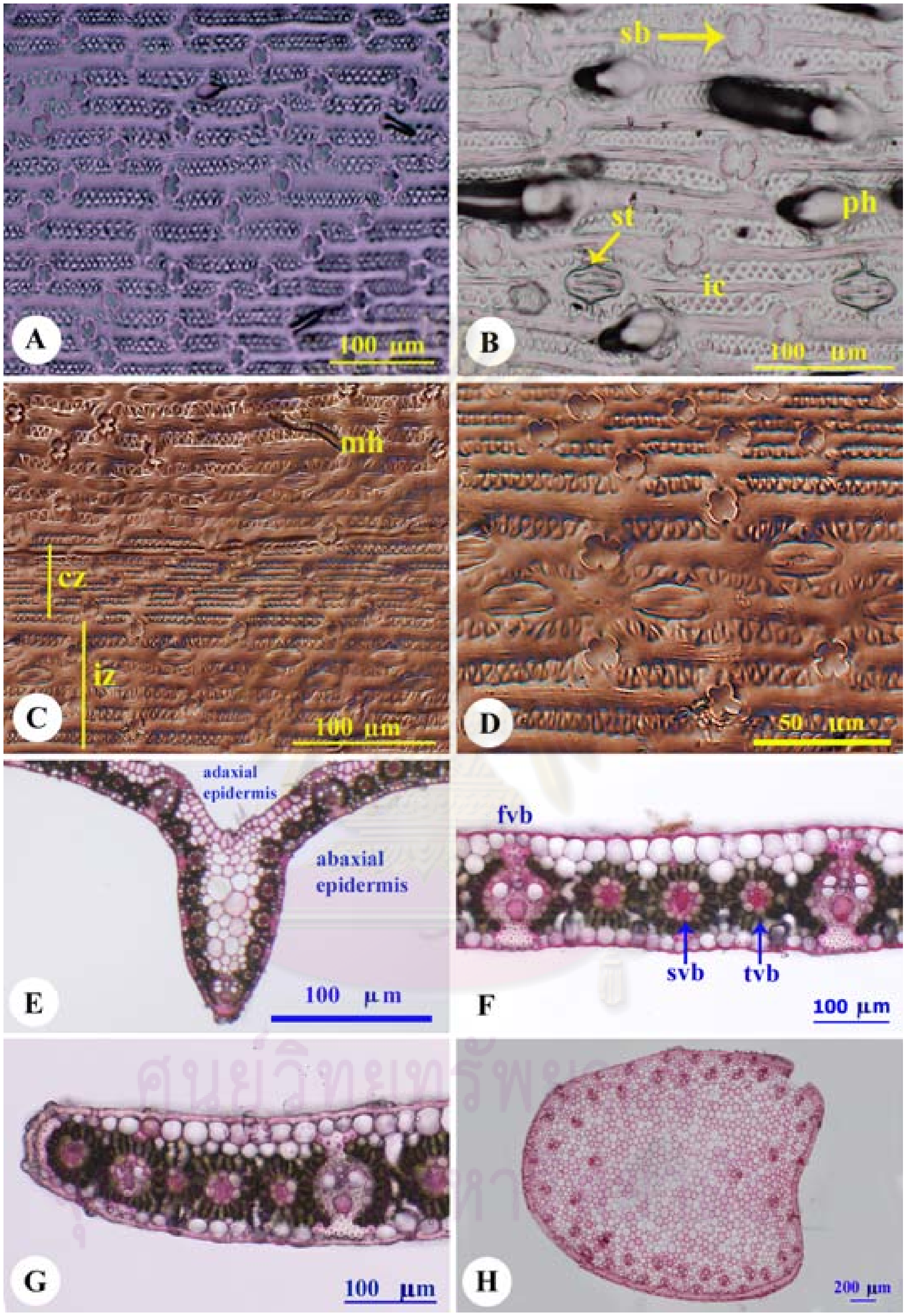

Figure 4.12 Leaf and culm anatomy of *Chrysopogon serrulatus*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (cz=costal zone, ic=interstomatal cell, iz=intercostal zone, mh=micro-hair, ph=prickle-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

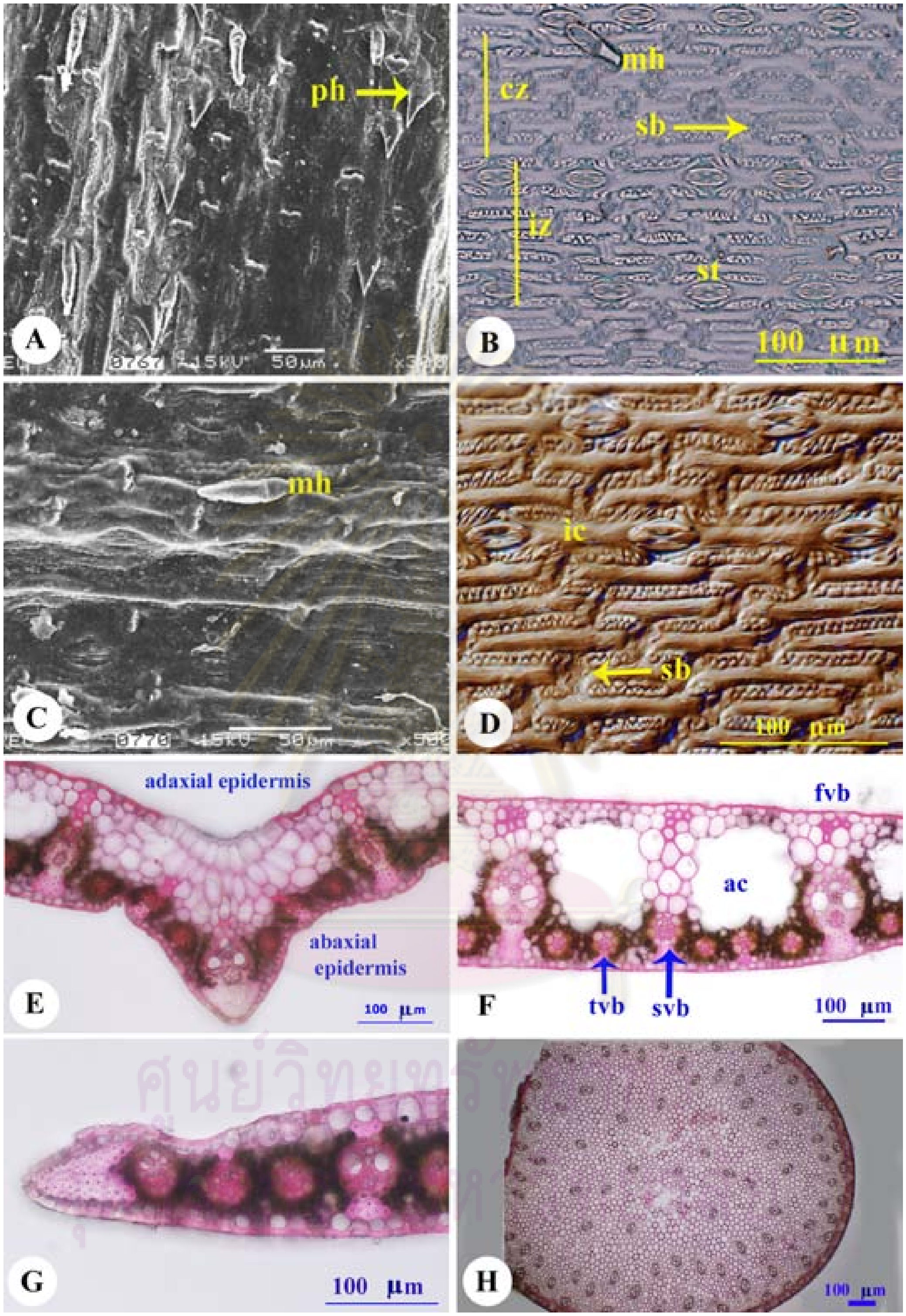

Figure 4.13 Leaf and culm anatomy of *Chrysopogon zizanioides*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (ac=air-cavity, cz=costal zone, ic=interstomatal cell, iz=intercostal zone, mh=micro-hair, ph=prickle-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

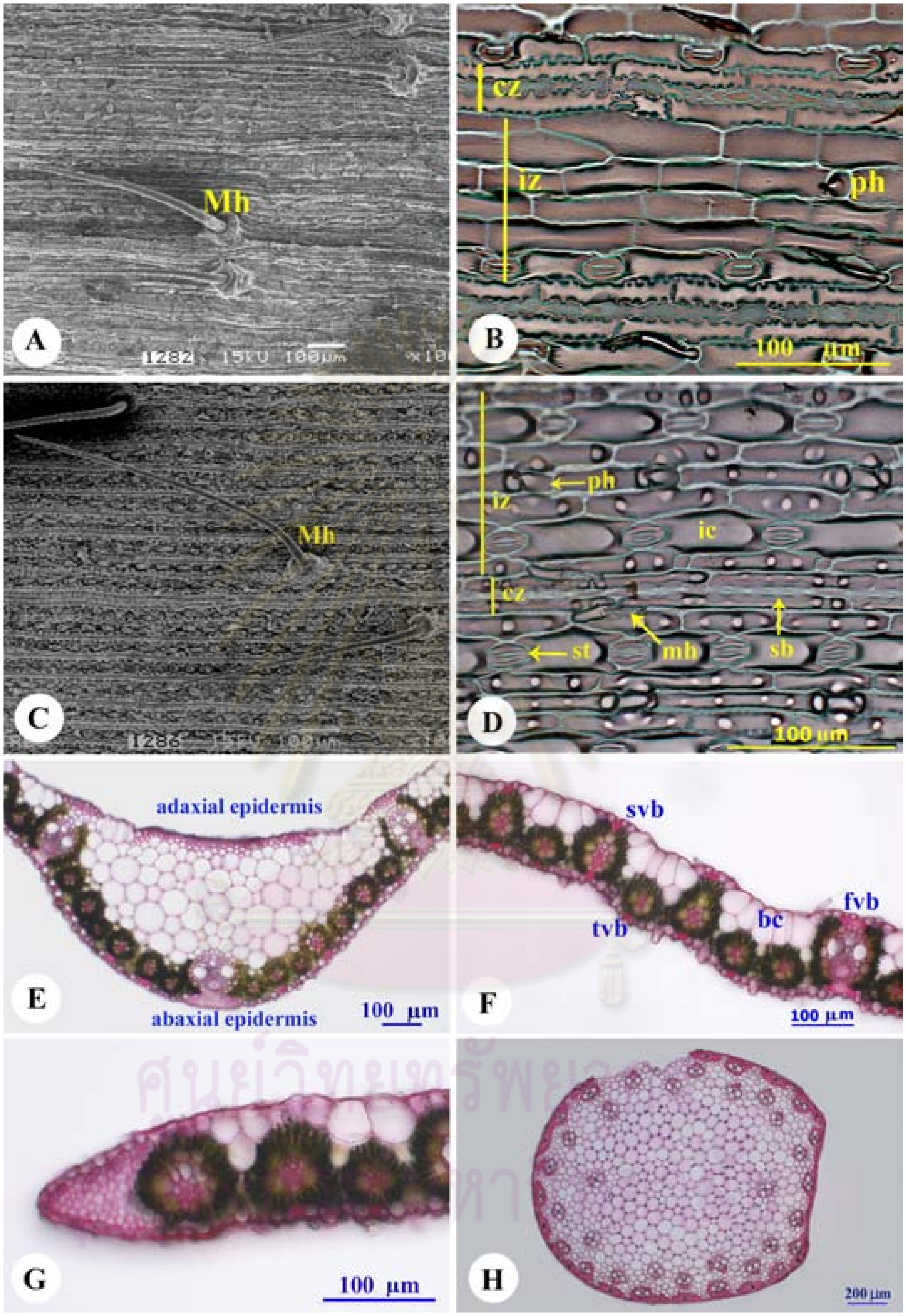

Figure 4.14 Leaf and culm anatomy of *Dichanthium annulatum*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (cz=costal zone, ic=interstomatal cell, iz=intercostal zone, Mh=macro-hair, mh=micro-hair, ph=prickle-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

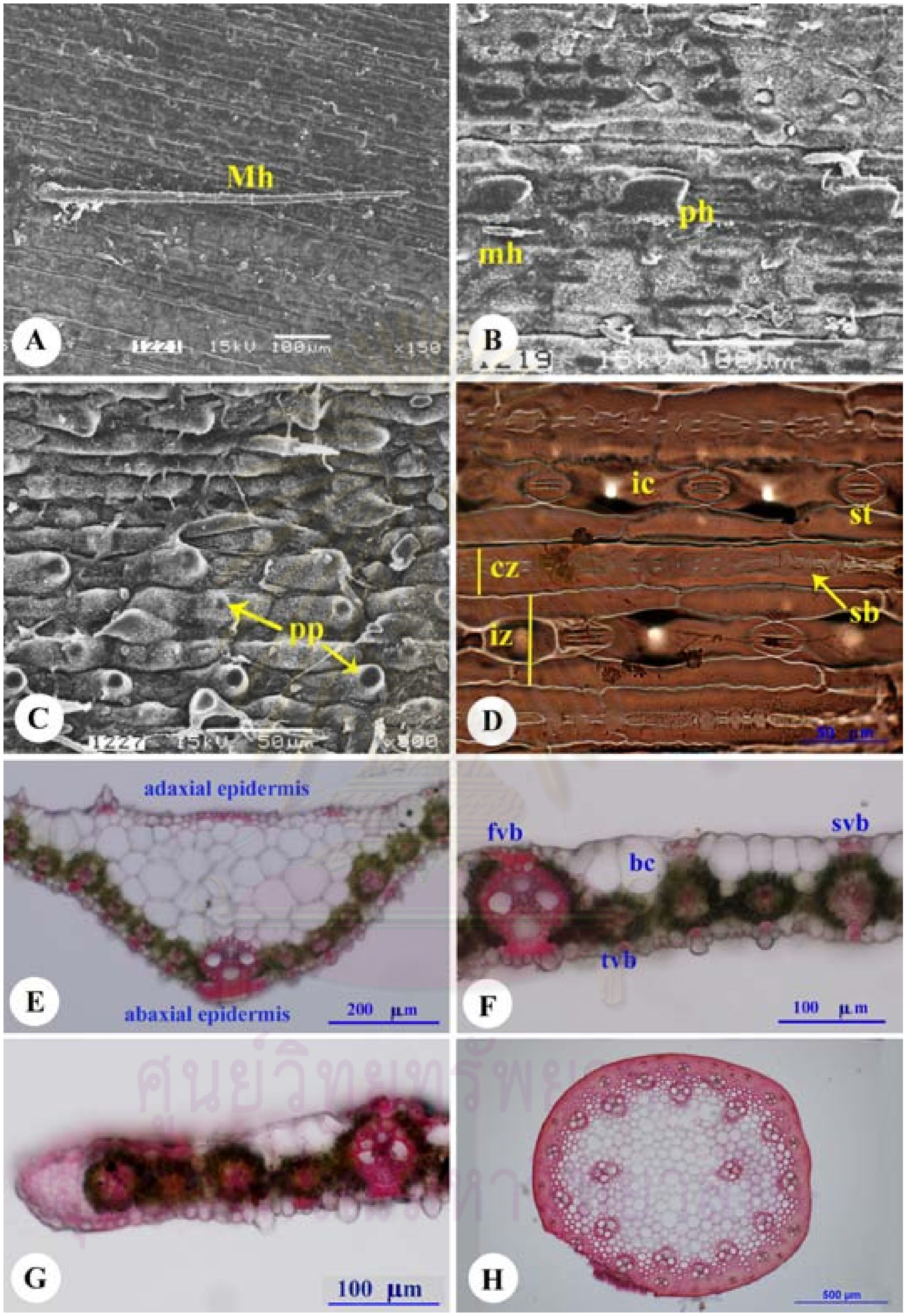

Figure 4.15 Leaf and culm anatomy of *Dichanthium aristatum*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (cz=costal zone, ic=interstomatal cell, iz=intercostal zone, Mh=macro-hair, mh=micro-hair, ph=prickle-hair, pp=papillae, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

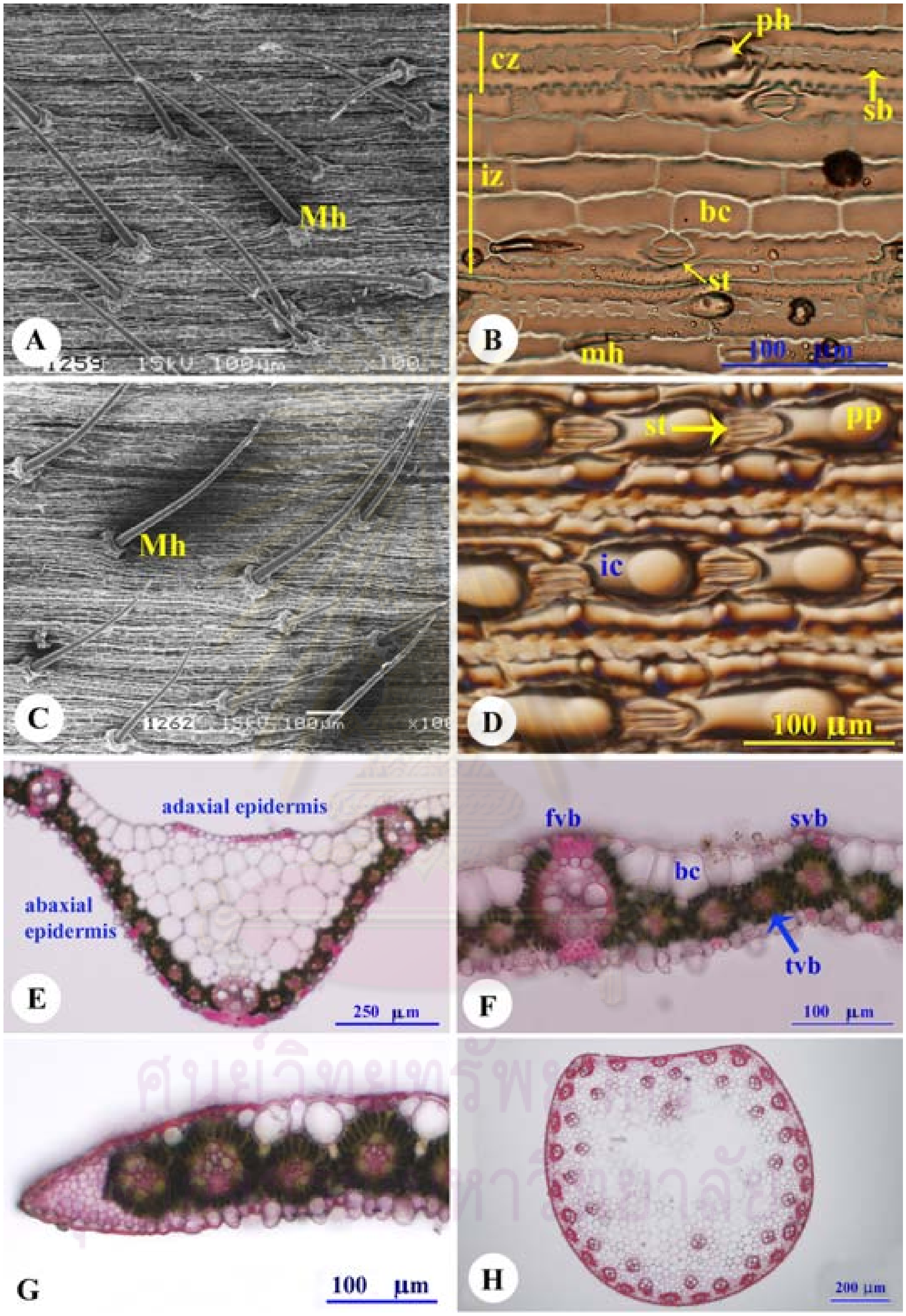

Figure 4.16 Leaf and culm anatomy of *Dichanthium caricosum*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (cz=costal zone, ic=interstomatal cell, iz=intercostal zone, Mh=macro-hair, mh=micro-hair, ph=prickle-hair, pp=papillae, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

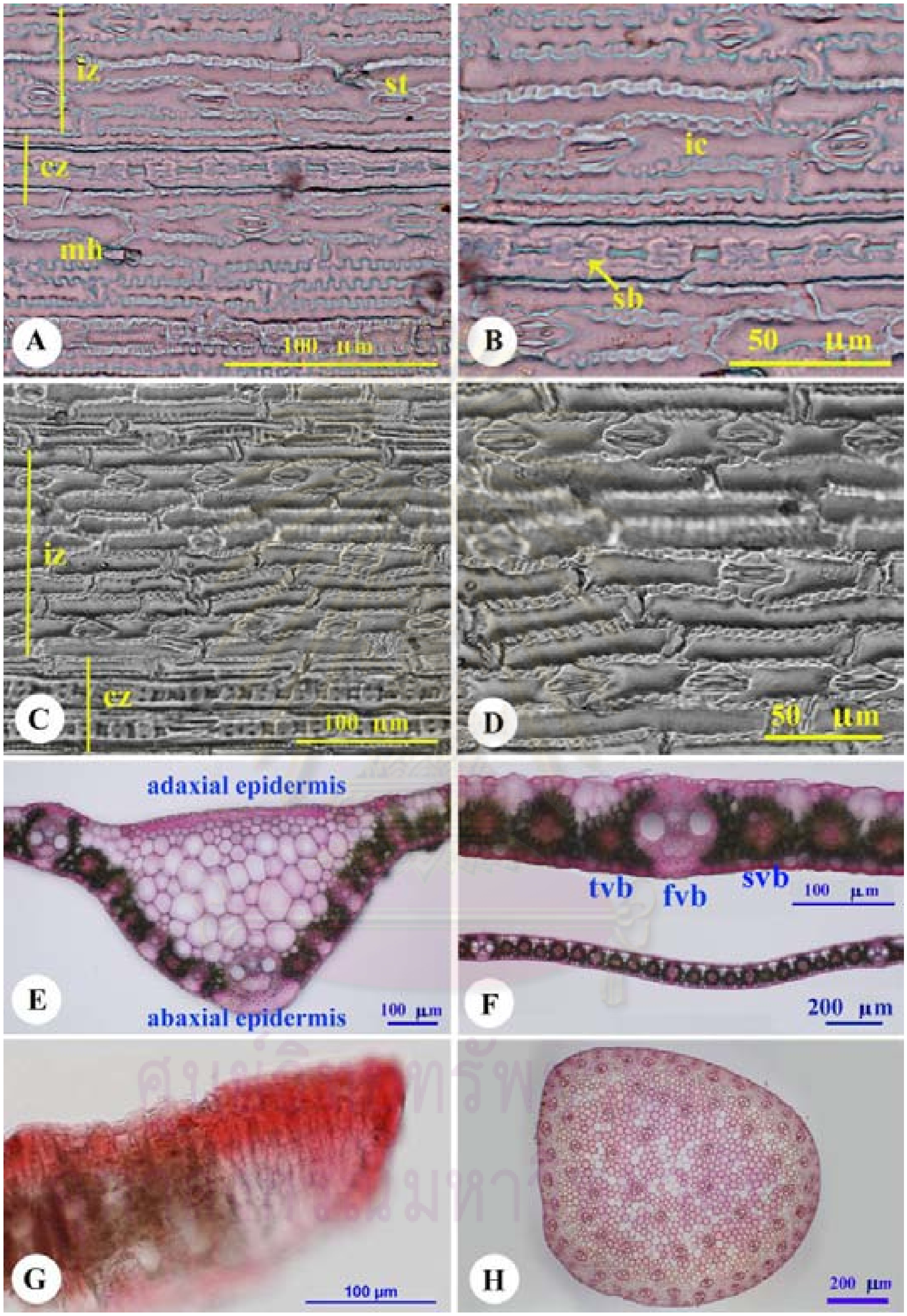

Figure 4.17 Leaf and culm anatomy of *Hemisorghum mekongense*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (cz=costal zone, ic=interstomatal cell, iz=intercostal zone, mh=micro-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

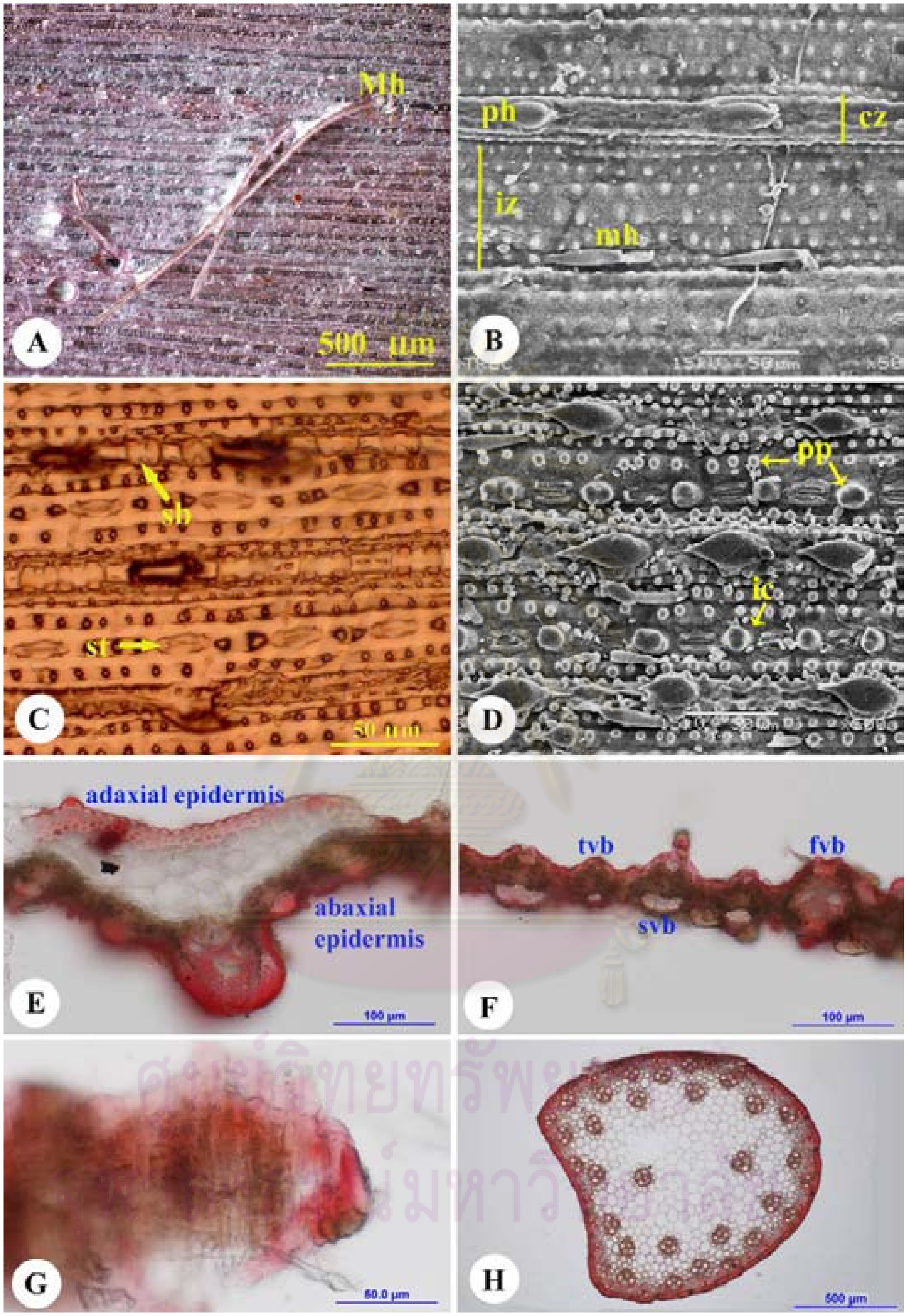

Figure 4.18 Leaf and culm anatomy of *Pseudosorghum fasciculare*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (cz=costal zone, ic=interstomatal cell, iz=intercostal zone, Mh=macro-hair, mh=micro-hair, ph=prickle-hair, pp=papillae, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

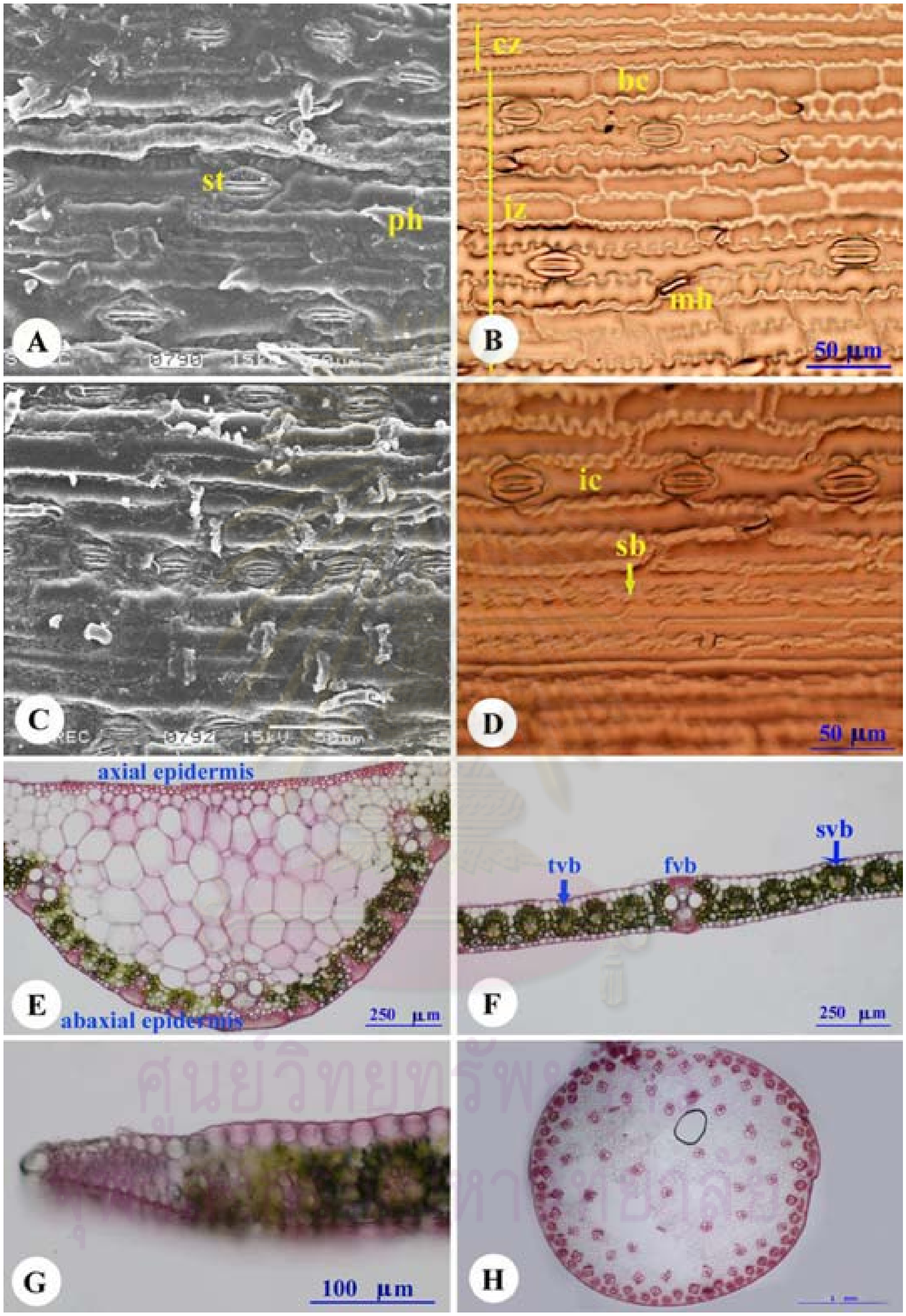

Figure 4.19 Leaf and culm anatomy of *Sorghum bicolor*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (bc=bulliform cell, cz=costal zone, ic=interstomatal cell, iz=intercostal zone, mh=micro-hair, ph=prickle-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

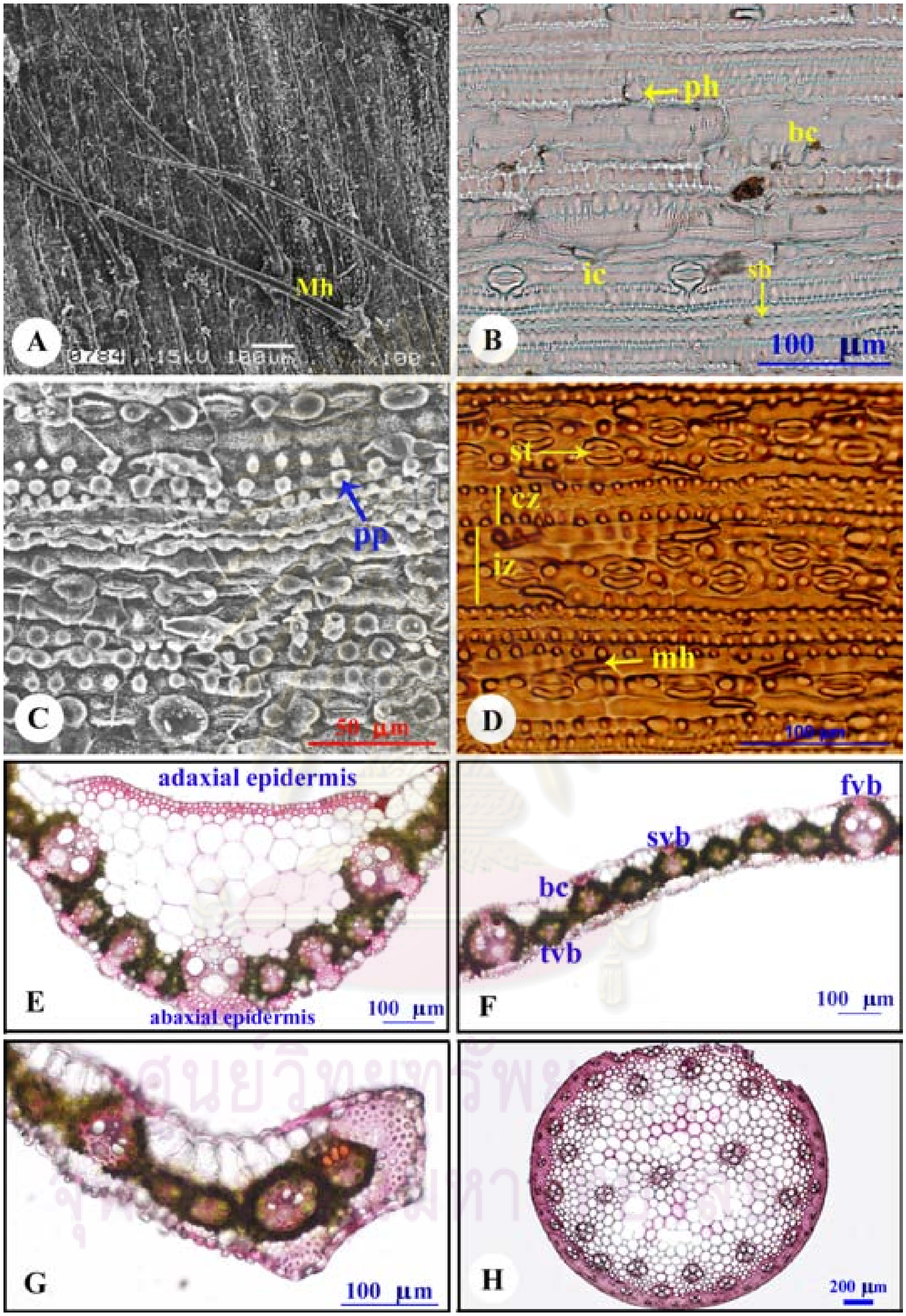

Figure 4.20 Leaf and culm anatomy of *Sorghum nitidum*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (bc=bulliform cell, cz=costal zone, ic=interstomatal cell, iz=intercostal zone, Mh=macro-hair, mh=micro-hair, ph=prickle-hair, pp=papillae, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

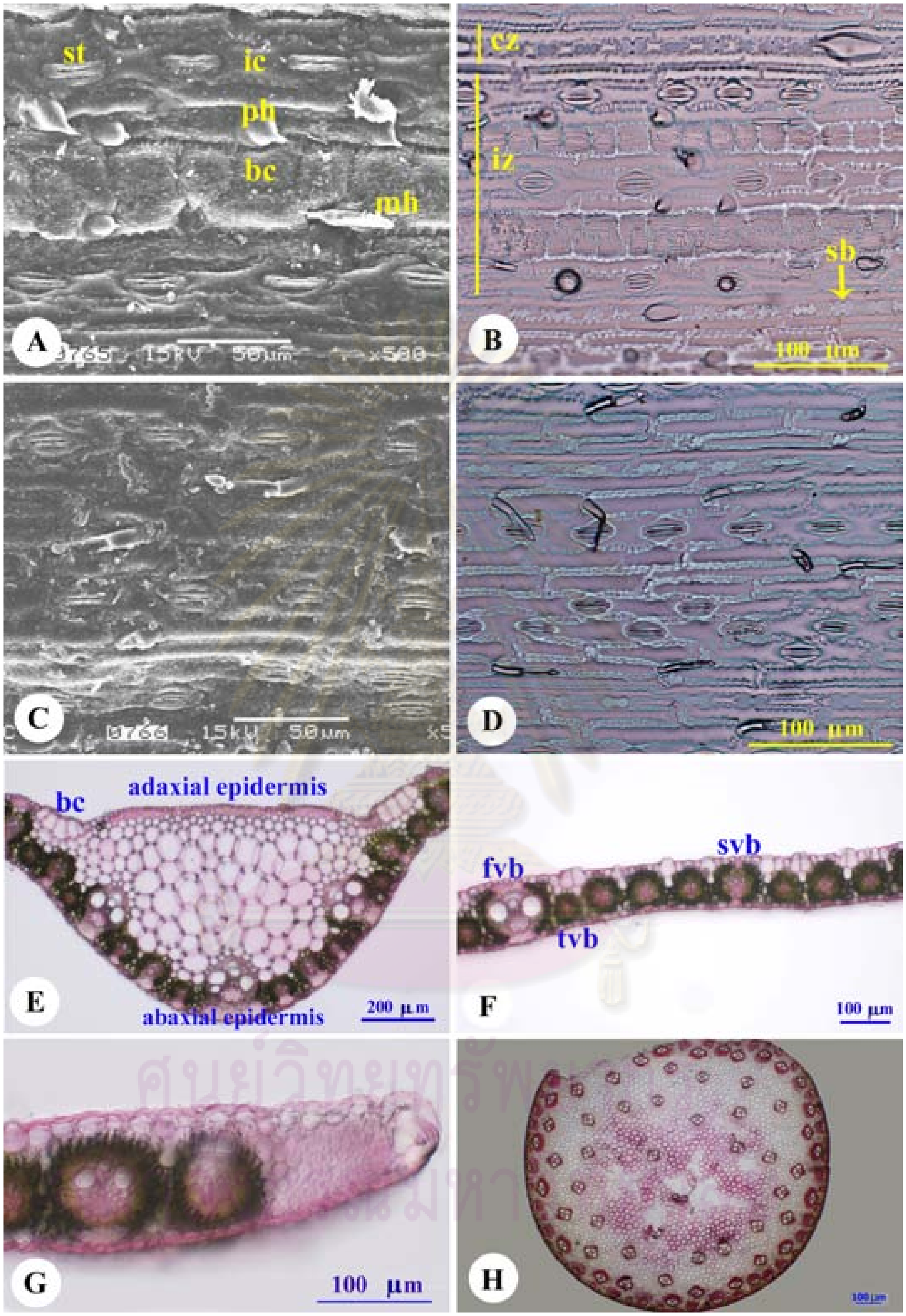

Figure 4.21 Leaf and culm anatomy of *Sorghum propinquum* var. *siamense*: A.-B. adaxial epidermis, C.-D. abaxial epidermis, E.-G. leaf in transverse section, H. culm in transverse section. (bc=bulliform cell, cz=costal zone, ic=interstomatal cell, iz=intercostal zone, mh=micro-hair, ph=prickle-hair, sb=silica body, st=stomata, fvb=first-ordered vascular bundle, svb=second-ordered vascular bundle, tvb=third-ordered vascular bundle)

CHAPTER V

TAXONOMIC TREATMENT

5.1 Introduction

The Sorghinae are a subtribe of the Poaceae. They are included in the tribe Andropogoneae, subfamily Panicoideae. There are approximately 151 species in 14 genera *Asthenochloa* Buse, *Bothriochloa* Kuntze, *Capillipedium* Stapf, *Chrysopogon* Trin. (including *Vetiveria* Bory), *Cleistachne* Benth., *Dichanthium* Willemet, *Euclasta* Franch., *Hemisorghum* C.E. Hubb., *Pseudodichanthium* Bor, *Pseudosorghum* A. Camus, *Sorghastrum* Nash, *Sorghum* Moench, and *Spathia* Ewart (Clayton and Renvoize, 1986). Recently, *Lakshmia* Veldk. has been added (Veldkamp, 2009, in press). It is noted that recent molecular studies have placed *Chrysopogon* in the *Ischaeminae*. Unfortunately, not all genera discussed here were included.

In Thailand, although there have been a number of studies in some genera of Sorghinae, it is still incomplete. For example, Sathagul (1990) found 4 species of *Dichanthium* and 6 species of *Bothriochloa* and Veldkamp (1999) published 8 species of *Chrysopogon* in Thailand. However, both studies are not up to date in nomenclature and species enumeration. Also, Nanakorn and Norsangsri (2001) recorded 39 species and 8 genera for Thailand in a checklist with neither a diagnostic key nor descriptions.

Accordingly, it is important to study the taxonomy of the Sorghinae in Thailand. This study provides fundamental information about the systematics, ecology, and geographical distribution. The outcome from this research will be beneficial to the Flora of Thailand part Poaceae targeted to be completed in 2009.

5.2 Materials and Methods

Morphological data were gathered from voucher specimens deposited in the Bangkok Herbarium (BK), the Forest Herbarium, Royal Forest Department (BKF), the Prince of Songkhla University Herbarium (PSU), and the Queen Sirikit Botanic Garden Herbarium (QBG). Visits were also made to the Herbarium Jutlandicum, University of Aarhus (AAU), the Botanical Museum Herbarium, University of Copenhagen (C), Denmark; the Natural History Museum (BM), the Royal Botanic Gardens, Kew (K), UK; the National Herbarium of The Netherlands, Leiden University (L), The Netherlands; and the Museum National d'Histoire Naturelle Paris (P), France to study type specimens and the libraries.

Field work was carried out to collect fertile materials throughout Thailand. Morphological observations together with habitat-associated species and ecological conditions were documented. Specimens were collected using standard collecting procedures (Boonkerd et al., 1987).

5.3 Results

Presently, twenty-nine species in seven genera are present in Thailand (Table 5.1).

Table 5.1. Present species of Sorghinae in Thailand comparing to previous works (- = not found, blank = not included in the study)

Accepted name in this study	Sathagul (1990)	Veldkamp (1999)	Nanakorn & Norsangsri (2001)	Notes
Bothriochloa bladhii	*B. caucasica* *B. glabra* *B. intermedia*		*B. caucasica* *B. glabra* *B. intermedia*	
B. ischaemum	*B. ischaemum*		*B. ischaemum*	
	B. insculpta		-	The specimen determined as *B. pertusa* in this study
B. pertusa	*B. pertusa*		*B. pertusa*	*B. pertusa*
Capillipedium assimile			*C. assimile*	
C. laoticum			*C. laoticum*	
C. longisetosum			*C. longisetosum*	
C. parviflorum			*C. parviflorum*	
C. sulcatum			*C. sulcatum*	
C. sp. 1			-	a new species in this study
C. sp. 2			-	a new species in this species
Chrysopogon aciculatus		*C. aciculatus*	*C. aciculatus*	
C. festucoides		*C. festucoides*	-	
C. fulvus		*C. fulvus*	*C. fulvus*	
C. gryllus subsp. *gryllus*		-	-	a new record in this species
C. lawsonii		*C. lawsonii*	*C. lawsonii*	
		-	*C. nemoralis*	specimens determined as *C. festucoides* and *C. zizanioides* in this study
C. orientalis		*C. orientalis*	*C. orientalis*	
C. perlaxus		*C. perlaxus*	*C. perlaxus*	
C. serrulatus		*C. serrulatus*	*C. serrulatus*	
			C. zeylanicus	Specimens not found in Thai and abroad herbaria by this study
C. zizanioides		*C. zizanioides*	*C. zizanioides*	

Table 5.1. (Continued)

Accepted name in this study	Sathagul (1990)	Nanakorn & Norsangsri (2001)	Notes
Dichanthium annulatum	*D. annulatum*	*D. annulatum*	
D. aristatum	*D. aristatum*	*D. aristatum*	
D. caricosum	*D. caricosum*	*D. caricosum* *D. theinlwinii*	
D. mucronulatum	-	*D. mucronulatum*	
	D. polyptichum	*D. polyptichum*	the specimen determined as *P. fasciculare* in this study
		D. siamensis	the specimen determined as *Dichanthium mucronulatum* in this study
Hemisorghum mekongense		*H. mekongense*	
Pseudosorghum fasciculare		*P. fasciculare* *P. zollingeri*	
		S.× almum	Only one specimen deposited at BKF with noted that introduced plant for forage research at Pak Chong Forage Research, Nakhon Ratchasima Province. From the forage researcher interviewing, it has never been distributed to Thai farmers and it is now disappear at this research station.
S. bicolor		*S. bicolor* *S. roxburghii* *S. saccharatum* *S. splendidum* *S. splendidum var. magnum*	*S. saccharatum and S. splendidum* not found in Thai and abroad herbaria by this study
S. halepense		*S. halepense*	
		S. miliaceum	the specimen determined as *S. propinquum* in this study
S. nitidum		*S. burmahicum* *S. nitidum*	
S. propinquum		*S. propinquum*	

SORGHINAE

Bluff, Nees & Schauer, Comp. Fl. Germ. ed. 2, 1: 46. 1836.— Type: Sorghum Moench.

Inflorescence terminal or rarely axillary, single, digitate or paniculate racemes, the latter often in whorls; racemes with fragile rachis and slender internodes, sometimes reduced to triads or single spikelets, occasionally with homogamous pairs. Spikelets paired, dissimilar. Sessile spikelet bisexual, usually dorsally compressed, the callus usually obtuse with cupuliform or truncate articulation but the callus sometimes oblique (always so when callus pungent); lower glume usually firm, ±convex on the back and abruptly rounded on the flanks (except *Hemisorghum*); lower floret reduced to a barren lemma; upper lemma linear to oblong, entire or bidentate, usually with a glabrous awn. Pedicelled spikelet male or barren, sometimes much reduced, rarely with a small callus.

KEY TO THE GENERA

1. Inflorescence a panicle with elongated central axis and whorled branches, raceme Internodes never with a translucent median line
    2. Lower glume of sessile spikelet dorsally compressed
        3. Jointed rachis and pedicel ciliate, lodicules hairy …….………… **7. *Sorghum***
        3. Jointed rachis and pedicel serrate, lodicules glabrous ……... **5. *Hemisorghum***
    2. Lower glume of sessile spikelet laterally compressed ………… **3. *Chrysopogon***
1. Inflorescence of a single or subdigitate racemes, if sometimes a panicle, then with an elongated central axis and raceme internodes with a translucent median line
    4. Joints of the rachis and pedicel with a translucent median line
        5. Inflorescence a panicle, racemes with 1-3 sessile spikelets … **2. *Capillipedium***
        5. Inflorescence composed of subdigitate racemes, each with more than 8 sessile spikelets ……………………………….………………….. **1. *Bothriochloa***
    4. Joints of the rachis and pedicel without a translucent median line
        6. All pairs of spikelets heterogamous …………...………… **6. *Pseudosorghum***
        6. Lower 1-3 pairs of spikelets homogamous …………......…....**4. *Dichanthium***

1. BOTHRIOCHLOA

Kuntze, Rev. Gen. Pl. 2: 762. 1891.— Type species: *Bothriochloa anamitica* Kuntze [= *Bothriochloa bladhii* (Retz.) S.T. Blake].

Andropogon L. sect. *Amphilophis* Trin., Mém. Acad. Imp. Sci. St. Pétersbourg, VI, Sci. Math. 2: 285. 1832. (rank indicated p. 279).— *Andropogon* L. subgen. *Amphilophis* Trin. ex Hack. in Mart., Fl. Bras. 2(3): 291. 1883.— *Amphilophis* Nash., Man. Fl. N. States: 71. 190.— *Bothriochloa* sect. *Amphilophis* Ohwi, Acta Phytotax. Geobot. 11: 166. 1942.— *Dichanthium* Willemet sect. *Amphilophis* Roberty, Boissiera 9: 167. 1960.— Lectotype species: *Andropogon laguroides* DC. [= *Bothriochloa laguroides* (DC.) Herter, designated here. The lectotype is not *Amphilophis torreyanus* (Steud.) Nash [= *Bothriochloa laguroides* (DC.) Herter var. *torreyana* (Steud.) M. Marchi & Longhi-Wagner, Bol. Inst. Bioci. Univ. Fed. Rio Grade do Sul 57: 52. 1998., f. 6, 19], fide ING, see note.

Perennials, tufted. *Culms* slender, simple or branched, bearded or beardless at the nodes. *Leaf-sheath* keeled, glabrous; *ligules* membranous*; leaf-blade* linear, narrow, flat. *Inflorescence* subdigitate or panicle, composed of many racemes, each raceme bearing several pairs of sessile and pedicelled spikelets with a terminal triad on many-jointed rachis; jointed rachis and pedicels with translucent longitudinal grooved, flattened, hairy on both margins. *Sessile spikelets* dorsally compressed, elliptic, oblong or lanceolate, short-bearded at short callus, 2-flowered; *lower glumes* as long as spikelet, smooth or pitted, 7-11-nerved, chartaceous to membranous, laterally 2-keeled, setose on keel near tip, apex acute, margin inflexed; *upper glumes* equally long or somewhat shorter, boat-shaped, 3-nerved, 3-keeled, subchartaceous to hyaline, apex acute, margin inflexed; *lower lemmas* nerveless, hyaline; *upper lemmas* linear, hyaline, continuous with the geniculate and twisted awned; *lower paleas* absent; *upper paleas* small or absent. *Pedicelled spikelet* 1- or 2-flowered, the lower floret male or neuter, the upper one neuter or more often suppressed; *lower glume* chartaceous, glabrous, margin inflexed; *upper glume* hyaline, glabrous, apex acute, margin inflexed; *lower lemmas* hyaline, glabrous; awnless.

Species 34. Throughout the tropics. 3 species in Thailand.

Notes.— *Andropogon* L. sect. *Amphilophis* Trin. is said to be lectotypified with *A. torreyanus* (Steud.) Nash. This is incorrect. *Amphilophis torreyanus* was based on *Andropogon torreyanus* Steud. [Nomencl. Bot., ed. 2, 1: 93. 1840.], nom. nov. pro *Andropogon glaucus* Torr. (1824), non Retz. (1789). This species is not to be found in Trinius, where the unranked (but see rank indicated p. 279) groups are a medley of taxa, now attributed to *Chrysopogon* (*Vetiveria*)*, Bothriochloa, Sorghastrum,* and *Sorghum.*

Species presently still in *Bothriochloa* are*: A. laguroides* DC. [*B. laguroides* (DC.) Herter], *A. saccharoides* Sw. [*B. saccharoides* (Sw.) Rydb.], *A. argenteus* DC. [*B. saccharoides*], *A. caucasicus* Trin. [*B. caucasica* (Trin.) C.E. Hubb.], *A. punctatus* Roxb. [*B. bladhii* (Retz.) S.T. Blake], and from these *A. laguroides* was selected.

Sathagul (1990) reported 6 species of *Bothriochloa*: *B. caucasica, B. glabra, B. insculpta, B. intermedia, B. ischaemum,* and *B. pertusa.* In the present study only 3 are maintained: *B. bladhii, B. ischaemum*, and *B. pertusa*. *Bothriochloa insculpta* turned out to have been misapplied to *B. pertusa*. The names *B. caucasica*, *B. intermedia*, and *B. glabra* presently are regarded as synonyms of *B. bladhii.*

KEY TO THE SPECIES

1\. Inflorescence panicle, lowest raceme shorter than main axis of inflorescence ………………………………………………………………………….. 1**. *B. bladhii***

1\. Inflorescence subdigitate, lowest raceme longer than main axis of inflorescence

  2. Lower glume of sessile spikelet without a circular pit …………... 2. ***B. ischaemum***

  2. Lower glume of sessile spikelet with a circular pit ………………...… 3. ***B. pertusa***

1. *Bothriochloa bladhii* (Retz.) S. T. Blake, Proc. Roy. Soc. Queensland 80(6): 62. 1969.— *Andropogon bladhii* Retz., Observ. Bot. 2: 27. 1781.— *Andropogon annulatus* Forssk. var. *bladhii* (Retz.) Hack. in A. DC., Monogr. Phan. 6: 572. 1889.— *Dichanthium bladhii* (Retz.) Clayton, Kew Bull. 32: 3. 1978.— Type: China, *Bladh* s.n. *in Herb. Retzius* (holo: LD, 94/019-0745, SI, photo).

Andropogon caucasicus Trin., Mém. Acad. Imp. Sci. St. Pétersbourg, VI, Sci. Math. 2: 286. 1832.— *Andropogon intermedius* R. Br. var. *caucasicus* (Trin.) Hack. in A. DC., Monogr. Phan. 6: 486. 1889.— *Bothriochloa caucasica* (Trin.) C.E. Hubb., Bull. Misc. Inform. Kew 1939: 101. 1939.— *Dichanthium caucasicum* (Trin.) S.K. Jain & Deshp., Bull. Bot. Surv. India 20: 133. 1979 (“1978”).— *Sorghum caucasicum* (Trin.) Griseb. in Ledeb., Fl. Ross. 4: 476. 1853.— Type: *E. Caucasus Wilhelms* s.n. *A˚ 1827 in Herb. Trinius* 178.1 (holo: LE, IDC microfiche BT-16/1).

Andropogon glaber Roxb. Fl. Ind. 1: 271. 1820.—*Andropogon intermedius* R. Br. subvar. *glaber* (Roxb.) Hack. in A. DC., Monogr. Phan. 6: 487. 1889.— *Amphilophis glabra* (Roxb.) Stapf in Prain, Fl. Trop. Afr. 9: 172. 1917.— *Bothriochloa glabra* (Roxb.) A. Camus, Ann. Soc. Linn. Lyon II, 76: 164. 1931.— [*Dichanthium ischaemum* (L.) Roberty subvar. *glabrum* (Roxb.) Roberty, Boissiera 9: 159. 1960, nom. inval.].— Type: *Roxburgh* s.n. (holo: BM; BR, G; Icon. ined. 1194: CAL, K).

Andropogon intermedius R. Br., Prodr. 1: 202. 1810.— *Amphilophis intermedia* (R. Br.) Stapf, Agric. News (Barbados) 15: 179. 1916; in Prain, Fl. Trop. Afr. 9: 174. 1917.— [*Andropogon intermedius* var. *genuinus* Hack. in A. DC., Monogr. Phan. 6: 485. 1889, nom. inval.].— *Bothriochloa intermedia* (R. Br.) A. Camus, Ann. Soc. Linn. Lyon II, 76: 164. 1931.— *Dichanthium* compilospecies *intermedium* (R. Br.) De Wet & J.R. Harlan, Amer. J. Bot. 53: 97. 1966.— *Sorghum intermedium* (R. Br.) Kuntze, Rev. Gen. Pl. 2: 792. 1891.— Type: Australia, *R. Brown* 6184 (holo: BM!, photo in BRI, K).

Andropogon intermedius R. Br. subvar. *puberulus* Hack. in A. DC., Monogr. Phan. 6: 487. 1889.— Type: *Not indicated*, material in W to be studied.

Andropogon odoratus Lisboa, J. Bombay Nat. Hist. Soc. 4: 123. 1889.— *Amphilophis odorata* (Lisboa) A. Camus, Rev. Int. Bot. Appl. Agric. Trop. 1: 305. 1921.— *Bothriochloa odorata* (Lisboa) A. Camus, Ann. Soc. Linn. Lyon II, 76: 165. 1931. — Type: NW India, Khandesh, Lanowli (possibly in BLATT or DD).

Andropogon pertusus (L.) Willd. var. *vegetior* Hack., Monogr. Phan. 6: 481. 1889.— Type: Sudan, *G.A. Schweinfurth* 1027 (holo: W; iso: K!)

Bothriochloa anamitica Kuntze, Revis. Gen. Pl. 2: 762. 1891.— Type: Vietnam: Annam, Turong, *Kuntze* s.n. (holo: NY)

Rhaphis stricta Nees, Hooker's J. Bot. Kew Gard. Misc. 2: 99. 1850.— *Andropogon leptanthus* Steud., Syn. Pl. Glumac. 1: 391. 1854, non *Andropogon strictus* Host. (1802).— Type: *Cuming* 1400 (holo: K!).

Culms erect, stout, up to 2 m high, nodes glabrous or pubescent, internodes terete or grooved on one side. *Leaf-sheaths* terete, keeled in the upper part; *ligules* 1 mm long; *leaf-blades* up to 43 by 1 cm, lower surface glabrous, upper surface scabrous and covered with long hairs at basal part, base subcordate, apex long acuminate, margin scaberulous. *Inflorescence* a large panicle, branches whorled, 12-17 by 4-5 cm, primary branches simple or divided, racemes up to 5 cm long. *Sessile spikelets* elliptic, 2.5-3 mm long, callus 0.2-0.5 mm long; *lower glumes* elliptic to oblong, 2.5-3 mm long, obscurely 7-9-nerved, greenish yellow, occasionally 1-pitted; *upper glumes* elliptic to oblong, 2.5-3 by 1-1.2 mm, greenish yellow, glabrous, sparsely hairy on the upper part of the keel; *lower lemmas* lanceolate, 2-2.5 by 0.5-0.7 mm, glabrous, apex obtuse; *upper lemmas* 1.5 mm long, awn 1.5 mm long; lodicules 0.2 mm long; *anthers* 1.5 mm long. *Pedicelled spikelets* 2.5-3 mm long, callus short; *lower glumes* lanceolate, c. 3 by 1 mm, 6-nerved, greenish yellow, pectinately setose on keels, apex acute; *upper glumes* lanceolate, 2-2.8 by 0.5-0.8 mm, 3-nerved; *lower lemmas* lanceolate, 2 by 0.5 mm, apex acute; *anthers* c. 1 mm long, sometimes barren. (**Figure 5.1, Figure 5.28 A-B**)

Thailand.— NORTHERN: Chiang Mai [Doi Suthep, 6 Oct 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 5481 (K, C); Doi Suthep, 25 Oct 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 5891 (K, C); Doi Angkhang, 4 Jun. 1973, *J. Sadakorn* 208 (BK); Jom Thong, 22 Sep 1992, *J.F. Maxwell* 92-567 (P); c. 2 km West of Mae Rim, 56º00´ E 18º55´N, 12 Oct. 2001, *S. Lægaard* and *M. Norsangsri* 21693 (AAU); along road Mae Rim-Samoeng, 98º47´E 18º52´N, 21 Oct. 2001, *S. Lægaard* 21758 (AAU)]; Chiang Rai [Wiang Pa Pao, 24 Feb 2005, *O. Neamsuvan* 184 (BCU)]; Nan [Pua, 19 Mar 2005, *O. Neamsuvan* 199 (BCU); Doi Phukha National Park, 4 Apr 2006, *O. Neamsuvan* 227 (BCU)]; Tak [along road to Teelosu waterfall, Umphang, 28 Feb 2005, *O. Neamsuvan* 219 (BCU)]; Sukhothai [dry savannah forest, 24 Jul. 1973, *G. Murata, N. Fukuoka* and *C. Phengklai* T. 16986 (P)]; NORTH-EASTERN: Phetchabun [Khao Kho, 20 March 2005, *O. Neamsuvan* 201 (BCU)]; Loei [Phu Kradueng, 16 Oct. 1954, *T. Smitinand* 2035 (K); Phu Kradueng, 10 Nov. 1970, *Ch. Charoenphol, K. Larsen* and *E. Warncke* 4878 (K); Km 43 on road 201 South of Loei, 30 Oct. 2001, *S. Lægaard* and *M. Norsangsri* 21875 (AAU)]; Sakon Nakhon [Phuphan National Park, 6 Jul 2005, *O. Neamsuvan* 210 (BCU)]; CENTRAL: Bangkok [Bang Bon, 19 Oct. 1924, A. Marcan 1815 (BM); 21 Apr. 1923, *A.F.G. Kerr* 6955 (K, BM); 27 Oct. 1919, *A.F.G. Kerr* 3842 (K, C); 2 Nov. 1924, *A.F.G. Kerr* 9354 (K, BM); 12 Oct. 1924, *Kerr* s.n. BM; Thonburi, 19 Oct. 1924, *A.F.G. Kerr* 9331 (K)]; Saraburi [Sahm Lahn Forest, 15 Jun. 1974, *J.F. Maxwell* 74-597 (BK, AAU)]; Lop Buri [Chaibadan, 15 Dec. 1923, *A. F. G. Kerr* 7987 (K, BM)], Nakhon Nayok [Nang Rong, 29 Jul. 1959, *T. Smitinand* 6087 (K)]; EASTERN: Nakhon Ratchasima [Pak Chong, 2 Jan. 1924, *A. Marcan* 1589 (K)]; SOUTH-EASTERN: Chon Buri [24 Nov. 1970, *M. Lazarides* 7445 (BKF, K, L)], Chantaburi [Pong Nam Rawn, 18 Jul. 1956, *T. Smitinand* 3416 (BKF); Khao Soi Dao, 10 Jun. 1963, *K. Larsen* 9993 (K, C)], Sa Kaeo [Aran Pratet, 19 Oct. 1928, *Put* 2049 (K, BM); Krabinburi, 8 Nov. 1930, *A.F.G. Kerr* 19781 (K)]; PENINSULAR: Chumphon [Bang Son, 9 Jan. 1927, *A.F.G. Kerr* 11334 (K, BM)]; Songkhla [Padang Besar, 23 Dec 1927, *A.F.G. Kerr* 13558 (K, BM); Prince of Songkhla University, near biology building, 2 Oct. 1985, *J.F. Maxwell* 85-928 (PSU, AAU); Prince of Songkhla University, 4 Mar 1976, *A. Yiamudorn* 38 (PSU)]; Krabi [Klong Paela, 25 km east of Krabi, 99º10´E 08º05´N, 23 Oct. 1991, *K. Larsen, S.S. Larsen, C. Niyomdham, W. Ueachirakan* and *P. Sirirugsa* 42528 (PSU, AAU)]; Yala [Than To waterfall, 45 km

South of Yala, 27 Nov. 1990, *K. Larsen, S.S. Larsen, A.S. Barfod, W. Nanakorn, W. Ueachirakan* and *P. Sirirugsa* 41757 (AAU); Bang Lang reservoir, Bannangsadaw, 7 Nov 1986, *J.F. Maxwell* 86-864 (PSU)]; Trang [Khao Chong, 99º45'E 07º30'N, 18 Nov 1990, *K. Larsen*, *S.S. Larsen, A.S. Barfod, W. Nanakorn, W. Ueachirakan* and *P. Sirirugsa* 41567 (PSU)]

Distribution.— Tropical Africa and Asia, introduced elsewhere

Ecology.— along roadside, open area, abandon field

Vernacular.— Ya khaem khok (หญ้าแขมโคก), Ya khi ma (หญ้าขี้หมา)

2. Bothriochloa ischaemum (L.) Keng, Contr. Biol. Lab. Chin. Assoc. Advancem. Sci., Sect. Bot. 10: 201. 1936.— *Andropogon ischaemum* L., Sp. Pl. 2: 1047. 1753.— Type: *Herb. Burser* 1: 101, UPS [LT designed by Scholz in Cafferty et al., Taxon 49 (2): 245. 2000]

Andropogon angustifolius Sibth. & Sm., Prodr. Fl. Graec. 1: 47. 1806.— Type: Greece, *Sibthorp* s.n. (holo: OXF).

Andropogon ischaemum L. var. *songaricus* Rupr. ex Fisch. & Meyen, Enum. Pl. Nov.: 2. 1841.— *Bothriochloa ischaemum* (L.) Keng var. *songarica* (Fisch. & Meyen) Celarier & J.R. Harlan, J. Linn. Soc. Bot. 55: 758. 1958.— *Andropogon ischaemum* L. forma *songaricus* (Fisch. & Meyen) Kitag., Jap. J. Bot. 36: 20. 1961.— Type: Songaria, *Schrenk* s.n. (holo: LE; iso K!).

Andropogon taiwanensis Ohwi, J. Jap. Bot. 12: 652. 1936.— Type: Taiwan, *Shimada 4766* (holo: KYO).

Creeping rhizomes. *Culms* 20-60 cm high, nodes usually bearded. *Leaf-sheaths* 4-6 cm long; *ligules* c. 1 mm long; *leaf-blades* 3-10 cm by 2-4 mm, hairy on both surfaces, margin scaberulous. *Inflorescence* subdigitate of 3-10 racemes, the lowest raceme longer than the axis of the inflorescence, racemes 4-6 cm long, rachis 2-2.5 mm long. *Sessile spikelets* lanceolate, c. 4 mm long, hairy, callus c. 0.5 mm long; *lower glumes* lanceolate, 3.8-4 by 0.7-1 mm, 7-nerved, green; *upper glumes* oblong, 3.5-4 by 1 mm, hairy on the upper part of nerves; *lower lemmas* lanceolate, 3 by 0.5 mm, glabrous, apex acute; *upper lemmas* 2 mm long, awn brown, 1.3 cm long, short hairy; lodicules 0.3 mm long; *anthers* 1-1.5 mm long. *Pedicelled spikelets* c. 3 mm long; pedicel 3 mm long, hairy on both margins; *lower glumes* oblong, 3 by 0.8-1 mm, 9-nerved, hairy on upper half part of keel, apex acute; *upper glumes* oblong, 3 by 1 mm, 3-5-nerved, margin ciliolate; *lower lemmas* obovate, 2-2.5 by 1-1.5 mm, apex obtuse to truncate; *anthers* c. 0.8-1 mm long, or barren. (**Figure 5.2**)

Thailand.— EASTERN: Buri Ram [Phanom Rung historical park, 27 Nov. 2005, *Y. Sirichamorn* 24 (BCU)]; CENTRAL: Bangkok [Bangkhen, 1 Dec. 1962, *P. Sirirugsa* 71 (BCU)], Suphan Buri [Derm Bang Nang Buad, 21 Sep. 1930, *A.F.G. Kerr* 19701 (K)]; SOUTH-WESTERN: Kanchanaburi [Kao Tawng, 31 Aug. 1930, A.F.G. Kerr 19651 (K)]

Distribution.— S Europe to China, introduced elsewhere, e.g. in Thailand.

Ecology.— open or shady deciduous forest.

3. Bothriochloa pertusa (L.) A. Camus, Ann. Soc. Linn. Lyon, n.s., 76: 164. 1931.— *Holcus pertusus* L., Mant. Pl. 2: 301-302. 1771.— *Andropogon pertusus* (L.) Willd, Sp. Pl. 4(2): 922. 1806.— *Amphilophis pertusa* (L.) Nash ex Stapf, Agric. News (Barbados) 15: 179. 1916.— *Bothriochloa pertusa* (L.) A. Camus, Ann. Soc. Linn. Lyon II, 76: 164. 1931.— *Lepeocercis pertusa* (L.) Hassk., Pl. Jav. Rar.: 52. 1848.— *Elionurus pertusus* (L.) Nees ex Steud., Syn. Pl. Glumac. 1: 364. 1854.— *Dichanthium pertusum* (L.) Clayton, Kew Bull. 32: 4. 1977.— Lectotype: "India orientalis." *Herb. Linn.* 1212.16 (holo: LINN!), designated by Clayton (Kew Bull. 32: 4. 1977).

Stoloniferous rhizome. *Culms* up to 80 cm high, grooved on one side, nodes bearded. *Leaf-sheaths* 3-5 cm long; *ligules* 0.5 mm long, tufted hairs 3 mm long on both sides of ligules; *leaf-blades* linear, 3-20 cm by 3 mm, sparsely short hairy on both surfaces, base subcordate to round, apex acuminate, margin scaberulous. *Inflorescence* digitate of 3-10 racemes, axis of inflorescence 0.5-2.5 cm long, the lowest raceme longer than the central axis of inflorescence, racemes 4-5 cm long; rachis 3 mm long. *Sessile spikelets* elliptic to oblong, 3 mm long, callus 0.4-0.5 mm long; *lower glumes* oblong, 2.5-2.8 by 1 mm, 9-11-nerved, shiny, 1-pitted; *upper glumes* oblong, 3-3.5 by 1 mm, glabrous; *lower lemmas* broadly ovate, 1.5-2.5 by 0.8 mm, 1-nerved, apex obtuse to truncate, margin ciliate at the upper part; *upper lemmas* 2 mm long, 1-nerved; awn 1.5-2 cm long, short hairy; lodicules 0.2 mm long; *anthers* 1-1.5 mm long. *Pedicelled spikelets* c. 3 mm long; callus 0.5 mm long, hairy; pedicel 3 mm long, covered by up to 3.5 mm long hairs on both margins; *lower glumes* oblong, 3.5 by 1.0-1.2 mm, 10-nerved, purple stripe near apex on back, 0-3-pitted, apex obtuse; *upper glumes* elliptic, 2.5 by 1 mm, 3-nerved; *lower lemma*s obovate, c. 2 by 1 mm, apex acute; *anthers* 0.8-1 mm long. (**Figure 5.3, Figure 5.28 C-D**)

Thailand.— NORTHERN: Chiang Mai [lawn in Chiang Mai University, 7 Oct 2004, *O. Neamsuvan* 163 (BCU)]; Chiang Rai [Wiang Pa Pao, 24 Feb 2005, *O. Neamsuvan* 185 (BCU)]; Nan [Doi Phukha National Park, 3 Apr 2006, *O. Neamsuvan* 226 (BCU)]; Lamphun [Hariphunchai, 27 Feb 2005, *O. Neamsuvan* 190 (BCU)]; Nakhon Sawan [50 km North of Nakhon Sawan, 31 Jul. 1966, *K. Larsen, T. Smitinand and E. Warncke* 1112 (K, AAU)]; NORTH-EASTERN: Phetchabun [Lom Sak, bus station, 30 Oct. 2001, *S. Lægaard* and *M. Norsangsri* 21885 (AAU)]; Loei [Kong Nor Reforestation, 14 Jan. 1982, *Y. Paisooksantivatana* 813-82 (BK); Km 43 on road 201 South of Loei, 101º51´E 17º08´N, 30 Oct. 2001, *S. Lægaard* and *M. Norsangsri* 21874 (AAU)]; Sakon Nakhon [Phuphan National Park, 6 Jul 2005, *O. Neamsuvan* 209 (BCU)]; Khon Kaen [Khon Kaen University, central campus, 16 Dec. 1976, BR D57 (AAU); Ban Naeong Kung, 22 Dec. 1964, *C. Chermsirivathana* 201 (BK)]; EASTERN: Chaiyaphum [Phu Khiao, 8 Jul 2005, *O. Neamsuvan* 212 (BCU)]; Nakhon Ratchasima [25 km north of Korat, 24 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 2477 (L, C); Korn Buri, Sommai 63 (KU)]; Buri Ram [Prasat Hin Muang Tum, 27 Nov 2005, *Y. Sirichamorn* 23 (BCU)]; Ubon Ratchathani [near Ban Soysuwanna, Pha Taem national park, 30 Nov 2004, *O. Neamsuvan* 167 (BCU)]; CENTRAL: Bangkok [13 Feb. 1932, *Put* s.n. (BK); 9 Jan 1948, *Dee* 8523 (K); 15 Nov. 1919, *A.F.G. Kerr* 3858 (K); 80 km north of Bangkok, wayside, 12 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 2061 (C)]; Lop Buri [along road, 23 Sep. 1971, *G. Murata, K. Iwatsuki* and *C. Phengklai* T-14816 (P, L)], Ayutthaya [24 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 2516 (P, L, C)]; Samut Prakan[Paknam, 10 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 2031 (P, C)], Saraburi[Sahm

Lahn forest, 1 July 1974, *J.F. Maxwell* 74-654 (L, AAU)]; Nakhon Pathom [Kasetsart University, Kamphaengsaen, 3 Jul 2006, *O. Neamsuvan* 235 (BCU)]; SOUTH-WESTERN: Prachuap Khiri Khan [Hua Hin, 5 Nov. 1927, *A.F.G. Kerr* 13432 (BK, K, BM); Klong Wan, 23 Oct. 1964, *C. Chermsirivathana* 143 (BK)], Kan chanburi [Khao Salop National Park, 19 Nov. 1970, *M. Lazarides* 7434 (BKF, K, L, C); Ban Kao, Foothills of Pattavee, dry deciduous forest, 18 Nov. 1961, *K. Larsen* 8304 (C)]; PENINSULAR: Chumphon [roadside to Cabana beach, 5 Feb 2005, *O. Neamsuvan* 172 (BCU)]; Songkhla [Songkhla-Pattani road, c. 55 km from Songkhla, 31 Oct. 1990, *K. Larsen, S.S. Larsen, A.S. Barfod, W. Nanakorn, W. Ueachirakan* and *P. Sirirugsa* 41014 (PSU, AAU)]; Trang [Khao Chong, 15 km East of Trang, 99º45´E 07º30´N, 18 Nov. 1990, *K. Larsen, S.S. Larsen, A.S. Barfod, W. Nanakorn, W. Ueachirakan* and *P. Sirirugsa* 41566 (PSU, AAU)]

Distribution.— S Africa to Thailand, introduced elsewhere.

Ecology.— open area, along road side

Vernacular.— Ya tot lueat (หญ้าตดเลือด), Ya hom (หญ้าหอม), Ya hang ma (หญ้าหางหมา)

Note.— Sommai's specimen number 63 was treated as *Bothriochloa insculpta* in Sathagul (1990), however, it turned out to belong to *B. pertusa* in this study.

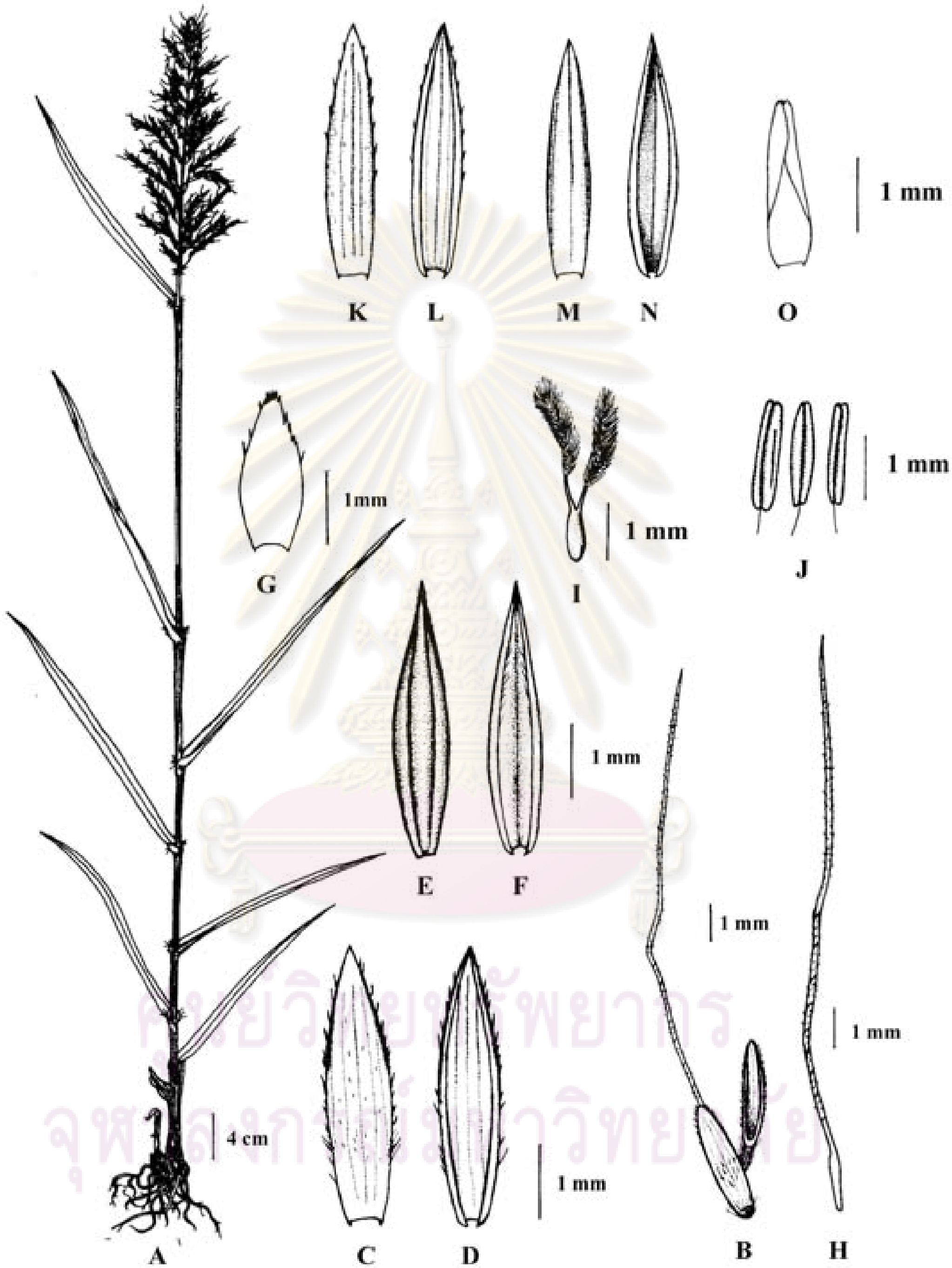

Figure 5.1 *Bothriochloa bladhii*: A. habit. B. spikelet pair. C.-J. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma; I. pistil; J. stamens. K.-O. pedicelled spikelet: K.-L. lower glume; M.-N. upper glume; O. lower lemma.

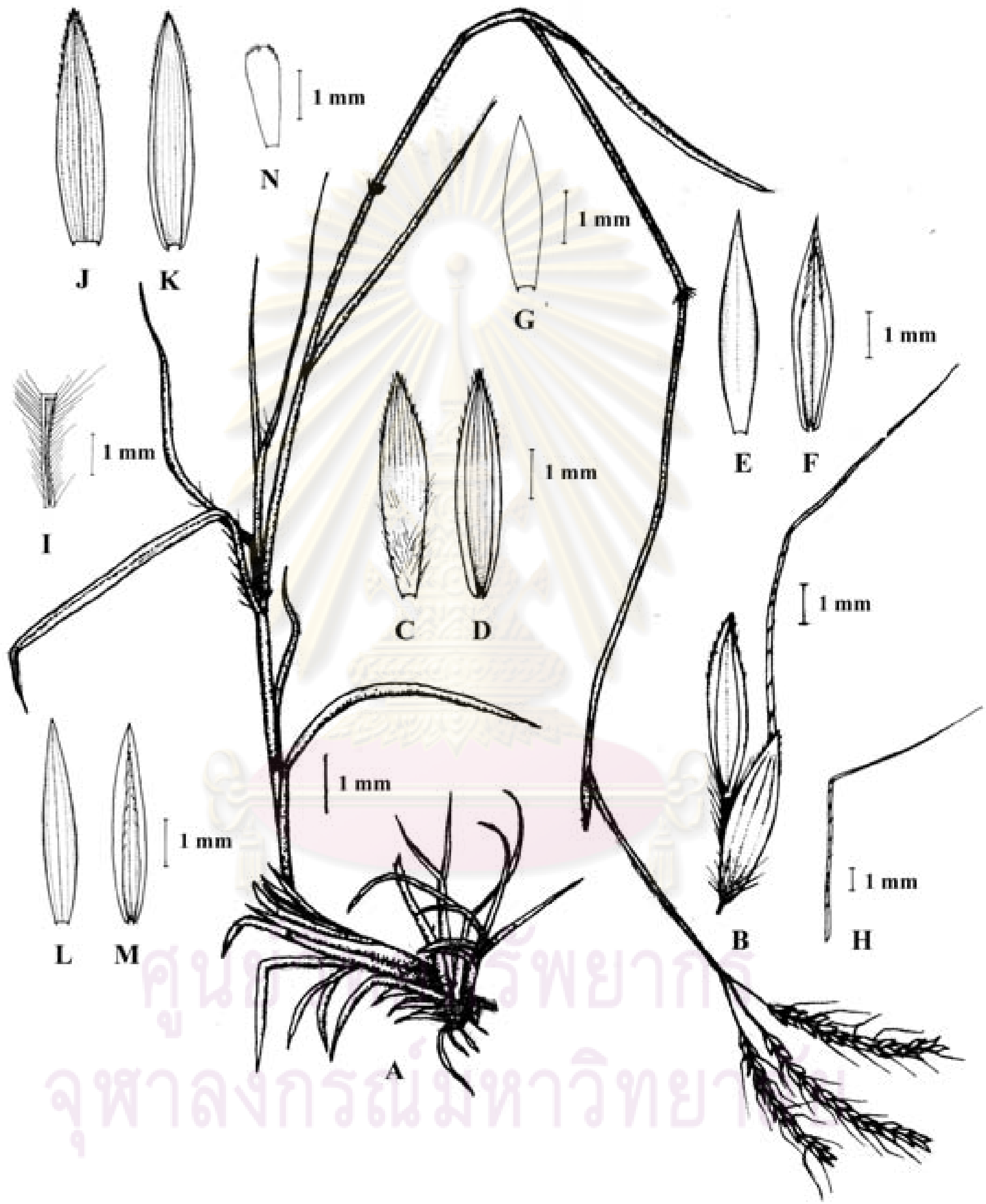

Figure 5.2 *Bothriochloa ischaemum*: A. habit. B. spikelet pair. C.-H. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma. I.-N. pedicelled spikelet: I. pedicel; J.-K. lower glume; L.-M. upper glume; N. lower lemma.

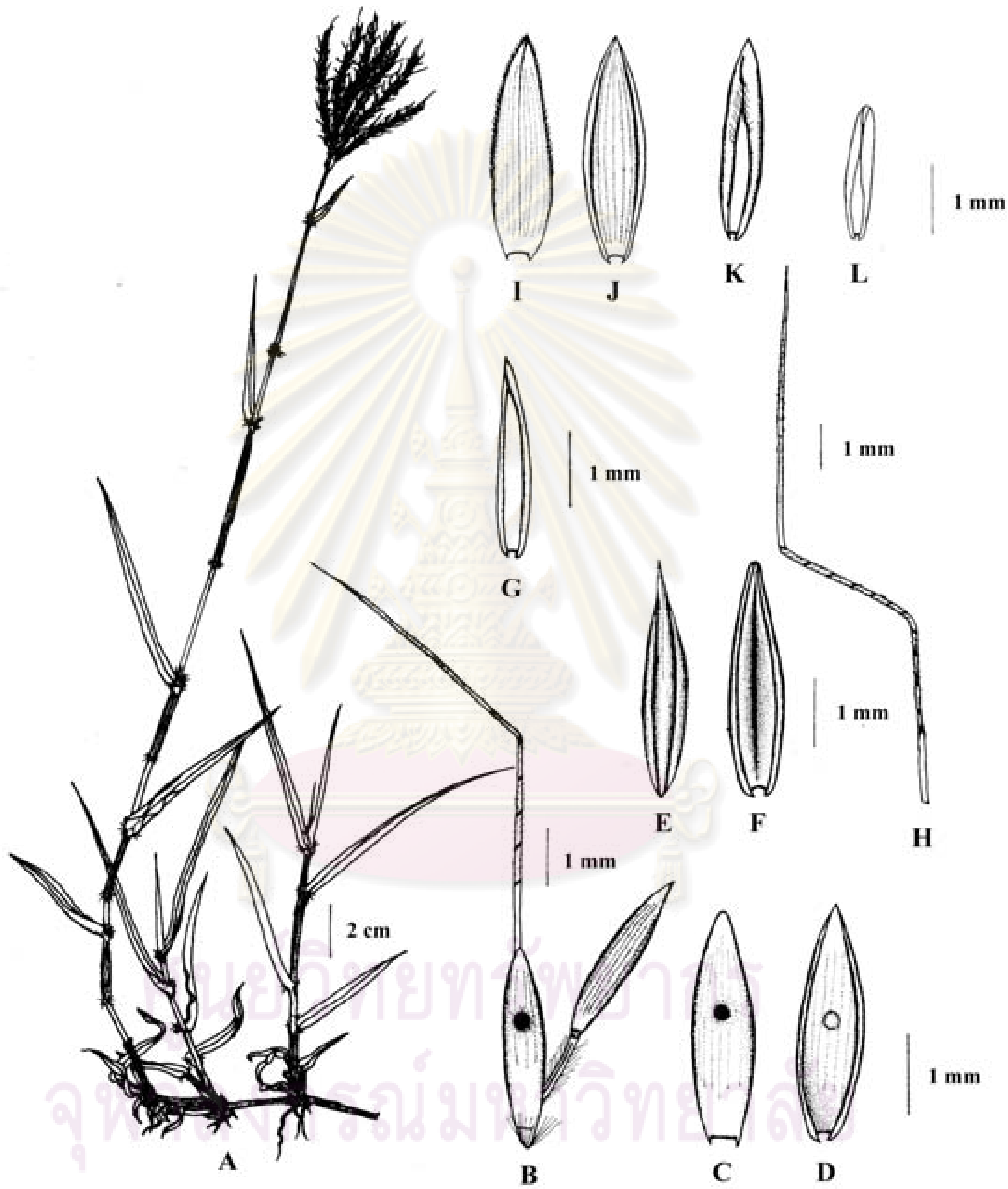

Figure 5.3 *Bothriochloa pertusa*: A. habit. B. spikelet pair. C.-H. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma. I.-L. pedicelled spikelet: I.-J. lower glume; K. upper glume; L. lower lemma.

2. CAPILLIPEDIUM

Stapf in Prain, Fl. Trop. Afr. 9: 169. 1917; Raizada & S.K. Jain, Indian Forest Rec., n.s. Bot. 4: 73. 1951.— *Andropogon* L. (unranked) *Cappilipedes* Hack. in A. DC., Monogr. Phan. 6: 488. 1889.— *Bothriochloa* Kuntze sect. *Capillipedium* Ohwi, Acta Phytotax. Geobot. 11: 166. 1942.— Lectotype species: *Capillipedium parviflorum* (R. Br.) Stapf designated by Niles & Chase [Contr. U.S. Natl. Herb. 24: 205. 1925.] and Raizada & S.K. Jain (1951).

Annuals or perennials, tufted. *Culms* erect or decumbent, simple or branched. *Leaf-sheaths* keeled, glabrous or puberulous; *ligule* ciliolate membranous, truncate, short; *leaf-blades* linear, flat. *Inflorescence* an open panicle, composed of many racemes, rachis internodes and pedicels slender with translucent longitudinal grooves; racemes short, bearing several pairs of sessile and pedicelled spikelets with a terminal triad, or reduced to a single triad. *Sessile spikelets* dorsally compressed, 2-flowered, the lower floret sterile, the upper one bisexual, callus truncate; *lower glumes* coriaceous or chartaceous, 2-keeled, keels ciliate, dorsally slightly convex or groovy; apex acute, obtuse or truncate; margins inflexed; *upper glumes* boat-shaped, 3-nerved, 3-keeled, margin inflexed; *lower lemma* hyaline, glabrous; *upper lemmas* linear, hyaline, geniculately awned with twisted column; *palea* absent. *Pedicelled spikelet* 1-flowered, male; *lower glume* ± flat, 2-keeled, chartaceous, apex acute or obtuse, margin inflexed; *lower lemma* hyaline, glabrous; epaleate; stamens 3.

Species ± 17. Eastern Africa, tropical Asia and Australia. Open grassy places. 7 species in Thailand.

Note.— Nanakorn & Norsangsri (2001) listed five species for *Capillipedium*: *C. assimile, C. laoticum, C. longisetosum, C. parviflorum*, and *C. sulcatum.* This list is here confirmed, and two more taxa are reported and described.

KEY TO THE SPECIES

1. Perennials, sessile spikelet up to 3 mm long
   2. Lower glume of sessile spikelet dorsally flattened …………...….. **1. *C. assimile***
   2. Lower glume of sessile spikelet dorsally grooved……….…… **4. *C. parviflorum***
1. Annuals, sessile spikelet 4-7 mm long
   3. Panicle branches and axis glabrous
      4. Lower glume of sessile spikelet dorsally convex …..……. **3. *C. longisetosum***
      4. Lower glume of sessile spikelet dorsally with a deep groove … **5. *C. sulcatum***
   3. All panicle branches and axis more or less densely hairy or at least the upper 2/3 part of the peduncle of the raceme villous.
      5. Lower glume deeply grooved, panicle brance and axis pubescent … **6. *C.* sp. 1**
      5. Lower glume flat to very shallowly concave, at least upper part of receme peducle with long hairs
         6. Upper part of raceme peduncle with 2-3 mm long tubercle-based hairs ……………………………………...……………………….. **2. *C. laoticum***
         6. Throughout raceme peduncle and upper part of panicle axis covered with 2 kinds of hairs: pubescent with 0.2 mm long hairs and villous with 0.5-1 cm long tubercle-based hairs ………………………………...……… **7. *C.* sp. 2**

1. ***Capillipedium assimile*** (Steud.) A. Camus, Fl. Indo-China 7: 314. 1922.— *Andropogon assimilis* Steud., Syn. Pl. Glumac. 1: 397. 1854.— *Andropogon montanus* Roxb. var. *genuinus* Hack. in A. DC., Monogr. Phan. 6: 490. 1889, nom. inval.— *Bothriochloa assimilis* (Steud.) Ohwi, Acta Phytotax. Geobot. 11: 165. 1942.— Type: Indonesia, Java, *Herb. Zollinger* 859 (iso: P!)

Andropogon glaucopsis Steud., Syn. Pl. Glumac. 1: 397. 1854 [N.B.: *Andropogon glaucopsis* (Elliott) Trin. ex Steud, Nomencl. Bot., ed. 2: 91. 1840, is invalid, being cited in the synonymy].— *Andropogon montanus* Roxb. var. *glaucopsis* (Steud.) Hack. in A. DC., Monogr. Phan. 6: 490. 1889.— *Capillipedium assimile* (Steud.) A. Camus var. *glaucophyllum* (Henrard) Jansen, Reinwardtia 2: 251. 1953, nom. superfl.— *Capillipedium glaucopsis* (Steud.) Stapf in Hooker's Icon. Pl.: t. 3085. 1922, nom. superfl.— [*Capillipedium parviflorum* (R. Br.) Stapf forma *glaucopsis* (Stapf) Roberty, Boissiera 9: 154. 1960., nom. inval.; var. *glaucopsis* l.c.: 155, nom. inval.].— *Capillipedium subrepens* Henrard var. *glaucophyllum* Henrard, Blumea 3: 463. 1940, nom. superfl.— Type: Nepal, *Wall. Cat.* 8787 (holo: P!; iso: K!).

Andropogon subrepens Steud., Syn. Pl. Glumac. 1: 397. 1854.— *Capillipedium subrepens* (Steud.) Henrard, Blumea 3: 463. 1940, nom. superfl.— Type: Nepal, *Wall. Cat*. 8790 (holo: P!; iso: K!).

Capillipedium scabridum Ridl., J. Malayan Branch Roy. Asiat. Soc. 10: 109. 1923.— Type: Sumatra, *H.N. Ridley* s.n. (holo: K!).

Chrysopogon pictus Hance, Ann. Sci. Nat., Bot. V, 5: 252. 1866. — Type: China, Canton *C.F.M. de Grijs* s.n. (holo: BM).

Perennial. *Culms* erect or decumbent-ascending, rooting from lower nodes, lateral branches suffrutescent. *Leaf-sheaths* keeled at upper part, 7-9 cm long, glabrous; *ligules* 2-4 mm long; *leaf-blades* 8.5-9 cm by 4-7.8 mm, upper surface sparsely hairy, lower surface densely hairy, base tapering, apex long acuminate, margin scaberulous. *Inflorescence* 8-13 cm long, rachis internodes 0.8-3 cm long, branches pilose in the axils, raceme peduncles 5-7 mm long, racemes composed of triads or sometimes with 1 or 2 additional spikelet pairs below. *Sessile spikelets* lanceolate, 2.5-2.7 mm long (including callus); callus covered by c. 1 mm long; *lower glumes* oblong to lanceolate, 2.2-2.4 by 0.8-1 mm, 2-5-7-nerved, chartaceous, light green apically red, glabrous, apex truncate; *upper glumes* oblong, 2.2-2.5 by 0.6-1 mm, chartaceous, light green apically red, glabrous except for the upper half of margins, apex acute; *lower lemmas* oblong, 1-1.5 by 0.5 mm, apex acute; *upper lemmas* 1-1.5 mm long, awn c. 1 cm long; *anthers* 0.6 mm long. *Pedicelled spikelets c.* 2.5-3.5 mm long (including callus); pedicel 1.2-1.3 mm long, hairy on both margins, hairs 1-1.2 mm long: *lower glumes* oblong, 2-3 by 0.5-1 mm, 7-nerved, red to purple, glabrous except for the keels, apex acute; *upper glumes* oblong-lanceolate, boat-shaped, c. 3 by 1 mm, 3-nerved, sub-chartaceous, pale green with apically red, glabrous, apex acute; margin inflexed, ciliolate; *lower lemmas* obovate, 2.5-3 by 1.1-1.2 mm, apex obtuse to round; margin inflexed, ciliolate at upper half part; *anthers* 1.5 mm long. (**Figure 5.4, Figure 5.29A**)

Thailand.— NORTHERN: Mae Hong Son [Doi Chang, 19º25´N 98º18´ E, 17 Feb. 1968, *B. Hansen* and *T. Smitinand* 12610 (C)]; Chiang Mai [Fang, 26 Jul. 1968, K. Larsen, T. Santisuk and E. Warncke 2734 (K, P, AAU); Pah Hom Pok, 25 Feb. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 1673, 1686 (C); Pah Hom Pok, 25 Feb. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 1683 (K, C); Pah Hom Pok, 25 Feb. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 1682, 1685 (P, C); lower elevation of Doi Suthep, 8 Sep. 1967, *K. Iwatsuki, H. Koyama* and *N. Fukuoka* T-9434 (AAU); c. 2 km west of Mae Rim, 56º00´ E 18º55´N, 12 Oct. 2001, *S. Lægaard* and *M. Norsang* 21692 (AAU); km 8.3 along road towards Chiang Doi hills, 54º00´E 19º20´N, 28 Sep. 2001, *S. Laegaard* and *M. Norsangsri* 21628 (AAU); km 24-28 along road Mae Rim-Samoeng, 98º47´E 18º52´N, 21 Oct. 2001, *S. Lægaard* 21766 (AAU); Doi Khun Huai Pong, 18º58´N 98º10´ E, 3 Mar. 1968, *B. Hansen* and *T. Smitinand* 12773 (C); Wang Tao, north of Chiang Mai, 13 Feb. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 1046 (C); Jawm Tong, Awp Luang National Park, 21 Aug. 1993, *J.F. Maxwell* 93-939 (CMU, L); Me Tun, 3 Jun. 1922, *A.F.G. Kerr* 6216 (BM); Doi Suthep, 4 July 1987, *J.F. Maxwell* 07-606 (BKF); Doi Suthep, 29 Sep. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 5331 (BKF, K, C); Doi Suthep, 27 Aug. 1911 *A. F.G. Kerr* 1982 (BM, P), Doi Suthep, 6 Oct. 1990, *P. Chantaranothai, J. Parnell, D. Simpson* and *R. Pooma* 90/594 (K); Doi Suthep, 30 November 1959, *T. Smitinand* and *E.C. ABBE* 6181 (K); Doi Suthep, 19 Oct. 1948, Plernchit 83 (K); Doi Suthep, 18 Sep. 1967, *T. Shimizu, H. Koyama* and *M. Hutoh* T-10471 (K, AAU); Doi Suthep, 4 Dec. 1912 *A.F.G. Kerr* 2803 (BM); Doi Sutep-Pui National Park, 15 Oct. 1992, *J.F. Maxwell* 92-621 (P); Camp Hoi Chan Kiang, Doi Suthep, 25 Oct.-1 Nov. 1920, *J.F. Rock* 143 (P); Doi Suthep, summit, 19 Dec. 1987, *J.F. Maxwell* 87-1624 (L); Doi Sutep, 10 Feb. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 970, 981 (C); Doi Sutep, open quercous-Dipterocarp forest, 5 Oct. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 5764 (C); Doi Chiangdao, 3 Jan. 1966, *M. Tagawa, K. Iwatsuki and N. Fukuoka* T-4068 (BKF); Doi Chiang Dao, 8 Dec. 1957, *T. Smitinand* 3942 (K); Doi Chiang Dao, 20 Dec. 1931, *Put* 4435 (K, BM); Doi Chiang Dao, 18 Feb. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 1318 (C); Doi Inthanond, Nov. 1986, *C. Phengklai* and *T. Smitinand* 6077 (K, C); Me Tan, 3 Jun. 1922, *A.F.G. Kerr* 6216 (BM); Mae Dtang, Doi Sahng Liang, 10 Nov. 1997, *J.F. Maxwell* 97-1338 (CMU, L)]; Chiang Rai [1 Jan 2007, *O. Neamsuvan* 248 (BCU)]; Lampang [Doi Luang National Park, 11 Dec. 1998, *O. Petrmitr* 386 (CMU, BKF); Doi Luang National Park, west side of and below Doi Newk, 7 Nov. 1998, *O. Petrmitr* 342 (CMU, L); 20 Feb. 1958, *Th. Sørensen*, *K. Larsen* and *B. Hansen* 1391 (BKF)]; Lampoon [Doi Kuhn Dahn National Park, base of the west side at Bah Dteung Station, 28 Jul 1994, *J.F. Maxell* 94-811 (CMU, L)]; NORTH-EASTERN: Loei [Phu Kradueng, 16 Oct. 1954, T. Smitinand 2029 (K)]; SOUTH-WESTERN: Kanchanaburi [Huay Ban Kan, 9 Nov. 1971, *C.F. van Beusekom* and *R. Geesink*. 3599 (BKF); Huay Ban Kan, 10 Nov. 1971, *C.F. van Beusekom*, *R. Geesink*, *C. Phengklai* and *B. Wongwan* 3653 (BKF, BK, P, C)]

Distribution.— Sikkim, Bhutan, India to Japan, and Malesia.

Ecology.— This grass grows on hill or mountain slopes, deciduous-dipterocarp or evergreen forest, in open or shady area, flowering from October to February.

Vernacular.— Ya yung (หญ้ายุง)

2. ***Capillipedium laoticum*** A. Camus, Bull. Mus. Natl. Hist. Nat. 31: 207. 1935. Type: Laos, *Massie* s.n. (holo: P!).

Annual. *Culms* solitary, up to 70 cm long, nodes white hairy, hairs 1 mm long; *Leaf-sheaths* keeled, 9-11 cm long, glabrous; *ligules* membranous, 2-4 mm long; *leaf-blades* 10-20 cm by 5 mm, both surfaces scabrous, apex long acute, margin scaberulous; *Inflorescence* 6-10 cm, axes dark violet, upper part of raceme peduncles covered by tubercle-based hairs, hairs 2-3 mm long, racemes with few sessile spikelets. *Sessile spikelets* 4.5-5 mm long (including callus); *lower glumes* lanceolate, 4-4.5 by 2 mm, 5-nerved, wing, hairy on keels, coriaceous, pubescent in the upper half part, lower half part glabrous and shiny, apex truncate; *upper glumes* lanceolate, 4.8 by 1.2 mm, mid-nerve wide and conspicuous, chartaceous, light green, glabrous and shiny, apex acute; *lower lemmas* oblong, 2.5 by 0.5 mm, apex obtuse; *upper lemmas* 2.2 mm long, awn 40 mm long, hairy; *lodicules* cuneate, 0.5 mm long; *anthers* 1.5-2 mm long. *Pedicelled spikelet* lanceolate, 3.8-4 mm long; *pedicel* 3 mm long, hairy on both margins, hairs up to 2 mm long; *lower glumes* lanceolate, 4 by 0.8 mm, 9-nerved, glabrous, apex acute, keel hairy; *upper glumes* lanceolate, 3 by 0.5 mm, 5-nerved, subchartaceous, glabrous, apex acute, margin inflexed, margins hairy in the 1/3 upper part; *lower lemmas* narrowly lanceolate, 1.5-3 by 0.2-0.5 mm, apex obtuse, margin inflexed. (**Figure 5.5, Figure 5.29B**)

Thailand.— NORTHERN: Chiang Rai [Chiang Khom, 20 Dec. 1967, *Prayad* 1138 (BK)]; Chiang Mai [Doi Sutep, 29 Nov. 1911, *A.F.G. Kerr* 2254 (K, P, BM); Rachapat Institute, 14 Nov. 2001, *J.F. Maxwell* 01-605 (CMU)]; SOUTH-WESTERN: Uthai Thani [Huay Kha Khaeng Wildlife Sanctuary, 23 Dec 2008, *O. Neamsuvan* 269 (BCU)]; Kanchanaburi [Ban Kao, Mouth Pattavee, 18 Nov. 1961, *K. Larsen* 8313 (C); Sai Yok, 9 Dec. 1961, *K. Larsen* 8644 (C)]

Distribution.— Laos.

Ecology.— Open, fire-damaged, degraded, deciduous dipterocarp-oak, seasonal, hardwood forest, poor, rocky soil, granite bedrock

Notes.— Roberty (1960) regarded this species as a variety of *Capillipedium parviflorum*, *C. parviflorum* var. *laoticum* (A. Camus) Roberty, but I do not agree with him due to some different appearances. *Capillipedium parviflorum* has a shallow groove or channel on the back of the lower glume of the sessile spikelet, while this is rarely found or very shallow to flattened in *C. laoticum*. In addition, the sessile spikelet of *C. laoticum* is about 1.5-2 times longer than *C. parviflorum*. Moreover, the texture of the lower glume of the sessile spikelet is thicker and shinier than that in *C. parviflorum*.

3. ***Capillipedium longisetosum*** Bor**,** Brittonia 16: 227. 1964.— Type: E. Thailand, Nakhon Ratchasima*,* Bua Yai, *Put* 4247 (holo: K!; iso: BK!, BM!, C, L!).

Annual. *Culms* up to 50 cm high, erect, nodes pubescent. *Leaf-sheaths* 2.5-7 cm long, glabrous; *ligules* 0.5 mm long; *leaf-blades* 4-6 cm by 1-2 mm, upper surface sparsely hairy, lower surface densely hairy, apex long-acuminate. *Inflorescence* up to 7 cm long, racemes composed of triads only or sometimes with 1 or 2 additional spikelet pairs below. *Sessile spikelets* lanceolate, 5.2 mm long (including callus), callus covered by 1 mm long hairs; *lower glumes* ovate-oblong to oblong, 4.9 by 2 mm, 7-nerved, sub-coriaceous, apex acute; *upper glumes* lanceolate, 4.5-5 by 1.2-1.4 mm, chartaceous, glabrous, apex acute to obtuse; *lower lemmas* ovate, c. 2 by 1 mm, apex truncate; *upper lemmas* 2 mm long, awn 3 cm long; *lodicules* cuneate, 0.5 mm long; *anthers* 1.1 mm long. *Pedicelled spikelets* lanceolate, 4.3-4.5 mm long (including callus), callus glabrous; pedicel 3.8-4 mm, hairy at one side; *lower glumes* lanceolate, 3.8-4 by 0.6-0.7 mm, 9-nerved, nerves hairy in the upper 1/3 part, apex acute; *upper glumes* lanceolate, 2.9 by 0.6 mm, 5-nerved, sub-chartaceous, apex acuminate; margin inrolled, hairy in the upper half. (**Figure 5.6**)

Thailand.— EASTERN: Nakhon Ratchasima [Bua Yai, 1 Nov. 1931, *Put* 4247 (BK, BM, C, K, L)]; Pakchong, 5 Nov. 1970, *Umpai* 405 (BK); Chan Tuk, 19 Dec. 1923, *A.F.G. Kerr* 8062 (BK, BM, K)]; SOUTH-EASTERN: Chon Buri [Khao Khiew, Sriracha, 22 Nov. 1975, *J.F. Maxwell* 75-1095 (BK, AAU)], Sa Kaeo [Wattana Nakorn, 18 Nov. 1964, *S. Sutheesorn* 159 (BK)]; SOUTH-WESTERN: Kanchanaburi [17 km North of Kanchanaburi, 17 Nov. 1970, *M. Lazarides* 7405 (C, K, L)]

Distribution.— Endemic to Thailand

Ecology.— Open area, wet meadow, growing on sandy soil, flowering in November and December

Vernacular.— Ya phom hom (หญ้าผมหอม)

4. *Capillipedium parviflorum* (R. Br.) Stapf in Prain, Fl. Trop. Afr. 9: 169. 1917.— *Holcus parviflorus* R. Br., Prodr.: 199. 1810.— *Anatherum parviflorum* (R. Br.) Spreng., Syst. Veg. 1: 290. 1824.— *Andropogon micranthus* Kunth, Révis. Gramin.1: 165. 1829, non *A. parviflorus* Roxb. (1820).— *Andropogon micranthus* Kunth var. *muelleri* Hack. in DC., Monogr. Phan. 6: 489. 1889.— *Andropogon parviflorus* (R. Br.) Domin, Biblioth. Bot. 85: 263. 1915, non Roxb. (1820).— *Bothriochloa parviflora* (R. Br.) Ohwi, Acta Phytotax. Geobot. 11: 166. 1942.— *Chrysopogon parviflorus* (R. Br.) Nees, London J. Bot. 2: 411. 1843.— *Dichanthium parviflorum* (R. Br.) de Wet & J.R. Harlan, Amer. J. Bot. 54(3): 386. 1967.— *Rhaphis parviflora* (R. Br.) Chase, Contr. US Natl. Herb. 24: 205. 1925.— *Sorghum parviflorum* (R. Br.) P. Beauv., Ess. Agrostogr. 132, 165. 1812.— Lectotype: Australia, *R. Brown* 6188 (holo: K, BRI, photo; iso: BM!), designated by de Wet & J.R. Halan, Amer. J. Bot. 54(3): 386. 1967.

Andropogon alternans J. Presl in C. Presl, Reliq. Haenk. 1: 342. 1830.— Syntypes: Peru (error), *Haenke* s.n. (Peru, error; PR), Luzon, *Haenke* s.n. (Luzon; PR, US-*76233*, fragm.)

Andropogon capilliflorus Steud in Zoll., Syst. Verz.: 58. 1854, nomen; Syn. Pl. Glumac. 1: 397. 1854.— *Capillipedium parviflorum* (R. Br.) Stapf subsp. *capilliflorum* (Steud.) Henrard, Blumea 3: 457. 1940.— Type: Japan, *Bürger in Herb. Von Siebold* s.n. (lectotype: P; isolectotype: L no. *908.83-814, 908.86-882, 956.136-027*), designated here. Syntype: Java, Tengger, *Zollinger* HZ 564

Andropogon cinctus Steud., Syn. Pl. Glumac. 1: 398. 1854.— *Capillipedium cinctum* (Steud.) A. Camus, Rév. Int. Bot. Appl. Agric. Trop. 1: 306. 1921; Fl. Indo-Chine 7: 313. 1922.— Type: China, *Fortune* 13 (holo: P!; iso: K!)

Andropogon parvispica Steud., Syn. Pl. Glumac. 1: 397. 1854.— Type: Nepal, *Royle* 283 (holo: P; iso: LIV, K!)

Andropogon quartinianus A. Rich., Tent. Fl. Abyss. 2: 469. 1850.— Type: Abyssinia, Prov. Chiré, Beless, *Quartin Dillon* s.n. (holo: P, K! fragm.).

Andropogon villosulus Nees ex Steud., Syn. Pl. Glumac. 1: 397. 1854.— *Chrysopogon villosulus* (Steud.) Wm. Watson in E.I. Atk., Gaz. NW Prov. India 10: 392. 1882; Vidal [Phan. Cuming. Philip.: 29, 158. 1885, nomen] Revis. Pl. Vasc. Filip.: 291. 1886, isonym.— Syntypes: Nepal, *Royle 93* (LIV, P), *Royle 282* (LIV, photo in BRI; P).

Bothriochloa parviflora (Stapf) Ohwi var. *mutispicula* Ohwi, Bull. Tokyo Sci. Mus. 18: 13. 1947.—*Andropogon micranthus* Kunth var. *mutispiculus* (Ohwi) Reeder, J. Arnold Arbor. 29: 365. 1948.— *Capillipedium parviflorum* (R. Br.) Stapf var. *mutispiculum* (Ohwi) Jansen, Reinwardtia 2: 247. 1953.— Type: New Guinea, Cycloop Mts., *Meijer Drees* 80 (holo: BO).

Chrysopogon violascens Trin., Mém. Acad. Imp. Sci. St. Pétersbourg, VI, Sci. Math. 2: 319. 1832.— Type: Australia, *Sieber Agrostotheca* 65 (holo: LE, not found in LE-Trinius; iso: L!).

Perennials. *Culms* erect, branching or not, nodes short hairy, up to 100 cm high. *Leaf-sheaths* 5-8 cm long, glabrous; *ligules* 1 mm long; *leaf-blades* 8-15 cm by 3-7 mm, lower surface glabrous, upper surface scabrid, base more or less rounded, apex long-acuminate, margin scaberulous. *Inflorescence* an open or dense panicle, 10-14 by 6-10 cm, racemes composed of triads only or sometimes with 1 or 2 additional spikelet pairs below. *Sessile spikelets* lanceolate, callus hairy; *lower glumes* oblong to laceolate, 2.1-2.5 by 0.8-1 mm, 4-6-nerved, chartaceous, greenish or purplish, shortly hispid and grooved on the back, apex truncate; *upper glumes* c. 2.5 by 1 mm, subchartaceous, greenish or purplish, glabrous; apex acute or mucronate, mucro c. 0.1-0.3 mm long; *lower lemmas* oblong, c. 1.5 by 0.5 mm, apex obtuse or truncate and erose; *upper lemma* 3 mm long, awn 6-11 mm long; *lodicules* 0.2-0.3 mm long; *anthers* c. 1.5 mm long. *Pedicelled spikelets* well-developed often staminate, sometimes reduced and barren; short callus covered by short hairs; pedicel c. 1.5 mm long, covered by short hairs on both surfaces; *lower glumes* ovate, 2.5-3 by 1-1.2 mm, 8-nerved, purple, nerves hispid, apex obtuse; *upper glumes* elliptic, 2.5-3 by 1-1.2 mm, 3-5-nerved, sub-chartaceous with hyaline at margin, purple, midrib hairy, apex truncate, margin inrolled; *lower lemmas* ovate, 2.5-2.8 by 1 mm, apex obtuse to truncate; *anthers* c. 1.3 mm long. (**Figure. 5.7**, **Figure 5.29C**)

Thailand.— NORTHERN: Chiang Mai [Doi Sutep; 26 Oct. 1958, *Th. Sørensen*, *K. Larsen* and *B. Hansen* 5916 (C); Doi Suthep, 30 Nov. 1959, *T. Smitinand & E.C. Abbe* 6184 (BKF, K); Doi Suthep, 11 Dec. 1957, *T. Smitinand* 3959 (K), Doi Suthep, 10 Nov. 1987, *J.F. Maxwell* 87-1397 (BKF); Doi Sutep-Pui, 7 Jan. 1993, *J.F. Maxwell* 93-25 (P, L, AAU); Doi Sutep-Pui National Park, summit of Doi Suthep at Sahn Goo Ruins, 1 Jan. 1991, *J.F. Maxwell* 91-6 (L, AAU); Doi Sutep-Pui National Park, east side, below Doi Sutep Temple, 27 Dec. 1990, *J.F. Maxwell* 90-1369 (L, AAU); Doi Inthanon, along road summit c. 5 km toward entrance, 98º30´E 18º35´N, 16 Oct. 2001, *S. Lægaard* and *M. Norsangsri* 21732 (AAU); Doi Inthanond, 3 Jan. 1975, *R. Geesink, P. Hiepko and C. Phengklai* 8037 (BKF, K, C); Doi Inthanon, Kun Wang district, route, along road through dist. Pine forest, 3100E 1834N, 22 Sep. 2001, *S. Lægaard* and *M. Norsangsri* 21600 (AAU); Doi Chiangdao, 3 Dec. 1961, *T. Smitinand* and *Anderson* 7336 (BKF); Doi Chiangdao, 7 Dec. 1959, *T. Smitinand* and *E.C. Abbe* 6264 (BKF, K); Doi Chiangdao, 25 Dec. 1931, *Put* 4537 (K, BM); Mai Muang Nao Arboretum, 3 Nov. 2001, *W. Sankamethawee* 340 (BKF, BK, CMU); Doi Khun Huai Pong, 6 Mar. 1968, *B. Hansen and T. Smitinand* 12855 (BKF, K, L, P, C, AAU); Doi Suthep, 4 Mar. 1966, *C. Chermsirivathana* 440 (BK);

Phrao, 10 Sep. 1977, *S. Sutheesorn* 4196 (BK); Doi Angkhang, 5 Aug. 1974, *S. Sutheesorn* 3069 (BK); Mae Jam, 14 Jan 1997, *J.F. Maxwell* 97-36 (CMU, L)]; Tak [Doi Musor, 9 Dec. 1960, *T. Smitinand* 7081 (BKF)]; Phitsanulok [Thungsalangluang National Park, 25 Oct 2005, *O. Neamsuvan* 218 (BCU)]; NORTH-EASTERN: Phetchabun [Nam Nao National Park, 2 Jan 2007, *O. Neamsuvan* 249 (BCU)]; Loei [Phuluang National Park, 9 Jan 2007, *O. Neamsuvan* 258 (BCU)]; SOUTH-WESTERN: Kanchanaburi [Huay Ban kan, 9 Nov. 1971, *C.F. van Beusekom, C. Phengkhlai, R. Geesink* and *B. Wongwan* 3585 (BK, K, P, L, C)]

Distribution.— Africa, Arabia, China, and eastern Asia, India, Indo-China, Malesia, and north Indian ocean, Australasia, Pacific.

Ecology.— This grass grows on hill or mountain slope, in open or shady area, deciduous or evergreen forest, flowering between August to March.

Vernacular.— Ya yung (หญ้ายุง)

5. ***Capillipedium sulcatum*** Bor, Bot. Tidsskr 67(4): 324. 1973.— Type: NE Thailand, Loei, foothills of Phu Kradueng, *Ch. Chareonphol, K. Larsen & E. Warncke* 4878 (holo: AAU!)

Annual. *Culms* decumbent, 20-80 cm high, nodes bearded. *Leaf-sheaths* 6-11 cm long, puberulous with bulbous-based long hairs especially near margin; *ligules* 1.5 mm long; *leaf-blades* 13-32 cm by 3.5-5.5 mm, upper and lower surfaces densely hairy, base tapering, apex long-acuminate, margin scaberulous. *Inflorescence* 6-11 cm long, axils pilose, racemes composed of triads only or sometimes with 1 or 2 additional spikelet pairs below. *Sessile spikelets* lanceolate, 6-7 mm long, callus covered by long hairs; *lower glumes* lanceolate, 5.5-6.5 by 2 mm, 9-11-nerved, coriaceous, light green, dorsally grooved, apex obtuse, upper part of margin hairy; *upper glumes* lanceolate, 5-6 by 1-1.5 mm, subcoriaceous, glabrous, light green, apex acute to obtuse; *lower lemmas* ovate, 2.3-2.5 by 1 mm, apex obtuse; *upper lemmas* 4.5-6 mm long, awn 2.5-3 cm long; *lodicules* cuneate, 0.4 mm long; *anthers* 3 mm long. *Pedicelled spikelets* lanceolate, 6-7 mm long; callus short, hairy; pedicel 3-4 mm long, hairy at one side; *lower glumes* lanceolate, 6-7 by 1 mm, 11-nerved, nerves hairy, apex acute, margins sparsely short-hairy; *upper glumes* lanceolate, 6.5 by 1 mm, 3-5-nerved, sub-chartaceous, light green, apex acute, margin inrolled; *lower lemmas* ovate to lanceolate, 3-5 by 1.3-1.5 mm, apex obtuse to truncate, margin ciliolate; *lodicules* cuneate, 0.2 mm long; *anthers* 2.5 mm long. (**Figure 5.8**, **Figure 5.29D**)

Thailand.— NORTHERN: Nakhon Sawan [Chong Ke, 28 Nov. 1828, *Put* 2160 (K, BM); Ta Kli, 26 Nov. 1926, *Put* 2135 (BM)]; NORTH-EASTERN: Loei [foothill of Phu Kradueng, 16º53´N 101º53´E, 10 Nov. 1970, *Ch. Chareonphol, K. Larsen* and *E. Warncke* 4878 (AAU)]; SOUTH-WESTERN: Petchaburi [Bo Fai, 9 Nov. 1931, *A.F.G. Kerr* 2742 (K)]

Distribution.— Endemic to Thailand

Ecology.— Grows on hills, shady areas in deciduous forest, rarely in open areas on beaches, flowering from October to November

Note.— *Ch. Charoenphol, K. Larsen* and *E. Warncke* 4878, the type of *Capillipedium sulcatum* in K is *Bothriochloa bladhii* (Retz.) S.T. Blake.

6. *Capillipedium* sp.1

Annual. *Culms* up to 120 cm, nodes bearded. *Leaf-sheaths* 12-17.5 cm long, puberulous, sparsely tubercle-based hairy near the base of the sheath, hairs 5-6 mm long; *ligules* membranous, 1 mm long; *leaf-blades* 15-30 by 0.8-1.3 cm, both surfaces puberulous, base attenuate, margin scaberulous. *Inflorescence* 8-13 cm long, branches and axis of panicle pubescent, racemes composed of triads only or sometimes with 1 or 2 additional spikelet pairs below. *Sessile spikelets* 5.5-6 mm long (including callus); callus hairy, hairs c. 1.5 mm long; *lower glumes* lanceolate, 5-5.5 by 1.5 mm, 6-10-nerved, coriaceous, dorsally grooved, apex acute, hairy at the area from keel to margin at upper half part; *upper glumes* lanceolate, 5.5 by 1.8 mm, subchartaceous, glabrous, apex truncate, margin ciliolate; *lower lemmas* ovate, 2 by 0.5 mm, apex acute; *upper lemmas* 3.5 mm long, awn 3 cm long; anther 3 mm long. *Pedicelled spikelets* lanceolate, c. 6 mm (including callus), callus glabrous; lower glumes lanceolate, 5.5 by 1.3 mm, 9-nerved, chartaceous, apex acute, hairy at the area from keel to margin; *upper glumes* lanceolate, 5 by 1.2 mm, 5-nerved, subchartaceous to hyaline, apex acute, margin inflexed and ciliolate; *lower lemmas* lanceolate, 4 by 1.1 mm, apex acute, margin ciliolate in the upper half; *anthers* 2.5 mm long. (**Figure 5.9**)

Thailand.— PENINSULAR: Songkhla [Samila beach, 24 October 2007, *Y. Sirichamorn* 35 (BCU)]

Ecology.— Open area, on the rock, by the sea

Notes.— In Thailand, this specimen is most similar to *Capillipedium sulcatum*, especially by the deep dorsal groove of the lower glume of the sessile spikelet. However, it differs from *C. sulcatum* by the wider leaves, the pubescence of the panicle branches and axis and thinner lower glume texture. It is also very similar to *Capillipedium leucotrichum* (A. Camus) M. Schmid ex Veldk. from Cambodia, especially because of the pubescence of the panicle branches and axis. However, it differs by bearing (1)-3 sessile spikelets per raceme, while only a triad is present in *C. leucotrichum*. Habitat-wise, this taxon grows on a mound of the rock near the sea which is a habitat not shared with the rest of the Thai members of this genus. In Taiwan, Botel Tobago, the Ryu Kyu Isl., and the Philippines such a habitat has been reported for *C. kwashotense* (Hayata) C.C. Hsu, but this clearly is a different species. After examining, this specimen should be a new species.

7. *Capillipedium* sp2.

Annual. *Culms* 45-50 cm high, erect, nodes pubescent. *Leaf-sheaths* 5-8 cm long, glabrous; *ligules* 1.5-2.0 mm long; *leaf-blades* 7-31 cm by 1-4 mm, densely hairy on both surfaces, base rounded, apex long-acuminate. *Inflorescence* 4-10 cm long, a raceme composed of 1 or 2 sessile spikelets, panicle axis and branches densely covered by 2 kinds of hairs: 0.2 mm long hairs and villous with tubercle-based 0.5-1 cm long hairs, axis pinkish. *Sessile spikelets* lanceolate, c. 4 mm long (including the short callus), callus covered by c. 1.5 mm long hairs; *lower glumes* ovate, c. 3.5 by 1.5 mm, 5- or 6-nerved; keels winged, hairs c. 8 mm long; coriaceous, rough above, shiny, apex truncate; *upper glumes* lanceolate, 3.6-3.7 by 0.9-1 mm, subcoriaceous, dorsally hairy in the upper 1/3 part, apex truncate; *lower lemmas* ovate, c. 1 by 0.5 mm, apex obtuse; *upper lemmas* 2 mm long, awn 2.5-3 cm long; *lodicules* cuneate, 1 mm long. *Pedicelled spikelets* lanceolate, c. 5.5 mm long (including callus), callus covered by 1 mm long hairs; pedicel 2 mm long, hairy on both sides; *lower glumes* lanceolate, c. 5 by 1 mm, 11-nerved, nerves hairy in the upper 1/3 part, apex acute; *upper glumes* lanceolate, 4.0-4.1 by 0.5-0.6 mm, 5-nerved, chartaceous, nerves hairy in the upper half, apex acute, margin inrolled; *lower lemmas* oblong, c. 3 by 1 mm, apex obtuse; margin inflexed, ciliolate at upper part of margin; *lodicules* 0.1 mm long. (**Figure 5.10**)

Thailand.— CENTRAL: Saraburi [Sahm Lahn, 27 Oct. 1973, *J.F. Maxwell* 73-562 (AAU, BK); Sahm Lahn forest, 19 Oct. 1974, *J.F. Maxwell* 74-945 (AAU, BK, L).

Ecology.— Open or shaded areas, rocky, on mountain, in dipterocarp, bamboo or hardwood forest, alt.c. 200 m, flowering in October.

Notes.— These specimens are very similar to *C. laoticum*, especially due to its wings of the lower glume of the sessile spikelet and tubercle based-hairs of the peduncle of the raceme. However, it differs from *C. laoticum* as its 5-10 mm long tubercle based-hairs cover throughout the panicle branches and at the upper part of panicle axis, whereas those in *C. laoticum* cover with 2-3 mm long tubercle based-hairs only the upper part of the raceme peduncles. Moreover, among tubercle-based hairs, it is mixed with very short hairs, while it is glabrous among tubercle-based hairs in *C. laoticum*. In addition, the panicle axis of *C.* sp.2 is pinkish, while it is dark violet in *C. laoticum*.

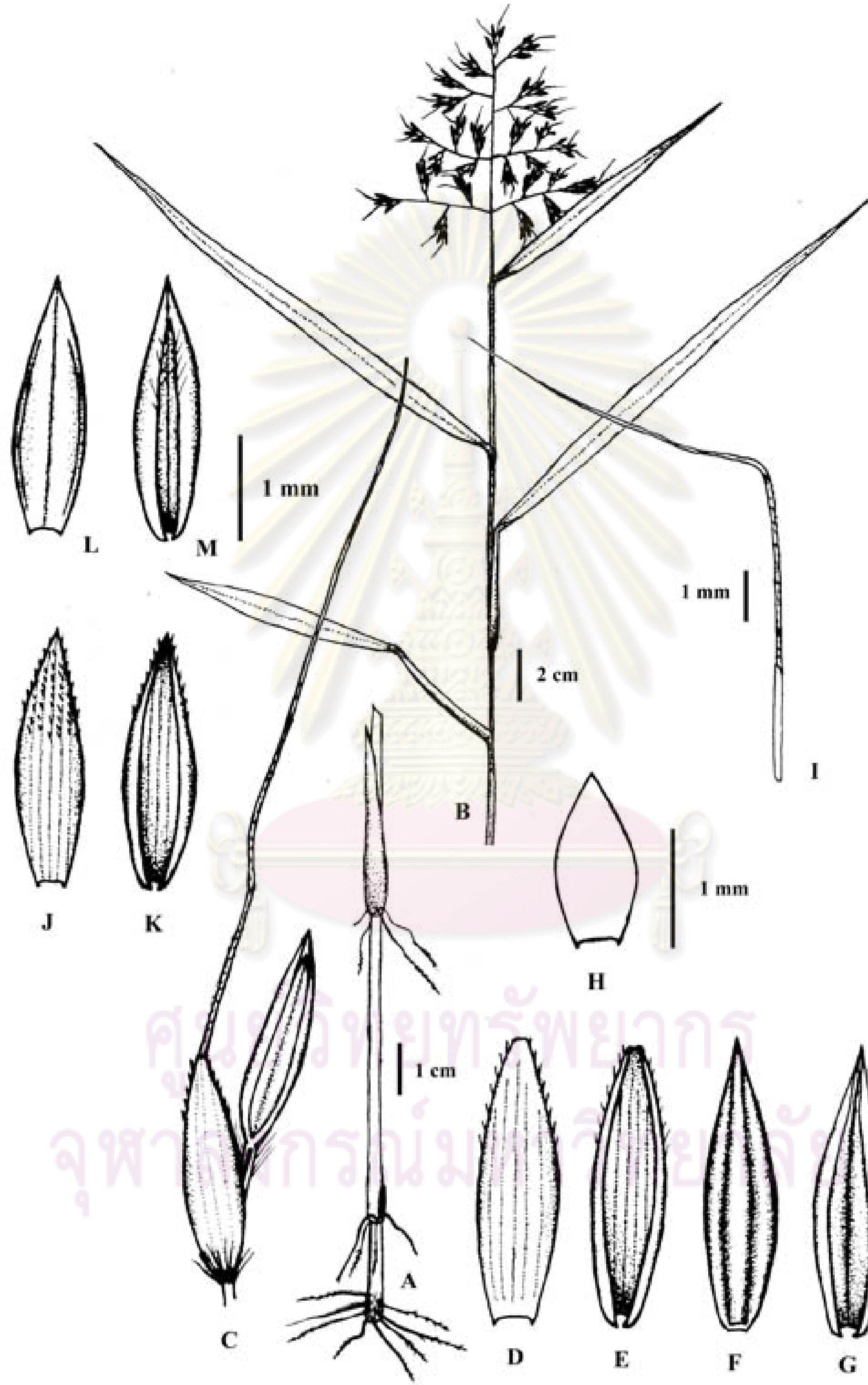

Figure 5.4 *Capillipedium assimile*: A. habit. B. inflorescence. C. spikelet pair. D.-I. sessile spikelet: D.-E. lower glume; F.-G. upper glume; H. lower lemma; I. upper lemma. J.-M. pedicelled spikelet: J.-K. lower glume; L.-M. upper glume.

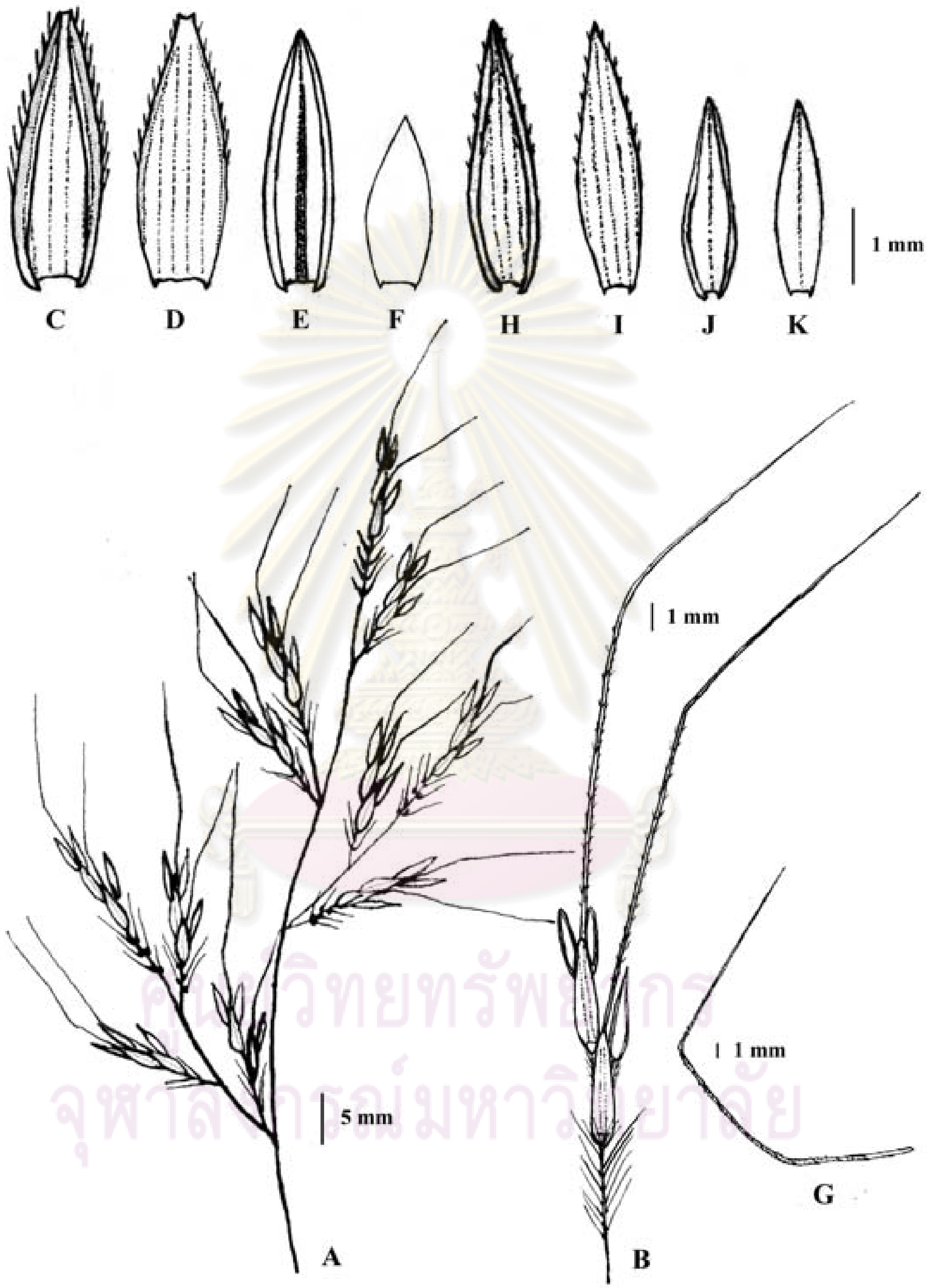

Figure 5.5 *Capillipedium laoticum*: A. inflorescence. B. a raceme showing tubercle-based hairs at upper part of peduncle. C.-G. sessile spikelet: C.-D. lower glume; E. upper glume; F. lower lemma; G. upper lemma. H.-K. pedicelled spikelet: H.-I. lower glume; J.-K. upper glume.

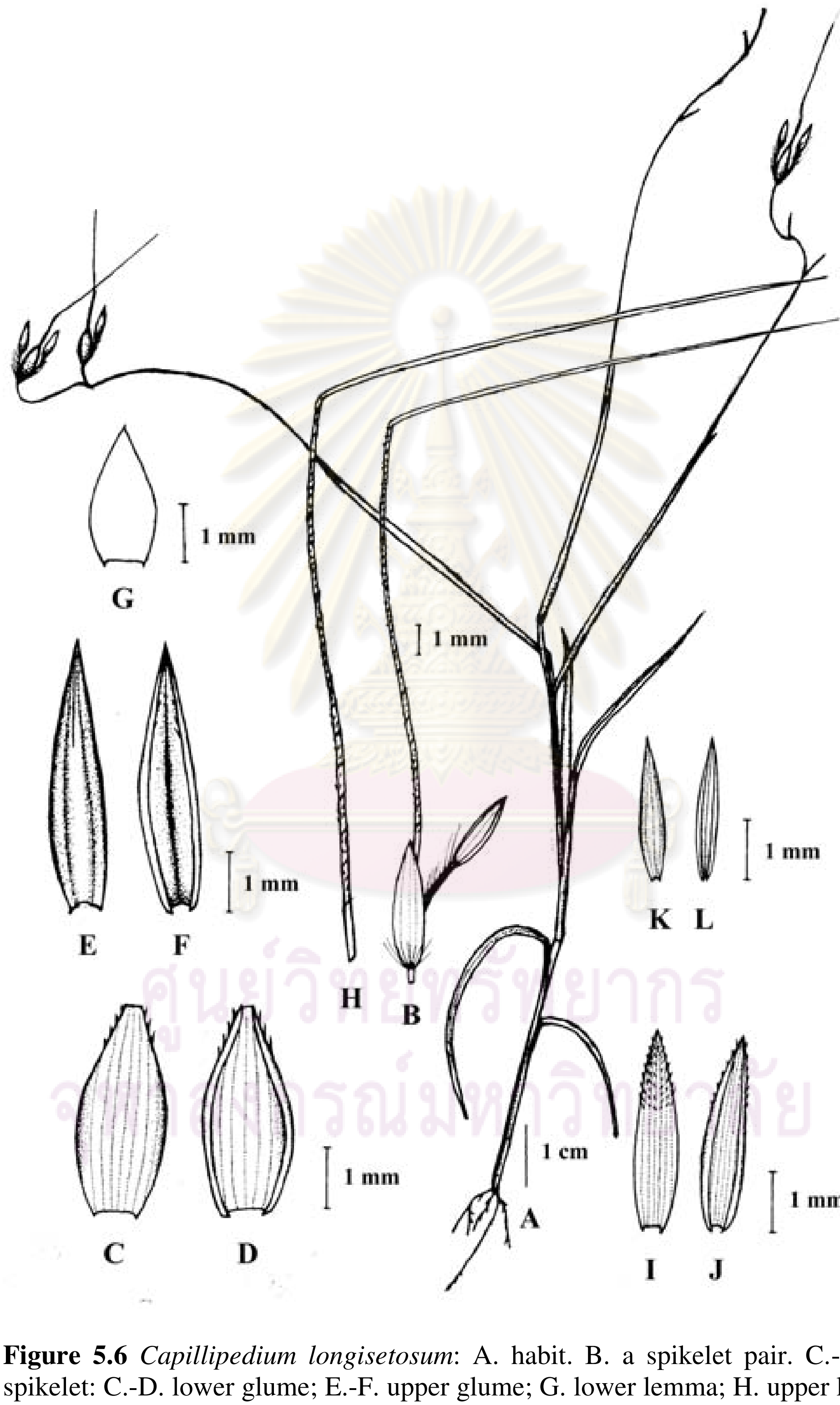

Figure 5.6 *Capillipedium longisetosum*: A. habit. B. a spikelet pair. C.-H. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma. I.-L. pedicelled spikelet: I.-J. lower glume; K.-L. upper glume.

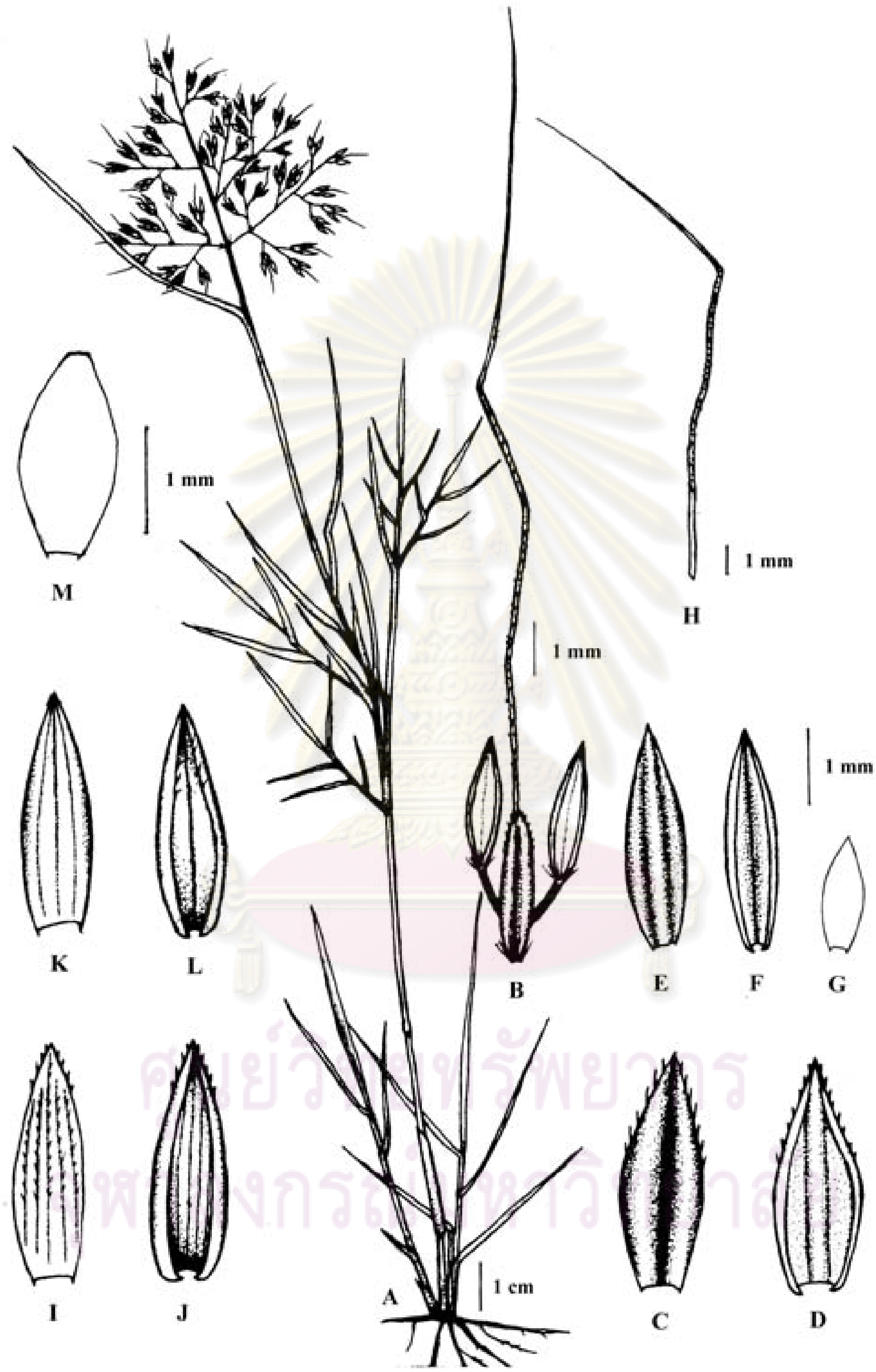

Figure 5.7 *Capillipedium parviflorum*: A. habit. B. spikelet group. C.-H. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma. I.-M. pedicelled spikelet: I.-J. lower glume; K.-L. upper glume; M. lower lemma.

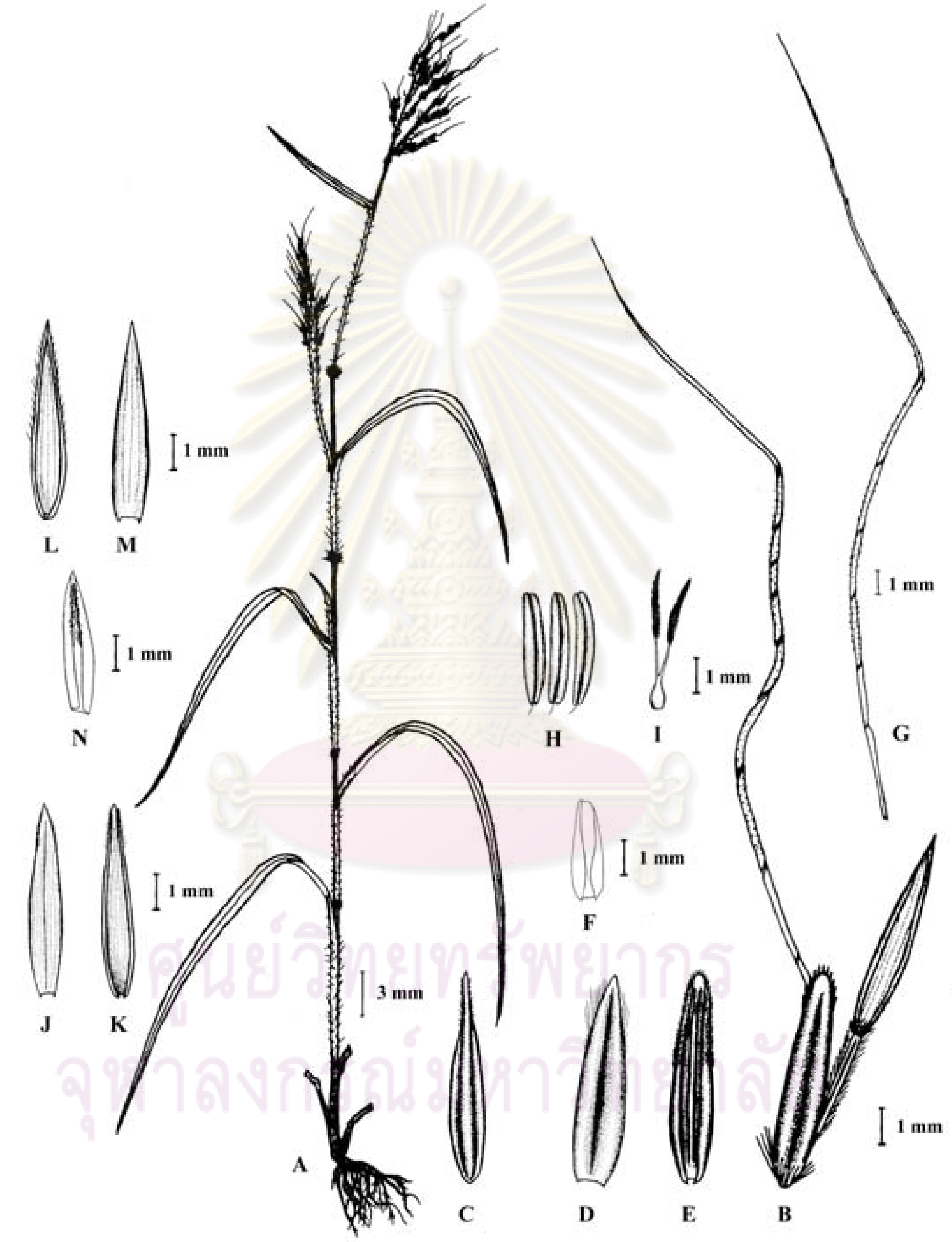

Figure 5.8 *Capillipedium sulcatum*: A. habit. B. spikelet pair. C.-I. sessile spikelet: C. upper glume; D.-E. lower glume; F. lower palea; G. upper palea; H. stamen; I. pistil. J.-N. pedicelled spikelet: J.-K. lower glume; L.-M. upper glume; N. lower palea.

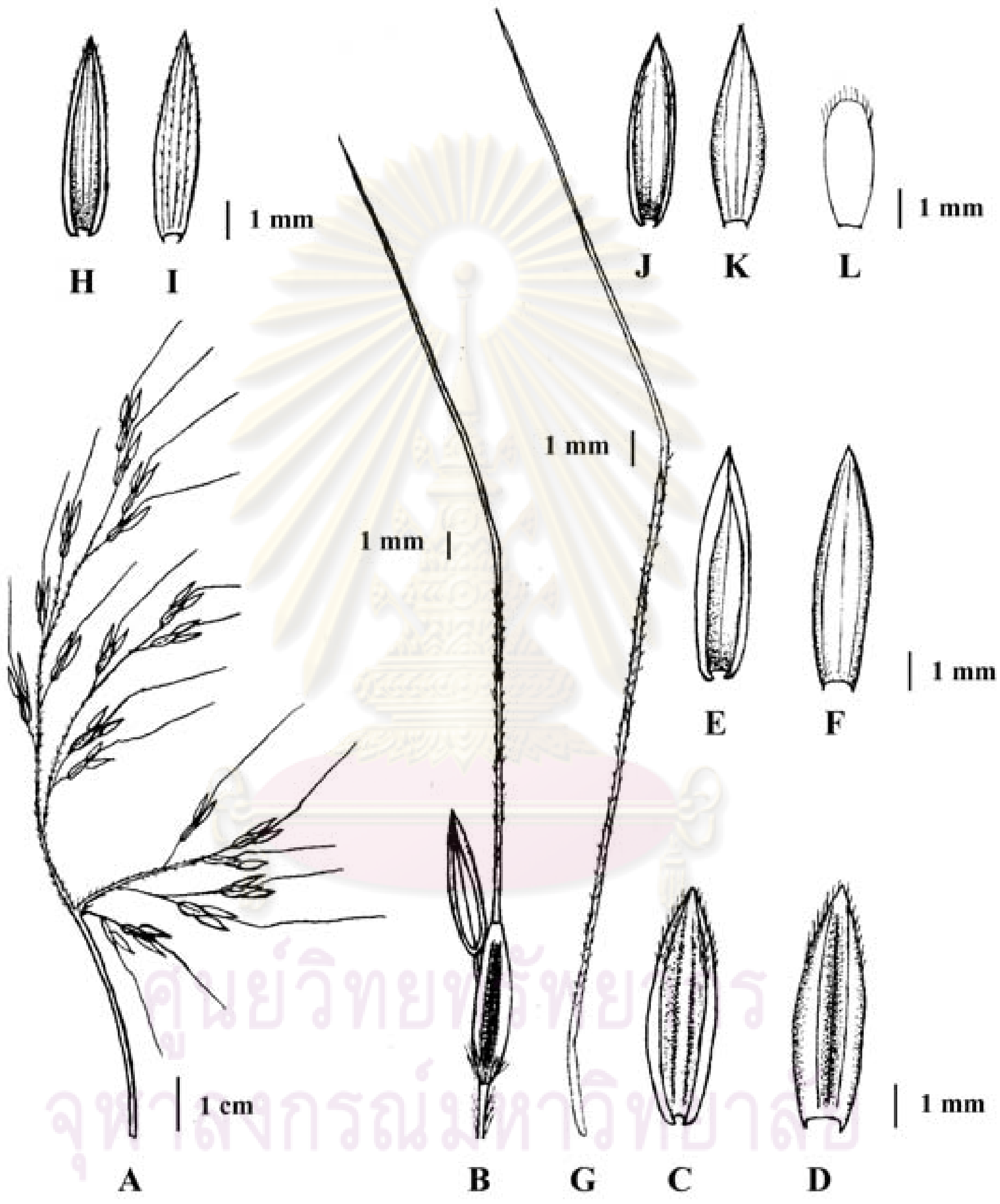

Figure 5.9 *Capillipedium* sp.1: A. inflorescence showing pubescent at panicle branches. B. spikelet pair. C.-G. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. upper lemma; H.-L. pedicelled spikelet: H.-I. lower glume; J.-K. upper glume; L. lower lemma

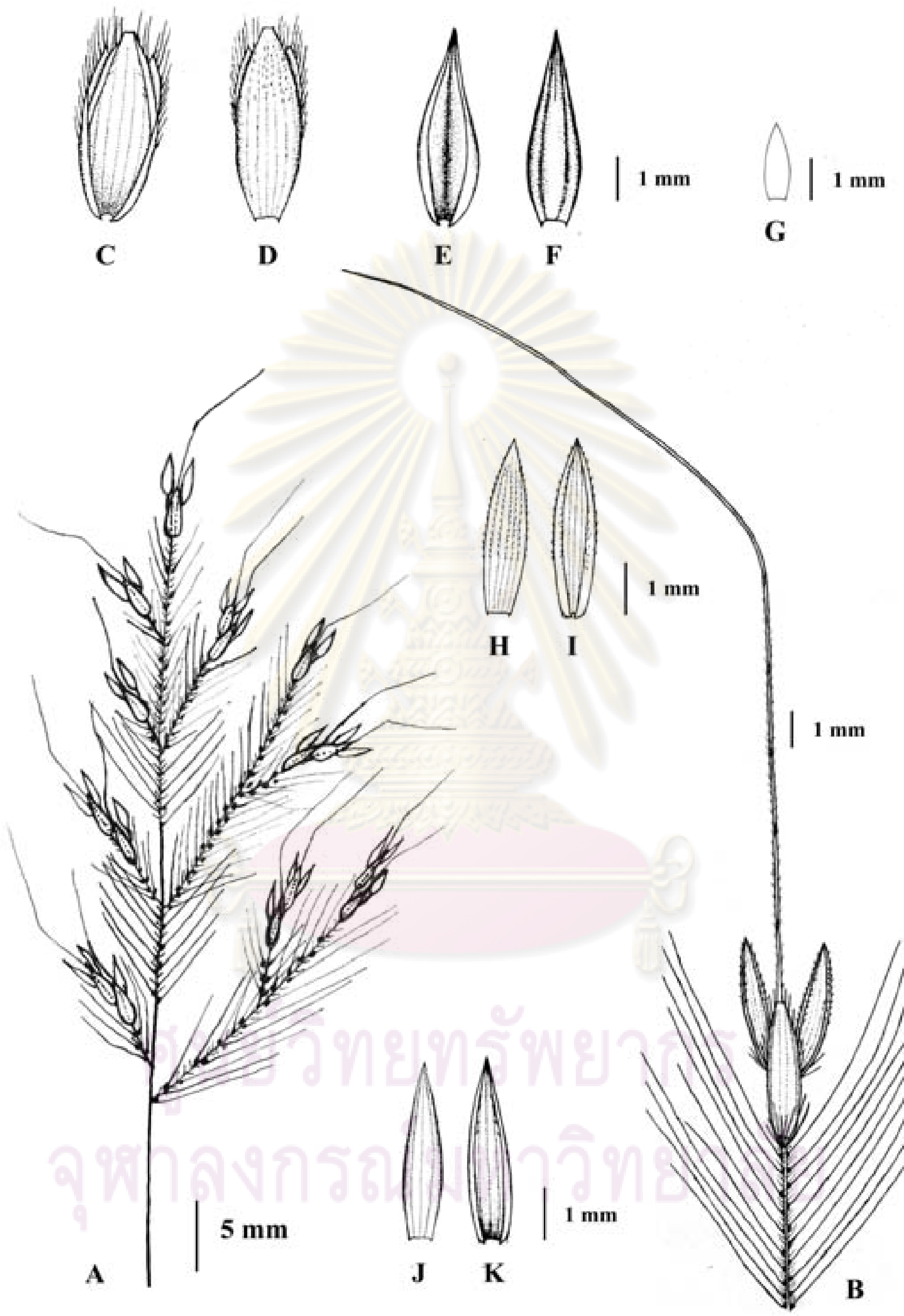

Figure 5.10 *Capillipedium* sp: 2. A. inflorescence showing pubescent at panicle branches and panicle axis. B. a raceme with hairy peduncle showing 2 kinds of hairs. C.-G. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H.-K. pedicelled spikelet: H.-I. lower glume; J.-K. upper glume.

3. CHRYSOPOGON

Trin., Fund. Agrost.: 187. 1822; Veldk., Austrobaileya 5: 503. 1999.; nom. cons.— *Andropogon* subgen. *Chrysopogon* (Trin.) Hack., Nat. Pflanzenfam. 2, 2: 28. 1887; in A. DC., Monogr. Phan. 6: 547. 1889.— *Chalcoelytrum* Lunell, Am. Midl. Naturalist 4: 212.1915, nom. superfl.— *Phoenix* Haller, Hist. Stirp. Helv. 2 (1768) 202, non L. (1753).— *Pollinia* Spreng., Pl. Min. Cogn. Pug. 2: 10. 1815., nom. rej.— Lectotype species: *Chrysopogon gryllus* (L.) Trin., designated by Pfeiffer (Nomencl. Bot. 1: 745. 1873).

Centrophorum Trin., Fund. Agrost.: 106. 1820, t. 5, nom. rej.— Type: *Centrophorum chinense* Trin. [= *Chrysopogon aciculatus* (Retz.) Trin.].

Rhaphis Lour., Fl. Cochinch. 538: 552. 1790. nom. rej.— *Chrysopogon* Trin. sect. *Rhaphis* Roberty, Bull. Inst. Franç. Afrique Noire 22: 106. 1960.— Type: *Rhaphis trivialis* Lour., nom. superfl. [= *Chrysopogon aciculatus* (Retz.) Trin.]

Vetiveria Bory in Lemaire Bull. Sci. Soc. Philom.: 43. 1822.— *Andropogon* L. sect. *Vetiveria* Thouars ex Benth., J. Linn. Soc., Bot. 19: 72. 1881.— *Andropogon* L. subgen. *Vetiveria* Hack. in Mart., Fl. Bras. 2, 4: 294. 1883.— *Chrysopogon* Trin. sect. *Vetiveria* Roberty, Bull. Inst. Franç. Afrique Noire 22: 106. 1960., nom. inval.; Boissiera 9: 291. 1960 (valid).— Type: *Vetiveria odoratissima* Bory, nom. illeg. [= *Chrysopogon zizanioides* (L.) Roberty].

Perennials. Leaves mostly basal; *ligule* membranous, a fringe of hairs; *leaf-blades* conduplicate to flat. *Inflorescence* terminal, an open panicle, branches whorled, usually simple; racemes usually reduced to a triad of one sessile and two pedicelled spikelets, sometimes with several pairs of sessile and pedicelled spikelets with a terminal triad on a many-jointed rachis, joints and pedicels slender. *Sessile spikelets* 2-flowered, the lower floret epaleate, sterile, the upper bisexual; lanceolate in outline, laterally compressed; callus usually pungent, oblique, sometimes rounded and blunt, usually distinctly bearded; *lower glume* chartaceous to coriaceous, dorsally convex; *upper glume* boat-shaped, keeled, apex usually long-mucronate; *lower lemma* hyaline, glabrous; *upper lemma* hyaline, glabrous, rounded to bifid, usually awned, awn terminal or from a small sinus; *lodicules* glabrous; stamens 3, rarely 2. *Pedicelled spikelets* dorso-ventrally compressed, male; *lower glumes* chartaceous; *upper glumes* glabrous; *lower lemmas* 2-nerved, hyaline, glabrous; *upper lemmas* 1-nerved, hyaline, glabrous; *upper palea* present or absent, if present hyaline and glabrous.

Species 48. The Old World tropics, with 1 in Cuba and Florida. 9 in Thailand.

Note.— *Vetiveria* was included in *Chrysopogon* by Veldkamp (1999). In total he recorded 8 species for Thailand. This study, however, found one more taxon in addition to 8 taxa of Veldkamp, i.e. *C. gryllus*. Accordingly, nine taxa of present *Chrysopogon*, including 3 species of formerly classified as members of *Vetiveria*, are composed of *C. aciculatus, C. festucoides, C. fulvus, C. gryllus, C. lawsonii, C. orientalis, C. perlaxus, C. serrulatus, C. zizanioides.*

Chrysopogon nemoralis, a name widely used in various papers of Thailand, is included in a key without a description because no specimens were collected in Thailand by this study.

KEY TO THE SPECIES

1. Sessile spikelets 1, rarely 2 per raceme
   2. Upper glume of sessile spikelet dorsally with a tuft of brown hairs
      3. Spikelet yellow, lower glume of sessile spikelet distally pilulose …………………………………………………………………. **3. *C. fulvus***
      3. Spikelet purple, lower glume of sessile spikelet glabrous ……... **7. *C. perlaxus***
   2. Upper glume of sessile spikelet dorsally glabrous.
      4. Pedicel of pedicelled spikelet glabrous
         5. Stem creeping at base, awn straight ………….……………. **1. *C. aciculatus***
         5. Stem erect, awn geniculate ……………………………….…... **4. *C. gryllus***
      4. Pedicel of pedicelled spikelet hairy
         6. Pedicel of pedicelled spikelet longer than half length of sessile spikelet, sessile spikelet excluding callus shorter than pedicelled spikelet ……………………………………………...…………... **6. *C. orientalis***
         6. Pedicel of pedicelled spikelet shorter than half the length of sessile spikelet, sessile spikelet excluding callus as long as pedicelled spikelet ……………………………………………………………… **8. *C. serrulatus***
1. Sessile spikelets 2-14 per raceme
   7. Awn geniculate, sessile spikelet without callus shorter than pedicelled spikelet
      8. Sessile spikelets 2-8, awn geniculate …………………………... **5. *C. lawsonii***
      8. Sessile spikelets 2-3, awn straight ……………………………... ***C. nemoralis***
   7. Awn straight, sessile spikelet without callus as long as pedicelled spikelet
      9. Apex of upper glume of sessile spikelet muticous, upper lemma of sessile spikelet awn, awn exserted ……………………………….……. **2. *C. festucoides***
      9. Apex of upper glume of sessile spikelet muticous, upper lemma of sessile spikelet muticous or short awn, awn usually enclosed ……… **9. *C. zizanioides***

1. *Chrysopogon aciculatus* (Retz.) Trin., Fund. Agrost. 188. 1820.— *Andropogon aciculatus* Retz., Observ. Bot. 5: 22. 1789.— *Andropogon acicularis* Willd., Sp. Pl. ed. 4, 4: 906. 1806 (sphalm.).— *Holcus aciculatus* R. Br., Narr. Travels Africa, App.: 244. 1826. ('*acicularis*').— *Chrysopogon trivialis* Nees, Nova Acta Phys. Med. Acad. Caes. Leop. Carol. Nat. Cur. 19, Suppl. 1: 61. preprint 1841; 171. 1843 (by inference, reference to basionym not given, no description), nom. superfl.— *Rhaphis aciculatus* Desv., Mém. Soc. Agric. Angers 1: 173. 1831; Opusc. Sci. Phys. Nat.: 69. 1831. (repr.: '*acicularis*'); Honda, Bot. Mag. (Tokyo) 40: 103. 1926, isonym.— *Rhaphis trivialis* Lour., Fl. Cochinch.: 553. 1790. nom. superfl. ('*trivalvis*').— [*Rhaphis zizanioides* (L.) Roberty var. *aciculatus* Roberty, Petite Fl. Ouest-Afr.: 403. 1954, comb. inval.].— Lectotype: *König in Herb. Retzius* (holo: LD!, K neg. 7082, photo in BRI; iso: C!), designated by Veldkamp (Austrobaileya 5: 509. 1999).

Andropogon subulatus J. Presl in C. Presl, Reliq. Haenk. 1: 341. 1830.— *Chrysopogon subulatus* Trin. ex Steud., Nomencl. Bot., ed. 2, 1: 93, 360. 1840.— Type: *Haenke* s.n. (holo: PR).

[*Kudirra-pullu* Rheede, Hort. Malab. 12: 79 ('97'), t. 43. 1693, nom. inval.].

[*Gramen aciculatum* Rumph., Herb. Amboin. 6:13, t. 5, f. 1. 1750, nom. inval.— Voucher: *Robinson Pl. Rumph. Amboin.* 45 (A, BM, BO, F, K, MO, NSW, NY, US)].

Rhaphis javanica Nees in Hooker's J. Bot. Kew Gard. Misc. 2: 99. 1850, nomen. for *Cuming* 555 from the Philippines; the specimen in TCD was labelled "*Chrysopogon javanicum*" by Nees himself.].— *Andropogon javanicus* Steud., Syn. Pl. Glumac. 1: 396. 1854 ('Java').— Lectotype: *Junghuhn* s.n. (holo: P) designated by Veldkamp (Austrobaileya 5: 510. 1999).

Chrysopogon aciculatus var. *longifolius* Buse, Pl. Jungh. 3: 361. 1854.— Type: *Junghuhn* s.n. (holo: L!, no. 908.86-159, L 0043949).

Mat forming, stoloniferous perennials. *Culms* 20-50 cm high. *Leaf-sheaths* 2.5-3 cm long; *ligules* 0.1 mm long, membranous; *leaf-blades* linear, 4-9 cm by 4-5 mm, glabrous, apex acute or obtuse, margin scaberulous. *Inflorescence* oblong, 6-11 cm long, purple, racemes usually reduced to a single terminal triad, sometimes with 1 or more paired spikelets below. *Sessile spikelets* ovate-lanceolate, glabrous; callus filiform, pungent with brown hairs; *lower glumes* ovate-lanceolate, 3.5-4 by 0.7-1 mm, 3-nerved, laterally 2-keeled, scabrid on the upper part, chartaceous, purple, hairy on upper part, apex emarginate, margin inflexed; *upper glumes* ovate-oblong, 2.5-3.5 by 1 mm, 3-nerved, chartaceous, purple, glabrous except for the hairy upper part of the keel, apex mucronate, mucro c. 2 mm long, margin hyaline; *lower lemmas* obovate-lanceolate, 2.5-3 by 0.5 mm, apex obtuse, margin ciliate along the upper part; *upper lemmas* oblong, 2 by 0.3 mm, apex acute; awn straight, 5.5 mm long; *upper palea* ovate-lanceolate, 1.5 by 0.4 mm, hyaline, apex obtuse; *lodicules* 0.5 mm long; *anthers* 1 mm long. *Pedicelled spikelets* lanceolate; pedicel 2.5 mm long, glabrous; *lower glumes* lanceolate, 5 by 0.8 mm, 3-nerved, keel hairy on the upper part, purple, apex acuminate to mucronate, mucro 0-0.5 mm long; *upper glumes* ovate-lanceolate, 4.2 by 0.8 mm, 1-nerved, chartaceous, purple, apex acuminate to mucronate, margin ciliate; *lower lemmas* ovate-lanceolate, c. 3 by 0.5 mm, apex acute, margin ciliolate in the upper part; *upper lemmas* ovate-lanceolate, 2 by 0.5 mm, apex acute, margin ciliolate in the upper half; *upper paleas* obovate-lanceolate, 1.8 by 0.1 mm, apex acute, margin ciliolate; *lodicules* 0.2 mm long; *anthers* 1.8-2 mm long. (**Figure 5.11, Figure 5.30A-B**)

Thailand.— NORTHERN: Chiang Rai [Fang, 21 Feb. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 1421 (C); Doi Luang National Park, east side, Bu Gang Falls, 16 Jun. 1997, *J.F. Maxwell* 97-638 (L)], Chiang Mai [Doi Suthep, 22 Jun. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 3700 (K, C); 17 Oct. 1909, *A.F.G. Kerr* 842 (K); Doi Chiang Dao, Animal Sanctuary, 27 Jul. 1990, *H. Banziger* 698 (L); Doi Sutep-Pui National Park, 7 Sep. 1990, *J.F. Maxwell* 90-938 (L, AAU); Doi Chiang Dao Animal Sanctuary, Ban Yang Toong Bong Forest Station, 27 Oct. 1990, *J.F. Maxwell* 90-1181 (L, AAU)]; Uttaradit [Den Chai, 2 Oct. 1929, *C.W. Franck* s.n. (C)]; NORTH-EASTERN: Loei [Phu Kradueng, 20 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 2358 (C)]; Udon Thani [Aug. 1976, *C.W. Heckman* 107 (K)]; Sakon Nakhon [Phuphan National Park, 7 Jul 2005, *O. Neamsuvan* 211 (BCU)]; EASTERN: Nakhon Ratchasima [Kao Yai National Park, 19 Jul. 1973, *G. Murata, N. Fukuaka* and *C.

Phengklai T-16441 (K, P, L, C); North of Korat, 5 Jul. 1959, *F. Floto* 7311 (K, C)]; Buri Ram [along route 219, 103º4´E 14º40´N, 4 Oct. 1984, *G. Murata, C. Phengklai, S. Mitsuta, H. Nagamasu* and *N. Nantasan* T-37438 (L)]; CENTRAL: Bangkok [15 Jul. 1923; *A. Marcan* 1409 (BM); Aug. 1922, *E. Smith* 932 (BK, K); 29 Sep. 1919, *A.F.G. Kerr* 3787 (K); north of Bangkok, wayside, 12 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 2060 (P, L, C)], Ayutthaya [20 km. east of Saraburi, 12 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 2103 (P, L, C); 7 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 1964 (C)]; SOUTH-EASTERN: Chantaburi [Makam forest station, 26 Aug. 1966, *K. Larsen* 1830 (P, C, AAU)]; Prachinburi [Khao Yai National Park, Kong Keo, weed around rest house, 9 Jul. 1966, *K. Larsen, T. Smitinand* and *E. Warncke* 185, 169 (AAU)]; SOUTH-WESTERN: Kanchanaburi [Noi River Basin Exp., 9 May 1946, *G. den Hoed* 249 (BK, K, L); Kwae Noi Basin Expedition, 19-22 Jun. 1946, *Den Hoed* and *Kostermans* 642 (L)]; PENINSULAR: Chumphon [lawn, Muaeng district, 12 Aug. 2004, *O. Neamsuvan* 161 (BCU); 17 Oct. 1909, *A.F.G. Kerr* 842 (BM)]; Surat Thani [Bandon River, 8 Nov. 1935, *G. Seidenfaden* 2219 (C)]; Songkhla [Muaeng Songkhla, 17 May 1970, *S. Suthesorn* 1758 (BK); Prince of Songkhla University, 26 Nov 1975, *A. Yiamudan* 13 (PSU); Kukut, Songkhla Lake, Sathingpra, 26 May 1984, *P. Sirirugsa* 842 (PSU)], Phangnga [Khlong Nang Yon, 9º15´N 98º20´E, 28 Apr. 1973, *R. Geesink* and *T. Santisuk* 4991 (L, C)], Narathiwat [Kuchem, Tak Bai, 18 Sep. 1987, *C. Niyomdham* and *D. Sriboonma* 1630 (K, P, L, C, AAU)].

Distribution.— Tropical Asia to Polynesia, introduced as a lawn grass elsewhere.

Ecology.— Dry and open area, common in lawn and road side.

Vernacular.— Ya klon (กล่อน), Yak hi khrok (หญ้าขี้ครอก), Ya chao chu (หญ้าเจ้าชู้), Ya nok khum (หญ้านกคุ่ม), Ya kon (หญ้าขน), Ya ka troei (หญ้ากะเตรย), Yak hi troei (หญ้าขี้ เตรย), Ya nam luek (หญ้าน้ำลึก).

2. *Chrysopogon festucoides* (Presl) Veldk., Austrobaileya 5(3): 512. 1999.— *Andropogon festucoides* J. Presl in C. Presl, Reliq. Haenk. 1: 340.1830.— *Vetiveria festucoides* (J. Presl) Ohwi, Bull. Tokyo Sci. Mus. 18: 4. 1947.— Type: *Haenke* s.n. (holo: PR; iso: W no. 257377 , neg. 1220; s.n., neg. 1221; US no. 76466).

Andropogon anias Llanos, Fragm. Pl. Filip.: 29. 1851.— Type: not extant.— Neotype: *Merrill Sp. Blancoan.* (*J.K. Santos*) 389 (holo: US; iso: BO, K!, L!, MO, NSW, NY, P!), probably the same as *BS* 22238 *(J.K. Santos)* (K, L) which was collected on the same date in the same place and so seems a double-numbered gathering. Designated by Veldkamp [Austrobaileya 5: 512. 1999].

Andropogon muricatus Retz. var. *aristatus* Buse in De Vriese, Pl. Ind. Bat. Orient.: 104. 1857.— Type: *Kleinhoff* s.n. in *Herb. Reinwardt* (holo: L no. *903.342-379*).

Culms 42-180 cm high. *Leaf-sheaths* terete, 6.5-11 cm long, glabrous; *ligules* a fringe of hairs, 0.4 mm long; *leaf-blades* linear, 10-45 by 0.5-0.8 cm, base rounded, apex long-acuminate, margin scaberulous in the upper part, adaxially at base sparsely hairy. *Inflorescence* up to 25 cm long, raceme peduncles 1-2.5 cm long, racemes 5.5-7.5 cm long, each with 6-11 pairs of spikelets. *Sessile spikelets* 3.3-4.1 mm long; callus c. 0.7 mm long, covered by golden hairs c. 1 mm long; *lower glumes* oblong, 3.1-4 by 1 mm, 2-keeled, coriaceous, spinulose, aculeate especially on the nerves, apex acute, margin entire; *upper glumes* lanceolate, 3.5-4 by 1 mm, 3-nerved, coriaceous, spinulose, aculeate especially on the midrib, apex mucronate, mucro c. 0.5-1 mm long, margin hyaline and ciliate; *lower lemmas* lanceolate, 3-3.5 by 0.5-0.7 mm, 3-nerved, margin inflexed and ciliolate; *upper lemmas* narrowly lanceolate, c. 3 by 0.5 mm, 1-nerved, apex bifid, exerted awn c. 3 mm long; *anthers* c. 2 mm long. *Pedicelled spikelets* 4.2-4.4 mm long; pedicel 4-5.5 mm long, scaberulous; *lower glumes* lanceolate, c. 4 by 1 mm, 5-nerved, 2-keeled, scaberulous, aculeate especially on the nerves, apex acute; *upper glumes* lanceolate, 3.8-4 by 1-1.2 mm, 3-nerved, chartaceous, upper part of mid-nerve spinulose; *lower lemmas* oblong, 3.2-3.8 by 0.6-1 mm, apex acute to obtuse, margin inflexed and ciliolate; *upper lemmas* lanceolate, 2.5-3.5 by 0.4-0.5 mm, apex mucronate, margin ciliolate in the upper half; *upper paleas* elliptic, c. 1 by 0.5 mm, apex obtuse; *anthers* c. 2 mm long. (**Figure 5.12**)

Thailand.— NORTHERN: Chiang Mai [Mae Tang, 19 Oct. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 5768 (K, C)]; Nakhon Sawan [50 km north of Nakhon Sawan, 31 Jul. 1966, *K. Larsen*, *T. Smitinand and E. Warncke* 1113 (K, AAU)]; CENTRAL: Bangkok [12 March, 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 2105 (K); 24 Sep. 1923, *A.F.G. Kerr* 7852 (K, BM)], Ang Thong [30 Dec. 1929, *Put* 2593 (K, BM); 27 Dec. 1929, *Put* 2576 (K)], Chai Nat [Manorom, 19 Sep. 1930, *A.F.G. Kerr* 19669 (K)], Nakhon Nayok [Nang Rong, 29 Jul. 1959, *T. Smitinand* 6078 (K)]

Distribution.— India (Assam), Upper Burma, S Laos, Cambodia, Vietnam, scattered in Malesia.

Vernacular.— Ya faek (หญ้าแฝก).

Ecology.— rice fields on humid to swampy soil .

3. *Chrysopogon fulvus* (Spreng.) Choiv., Fl. Somala 1: 327. 1929.— *Pollinia fulva* Spreng., Pl. Min. Cogn. Pug. 2: 10. 1815.— *Andropogon sprengelii* Kunth, Revis. Gramin. 1: 166. 1829, non *A. fulvus* Spreng. (1815).— Type: India, Bengal (holo: possibly in B; iso: *Herb. Trinius 337.1*, LE, left satchel, IDC microfiche BT-16/1).

Chrysopogon montanus Trin. in Spreng., Neue Entd. 2: 93. 1821.— *Andropogon monticola* Schult. & Schult. f., Mant. 3: 665. 1827, non *A. montanum* Roxb. (1820).— *Chrysopogon monticola* (Schult. & Schult. f.) Haines, Indian Forester 40: 495. 1914, nom. superfl.— [*Andropogon monticola* Schult. & Schult. f. var. *genuinus* Hack. in A. DC., Monogr. Phan. 6: 558. 1889, nom. inval.— [*Chrysopogon fulvus* (Spreng.) Chiov. subvar. *montanus* (Trin.) Roberty, Boissiera 9: 283, 287. 1960, nom. inval.].— Type: *König* s.n. *ex Herb. Banks* in *Herb. Jacquin* (holo: W; iso: BM, *Herb. Trinius* 337.1, LE, IDC microfiche BT-16/1).

Tufted. *Culms* 1-1.5 m high. *Leaf-sheaths* keeled, 5-9 cm long, glabrous; *ligules* fringed, membranous, 0.5-1 mm long; *leaf-blades* long linear, 12-40 by 0.3-0.7 cm, scabrous, apex long-acuminate, margin scaberulous, above with 3-4 mm long hairs when young. *Inflorescence* 7-14 cm long, raceme peduncle 2.5-5 cm long, ending in a triad. *Sessile spikelets* lanceolate, 5-6 mm long; callus 1-1.5 mm long, covered by brown to golden hairs; *lower glumes* obovate-lanceolate, 5-6.5 by 1-2 mm, 3-nerved, 1-keeled, glabrous but for the distally hairy keel, coriaceous, yellowish brown, apex obtuse; *upper glumes* lanceolate, 5.5-6 by 1-2 mm, 3-nerved, coriaceous, brownish golden, glabrous but for a fringe of brown hairs on keel, apex mucronate, mucro 1 mm long; margin hyaline, ciliolate; *lower lemmas* lanceolate, 4-5 by 0.4-0.5 mm, brownish, apex acute; *upper lemmas* linear to oblong, 1.7-2 by 0.4 mm, 2-nerved, brownish, apex bifid, awn from sinus; the awn 1.5-3 cm long, exserted, geniculate and twisted, puberulous; *lodicules* 0.5 mm long; *anthers* 3.5 mm long. *Pedicelled spikelets* lanceolate, 4.3-8 mm long; pedicels 2-2.5 mm long, brownish golden hairs on both margins; *lower glumes* lanceolate, 4.5 by 1.2 mm, 3-5-7-nerved, laterally 2-keeled, purplish, margins inflexed, apex muticous to mucronate; mucro straight, 0-2 mm long, glabrous; *upper glumes* ovate-lanceolate, 4.2-7 by 1-1.2 mm, 2-nerved, subchartaceous, brownish, apex acute, margin ciliate; *lower lemmas* lanceolate, 5-6 by 0.5 mm, margin ciliolate; *upper lemmas* lanceolate, 0.5 mm long, margin ciliolate; *upper palea* absent; *anthers* 2.5 mm long. (**Figure 5.13, Figure 5.30C-D**)

Thailand.— NORTHERN: Lamphun [Jahm Chompoo village area, 29 Nov. 2004, *J.F. Maxwell* 04-751 (CMU)], Tak [Ma Bon, 5 Dec. 1957, *J.V. Santos* 6686 (L); SOUTH-WESTERN: Kanchanaburi [Khao Salop National Park, 18 Nov. 1970, *M. Lazarides* 7420 (BKF, K, L, C)]; SOUTH-EASTERN: Chon Buri [Kao Pra Dang, 19 Oct 1904, *C.C. Hosseus* 160 (BKF, K, BM, L)]

Distribution.— Sri Lanka, S India.

Ecology.— Open dry deciduous forest, grassland.

4. *Chrysopogon gryllus* (L.) Trin. subsp. *gryllus*, Fund. Agrost.: 188. 1820.— *Andropogon gryllus* L., Cent. Pl. 2: 33. 1756.— *Sorghum gryllus* Kuntze, Rev. Gen. 2: 791. 1891.— *Chloris gryllus* Honck., Syn. Pl. Germ. 1: 437. 1792.— *Holcus gryllus* R. Br., Prodr.: 199. 1810, pro comb.— *Pollinia gryllus* Spreng., Pl. Min. Cogn. Pug. 2: 10. 1815.— *Apluda gryllus* (L.) P. Beauv., Essai Agrost.: 133, 150, 151, 164. 1812, pro comb., excl. t. 23, f. 6; C. Presl, Cyper. Gramin. Sicul.: 55. 1820, isonym.— *Rhaphis gryllus* Desv., Opusc. Sci. Phys. Nat.: 69. 1831.— [*Andropogon gryllus* L. subsp. *genuinus* Hack. & subvar. *typicus* Hack. in A. DC., Monogr. Phan. 6: 551. 1889, nom. inval.].— *Sorghum gryllus* Kuntze, Rev. Gen. 2: 791. 1891.— [*Andropogon gryllus* L. subsp. *eugryllus* & forma *typicus* Asch. & Graebn., Syn. Mitteleur. Fl. 2: 44. 1899, nom. inval.].— Lectotype: *Séguier* s.n. (holo: LINN!), designated by Meikle, Fl. Cyprus 2: 1863. 1985.

Culms 1-1.5 m high. *Leaf-sheaths* keeled, 7-19 cm long, glabrous; *ligules* a fringe of hairs, 0.2 mm long; *leaf-blades* long linear, 42-64 cm by 2-5 mm, sparsely hairy on both sides, apex obtuse, margin scaberulous. *Inflorescence* large, 16-21 cm long; raceme peduncle 2-5 cm long, raceme with a terminal triad, rarely with a pair of spikelets below. *Sessile spikelets* oblong, callus 1 mm long covered with golden hairs; *lower glumes* ovate-lanceolate, 5-6 by 1.3-1.5 mm, 5-nerved, 2-keeled, chartaceous, smooth, but with a row of black tubercle-based hooks on both sides of the midrib, purplish, apex acuminate-notched; *upper glumes* ovate-lanceolate, 6 by 1.2-2 mm, 3-nerved, coriaceous, glabrous except for some hairs on keel, purplish green, apex mucronate, mucro 3-4 mm long, margin hyaline; *lower lemmas* lanceolate, 4-5 by 1-1.5 mm, 2-nerved, purplish, apex obtuse, margin inflexed; *upper lemmas* lanceolate, 5 by 1 mm, 1-3-nerved, apex bifid; awn 1.2-1.5 cm, geniculate, twisted, puberulous; *upper paleas* lanceolate, 3.5 by 0.2-0.5 mm, hyaline, apex obtuse; *lodicules* 0.5 mm long; *anthers* 1.5-2 mm long. *Pedicelled spikelets* lanceolate, 7.5-10 mm long; pedicel 4-5 mm long, glabrous; *lower glumes* ovate-lanceolate, c. 10 by 2 mm, 5-nerved, nerves hairy in the upper part, purplish, apex mucronate; *upper glumes* ovate-lanceolate, 8 by 1.5 mm, 3-nerved, subchartaceous, purplish, apex acuminate; *lower lemmas* lanceolate, 6.5 by 0.8-1 mm, purplish, apex acute; *upper lemmas* ovate-lanceolate, 6 by 0.7 mm, apex acuminate; *upper paleas* lanceolate, 4 by 0.5 mm, apex acuminate; *lodicules* 0.5 mm long; *anthers* 4 mm long. (**Figure 5.14**; **Figure 5.31A-B**)

Thailand.— NORTHERN: Lampang [Doi Luang National Park, 6 Nov. 1998, *O. Petrmitr* 331 (CMU)]; NORTHERN: Chiang Rai [Phu Chi Fa Wildlife Reserve, 27 Nov. 2004, *O. Neamsuvan* 165 (BCU, L)]; Loei [Pha Taa Lern, Phuluang National Park, 13 Oct. 2000, *M. Norsangsri* 1019 (QBG); Pha Taa Lern, Phuluang National Park, 10 Jan 2007, *O. Neamsuvan 261*(BCU)]

Distribution.— Mediterranean to the Caucasus, Iraq, and Arabia, Nepal, India (Assam, W Bengal, Bihar, Himachal Pradesh, Karnataka, Meghalaya, Nagaland), S China (S Xizang, Yunnan).

Ecology.— Open fire damaged grass land, bordering primary evergreen, seasonal hardwood forest on granite bedrock, 1250-1500 m alt., on cliff exposed to strong wind.

Notes.— This is a new record for Thailand, see Neamsuvan, Seelanan & J.F. Veldkamp (in press) for a more extensive discussion. Interestingly, its distribution was reported from Europe to South China (Cope, 1980), thus, this study shows that its geographical distribution should extend to Thailand.

5. *Chrysopogon lawsonii* (Hook. f.) Veldk., Austrobaileya 5: 515. 1999.— *Andropogon lawsonii* Hook. f., Fl. Brit. India 7: 187. 1897.— *Vetiveria lawsonii* (Hook. f.) Blatter & McCann, J. Bomb. Nat. Hist. Soc. 32: 409. 1928.— [*Chrysopogon lawsonii* (Hook. f.) Roberty, Boissiera 9: 290. 1960, nom. inval.].— Type: India, *Lawson* 28 (holo: K!).

Tufted. *Culms* up to 1 m high. *Leaf-sheaths* keeled, 4-20 cm long, glabrous; *ligules* membranous, 0.1-0.2 mm long; *leaf-blades* linear, up to 60 cm by 5 mm, glabrous, apex acuminate, margin scaberulous. *Inflorescence* up to 20 cm long, racemes with 2-8 pairs of spikelets. *Sessile spikelets* c. 5 mm long; callus 1 mm long, hairy; *lower glumes* lanceolate, c. 5 by 1 mm, 4-nerved, coriaceous, spinulose on the two lateral nerves, aculeate, margin inflexed, apex truncate; *upper glumes* lanceolate, 5 by 1-1.5 mm, 3-nerved, coriaceous, but thinner than the lower glume, midrib distally spinulose, margin hyaline, apex bifid; awn 4-4.5 mm long; *lower lemmas* oblong, 4 by 1 mm, 3-nerved, apex acute; *upper lemmas* oblong, 3 mm long, 1-nerved, apex bifid; awn twisted, geniculated, c. 2 cm long; *lodicules* 0.5 mm; *anthers* 2.5 mm long. *Pedicelled spikelets* 6.2 mm long, callus 0.2 mm long; pedicels 5 mm long, flattened, glabrous; *lower glumes* lanceolate, 6-7 by 1-1.3 mm, 5-nerved, glabrous, with a row of short spicules near each margin, apex acuminate to mucronate, mucro 0-5 mm long; *upper glumes* lanceolate, 6 by 1.2 mm, 3-nerved, chartaceous, margin hyaline, apex acute; *lower lemmas* lanceolate, 4.5-5 by 1-1.3 mm, apex acute, margin ciliolate; *upper lemmas* oblong, 3.5 by 1 mm, apex acute, margin ciliolate near apex; *upper paleas* oblong, 2-2.5 by 0.5 mm, apex obtuse to truncate, margin ciliolate; *lodicules* 0.2 mm long; *anthers* 2.5 mm long.

Thailand.— NORTHERN: Chiang Mai [Sai Thong Waterfall, Doi Inthanon, Nov. 1986, *C. Phengklai* and *T. Smitinand* 6085 (BKF, K); Jeng Hua Lin, 21 Sep. 1921, *Noi Mao* s.n. (BKF)]

Distribution.— S India (NW Andhra Pradesh, S Karnataka, S Maharashtra, Tamil Nadu: Nilgiris). Note the disjunction.

Ecology.— Common in open area, moist soil, river bank, sandy.

Vernacular.— Ya Fek Lao (หญ้าแฝกลาว)

Notes.— I have never seen this species in the natural habitat. Then, the specimens studied here were from previous collections in Thai and abroad herbaria.

* **Chrysopogon nemoralis** (Balansa) Holtt., Gard. Bull. Singapore 11: 297. 1947.— *Andropogon nemoralis* Balansa in Morot, J. Bot. 4: 113. 1890.— *Vetiveria nemoralis* (Balansa) A. Camus, Fl. Gen. I.-C. 7: 329. 1922.— Type: *Balansa* s.n. (holo: L no. 908. 83-373; iso: P)

Chrysopogon nemoralis (Balansa) Holtt. is mentioned in several papers as native to Thailand and used in erosion control (The Chaipattana Foundation and The Mae Fah Luang Foundation, 1996). A few specimens seen were identified as *C. zizanioides* and *C. festucoides*.

Veldkamp (1999) very much questioned the reported occurrence of *C. nemoralis* in Thailand and suspected a misapplication of the name to *C. zizanioides* because only one single Thai collection was available to him that was labelled with *C. nemoralis* but belonged to *C. zizanioides*. In addition, my present study found a specimen that was labelled with *C. nemoralis* but belonged to *C. festucoides*.

Traditionally, *C. nemoralis* is called “Fek Don” in Thailand, which refers to a dry hill habitat, while *C. zizanioides* is called “Fek Loom”, which refers to a swampy area. Plants under both names are very similar, and have many spikelet pairs per raceme and it is here concluded that actually “*C. nemoralis”* in Thailand belongs to either *C. zizanioides* or *C. festucoides* (closely related taxon to *C. zizanioides*).

Chrysopogon nemoralis is very different from *C. festucoides* and *C. zizanioides*, for instance by having only 1 or 2 spikelet pairs per raceme. Plants referable to this rare species are known from only very well collections in Vietnam, Philippines, and the Malaysian Peninsula but have not been seen among Thai materials. Deu to the gap of distribution between Vietnam and Malaysia occurring in Thailand cannot be ruled out, but it has to be collected.

6. *Chrysopogon orientalis* (Desv.) A. Camus in Lecomte, Fl. Indo-Chine 7: 332. 1922. — [*Andropogon gryllus* auct. non L.: Rottler, Neue Schriften Ges. Naturf. Freunde Berlin 4: 207. 1803; Willd., Sp. Pl., ed. 4, 4, 2: 69. 1806, pro specim. Ind. Or.].— *Rhaphis orientalis* Desv., Mém. Soc. Agric. Angers. 1: 173. 1831.— [*Chrysopogon verticillatus* (Roxb.) Trin. ex Steud. var. *orientalis* (Desv.) Roberty, Boissiera 9: 283, 285. 1960, comb. inval.].— Type: *Rottler ("Klein")* 392 in Herb. Willdenow 18636 (sheet 4) (holo: B, IDC microfiche 7440).

Andropogon breviaristatus Steud., Syn. Pl. Glumac. 1: 396 ("*breviaristaus*"), 436. 1854. —*Andropogon aristulatus* Hochst. ex Hack. in A. DC., Monogr. Phan. 6: 556. 1889, non Steud. (1854), nomen superfl.— *Rhaphis aristulatus* (Steud.) Steud. ex Hitchc. in Groff, Ding & Groff, Lingnaam Agric. Rev. 1: 45. 1923, nom. superfl. — Type: India, Tamil Nadu, *F. Metz in Hohenacker* 1285 (holo: P!; iso: K!, L!)

Andropogon distichophyllus Hook. f., Fl. Brit. India: 191. 1897.—Type: Burma, *Kurz* s.n. (holo: K!)

Andropogon wightianus Nees ex Steud., Syn. Pl. Glumac. 1: 395. 1854.— *Chrysopogon wightianus* Nees ex Steud., [Nees in Wight, Cat. Indian Pl.: 98. 1834, nomen] Thwaites, Enum. Pl. Zeyl.: 366. 1864.— Lectotype: India, *Herb. Wight 1676* [*'1675'* in Roberty; holo: P!; iso: K!, NY, LE (*Herb. Trinius 339.1* as *Wight 355 ex Herb. Kunth*, IDC microfiche BT-16/1], designed by Veldkamp, Austrobaileya 5: 518. 1999.

Chrysopogon collinus Ridl., J. Malayan Branch Roy. Asiat. Soc. 82: 203. 1920.— Type: Malaysia, *Haniff SF* 649 (holo: SING; iso: K!).

Chrysopogon sinensis Rendle, J. Lin. Soc. Bot. 36: 368. 1904.— Type: *Sampson* in Herb. Hance 34453 (holo: BM; iso: US)

Tufted. *Culms* up to 1 m high. *Leaf-sheaths* keeled, 6-11 cm long, glabrous or puberulous; *ligules* fringed membranous, 5 mm long; *leaf-blades* linear, 15-40 by 0.4-0.8 cm, sparsely to densely short hairy on upper surface, apex long-acuminate, margin scaberulous. *Inflorescence* large, 9-18 cm long, raceme peduncle 1.5-5 cm long, racemes reduced to a triad. *Sessile spikelets* linear-lanceolate; 6-9 mm long, callus c. 1-2 mm long, golden hairy; *lower glumes* lanceolate, 5-8 by 1-1.5 mm, 2-nerved, chartaceous, glabrous except for the distally puberulous midrib, yellowish green, apex obtuse or mucronate, mucro 0-10 mm long; *upper glumes* lanceolate, 6-12 by 1.5-2 mm, 1-nerved, coriaceous, purplish green, glabrous except for the subapically puberulous midrib, apex mucronate, mucro 12-14 mm long, margin hyaline; *lower lemmas* lanceolate, 5.5 by 1 mm, apex obtuse, margin ciliate; *upper lemmas* lanceolate, 5.5 by 1 mm, 1-nerved, apex acute; awn 3.2-4.5 cm long, puberulous; *upper palea* linear, 2.5 by 0.2 mm, hyaline, apex acute; *lodicules* 0.5 mm long; *anthers* 3.5 mm long. *Pedicelled spikelets* 5.5-8 mm long; pedicel 2.7-4 mm long, brown hairy on both sides; *lower glumes* lanceolate, 6.5-7 by 1.8-2 mm, 7-nerved, dorsally sparsely short hairy, purplish, apex acute; awn 5-9.5 mm long, scaberulous; *upper glumes* lanceolate, 7-7.5 by 1-1.5 mm, 3-nerved, subchartaceous, apex acute to mucronate, mucro 0-7 mm long, margin ciliolate; *lower lemmas* lanceolate, 4.5-7 by 1-1.2 mm, apex acute, margin ciliolate; *upper lemmas* lanceolate, 5.5 by 0.7 mm, apex acute, margin ciliolate; *upper palea* lanceolate, 3 by 0.5 mm, apex obtuse; *lodicules* 0.5 mm long; *anthers* 4-4.5 mm long. (**Figure 5.15, Figure 5.31C-D**)

Thailand.— NORTH-EASTERN: Loei [Na Noi, foot hill of Phu Kradueng, 18º15´ N 100º35´E, 11 Nov. 1970, *Ch. Charoenphol, K. Larsen* and *E. Warncke* 4915 (AAU)]; Sakon Nakhon [Ladkracher, 22 Nov. 1962, *Adisai* 138 (BK); Phu Phan National Park, 18 Dec. 1963, *T. Smitinand* and *C. Hambananda* 28171 (K)]; Phu Phan National Park, 14 Oct. 1990, *C. Chantaranothai* and *J. Parnell* 90/742 (K)]; EASTERN: Nakhon Ratchasima [Bua Yai, 31 Oct. 1931, *Put* 4233 (K, BK, BM)], Chaiyaphum [Kaset Somboon, 26 Oct. 1965, *S. Sutheesorn* 648 (BK)]; Ubon Ratchathani [c. 2 km south of Krong Chiam, 105º29´E 15º16´N, 27 Oct. 2001, *S. Lægaard, M. Norsangsri, P. Pornpongrungrueng* and *S. Khoomrathok* 21838 (AAU)]; SOUTH-EASTERN: Chanthaburi [Khung Kra Ben, 1 Nov. 1997, *C. Niyomdham* 5217 (BKF); Ban Kao, foothill of Pattavee, 18 Nov. 1961, *K. Larsen* 8301 (K, C)], Rayong [Ban Nong Sanom, 21 Nov. 1980, *Y. Paisooksantivatana* 461-80 (BK)], Chon Buri [Kao Kram, island off Toong Brong, 19 Oct. 1969, J.F. Maxwell 69 (L, AAU); Sattahip, 4 Nov. 1972, *J.F. Maxwell* 72-586 (BK, AAU); Si Chang Island, 7 Nov. 1992, *J.F. Maxwell* 92-692 (CMU, P, L)], Sa Kaeo [Wattana Nakorn, 17 Nov. 1964, *S. Sutheesorn* 155 (BK)], Prachin Buri [Ban Kao, Krabinburi, 11 Nov. 1961, *K. Larsen* 8137 (K, C)]; SOUTH-WESTERN: Kanchanaburi [19 Oct. 1930, *A.F.G. Kerr* 19768 (BK, K,); Sri Sawat, 16 Nov. 1971, *C.F. van Beusekom, R. Geesink, C. Phengklai* and *B. Wongwan* 3816 (K, P, L, C); about 17 km north of Kanchanaburi, 17 Nov. 1970, *M. Lazarides* 7404 (BKF, K, L, C); Prachuap Khiri Khan [Hua Hin, 5 Nov. 1927, *A.F.G. Kerr* 13434 (BK, BM, K); Hua Hin, 6 Nov. 1927, *A. Marcan* 2242 (K); 30 Jun. 1924, *A.F.G. Kerr* 10721 (BK, BM, K); Huai Yang, 9 Aug. 1966, *K. Larsen, T. Smitinand* and *E. Warncke* 1283 (K, AAU)], Phetchaburi [Ban Cha am, 8 Oct. 1924, *A. Marcan* 1642 (K)]; PENINSULAR: Surat Thani [Ban Kawp Kep, 5 Aug. 1927, *A.F.G. Kerr* 13182 (BK, K); Koh Samui, Feb. 1995, *T.B. Ryves* KS95/019 (K)]; Songkhla [Tepa, 22 Mar. 1928, *A.F.G. Kerr* 14697 (BK, BM, K, P, L); near Gow Seng Hill, 9 Mar. 1985, *J.F. Maxwell* 85-265 (PSU, AAU); Kao Seng, Songkhla beach, 25 Sep 1981, *P. Sirirugsa* 477 (PSU); Songkhla-Pattani road, c. 55 km from Songkhla, 100º58E 06º50´N, 31 Oct. 1990, *K. Larsen, S.S. Larsen, A.S. Barfod, W. Nanakorn, W. Ueachirakan* and *P. Sirirugsa* 41023 (PSU, AAU); Songkhla beach, 4 Oct 1982, *P. Sirirugsa* 573 (PSU)], Trang [Dec. 1916, *H.C. Robinson* 6423 (K)], Pattani [Yaring, 12 Oct. 1991, *K. Larsen, S.S. Larsen, C. Niyomdham, W. Ueachirakan* and *P. Sirirugsa* 42337 (PSU, AAU)]; Phuket [Laem Promtep, 1 Dec. 1986, *J.F. Maxwell* 86-1024 (PSU, L)], Narathiwat [Swamp forest at Peiwan, Tak-Bai, 16 Oct. 1977, *S. Sutheesorn* 4139 (BK); Tak Bai, 19 Sep. 1965, *C. Pengklai* and *T. Smitinand* 1140 (K, L); Sandy sea shore, 6º26´N 101º50´E, 20 Oct. 1970, *Ch. Charoenphol, K. Larsen* and *E. Warncke* 4070 (K, L, AAU); Tak Bai, 2 Sep. 1988, C. Niyomdham and W. Ueachirakan 1926 (K, P, L, C, AAU)]

Distribution.— Sri Lanka, S India (Tamil Nadu), Burma to S China (Hainan, Fujian), Malesia (Malay Penins., Sumatra).

Ecology.— Meadows and roads, on limestone and coastal sandy areas, open deciduous forest, trampling and fire resistant, at low altitude.

Vernacular.— Ya khao nok khao (หญ้าข้าวนกเขา), Ya phung chu (หญ้าพุ่งชู้)

Notes.— This species is very common on the seashore.

7. *Chrysopogon perlaxus* Bor, Dansk Bot. Ark. 23: 157. 1965.— Type: Thailand, *Larsen* 8015 (holo: K!; iso: A, C)

Perennial. *Culms* erect, up to 1 m tall. *Leaf-sheaths* keeled, 5-9 cm long, glabrous; *ligule* a fring of hairs, 0.5-1 mm long; *leaf-blades* linear, 12-25 by 0.4-0.7 cm, scaberulous, hairy adaxially or glabrous and tubercle-based near the base, apex long-acuminate, margin scaberulous. *Panicle* large, open, 7-14 cm long, rachis internode 2-4; racemes whorled, peduncle 2.5-5 cm long; racemes with a terminal triad. *Sessile spikelets* 7-8 mm long; callus 1-1.5 mm long, covered by golden up to 2.5 mm long hairs; *lower glumes* lanceolate, 5-6.5 by 1-2 mm, 3-nerved, cartilaginous, apex mucronate, mucro ca. 1 cm long, margin hyaline; *upper glumes* lanceolate, boat-shaped, 6 by 1-2 mm, laterally-2-nerved, coriaceous, dorsally with a tuft of brown hairs on back, and hairy near the acute apex, margin hyaline and ciliolate; *lower lemmas* lanceolate, 4-5 by 0.5 mm, hyaline, glabrous, apex acute; *upper lemmas* linear, 6 mm long, 2-nerved, apex bifid, awned from the sinus, awn ca. 3 cm long; *anthers* 3.5 mm long. *Pedicelled spikelets* 6-8 mm long; pedicel ca. 2 mm long, brown hairy on both margins; *lower glumes* lanceolate, 6-6.5 by 1.5 mm, 3-5-7-nerved, chartaceous, purplish, glabrous to distally setulose, apex muticous to mucronate, mucro 0-1.5 mm long; *upper glumes* lanceolate, 5-7 by 1 mm, 1-3-nerved, chartaceous, purplish, glabrous except for the ciliate margin, apex acuminate; *lower lemmas* linear, 5-6 by 0.5 mm, hyaline, glabrous except for the ciliate margin; *upper lemmas* linear, 0.5 mm long, hyaline, glabrous except for the ciliolate margin.

Thailand.— EASTERN: Chon Buri [Dry hill, 1 Nov. 1961, *K. Larsen* 8015 (K, C)]

Distribution.— Endemic to Thailand.

Ecology.— Dry hill, c. 75 m alt.

Note.— This species is very similar to *C. fulvus*, especially the tuft of brown hairs at the back of the upper glume of the sessile spikelet. However, it differs from *C. fulvus* by its purple spikelets (yellow in *C. fulvus*) and its longer spikelets than in *C. fulvus*. This species is so far only known from the type.

8. *Chrysopogon serrulatus* Trin., Mém. Acad. Imp. Sci. St. Pétersbourg, VI, Sci. Math. 2: 318. 1832; Sp. Gram. 3:. 1835 t. 331.— *Andropogon trinii* Steud., Syn. Pl. Glumac. 1: 395. 1854, non *A. serrulatum* Link (1827).— *Chrysopogon trinii* (Steud.) Wm. Watson in E.I. Atk., Gaz. NW Prov. India 10: 392. 1882, nom. superfl.— [*Andropogon trinii* Steud. var. *genuinus* Hack. in A. DC., Monogr. Phan. 6: 558. 1889, nom. inval.].— *Andropogon monticola* Schult. var. *trinii* (Steud.) Hook. f., Fl. Brit. India 7: 193. 1896.— *Chrysopogon montanus* Trin. var. *serrulatus* (Trin.) Stapf in Prain, Fl. Trop. Afr. 9: 160. 1917, nom. superfl.— [*Chrysopogon fulvus* (Spreng.) Chiov. subvar. *serrulatus* (Trin.) Roberty, Boissiera 9: 284, 287. 1960, comb. inval.].— Type: Nepal, *Herb. Wallich* (= 8791) in *Herb. Trinius* 338.1 (holo: LE, IDC microfiche BT-16/1, K neg. 14023; iso: K, microfiche IDC 7394).

Chrysopogon wightianus Nees ex Steud. var. *leucanthus* Thwaites, Enum. Pl. Zeyl.: 366. 1864.— Type: India, *Thwaites* 2954 (iso: K!)

Tufted. *Culms* 50-60 cm high. *Leaf-sheaths* keeled, 8-10 cm long, glabrous, *ligule*~~*s*~~ a fringe of hairs, 0.1 mm long. *Leaf-blades* linear, 20-30 by 0.3-0.4 cm, glabrous to sparsely short-hairy, apex acute, margin scaberulous. *Inflorescence* 7-13 cm long, raceme with a terminal triad. Raceme peduncle 1-3 cm long, smooth to puberulous on both angles, hairs 0.5 mm long. *Sessile spikelets* lanceolate, callus 0.5 mm long, setose, hairs 1.6--1.9 mm long, golden; *lower glumes* lanceolate, 4.5-5 by 1 mm, 2-nerved, coriaceous, brown, glabrous, apex acute, margin hyaline; *upper glumes* lanceolate, 5 by 1.5 mm, 3-nerved, coriaceous, brown, glabrous, apex mucronate, mucro c. 6 mm long, margin hyaline; *lower lemmas* lanceolate, 3.5 by 0.7 mm, apex acute, margin ciliolate; *upper lemmas* linear, 5 mm long, awn 2.6 cm long, puberulous; *lodicules* cuneate, 0.5 mm long; *anthers* 2 mm long. *Pedicelled spikelets* lanceolate; pedicels 2 mm long, both margins with brown 2-3 mm long hairs; *lower glumes* lanceolate, 5-5.5 by 1.5 mm, 7-nerved, glabrous except for subapical short hairs on the mid-nerve, apex mucronate, mucro c. 3.5-5 mm long with short hairs at base, margin inflexed; *upper glumes* lanceolate, 5-5.5 by 1.2 mm, 3-nerved, sub-chartaceous, apex acute, margin hyaline, ciliolate; *lower lemmas* lanceolate, 5-5.5 by 1 mm, apex acute, margin ciliolate; *upper lemmas* lanceolate, 4.5 by 0.6 mm, apex acute, margin ciliolate; *upper palea* absent; *anthers* 1.8-2 mm long. (**Figure 5.16, Figure 5.32A-B**)

Thailand.— CENTRAL: Saraburi [Sam Lan Waterfall, 10 Dec 2006, *O. Neamsuvan* 247 (BCU)]; SOUTH-EASTERN: Rayong [Samed island, 8 Nov 2006, *O. Neamsuvan* 243 (BCU)]; Trat [Kao Rang Yai, 19 Nov. 1970, *Ch. Charoenphol, K. Larsen* and *E. Warncke* 5036 (BKF, K, L, AAU)]; PENINSULAR: Trang [7 Sep. 1917, *H.C. Robinson* 61108 (K)].

Distribution.— Rather disjunct: S Africa, Madagascar, Afghanistan and N India to Burma, Sri Lanka, Malesia (Malay Penins., S Sumatra).

Ecology.— Open deciduous forest, on sand beach, open field.

Note.— This species is very close to *C. orientalis*, but is easily distinguished by the pedicel that is shorter than half the sessile spikelet, while in *C. orientalis* more than half as long.

9. *Chrysopogon zizanioides* (L.) Roberty, Bull. Inst. Franç. Afrique Noire 22: 106. 1960; Boissiera 9: 291. 1960.— *Andropogon zizanioides* (L.) Urb., Symb. Antill. 4: 79. 1903.— *Anatherum zizanioides* (L.) Hitchc. & Chase, Contr. US Natl. Herb. 18: 285. 1917.— [*Holcus zizanioides* (L.) Kuntze ex Stuck., Anales Mus. Nac. Hist. Nat. Buenos Aires 11: 48. 1904 ('*zizaniodes*', not accepted by author, see p. 57), nom. Inval.].— *Phalaris zizanioides* L., Mant. Pl. Alt.: 183. 1771.— [*Rhaphis zizanioides* (L.) Roberty, Petite Fl. Ouest-Afr.: 404. 1954, comb. Inval.].— *Sorghum zizanioides* (L.) Kuntze, Revis. Gen. Pl. 2: 791. 1891.— *Vetiveria zizanioides* (L.) Nash in Small, Fl. SE US: 67, 1326. 1903; Stapf, Bull. Misc. Inform. 1906: 346, 362. 1906, isonym.— [*Vetiveria zizanioides* var. *genuina* A. Camus, Bull. Mus. Hist. Nat. (Paris) 25: 673. 1919, nom. inval.].— Type: India orientalis, *König in Herb. Linn.* 78.12 (holo: LINN!, IDC microfiche).

Andropogon muricatus Retz., Observ. Bot. 3: 43. 1783. ("*muricatum").— Anatherum muricatum* (Retz.) P. Beauv., Ess. Agrostogr.: 128 ('*mucronatum*'), 150, t. 22, f. 10. 1812.— *Vetiveria muricata* (Retz.) Griseb., Fl. Brit. W.I.: 560. 1864.— *Chamaeraphis muricata* (Retz.) Merr., Enum. Philipp. Fl. Pl. 1: 75. 1923, corrected on p. 459 to *C. squarrosa* (L. f.) Merr., hence invalid.— Type: India orientalis, *König* s.n. *in Herb. Retzius* (holo: LD, fragm. in K!).

Andropogon nardus Blanco, Fl. Filip. 39. 1837.— Type: not extant.— Neotype: Philippines, Luzon, *Merrill Sp. Blanc*. 355 (holo: US; iso: A, K!, L!, MO, NSW, NY), designated by Veldkamp, Austrobaileya 5: 522. 1999.

Vetiveria zizanioides (L.) Nash var. *tonkinensis* A. Camus, Bull. Mus. Nat. Hist. Nat. 25: 674. 1919.— Lectotype: Vietnam, *Anon* 73 (holo: P!), designed by Veldkamp, Austrobaileya 5: 522. 1999.

Tufted. *Culms* 1-1.5 mm high. *Leaf-sheaths* keeled, 6-14 cm long, glabrous; *ligule* a fringe of hairs, 0.1 mm long; *leaf-blades* linear, 20-40 by 0.2-1 cm, apex acute, margin scaberulous in the upper half, lower surface glabrous, upper surface scaberulous. *Inflorescence* large, up to 25 cm long, racemes with 5-10 pairs of spikelets. *Sessile spikelets* lanceolate, 4-5 mm long; callus 0.5-0.8 mm long, covered by white hairs; *lower glumes* ovate-lanceolate, 4-5 by 1.1-1.3 mm, 3- or 4-nerved, coriaceous, dorsally spinulose and rough, purplish, apex acute; *upper glumes* lanceolate, 4 by 1.2 mm, 1-nerved, keels spinulose, coriaceous, thinner than the lower glumes, dorsally rough, purplish, apex acute, margin hyaline; *lower lemmas* oblong, 3 by 1 mm, apex acute, margin ciliolate; *upper lemmas* oblong, 3 by 0.8 mm, 1-nerved, apex bifid, awn 0-2 mm long, upper part of the awn puberulous; *upper paleas* ovate, 1.5 by 0.5 mm long, hyaline, apex acute, ciliolate; *lodicules* 0.5 mm long; *anthers* 1.5 mm long. *Pedicelled spikelets* ovate-lanceolate, 3.5 mm long; pedicels 3.5 mm long, flattened, scaberulous; *lower glumes* ovate-lanceolate, 3.2-4 by 1 mm, 3-nerved, purplish, dorsally rough or with 3 rows of spines, apex acute; *upper glumes* lanceolate, 3.2-3.5 by 1 mm, 1-nerved, subchartaceous, purplish, apex acute, margin hyaline, *lower lemmas* ovate, 2-2.5 by 1 mm, apex acute; *upper lemmas* lanceolate, 3 by 0.5 mm, apex acute, margin ciliolate near the apex; *upper paleas* linear, 1.5 by 0.3 mm long, apex acute; *lodicules* 0.5 mm long; *anthers* 1.2 mm long. (**Figure 5.17**, **Figure 5.32C-D**)

Thailand.— NORTHERN: Mae Hong Son [Khun Yuam, 18º15´N 98º E, 5 Sep. 1974, *K. Larsen* and *S.S. Larsen* 34152 (L, AAU)]; Chiang Mai [Doi Suthep, 5 Sep. 1911, *A.F.G. Kerr* 2007 (K, BM); Phayao [Swamp by a lake, 2 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 1820 (C)]; Nakhon Sawan [Hua Wai, 31 Aug. 1931, *Put* 4103 (K); c. 10 km north-west of Nakhon Sawan, 21 Jul. 1973, *G. Murata, N. Fukuoka* and *C. Phengklai* T-16583 (L)]; Kamphaeng Phet [between Kamphaeng Phet and Sam Ngan, 29 Jul. 1973, G. Murata T-17267 (L)]; NORTH-EASTERN: Loei [Phu Kradueng, 14 Jul. 1959, *T. Smitinand* 59329 (K)]; Sakon Nakhon [Phuphan National Park, 6 Jul 2005, *O. Neamsuvan* 208 (BCU)]; Nakhon Phanom [Ta Uten, 16 Feb. 1924, *A.F.G. Kerr* 8464 (K, BM)], EASTERN: Chaiyaphum [Pa Hin Ngam, 23 Jun 2006, *O. Neamsuvan* 231 (BCU)]; Nakhon Ratchasima [Phimai, 27 Dec. 1958 *T. Smitinand* 5044 (K)]; SOUTH-EASTERN: Chachoengsao [Ang Rue Nai, 7 Sep 2005, *O. Neamsuvan* 215 (BCU)]; Chonburi [33 km south of Sri Racha, 24 Nov. 1970, *M. Lazarides* 7452 (BKF, K, L, C)]; CENTRAL: Bangkok [14 Sep. 1924, *A.F.G. Kerr* 9161 (BM); 14 Sep. 1924, *A. Marcan* 1809 (BM)], Ayutthaya [Bang Pa In, 23 Oct. 1924, *A.F.G. Kerr* 9336 (K, BM); Bang Pa In, 28 Jul. 1923, *A. Marcan* 1436 (BM)], Lop Buri [Chaibadan, 17 Dec. 1923, *A.F.G. Kerr* 8021 (K)]; Samut Prakan [Paknam, 3 Sep. 1922, *A. Marcan* 992 (BM)]; SOUTH-WESTERN: Uthai Thani [Khao Phetawee, 28 Jun. 1999, *M. Norsangsri* MN. 815 (L, AAU)]; Kanchanaburi [Kao Tong, 3 Aug. 1930, *A.F.G. Kerr 19636* (K, BM); Ban Kao, 10 Nov. 1961, *K. Larsen*

8115 (C)], Prachuap Khiri Khan [Nang Pong, 29 Oct. 1929, *A.F.G. Kerr* 17571 (K, BM); Hua Hin, 8 Nov. 1927, *A.F.G. Kerr* 13496 (K); Hua Hin, 8 Nov. 1927, *A. Marcan* 2280 (BM)]

Distribution.— Said (Nat. Res. Council, 1993) to have come originally from India, now distributed world-wide, and much more common and wide-spread than suggested by herbarium material, possibly because it is cultivated. Now widespread in (sub)tropical countries: Africa, China and eastern Asia, India, Indo-China, Malesia, and north Indian ocean, Pacific, North America, Brazil.

Ecology.— Low damp sites, swamps.

Vernacular.— Kaeng hom (แกงหอม), Kam hom (แคมหอม), Faek (แฝก), Ya faek hom (หญ้าแฝกหอม).

Use.— As the cultivated form ("Sunshine") does not produce fertile seeds and has no tillers, it cannot become a noxious weed and so is excellent in soil erosion control.

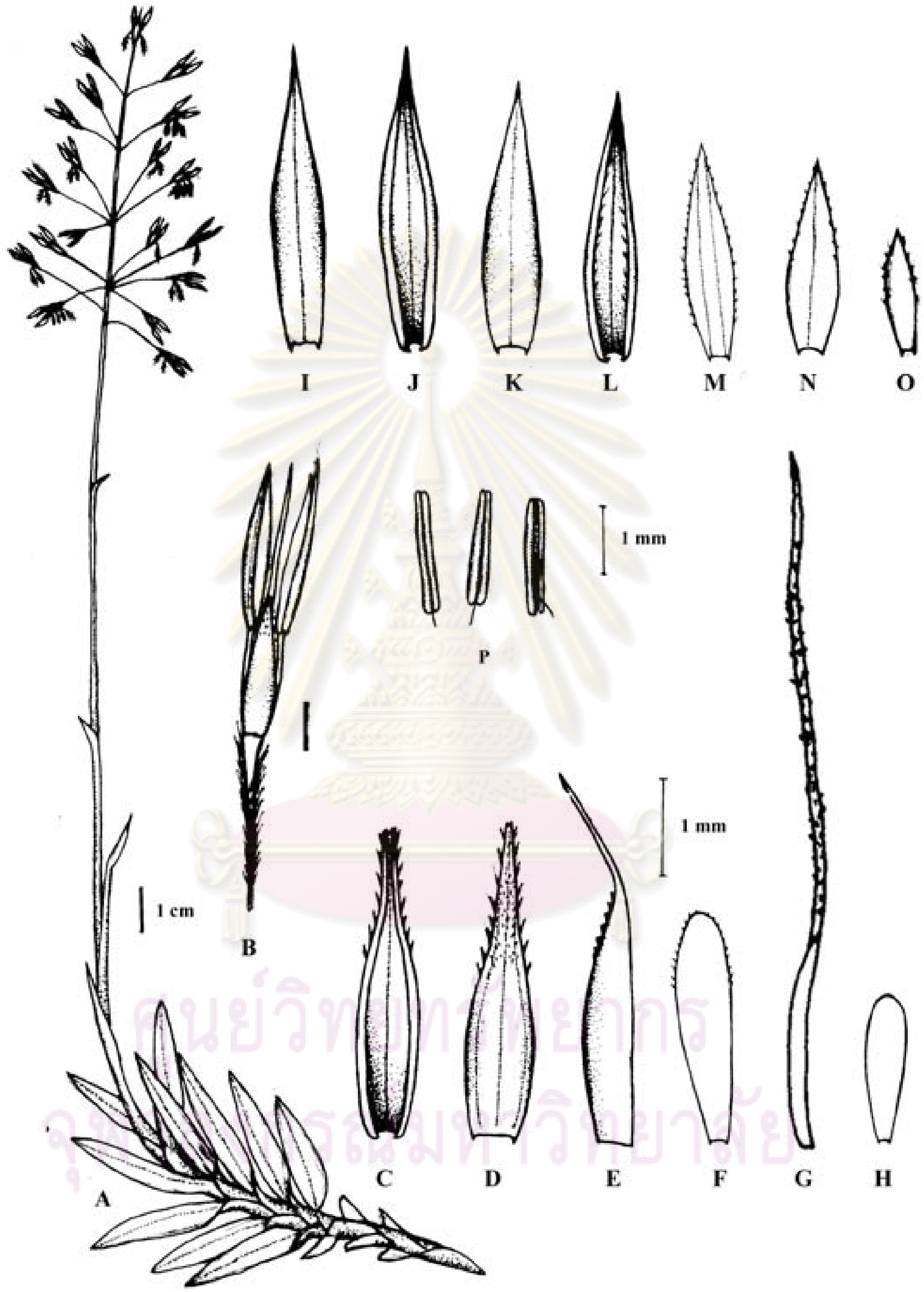

Figure 5.11 *Chrysopogon aciculatus*: A. habit. B. spikelet group. C.-H. sessile spikelet: C.-D. lower glume; E. upper glume; F. lower lemma; G. upper lemma; H. upper palea. I.-P. pedicelled spikelet: I.-J. lower glume; K.-L. upper glume; M. lower lemma; N. upper lemma; O. upper palea; P. stamen.

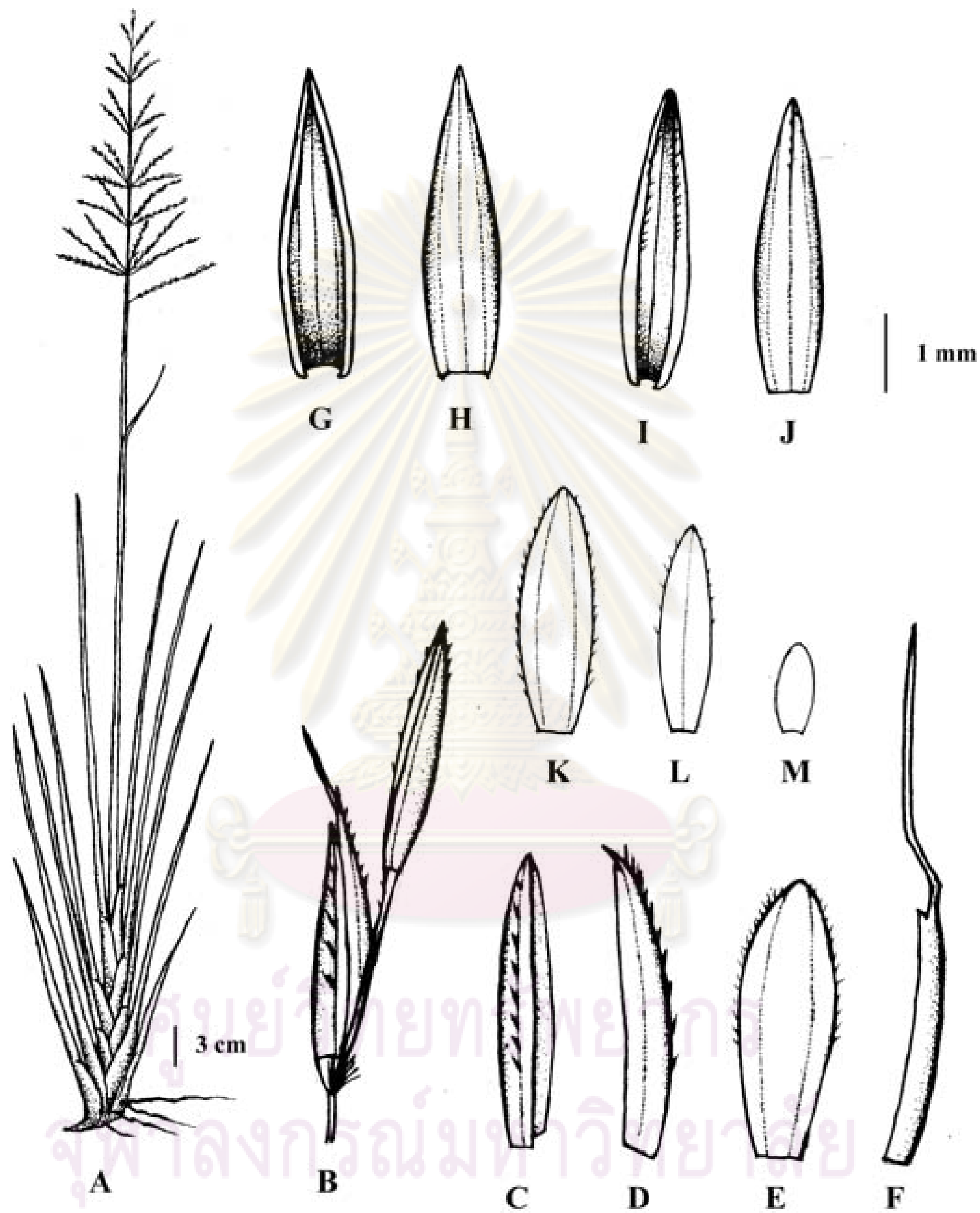

Figure 5.12 *Chrysopogon festucoides*: A. habit. B. a spikelet pair. C.-F. sessile spikelet: C. lower glume; D. upper glume; E. lower lemma; F. upper lemma. G.-M. pedicelled spikelet: G.-H. lower glume; I.-J. upper glume; K. lower lemma; L. upper lemma; M. upper palea.

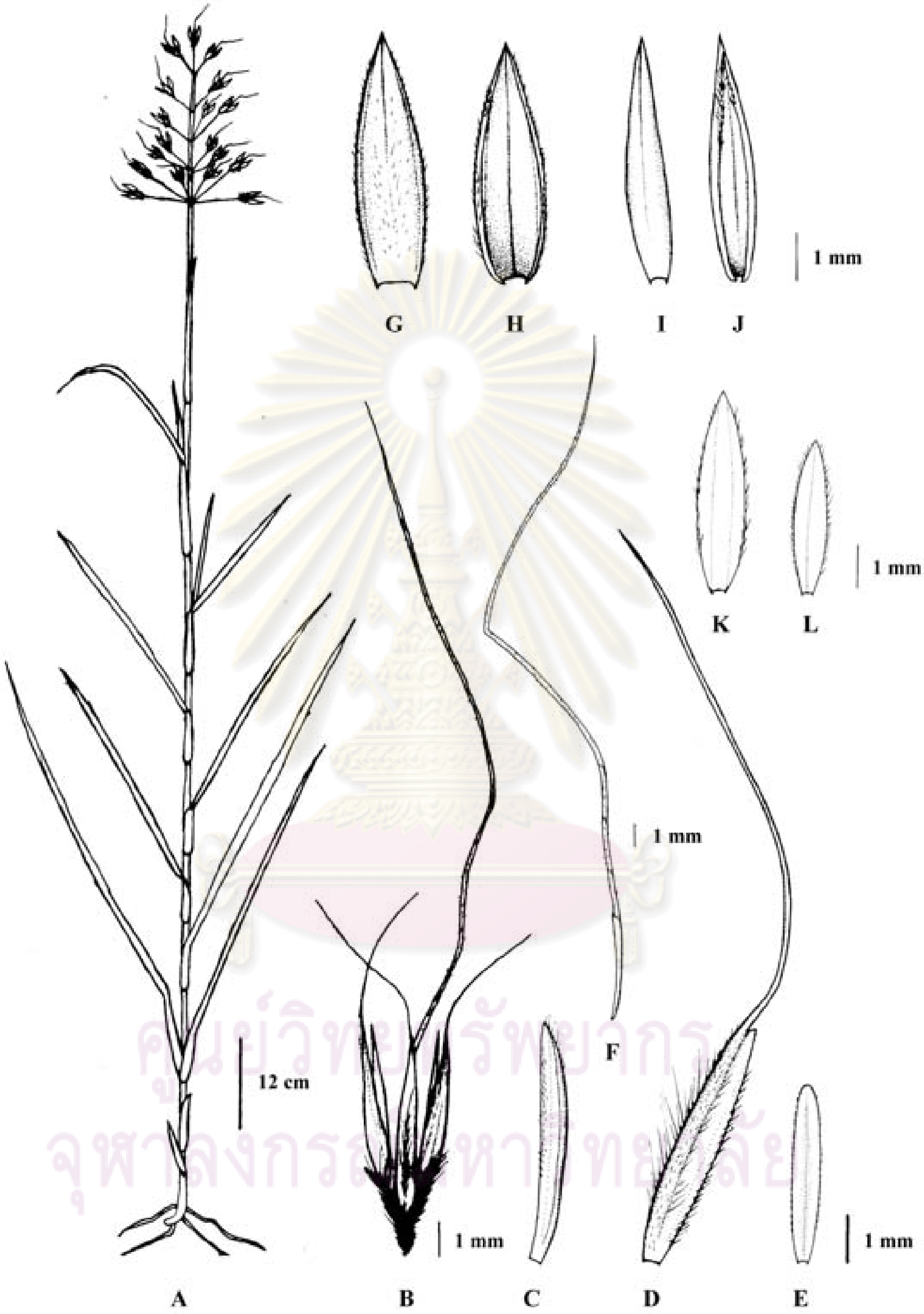

Figure 5.13 *Chrysopogon fulvus*: A. habit. B. spikelet group. C.-F. sessile spikelet: C. lower glume; D. upper glume; E. lower lemma; F. upper lemma. G.-L. pedicelled spikelet: G.-H. lower glume; I.-J. upper glume; K. lower lemma; L. upper lemma

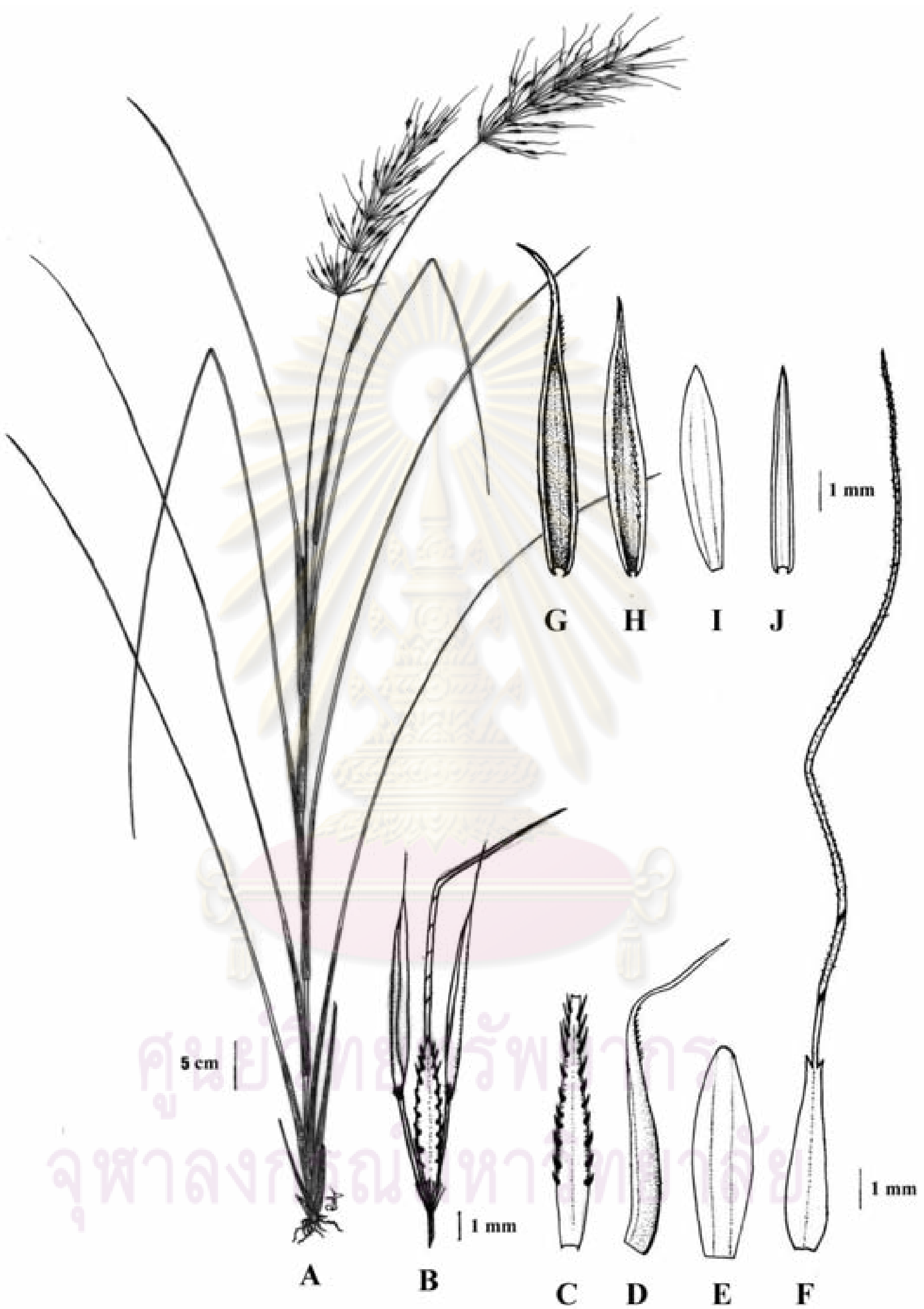

Figure 5.14 *Chrysopogon gryllus* subsp. *Gryllus*: A. habit. B. spikelet group. C.-F. sessile spikelet: C. lower glume; D. upper glume; E. lower lemma; F. upper lemma. G.-J. pedicelled spikelet: G. lower glume; H. upper glume; I. lower lemma; J. upper lemma.

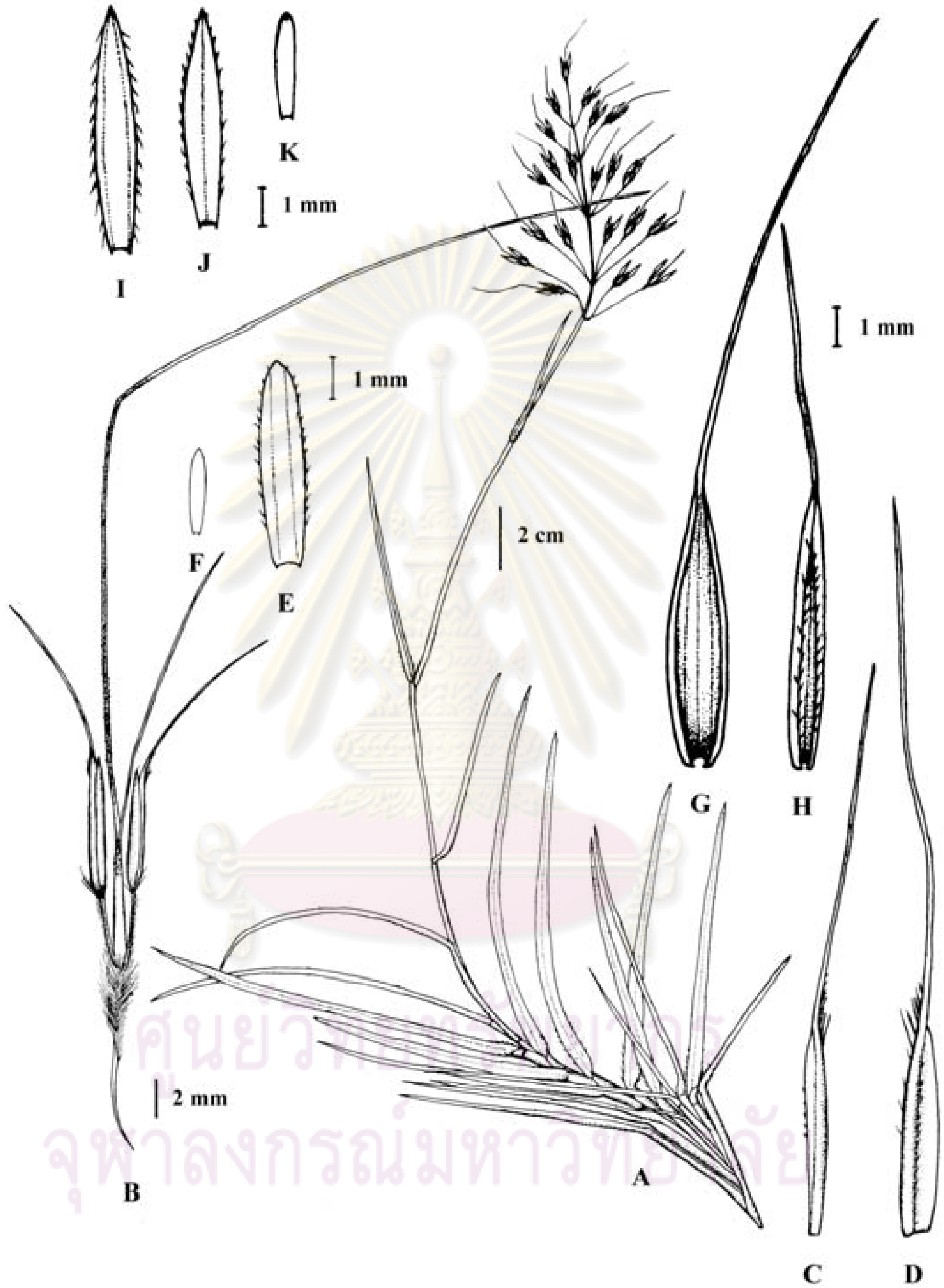

Figure 5.15 *Chrysopogon orientalis*: A. habit. B. spikelet group. C.-F. sessile spikelet: C. lower glume; D. upper glume; E. lower lemma; F. upper palea. G.-K. pedicelled spikelet: G. lower glume; H. upper glume; I. lower lemma; J. upper lemma; K. upper palea.

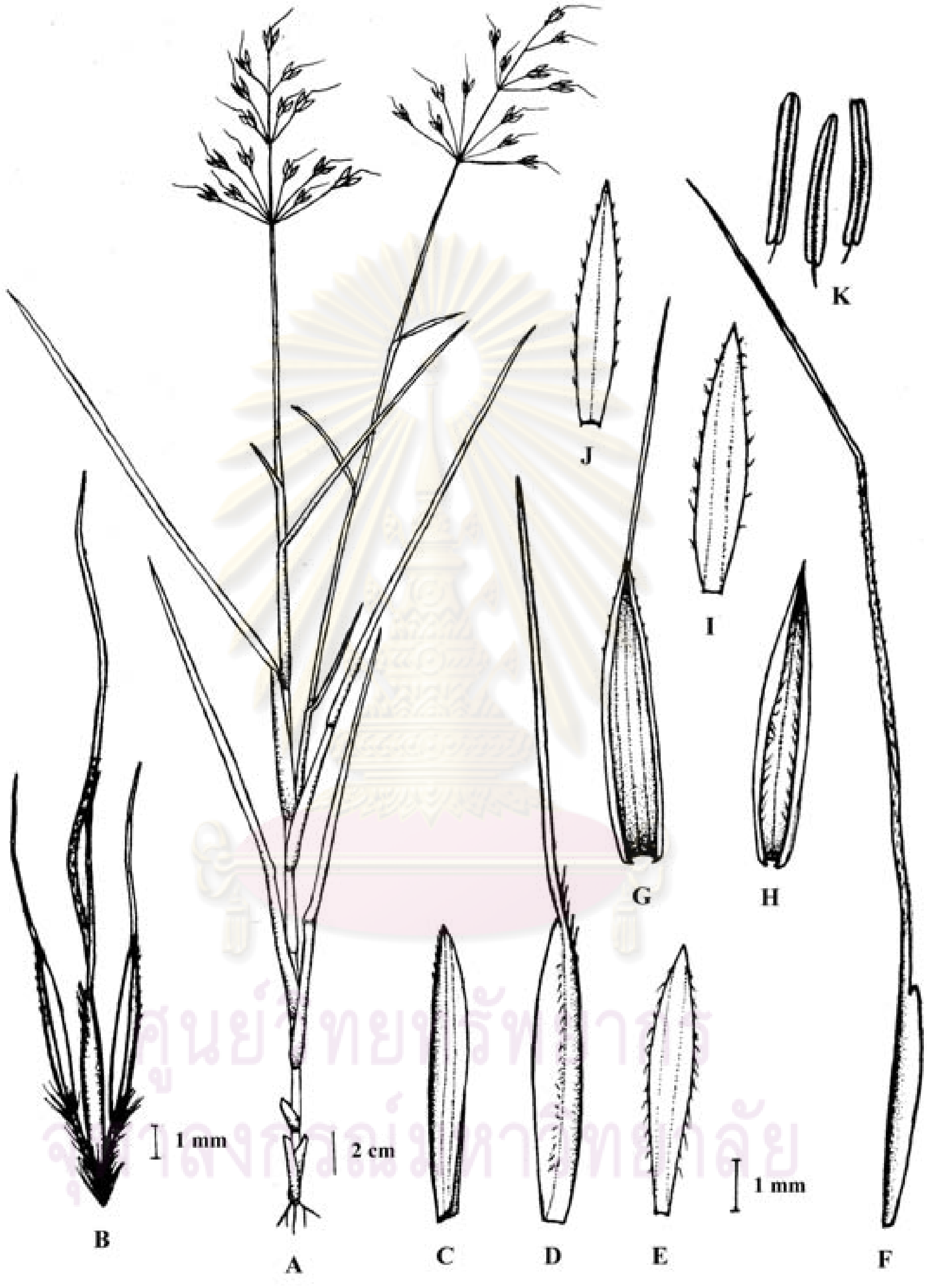

Figure 5.16 *Chrysopogon serrulatus*. A. habit. B. spikelet group. C.-F. sessile spikelet: C. lower glume; D. upper glume; E. lower lemma; F. upper lemma. G.-K. pedicelled spikelet: G. lower glume; H. upper glume; I. lower lemma; J. upper lemma; K. stamen.

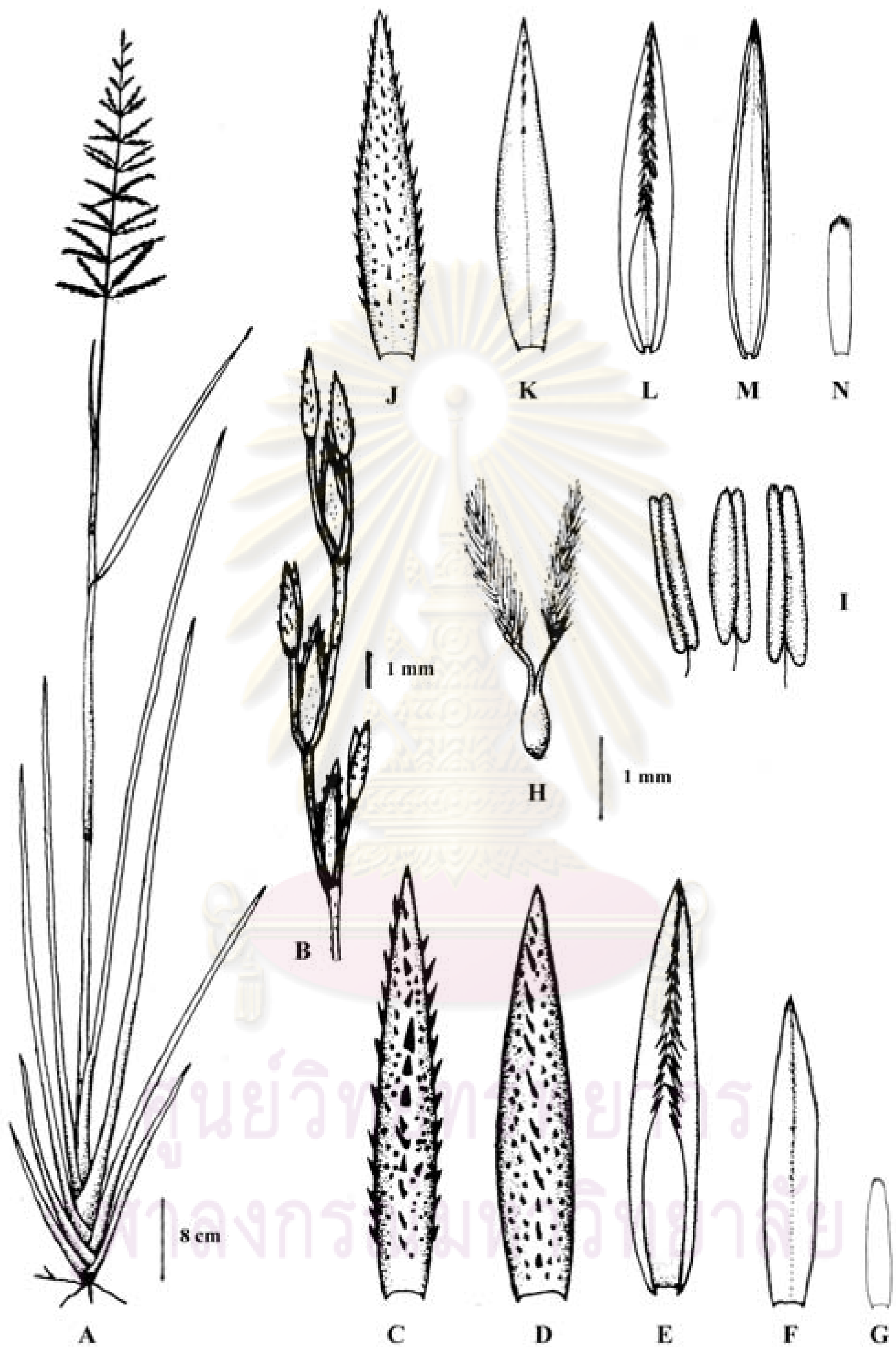

Figure 5.17 *Chrysopogon zizanioides*: A. habit. B. a part of raceme. C.-I. sessile spikelet: C. lower glume; D. upper glume; E. lower lemma; F. upper lemma; G. upper palea; H. pistil; I. stamen. J.-N. pedicelled spikelet: J. lower glume; K. upper glume; L. lower lemma; M. upper lemma; N. upper palea.

4. DICHANTHIUM

Willemet in Usteri, Ann. Bot. 18: 11. 1796; A. Camus, Bull. Mus. Hist. Nat. (Paris) 27: 548. 1921; De Wet & J.R. Harlan, Bol. Soc. Argent. Bot. 12: 206. 1968.— *Andropogon* L. subgen. *Dichanthium* (Willemet) Hack., Nat. Pflanzenfam. 2(2): 28. 1887; in A. DC., Monogr. Phan. 6: 566. 1889.— Type species: *Dichanthium nodosum* Willemet, nom. superfl. [= *Dichanthium annulatum* (Forssk.) Stapf].

Diplasanthum Desv., Mém. Soc. Agric. Angers 1: 170, t. 8, f. 1. 1831; Opusc. Sci. Phys. Nat. 1831: 67, t. 5, f. 1. 1831.— Type: *Diplasanthum lanosum* Desv. [= either *Dichanthium aristatum* (Poir.) C.E. Hubb. or *Dichanthium caricosum* (L.) A. Camus, fide Soreng & S.J. Penn., Contrib. US Natl. Herb. 46: 214. 2003].

Lepeocercis Trin., Fund. Agrost.: 203. 1822.— Type: *Lepeocercis serrata* (Retz.) Trin. [= *Dichanthium caricosum* (L.) A. Camus.].

Perennials, tufted, sometimes with extensive creeping stolons. *Ligules* membranous; *leaf-blades* linear, margin scaberulous. *Inflorescence* with a single or subdigitate racemes with a short central axis; racemes shortly peduncled, rachis many-jointed, bearing many pairs of sessile and pedicelled spikelets and a terminal triad, with homogamous spikelet-pairs at the base; rachis and pedicels filiform and solid, without a translucent median line. *Sessile spikelets* dorsally compressed, callus obtuse and bearded, 2-flowered; *lower glumes* 2-keeled, chartaceous, margin inflexed; *upper glumes* boat-shaped, 3-keeled, margin inflexed; *lower lemmas* hyaline, nerveless; *upper lemmas* linear, hyaline, entire or deeply bifid, with a twisted and geniculate awn; *lodicules* 2; stamens 3; caryopsis oblong. *Pedicelled spikelets* dorsally compressed, 1-flowered; *lower glumes* chartaceous, margin inflexed, laterally 2-keeled; *upper glumes* hyaline, nerves 3-5, margins inflexed, ciliolate; *lower lemma* hyaline, margin inflexed, nerveless; *upper lemma* when present hyaline; floret sterile or staminate.

Species ± 22. In the (sub)tropics of the Old World, 4 in Thailand.

Note.— Sathagul (1990) recorded four species of *Dichanthium*: *D. annulatum, D. aristatum, D. caricosum,* and *D. polyptichum*, while Nanakorn & Norsangsri (2001) added three more taxa: *D. mucronulatum, D. siamensis*, and *D. theinlwinii.* In the present study only four could be maintained: *D. annulatum, D. aristatum, D. caricosum* and *D. mucronulatum.* The other taxa turned out to be due to misidentification or have become synonyms. For examples, *M. Tagawa, K. Iwatsuki & N. Fukuoka* T-1039 was called *D. polyptichum*, but in fact was *Pseudosorghum fasciculare*; *Dichanthium siamensis* is an unpublished name of *D. mucronulatum*; *D. theinlwinii* is a synonym of *D. caricosum.*

KEY TO THE SPECIES

1. Upper lemma of sessile spikelet with a bifid apex ………....... **4.** ***D. mucronulatum***
1. Upper lemma of sessile spikelet with an entire apex
   2. Lower glume of sessile spikelet without winged keels ..……..... **1.** ***D. annulatum***
   2. Lower glume of sessile spikelet with winged keels
      3. Peduncle of racemes pubescent …………………..…..….…… **2.** ***D. aristatum***
      3. Peduncle of racemes glabrous ……………………...…….. **3.** ***D. caricosum***

1. ***Dichanthium annulatum*** (Forssk.) Stapf in Prain, Fl. Trop. Afr. 9: 178. 1917.— *Andropogon annulatus* Forssk., Fl. Aegypt. Arab.: 173. 1775. ('*annulatum*').— *Lepeocercis annulata* Nees, Fl. Afr. Austr. (1841) 98. 1841.— [*Andropogon annulatus* Forssk. var. *genuinus* Hack. in A. DC., Monogr. Phan. 6: 572. 1889, nom. Inval.].— *Andropogon nodosus* Nash in Britton, N Amer. Fl. 17, 2:122. 1912, nom. superfl.— [*Dichanthium caricosum* (L.) A. Camus subvar. *annulatum* Roberty, Boissiera 9: 164. 1960, & subvar. *nodosum* Roberty, p. 165, nom. inval.].— *Dichanthium nodosum* Willemet, Ann. Bot. (Usteri) 18: 11. 1796, nom. superfl., pro comb., descr. = *D. aristatum* (Poir.) C.E. Hubb.— Type: Egypt, *Herb. Forsskål 127* (holo: C!, microfiche IDC 2200; iso: Herb. Retzius, LD).

Bothriochloa tuberoculata W.Z. Fang, Bull. Bot. Res., Harbin 6(1): 97. 1986.— Type: China, Yunnan, Jian-shui Xian, *Hong-he Expedition* 810468 (holo: JSBI; iso: YUNU).

Often basally creeping. *Culms* slender, up to 80 cm high, internodes grooved or flattened at one side, nodes bearded. *Leaf-sheaths* terete, 3-13 cm long, glabrous; *ligules* c. 1 mm long; *Leaf blades* 4-30 cm by 2-5 mm, lower surface glabrous, upper surface scabrous and sparsely with bulbous-based hairs, base rounded, apex acuminate. *Inflorescence* digitate, composed of 3-many racemes, central axis 4-10 cm long; racemes 5-7 cm long, lowest raceme longer than the central axis; joints flattened, 1.5-2.5 mm long, ciliate on both margins. *Sessile spikelets* 3 mm long, hairy; callus 0.5 mm long; *lower glumes* oblong, 2.5 by 0.8 mm, 8-nerved, dorsally short-hairy especially in the lower half, near the margins usually with long tubercle-based hairs in the upper half, greenish with purplish stripes at the margins, apex obtuse or truncate; *upper glumes* 3 by 1 mm, 3-nerved, hyaline, scabrid on the keels and midnerve, apex acute; *lower lemmas* oblong, 2-2.3 by 0.3 mm, glabrous, apex obtuse; *upper lemmas* 2 mm long, glabrous, awn 1-1.3 cm long with short hairs in the lower half; *lodicules* 0.4 mm long; *anthers* c. 1-1.5 mm long. *Pedicelled spikelets* oblong, hairy, callus short with short hairs; pedicels flattened, 1.5-2.5 mm long, hairy on both margins; *lower glumes* ovate, 3 by 0.8-1 mm, 7-9-nerved, with bulbous-based hairs, purple, apex obtuse or truncate; *upper glumes* oblong, 2.5-2.7 by 1 mm, 3-nerved, keels hairy, apex obtuse to round; *lower lemmas* c. 2 by 0.8-1 mm, apex truncate; *anthers* c. 1 mm long, sometimes barren; some pedicelled spikelets have only a lower glume. (**Figure 5.18, Figure 5.33A-B**)

Thailand.— NORTHERN: Chiang Mai [near guesthouse of Queen Sirikit Botanic Garden, 30 Sep. 2001, *S. Lægaard* 21656 (AAU); Doi Sutep, 25 Oct. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 5884 (C); 13 Oct 1912, *A.F.G. Kerr* 2736 (K, BM)]; Chiang Rai [Doi Tung, 29 Sep. 2006, *J.F. Maxwell* 06-692 (CMU); south of

Chiang Rai, by irrigation-canal, 2 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 1817 (C)]; Nan [Pua, 19 March 2005, *O. Neamsuvan* 198 (BCU); Doi Phukha National Park, 3 Apr 2006, *O. Neamsuvan* 224 (BCU)]; Lampang [Ban Hawng Gawk, 3 Apr. 1993, *J.F. Maxwell* 93-315 (CMU)]; Lamphun [Doi Kuhn Dahn National Park, 29 Oct. 1994, J.F. Maxwell 94-1150 (BKF)]; Tak [Pha Charoen waterfall, 28 Feb 2005, *O. Neamsuvan* 193 (BCU)]; Phitsanulok [Phu Hin Rong Kla National Park, 17 Aug 2006, *O. Neamsuvan* 236 (BCU)]; NORTH-EASTERN: Petchabun [Khao Kho, 20 March 2005, *O. Neamsuvan* 202 (BCU)]; Sakon Nakhon [Phuphan National Park, 6 Jul 2005, *O. Neamsuvan* 207 (BCU)]; EASTERN: Udon Thani [9 Sep. 1976, *C.W. Heckman* 133 (K); Nakhon Ratchasima [Tub Kwang, 27 Mar. 1959, *Umpai* s.n. (BK)]; CENTRAL: Bangkok [Bangkhen, 1 Dec. 1966, *C. Chermsirivathana* s.n. (BK); Bangkhen, 22 Oct. 1962, *Pradit* s.n. (BK)], Lop Buri [Bencha Khiri temple, Phatthana Nikhom District, 30 Aug. 2001, *R. Pooma, W.J.J.O. de Wilde, B.E.E. Duyfjes, V. Chamchumroon* and *K. Phattarahirankanok* 3009 (L)]; Nakhon Pathom [Kasetsart University, Kamphaengsaen, 3 Jul 2006, *O. Neamsuvan* 233 (BCU)]; SOUTH-EASTERN: Chon Buri [Wat Bang Peng, 7 Feb 2005, *Y. Sirichamorn* s.n. (BCU)]; SOUTH-WESTERN: Kanchanaburi [Sai Yok, 4 Jul. 1963, K. Larsen 10508 (K, C)]; PENINSULAR: Chumphon [Chumphon Muang Mai, 7 Feb 2005, *O. Neamsuvan* 175 (BCU)]; Krabi [Klongtom, Ban Klong Rat, Group7, 29 Nov. 1986, *J.F. Maxwell* 86-980 (PSU, L)

Distribution.— NW Africa to China, Polynesia, Australia, introduced elsewhere.

Ecology.— Open areas, along road sides.

2. Dichanthium aristatum (Poir.) C.E. Hubb., Bull. Misc. Inform. Kew 1939: 654. 1939.— *Andropogon aristatus* Poir., Encycl., Suppl. 1: 585. 1811. ("*aristatum*").— Type: Mauritius: *Commerson* s.n. in Herb. Desfontaines (holo: FI).

Andropogon caricosus L. var. *heteropogonoides* Hack. in A. DC., Monogr. Phan. 6: 569. 1889.— Type: '*Ins. Timor'* (holo: W).

Andropogon mollicomus Kunth, Révis. Gramin. 1: 365, t. 96. 1830.— *Lepeocercis mollicoma* (Kunth) Nees, Edinburgh New Philos. J. 18: 185. 1835.— *Andropogon caricosus* L. subsp. *mollicomus* (Kunth) Hack. & var. *mollicomus* (Kunth) Hack. in A. DC., Monogr. Phan. 6: 569. 1889.— *Dichanthium caricosum* (L.) A. Camus var. *mollicomus* (Kunth) Haines, Bot. Bihar Orissa: 1039. 1924.— Type: Mauritius, *Sieber Herb. Maur. II, 48* (holo: B; iso: K!, L!, US).

Diplasanthum lanosum Desv., Mém. Soc. Agric. Angers 1: 170, t. 8, f. 1. 1831; Opusc. Sci. Phys. Nat. 67, t. 5, f. 1. 1831.— Type: India orientalis (holo: ? Angers, Jardin des Plantes; iso: possibly in P, P-JU, PC, B-Willd., FI, G, M).

Culms decumbent, up to 1 m. high, nodes usually white bearded. *Leaf-sheaths* keeled, 6-7 cm long, glabrous; *ligules* c. 1 mm long; *leaf-blades* 13-24 cm by 3-4 mm, glabrous with sparsely hairs at the inner base, base rounded, apex long-acuminate. *Inflorescence* digitate, composed of 2-5 racemes, peduncles pubescent; racemes 5-7.5 cm long; raceme peduncles filiform, 1-1.5 cm long, pubescent; joints filiform, ciliate on one margin. Homogamous pairs of spikelets 1 or 2, rarely more. *Sessile spikelets* elliptic, 3.5-4 mm long, hairy; callus 0.5-0.8 mm long, covered by white hairs 1-1.3 mm long; *lower glumes* elliptic, 4 by 2 mm, 9- nerved, purplish green, hairy on the back below the middle, apex truncate, keels distally winged, the narrow wings pectinately setose; *upper glumes* 4 by 1.5 mm, 3-nerved, subchartaceous, green, hairy on the back, apex truncate; *lower lemmas* lanceolate, 3.5 by 0.8 mm, apex acute; *upper lemmas* 2.5-3 mm long, awn c. 2.2-3 cm long with short hairs in the lower half; *lodicules* 0.5-0.7 mm long; *anthers* 2 mm long. *Pedicelled spikelets* elliptic, 4 mm long; callus 0.5 mm long, hairy; pedicel filiform, 2-4 mm long, ciliate on one margin; *lower glumes* elliptic, 4 by 2 mm, 15-nerved, purplish green, dorsally with 0.5 mm long tubercle-based hairs, apex obtuse, keels distally winged; *upper glumes* lanceolate, 4 by 0.8 mm long, 3-nerved, light green, apex acute, dorsally sparsely hairy in the upper 1/3; *lower lemmas* lanceolate, 3.5-4 by 1 mm, apex truncate; *upper lemmas* 2-2.5 by 0.2-0.4 mm, apex deeply bifid; *lodicules* 0.5 mm long; *anthers* 1-1.5 mm long, sometimes barren. (**Figure 5.19**, **Figure 5.33C**)

Thailand.— NORTHERN: Chiang Mai [km 24-28 along road Maerim-Samoeng, 98º47´E 18º52´N, 21 Oct. 2001, *S. Lægaard* 21752 (AAU)]; EASTERN: Nakhon Ratchasima [Tub Kwang, 27 Mar. 1959, *Umpai* s.n. (BK)]; CENTRAL: Bangkok [100º30´E 13º45´N, 16 Dec. 1990, *K. Larsen, S.S. Larsen, W. Nanakorn, W. Ueachirakan* and *Sirirugsa* 42005 (AAU)

Distribution.— Africa to India, introduced elsewhere.

Ecology.— Open fields, lawns, disturbed places.

Uses.— Cultivated for forage.

3. Dichanthium caricosum (L.) A. Camus, Bull. Mus. Natl. Hist. Nat. 27: 529. 1921; Fl. Indo-Chine 7: 318. 1922; Haines, Bot. Bihar Orissa: 1039. 1924 ; Stapf ex Ridl., Fl. Malay. Penins. 5: 210. 1925, isonyms.— *Andropogon caricosus* L., Sp. Pl. ed. 2: 1480. 1763. ('*caricosum*').— [*Andropogon caricosus* L. subsp. *genuinus* Hack. in A. DC., Monogr. Phan. 6: 568.1889, nom. inval.].— Lectotype: unresolved.

Andropogon serratus Retz., Observ. Bot. 5: 21. 1788, non Thunb. (1784).— *Andropogon filiformis* Pers., Syn. Pl. 1: 103. 1805.— *Lepeocercis serrata* (Retz.) Trin., Fund. Agrost.: 203, t. 18. 1820, nom. superfl.— Type: Bengal, *König* s.n. *in Herb. Retzius* (LD, holo).

[*Andropogon tenellus* Roxb., Hort. Beng.: 6. 1814, nom. inval.; Fl. Ind. 1: 259. 1820.— Type: India, *Roxburgh* 2921 (holo: BM!), *Icon. ined.* 1934 (CAL, K)].

Dichanthium theinlwinii Bor, Kew Bull. 4: 223. 1949.— *Dichanthium caricosum* (L.) A. Camus var. *theinlwinii* (Bor) De Wet & J.R. Harlan, Bol. Soc. Argent. Bot. 12: 217. 1968.— Type: Burma, *U Thein Lwin* s.n. (holo: K!).

Heteropogon concinnus Thwaites, Enum. Pl. Zeyl.: 368. 1864.— Type: Ceylon, *Thwaites* 3556 (holo: K!; iso: BM!, P!)

Often basally creeping. *Culms* slender, up to 50 cm high, nodes sparsely hairy. *Leaf-sheaths* keeled, c. 3 cm long, glabrous; *ligules* c. 2 mm long; *leaf-blades* 4.5-20 cm by 2-5 mm, sparsely hairy on both surfaces, base rounded, apex long-acuminate. *Inflorescence* digitate, composed of 1-10 racemes, racemes 3-8 cm long; raceme peduncles filiform, 0.5-1 cm long, glabrous; joints filiform, 1.3 mm long, ciliate on one margin. *Sessile spikelets* oblong, 3-4 mm long, hairy; callus 1 mm long, covered by white hairs 1-1.3 mm long; *lower glumes* obovate or oblong, 3-4 by 1.5 mm, 9-nerved, purplish green, hairy on the back, apex truncate, keels distally winged, the narrow wings pectinately setose; *upper glumes* 3.5 by 1.3-1.4 mm, 3-nerved, subchartacous, glabrous, light green, apex acute; *lower lemmas* oblong, 3-3.5 by 1-1.2 mm, glabrous, apex obtuse; *upper lemmas* 2-3 mm long, awn 1.5-2.5 cm long, lower half with short hairs; *lodicules* 0.3-0.5 mm long; *anthers* c. 1.8 mm long. *Pedicelled spikelets* oblong, 3.5-4.5 by 1.3 mm, hairy, callus 0.5 mm long with short hairs; pedicel filiform, 1.3-1.5 mm long, hairs on one margin, hairs up to 3 mm long; *lower glumes* obovate, 3.5 by 2 mm long, 17-nerved, dorsally hairy, purplish green, apex obtuse to truncate, keels winged, the narrow wings pectinately setose; *upper glumes* oblong, 3.2 by 1.3-1.5 mm, 3-nerved, apex obtuse to truncate; *lower lemmas* elliptic, 2.5-3 by 1-1.5 mm, glabrous, apex obtuse to truncate; *upper lemmas* spathulate, 3 by 0.5 mm, apex obtuse; *anthers* 2-2.5 mm long, sometimes barren. (**Figure 5.20, Figure 5.33D**)

Thailand.— NORTHERN: Chiang Mai [Fang, wayside, 28 Feb. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 1785 (C); Bantham, Chiang Dao, 15 Feb. 1958, *Khantachai* 720 (BKF, BK, K); Muang, below Doi Suthep temple, along main river, 1 Apr. 1988, *J.F. Maxwell* 88-408 (L)]; Chiang Rai [Rai Mae Fa Luang, 22 Nov 2007, *O. Neamsuvan* 267 (BCU)]; Nan [Doi Phukha National Park, 3 Apr 2006, *O. Neamsuvan* 225 (BCU)]; Lamphun [23 Feb. 1973, *J. Sadakorn* s.n. (BK)]; Nakhon Sawan [Takli, 27 Nov. 1828, *Put* 2146 (BK, BM, K)]; Tak [Sod district, 27 Feb 2005, *O. Neamsuvan* 191 (BCU)]; Sukhothai [Srisatchanalai, Ban Tah Chai, 19 Oct. 1992, *J.F. Maxwell* 92-628 (L, AAU); NORTH-EASTERN: Phetchabun [Nam Nao National Park, 3 Jan 2007, *O. Neamsuvan* 253 (BCU)]; Loei [km 43 on road 201, south of Loei, 30 Oct. 2001, *S. Laegaard* and *M. Norsangsri* 21872 (K, AAU); Khon Kaen [Khon Kaen University, 26 Oct. 2001, *S. Lægaard* and *M. Norsangsri* 21795 (AAU)]; EASTERN: Nakhon Ratchasima [23 Nov. 1923, *A.F.G. Kerr 7947* (BK, BM, K), 16 Mar. 1958, *Th. Sørensen, K. Larsen* and *B. Hansen* 2159 (K, C)]; SOUTH-WESTERN: Kanchanaburi [Thongphaphum, 30 Jan 2005, *O. Neamsuvan* 171 (BCU)]; Phetchaburi [Cha-um, 15 Apr. 1960, *C. Chermsirivathana* s.n. (BK)]; CENTRAL: Bangkok [dry paddy field, 13 May 1924, *A. Marcan* 1612 (BM); 13 Nov. 1924, *A.F.G. Kerr* 9361 (BK, BM, K, L); 6 Dec. 1925, A.F.G. Kerr 10092 (BK, BM, K); 26 Nov. 1926, *A.F.G. Kerr* 11096 (BK, BM, K); 8 Feb. 1925, *A.F.G. Kerr* 10052 (BK, BM, K); on waste ground, 13 Dec. 1919, *A.F.G. Kerr* 3894 (K, BM, AAU); 31 Dec. 1922, *A.F.G. Kerr* 6712 (K, BM); 6 Dec. 1925; *A. Marcan* 1935 (BM); 20 Jan. 1924, *A. Marcan* 1623 (BM)], Saraburi [Kaeng Khoi, 7 Dec. 1923, A.F.G. Kerr 7952 (K, BM); Phukhae Arboretum, 3 Dec. 1937, *J.V. Santos* 4477 (L)], Lop Buri [Chaibadan, 15 Dec. 1923, *A.F.G. Kerr* 7988 (BK, BM, K)], Chainat [December 1930, *A.F.G. Kerr* s.n. (K)], Ang Thong [24 Dec. 1829, *Put* 2536 (BK, BM, K); Tatad Kraud, 11 Jan. 1982, *Y. Paisooksantivatana* 765-82 (BK)]; Nonthaburi [Pakred, 6 Jan. 1924, *A. Marcan* 605 (BM); 14 Oct. 1923, *A. Marcan* 1489 (BM)], Nakhon Pathom [Mahodol University, Salaya Campus, 24 Jan. 1999, *J.F. Maxwell* 99-27 (CMU, L); Kasetsart University, Kamphaengsaen, 3 Jul 2006, *O. Neamsuvan* 234 (BCU)]; SOUTH-EASTERN: Chon Buri [Wat Bang Peng, 7 Feb 2005, *Y. Sirichamorn* s.n. (BCU)]; Sa Kaeo [Krabinburi, 22 Dec 1924, *A.F.G. Kerr* 9744 (BK, BM, K)]; PENINSULAR: Chumphon [Pathomphon intersection, 7 Feb 2005, *O. Neamsuvan* 173 (BCU)]; Songkhla [Kukut, Songkhla lake, 26 Feb 1984, *P. Sirirugsa* 767 (PSU)]; Trang [Ton Teh waterfall, south of Khao Chong, 14 Nov. 1990, *K. Larsen, S.S. Larsen, A.S. Barfod, W. Nanakorn, W. Ueachirakan* and *Sirirugsa* 41378 (PSU, AAU)]

Distribution.— India to S. China, introduced elsewhere.

Ecology.— Along road sides, open fields, abandon areas.

Vernacular.— Ya nuat chao chu (หญ้าหนวดเจ้าชู้), Ya wean (หญ้าแหวน)

Notes.— The specimen *O. Neamsuvan* 253 from Nam Nao National Park is different from others as it comprises 1-(2) racemes per inflorescence and then 2 or 3 inflorescences are clustered in a terminal or axillary group.

D. theinlwinii was reported as a distinct species by Nanakorn & Norsangsri (2001), however it was treated as a synonym of *D. caricosum* by Royal Botanic Gardens, Kew in GrassBase - The Online World Grass Flora (Clayton, Harman and Williamson, 2008). After more considering these specimens, I agreed with this treatment.

This species is very close to *D. aristatum* from which differs by the glabrous peduncle and glabrous stalk of racemes, but puberulous in *D. aristatum*. This species sometimes is very similar to *D. annulatum*, especially in the case of more than one raceme per inflorescence. However, it differs by the winged keels of the lower glumes of the sessile spikelets in not bearing any tubercle-based hairs near the margin.

4. Dichanthium mucronulatum Jansen, Act. Bot. Neerl. 1: 474. 1953; Gilliland, Rev. Fl. Malaya 3: 283. 1971.— Type: Malaysia, *Ridley* 8129 (holo: SING; iso: K!).

Culms up to 70 cm high, nodes glabrous. *Leaf-sheaths* almost keeled, 2.5-4.5 cm long, glabrous; *ligules* c. 3 mm long; *leaf-blades* 7-15 cm by 1-4 mm, glabrous, base long cuneate, apex long acuminate. *Inflorescence* a terminal raceme, racemes c. 2.5 cm long, rhachis and pedicel glabrous. *Sessile spikelets* 5.5-6 mm long; callus 0.5-1 mm long; *lower glumes* lanceolate, 5-6 by 1 mm, 8-nerved, greenish yellow, glabrous, apex obtuse with 2 lateral teeth; *upper glumes* lanceolate, 5-5.8 by 0.7-0.9 mm, 3-nerved, chartaceous, greenish yellow, glabrous, apex acute; *lower lemmas* ovate-lanceolate, 2 by 0.4 mm, apex acute; *upper lemmas* 3.5 mm long, 1-nerved, apex deeply bifid; awn 3.5-4 cm long, hairy. *Pedicelled spikelets* lanceolate, 4.5-5 mm long (including callus); pedicel 1.7-1.9 mm long, glabrous but for the hairy apex; *lower glumes* lanceolate, 4-4.5 by 1 mm, 8-10-nerved, glabrous, apex acute with 2 lateral teeth; *upper glumes* lanceolate, 4-4.3 by 0.7-1.2 mm, 3-5-nerved, glabrous, apex acute; *lower lemmas* lanceolate, 3-3.5 by 0.6 mm, apex obtuse, upper part of margin ciliolate; *upper lemmas* lanceolate, 3 by 0.4 mm, apex acute; *anthers* 1-1.2 mm long. (**Figure 5.21**)

Thailand.— SOUTH-WESTERN: Ratchaburi [Hard Palom, 20 Dec. 1961, K. Larsen 8838 (K, C); Tapoh, 4 Jan. 1962, *K. Larsen* 9142 (C)], Prachuap Khiri Khan [Sam Roi Yod, 30 Nov. 1929, Put 2480 (K)]

Distribution.— Malesia (Malay Penins.: Langkawi, Pahang, Selangor, once in Singapore in 1897).

Ecology.— Exposed limestone hills.

Note.— *Larsen* 8838 (K) was labeled as *D. siamense* Bor, sp. nov., which is an unpublished name.

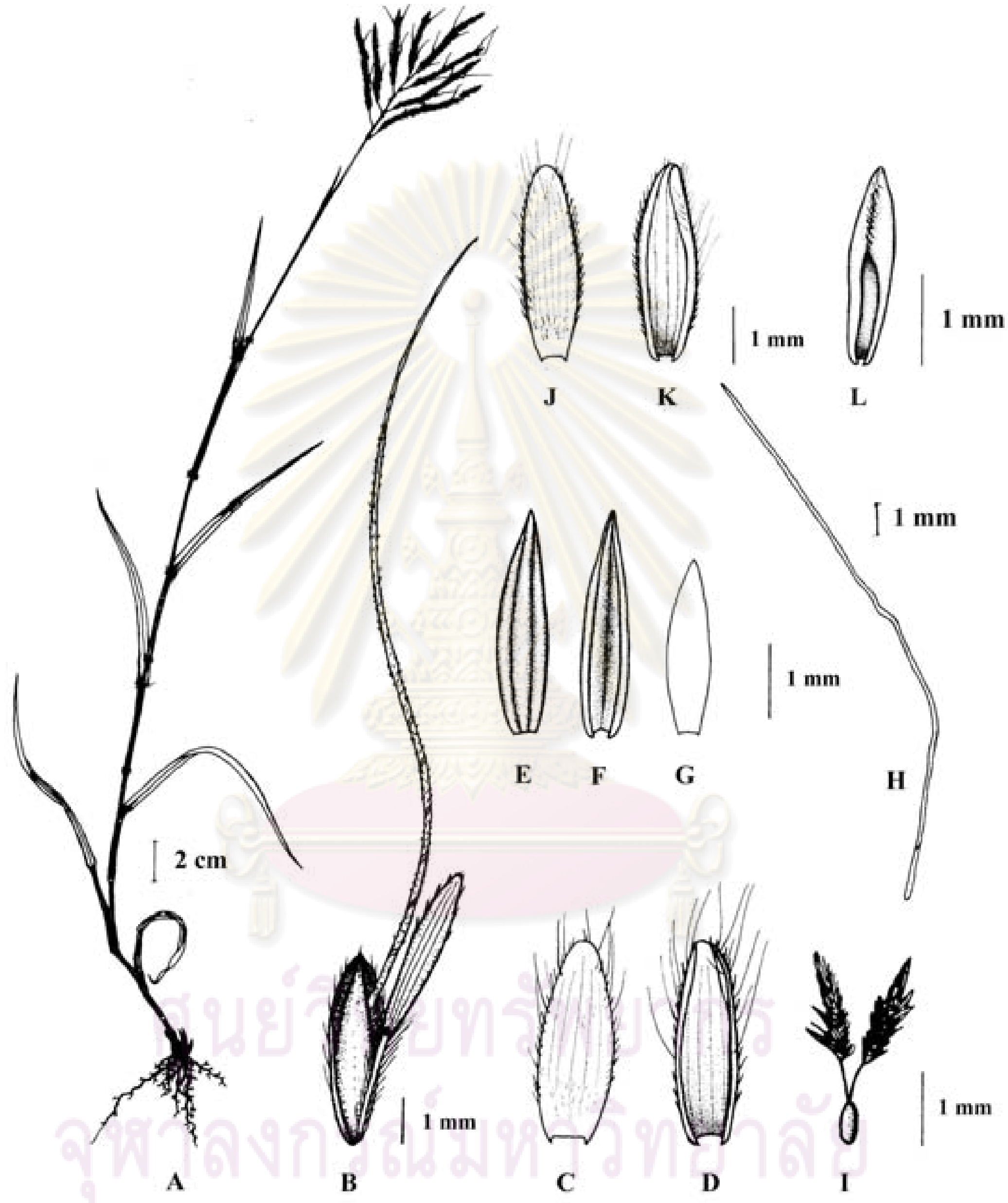

Figure 5.18 *Dichanthium annulatum*: A. habit. B. spikelet pair. C.-I. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma; I. pistil. J.-L. pedicelled spikelet: J.-K. lower glume; L. upper glume.

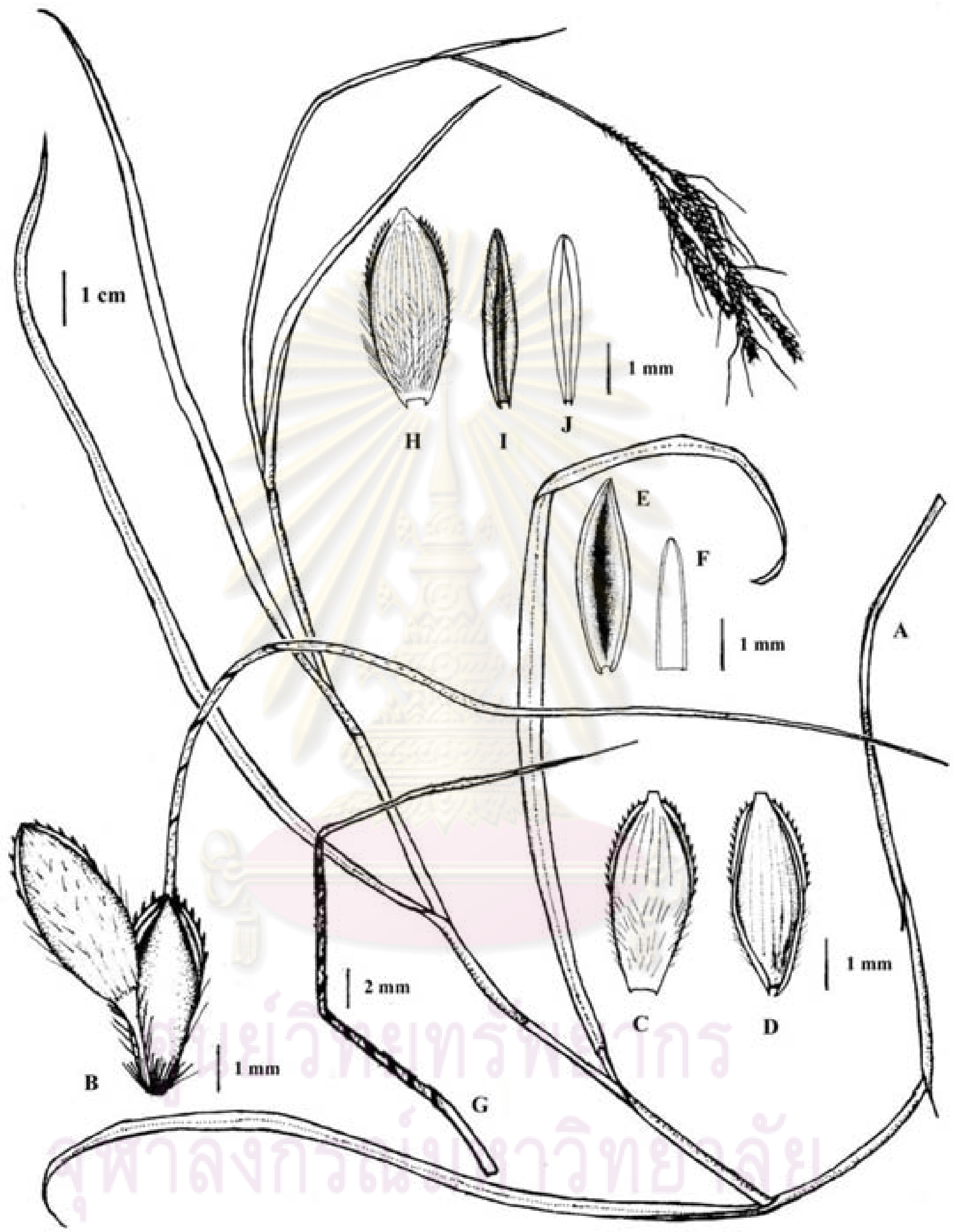

Figure 5.19 *Dichanthium aristatum*: A. habit showing pubescent at peduncle and stalk of raceme. B. spikelet pair. C.-G. sessile spikelet: C.-D. lower glume; E. upper glume; F. lower lemma; G. upper lemma. H.-J. pedicelled spikelet: H. lower glume; I. upper glume; J. lower lemma.

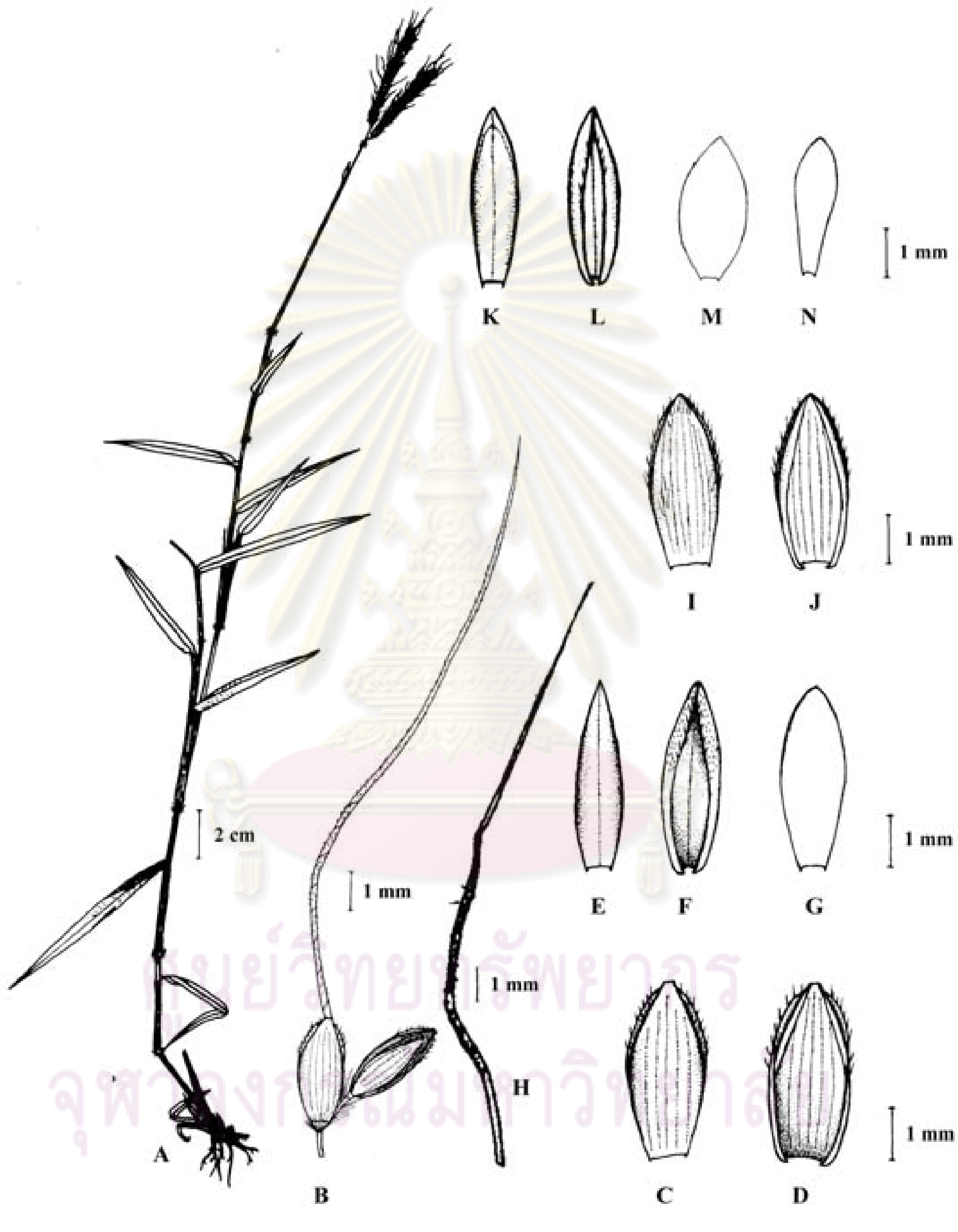

Figure 5.20 *Dichanthium caricosum*: A. habit. B. spikelet pair. C.-H. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma. I.-N. pedicelled spikelet: I.-J lower glume; K.-L. upper glume; M. lower lemma; N. upper lemma.

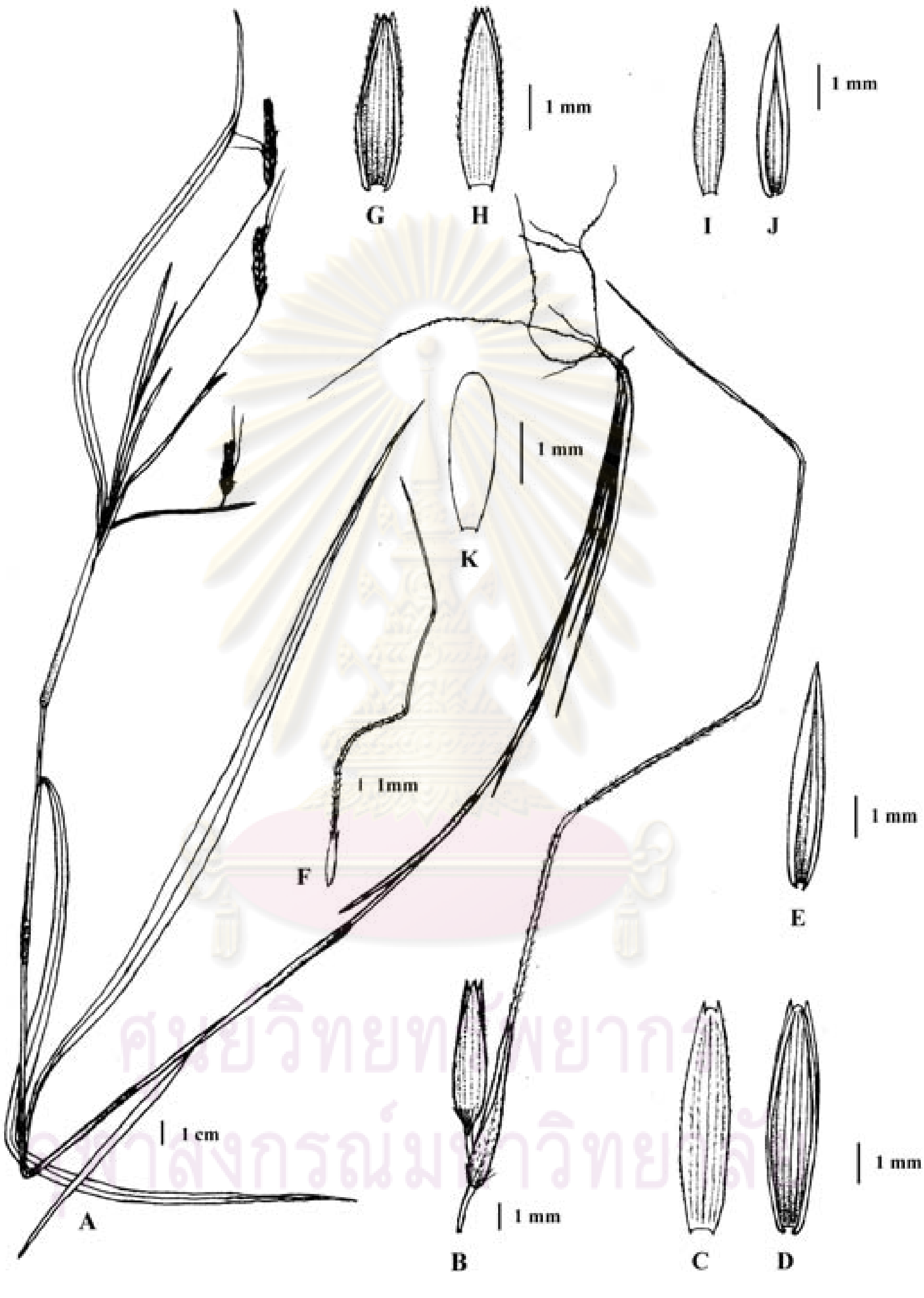

Figure 5.21 *Dichanthium mucronulatum*: A. habit. B. spikelet pair. C.-F. sessile spikelet: C.-D. lower glume; E. upper glume; F. upper lemma. G.-J. pedicelled spikelet: G.-H. lower glume; I.-J upper glume; K. lower lemma.

5. HEMISORGHUM

C. E. Hubb. in Bor, Grass. Burma, Ceylon, India & Pakistan: 686. 1960; Neamsuvan, Seelanan & Veldk., Gard. Bull. Singapore 61. 2009 (in press).— Type species: *Hemisorghum mekongense* (A. Camus) C. E. Hubb.

Tufted perennials. *Culms* erect. *Ligule* collar-shaped, fringed or ciliolate, membranous; *leaf blades* linear, broad, flat. Inflorescence a lax, espatheate panicle; the lowermost branches solitary to whorled, tenacious, glabrous; racemes long, with numerous pairs of sessile and pedicelled spikelets; joints and pedicels filiform, without a resinous channel, scaberulous, articulation transversal. *Sessile spikelets* tardily deciduous, with an obtuse, glabrous callus, dorsally compressed, 2-flowered; lower floret epaleate, neuter; upper floret perfect; *lower glumes* thinly coriaceous, flat on the back, 7-11-nerved, laterally 2-keeled, the margins sharply inflexed; *upper glumes* dorsally rounded, becoming 1-keeled upwards, 7-nerved, margins inrolled; *lower lemmas* hyaline; *upper lemmas* finely 1-nerved, awnless; *upper palea* hyaline or suppressed; *lodicules* 2, cuneate, glabrous; *Stamens* 3. *Pedicelled spikelets* very much reduced to 1 or 2 glumes rarely with a much reduced lemma, barren, deciduous, dorsally compressed, awnless.

Species 1. Burma, Thailand, Laos. *Hemisorghum venustum* (Thwaites) Clayton (Kew Bull. 27: 448. 1972) from Sri Lanka and W India has been included, but Veldkamp has transferred it to *Lakshmia* Veldk. (Rheedea 18: 2008, reprint not yet received).

1. *Hemisorghum mekongense* (A. Camus) C. E. Hubb. in Bor, Grass. Burma, Ceylon, India & Pakistan: 162, 687. 1960.— *Sorghum halepense* (L.) Pers. var. *mekongense* A. Camus, Bull. Mus. Hist. Nat. (Paris) 25: 497. 1919.— *Sorghum mekongense* (A. Camus) A. Camus, Fl. Indo-Chine 7: 323. 1922.— Type: Muong Mai, Laos, *Thorel* s.n. (lectotype: P!), designated here.

Culms up to 2 m high, basally with prop roots, nodes minutely puberulous. *Leaf-sheaths* terete, distally keeled, 10-15 cm long, glabrous; *ligules* 1-2 mm long; *leaf-blades* 25-60 by 1-4 cm, glabrous, margin scaberulous, apex long-acuminate. *Panicles* 30-50 cm long; primary branches 5-15 cm long, branched again, bearing 5-10 racemes; racemes 2-6 cm long, each with 2-7 spikelet pairs; rachis internodes slightly shorter than the sessile spikelet, filiform. *Sessile spikelets* 4-5 mm long (include callus); *lower glumes* ovate-lanceolate, 4-5 by 1.5-2 mm, 7- or 9-nerved, puberulous, keels serrate, apex acute; *upper glumes* lanceolate, 4-4.8 by 1.3-1.5 mm, 7-nerved, apically 1-keeled, chartaceous, puberulous, apex acute; *lower lemmas* ovate-lanceolate, 3.5-4 by c. 1 mm, hyaline, 2-nerved, apex acute; *upper lemmas* ovate, 2.5-3 by 0.8-1.2 mm; *upper paleas* narrowly ovate-lanceolate, c. 2.3 by 0.3 mm, apex narrow, acute; *lodicules* c. 0.3 mm long; *anthers* 1.5-1.8 mm long. *Pedicelled spikelets* usually very much reduced, rarely more or less developed; pedicels filiform, 3-4 mm long, 0.6-0.8 times as long as the sessile spikelet, serrulate on the edges; *lower glumes* narrowly ovate-lanceolate, 0.5-4 by 0.5-1 mm, 0-7-nerved, laterally 2-keeled, keels serrulate, chartaceous, glabrous to sparsely puberulous, margin inflexed, apex acute; *upper glumes* ovate-lanceolate, 0.5-4 by 0.6 mm, 0-5-nerved, membranous, apex acute, margin hyaline, ciliolate. (**Figure 5.22**, **Figure 5.34A-B**)

Thailand.— NORTH-EASTERN: Nakhon Phanom [Paknam Songkhram, 6 May 1932, *Kerr* 21356 (K); Lakhon, 1866-1868, *Thorel* s.n. (P)]; Nong Khai [Phonphisai, 17 October 2006, *O. Neamsuvan* 262, 263 (BCU)]

Distribution.— Burma (Tenasserim), Laos (Bolikhamsai, Champasak, Khammouane, Sayaboury, Vientiane).

Ecology.— Open sandy, weedy area along river, seasonally submerged, on sandstone, 75 m alt. Flowering February - May.

Vernacular.— Ya Phong (หญ้าพง)

Notes.— Being an annual the diaspores apparently survive long and deep submersion (up to 7 m; Maxwell, CMU, in litt.). It is very similar to *Sorghum halepense* and *S. propinquum.* It can be distinguished as follow:

1a. Rachis internode and pedicel serrate; spikelets rather slender; lower glume of sessile spikelet 2-keeled throughout, keels scabrous …………… ***H. mekongense***
1b. Rachis internode and pedicel ciliate; spikelets stout; lower glume of sessile spikelet becoming 2-keeled near the tip, keel ciliolate .... ***S. propinquum***

2a. Rachis internode and pedicel serrate, apex of lower glume acute … ………………………………………………………………….. ***H. mekongense***
2b. Rachis internode and pedicel ciliate, apex of lower glume minutely 3-teethed ………………………………………..……………...…………... ***S. halepense***

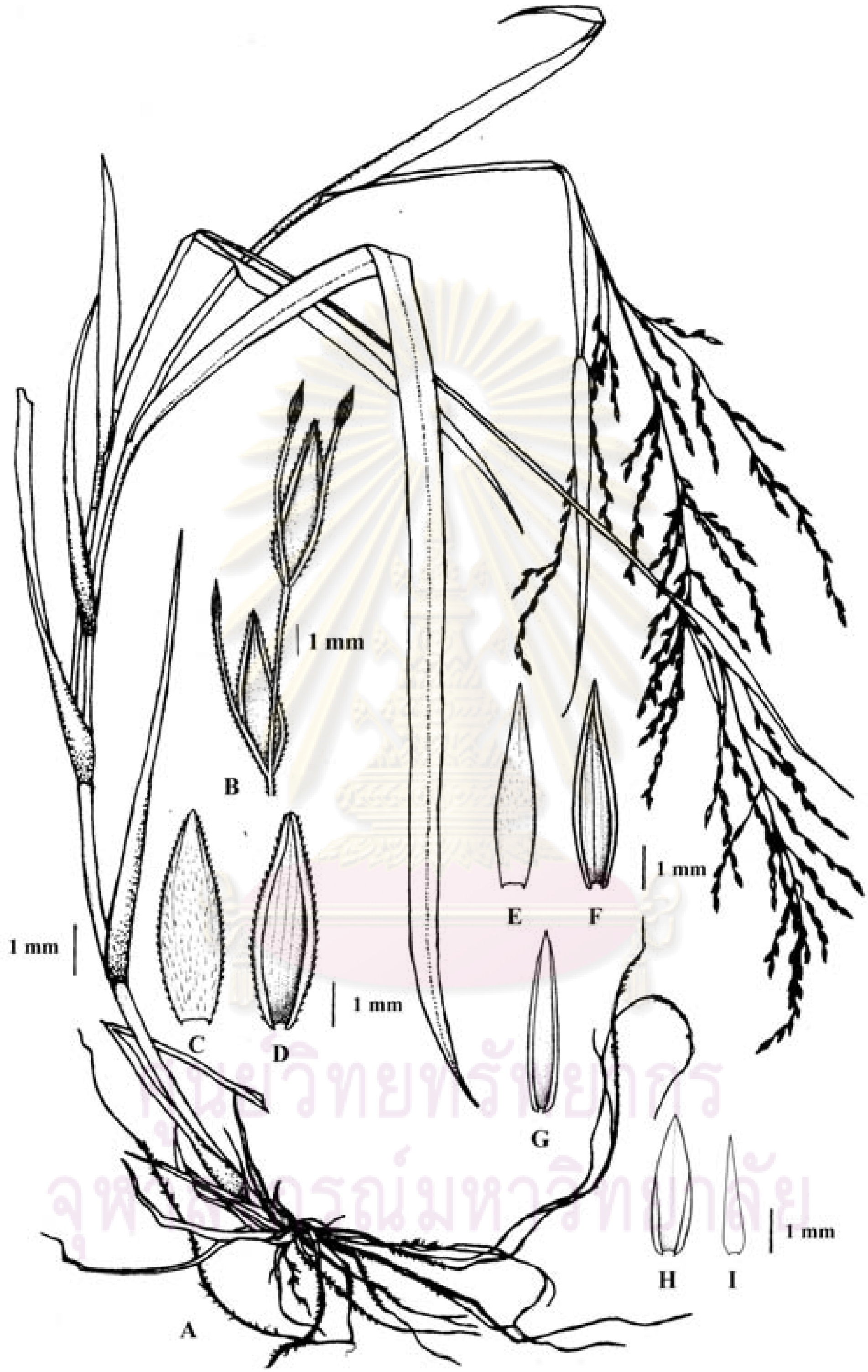

Figure 5.22 *Hemisorghum mekongense*: A. habit. B. a part of raceme. C.-F. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma; I. upper palea.

6. PSEUDOSORGHUM

A. Camus, Bull. Mus. Natl. Hist. Nat. 26: 662. 1921 (“1920”).— *Sorghum* Moench sect. *Pseudosorghum* Roberty, Boissiera 9: 308. 1960. ('*Pseudosorgum*').— Type species: *Pseudosorghum fasciculare* (Roxb.) A. Camus.

Annual. *Culm* internodes solid. *Leaf-blades* flat, linear; *ligule* membranous. *Inflorescences* terminal and lateral, paniculate, racemes sessile, fascicled at the nodes, sometimes branched, bearing numerous pairs of sessile and pedicelled spikelets, rachis disarticulating transversely; internodes and pedicels filiform, without a translucent median line. *Sessile spikelets* dorsally compressed; 2-flowered, the lower floret barren, the upper floret perfect; *lower glumes* not thickened, apically winged, 9-13 nerved; upper glume 7-nerved; *lower lemmas* hyaline; *lower paleas* absent; *upper lemmas* hyaline, deeply cleft, awned from the sinus; awns geniculate, glabrous; *upper paleas* reduced or absent; stamens 3. *Pedicelled spikelets* dorsoventrally compressed, 1-flowered, male or barren, awnless.

Species 1.— Tropical Asia. Damp or shady places.

Note.— This genus traditionally was regarded to contain 2 species, *P. fasciculare* (Roxb.) A. Camus and *P. zollingeri* Steud. The former would have pedicelled spikelets with 2 glumes and 1 sterile floret, while the latter would have 2 glumes, 2 lemmas, and a male floret.

Recently, Chen & Phillips (2006) have treated them as synonymous. I agreed with them since intermediate form were found. Sometimes in the pedicelled spikelets 2 glumes and 1 lemma, and even male florets were found in specimens of *P. fasciculare*. These intermediate forms were also found in type specimen.

1. *Pseudosorghum fasciculare* (Roxb.) A. Camus, Bull. Mus. Natl. Hist. Nat. 26: 662. 1921 (“1920”).— *Andropogon fascicularis* Roxb., Hort. Beng.: 82. 1814, nom. inval.; Fl. Ind. 1: 269. 1820.— *Sorghum fasciculare* (Roxb.) Haines, Bot. Bihar Orissa: 1034. 1924.— Syntype: *Icon. Ined.* 891 (CAL, K).

Andropogon gangeticus Hack. in A. DC., Monogr. Phan. 6: 539. 1889.— [*Sorghum gangeticum* (Hack.) Stapf ex Haines, Bot. Bihar Orissa: 1034. 1924, nom. inval.]. — Syntypes: India, Ganges Riv. Near Sahibgange, *Herb. Kuntze* (W), Maunbhum, *C.B. Clarke* 34420-B (W). http://gallica.bnf.fr/ark:/12148/bpt6k98237n.zoom.r=candolle.f543.langEN

Andropogon nitidulus Hook. f., Fl. Brit. India 7: 199. 1897.— Type: India, *J.F. Duthie* 10717 (holo: K!).

Andropogon tonkinensis Balansa in Morot, J. Bot.: 112. 1890.— Type: Tonkin, *B. Balansa* 1770 (holo: L!; iso: P!)

Andropogon zollingeri Steud. in Zoll., Syst. Verz.: 58: 1854; Syn. Pl. Glumac. 1: 369. 1854.— *Ischaemum zollingeri* (Steud.) Miq., Fl. Ned. Indië. 3: 499. 1857.— *Andropogon asperifolius* Hack., Flora 68: 140. 1885, nom. superfl.— *Sorghum zollingeri* (Steudel) Kuntze, Rev. Gen. Pl.: 792. 1891. (“*Sorgum*”); Roberty, Boissiera 9 (1960) 308, isonym.— *Pseudosorghum zollingeri* (Steud.) A. Camus, Bull. Mus. Hist. Nat. (Paris) 26: 662. 1921 (“1920”).— Type: Indonesia, Java, *H. Zollinger* 2802 (P: holo!; iso: G, W).

Bothriochloa gracilis W.Z. Fang, Bull. Bot. Res., Harbin 6(1): 100. 1986.— Type: China, Yunnan, Yuan-yang Xian, *Hing-he Exped.* 81269 (holo: JSBI; iso: Yunu).

Bothriochloa yunnanensis W. Z. Fang, Bull. Bot. Res., Harbin 6(1): 99. 1986.— Type: China, Yunnan, Meg-la Xian, *C.W. Wang* 8060 (holo: JSBI).

Annual. Culm leafy throughout, to 50 cm high. *Leaf-sheaths* 4-12 cm long, keeled, lower surface with bulbous-based hairs; *ligules* membranous, 2-4 mm long, hairs behind the ligule 5 mm long; *leaf-blades* linear, 5-55 cm by 4-9 mm, minutely hispid to glabrous. *Panicle* 6-13 cm long, rachis with 4-8 nodes, each node with 2-8 racemes, racemes c. 3 cm long. *Sessile spikelets* ovate-oblong, 4-5 mm long; callus short, covered by 1-2 mm long white hairs; *lower glumes* ovate-oblong to ovate-lanceolate, 4-5 by 1.2-1.5 mm, 7-9 nerved, laterally 2-keeled in the upper part, keels short hairy, chartaceous, light green to purple, glossy, glabrous, apex truncate, margin inrolled; *upper glumes* ovate-oblong to ovate-lanceolate, boat-shaped, 4.2-4.5 by 1.2-1.5 mm, 7-nerved, chartaceous but thinner than the lower glume, green, shiny, glabrous, apex acute, margin inflexed, margin distally ciliolate; *lower lemmas* ovate-lanceolate, 3.3-4 by 0.5-1 mm, laterally 2-nerved, hyaline, apex acute, margin inflexed, ciliolate; *upper lemmas* ovate-lanceolate, 1.5-3 by 1.2 mm, 1-nerved, hyaline, apex deeply bifid, awn 1.2-1.7 cm long; *upper paleas* elliptic, c. 1 by 0.5 mm, hyaline, apex acute; *lodicules* 0.2-0.3 mm long; *anthers* 1.3-1.5 mm long. *Pedicelled spikelets* 3.5-4 mm long; pedicel 2.5-3 mm long, hairy on both sides, hairs 1-1.2 mm long; *lower glumes* narrowly ovate-lanceolate, 3.5-4.5 by 1 mm, 9-nerved, chartaceous, purplish green, glabrous, apex acute; *upper glumes* narrowly ovate-lanceolate, 3.5-4 by 1 mm, 5-7-nerved, mid-keeled in the upper half, keel hairy, chartaceous but thinner than the lower ones, apex acute, margin inflexed; *lower lemmas* lanceolate, 2.5-3 x 0.5-0.7 mm, hyaline, apex obtuse to truncate. (**Figure 5.23**)

Thailand.— NORTHERN: Chiang Rai [Khun Chae National Park, 4 Dec. 1997, *J.F. Maxwell* 97-1458 (BKF); Doi Luang National Park, 30 Oct. 1997, *J.F. Maxwell* 97-1301 (BKF)]; Chiang Mai [Pong Dueat National Park, 98º45´E 19º08´N, 26 Nov. 1993, *K. Larsen, S.S. Larsen, Chr. T. Nørgaard, K. Pharsen, P. Puudjaa* and *W. Uerchirakan* 44896 (AAU)]; Doi Chiang Dao Wildlife Sanctuary, 14 Feb. 1996, *S. Gardner* G22 (CMU); Doi Chiang Dao, 7 Nov. 1958, *K. Bunchuai* 4008 (K); Mae Sa Mai (Hmong) Village, *R. Wehner* 38 (CMU); Doi Sahng Liang, 10 Nov. 1997, *J.F. Maxwell* 97-1337 (BKF); Doi Suthep, 3 Dec. 1911, *A.F.G. Kerr* 2267 (K, BM)], Lampang [Che Hom, 16 Jan. 1914, *A.F.G. Kerr* 3092 (K, BM)], Phrae [Mae Yom National Park, 7 Nov. 1991, *J.F. Maxwell* 91-985 (AAU); Mae Yom National Park, 10 Dec. 1993, *J.F. Maxwell* 93-1474 (CMU, L)], Nan [5 km north of Nan, 16 Nov. 1993, *K. Larsen, S.S. Larsen, Chr. T. Nørgaard, K. Pharsen, P. Puudjaa* and *W. Uerchirakan* 44439 (AAU)]; Nakhon Sawan [Mae Wong National Park, 25 Dec 2003, *Martin van de Bult* 725 (CMU); Tak [Lahn Sahng National Park, 23 Nov. 1965, E. Hennipman 3109 (BKF); Lahn Sahng, 27 Dec. 1974, *R. Geesink, P. Hiepko* and *C. Phengklai* 7926 (K, L, C)]; NORTH-EASTERN: Loei [Phu Kradueng, 9 Nov. 1954, *T. Smitinand* 2096 (BKF, BK, K); Phu Kradueng, 101º 48-50´ E 16º 52´ N, 4 Nov. 1984, *G. Murata, C. Phengklai, S. Mitsuta, T. Yahara, H. Nagamasu* and *N. Nantasan* T-43022 (L); Phu Luang, 3 Dec. 1965, *M. Tagawa, K. Iwatsiki and N. Fukuoka* T-1039 (BKF, AAU)], Petchabun [Lom Kao, 30 Oct 2001, *S. Laegaard* and *M. Norsangsri* 21878, 21880 (QBG, K, AAU, SING)], Khon Kaen [Phu Khieo, Game

Reserve, c. 80 km east of Phetchabun, 8 Nov. 1984, *G. Murata, C. Phengklai, S. Mitsuta, T. Yahara, H. Nagamasu* and *N. Nantasan* T-50046 (L); CENTRAL: Saraburi [Pasak river, Kaeng Khoi, 9 Dec. 1923, A.F.G. Kerr 7970 (K, BM); Muak Lek, 9 Nov. 1924, *A. Marcan* 1854 (BM)]; SOUTH-WESTERN: Kanchanaburi [Sai Yok, 8 Dec. 1961, *K. Larsen* 8617 (K, C); Sai Yok, 16 Dec. 1961, *K. Larsen* 8759 (K, C); Klang Dong, along trail, 30 Jan. 1962, K. Larsen 9405 (C); Huay Ban Kan, 13 Nov. 1971, *C.F. van Beusekom*, *R. Geesink, C. Phengklai and B. Wongwan* 3753 (BKF, BK, K, L, C)]

Distribution.— S and E India (Tamil Nadu to Assam) to S China (Yunnan), disjunct in Malesia (Java, Philippines).

Ecology.— On periodically dry, sunny or moderately shaded, less fertile soil, in grasslands and teak forests, along roads, locally abundant.

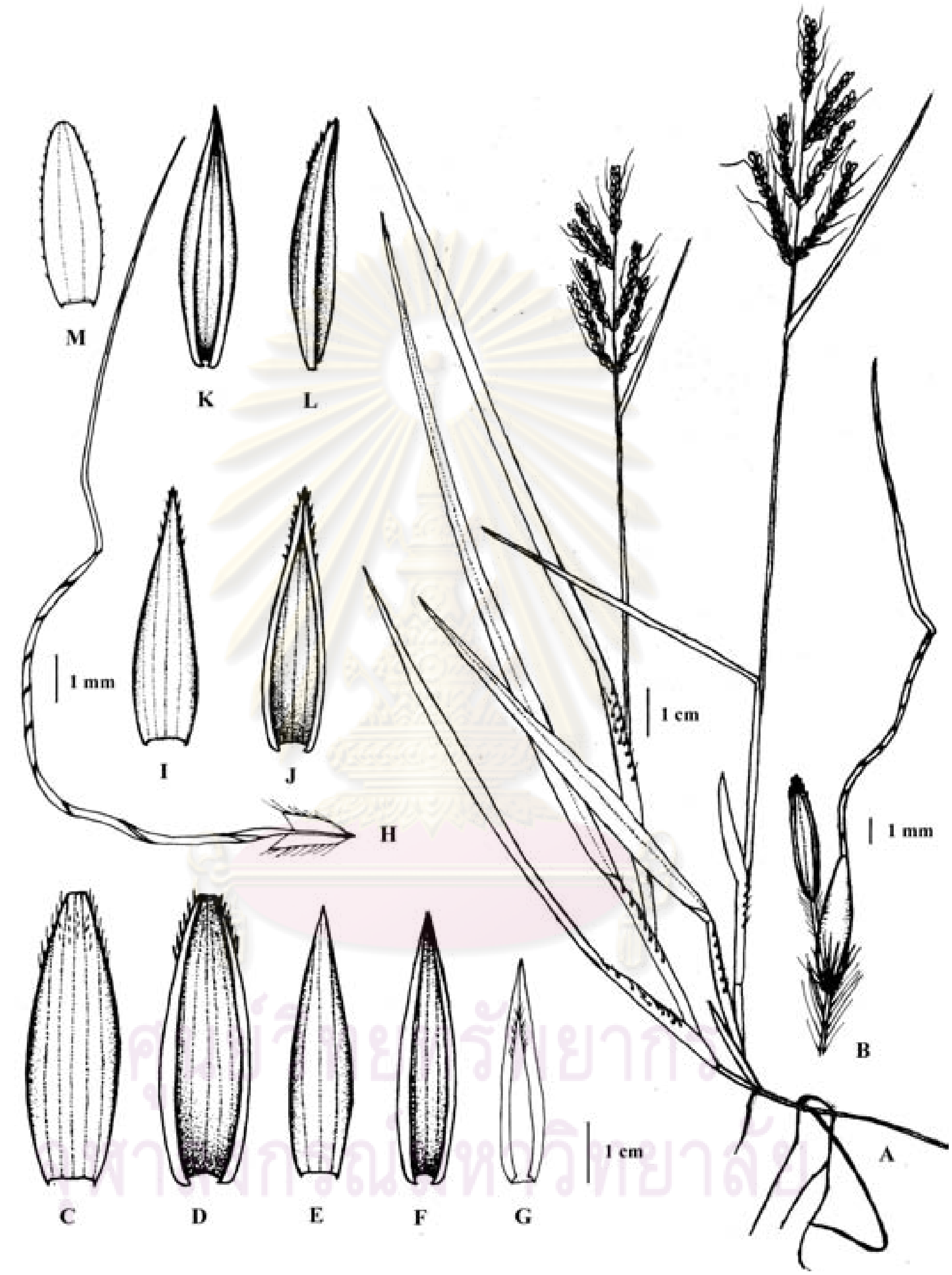

Figure 5.23 *Pseudosorghum fasciculare*: A. habit. B. spikelet pair. C.-H. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma. I.-M. pedicelled spikelet: I.-J. lower glume; K.-L. upper glume; M. lower lemma.

7. SORGHUM

Moench, Methodus 207. 1794, nom. cons.; Snowden, Bull. Misc. Inform.: 221. 1935; Cult. Races Sorghum: 1. 1936. (cultivated taxa); J. Linn. Soc., Bot. 55: 191. 1955. (wild taxa).— *Andropogon* L. subgen. *Sorghum* (Moench) Hack., Nat. Pflanzenfam. 2, 2: 28. 1887; in A. DC., Monogr. Phan. 6: 499. 1889.— Type species: *Sorghum bicolor* (L.) Moench, typ. cons.

Annuals or perennials, with or without rhizomes. *Culms* erect or weakly geniculate below. *Leaf-sheaths* terete, glabrous; *ligules* membranous or fringed membranous; *leaf blades* linear, often broad, margin scaberulous. *Inflorescence* a large terminal panicle, with tough persistent branches bearing fragile racemes; raceme short, bearing many pairs of sessile and pedicelled spikelets and a terminal triad; joints and pedicels filiform, ciliate. *Sessile spikelets* 2-flowered, the lower floret barren, the upper floret perfect, falling entire, dorsally compressed, callus obtuse; *lower glumes* ± coriaceous, broadly convex across the back, submarginally 2-keeled near the tip, narrowly winged on keel, margin inflexed; *upper glumes* coriaceous, margin inflexed, ciliolate; *lower lemmas* 2-nerved, hyaline, margin inflexed, ciliate; *upper lemmas* hyaline, bifid, with or without a glabrous awn from the sinus, sometimes entire and muticous; *upper paleas* hyaline, often minute, margin ciliolate; *lodicules* cuneate, ciliate. *Pedicelled spikelets* staminate or barren, mostly linear-lanceolate, usually much narrower than the sessile spikelet, awnless; *lower glumes* chartaceous, submarginally 2-keeled, margin inflexed.

Species ± 31. Tropics and subtropics of the Old World, one species endemic to Mexico, others have been introduced in America; 4 in Thailand.

Note.— Nanakorn & Norsangsri (2001) recorded 11 species for *Sorghum* but only 4 species: *S. bicolour, S. nitidum, S. halepense* and *S. propinquum*, appear to be present. This is because many names have been reduced to synonymys, for examples, *S. roxburghii* and *S. splendidum var. magnum* were included in *S. bicolor* (De Wet, 1978) and *S. burmahicum* belongs to *S. nitidum* (Spangler, 2003). In addition, two names were not found in any specimens deposited in Thai and abroad herbaria, such as *S. saccharatum* and *S. splendidum*. Moreover, *S. miliaceum* was determined as *S. propinquum*.

KEY TO THE SPECIES

1. Nodes of culm conspicuously bearded, panicle branches simple
 ……………………………………………………………………… **3. *S. nitidum***
1. Nodes of culm glabrous or shortly pubescent, panicle branches at least once dived
 2. Annual, rachis of racemes tough, not breaking up at maturity ...…..... **1*. S. bicolor***
 2. Perennial, rachis of racemes breaking up at maturity
  3. Culms slender, lower glume apex clearly 3-denticulate ..……. **2*. S. halepense***
  3. Culms robust, lower glume apex apiculate or obscurely denticulate
   …………….. …………………………..…………………... **4. *S. propinquum***

1. *Sorghum bicolor* (L.) Moench, Methodus : 207. 1794.

This cultivated species is extremely variable and there are too many synonyms to account for in this place. The reader is referred to Snowden (1935), Bor (1960), De Wet (1978), Doggett & Rao (1995), Stenhouse & Tippayaruk (1996), and Balole & Legwaila (2006).

Over the years the generic name of the complex has changed several times, while two of the epithets once in general use turned out to be inapplicable or illegitimate. Presently, the stabilised name is *Sorghum bicolour* (L.) Moench. The synonymy of the major combinations is:

Holcus bicolor L., Mant. Pl. Alt.2: 301. 1771.— *Milium bicolor* (L.) Cav., Elench. Pl. Hort. Matr.: 24. 1803.— *Sorghum vulgare* Pers. var. *bicolor* (L.) Pers., Syn. Pl. 1: 101. 1805; Eaton & J. Wright, Man. Bot., ed. 8: 438. 1840, isonym.— *Andropogon bicolor* (L.) Roxb., Hort. Bengal.: 7. 1814; Fl. Ind. 1: 272. 1820.— *Andropogon sorghum* (L.) Brot. var. *bicolor* (L.) L. ex Körn. & Wern., Handb. Getreidebau 1: 313. 1885; Hack. in A. DC., Monogr. Phan. 6: 519. 1889, isonym. — *Andropogon halepensis* (L.) Brot. var. *bicolor* (L.) Vines & Druce, Acc. Morison. Herb.: 116. 1914.— *Sorghum vulgare* Pers. subsp. *bicolor* (L.) Maire & Weiller, Fl. Afr. Nord 1: 270. 1952, nom. superfl.— [*Sorghum halepense* (L.) Pers. subvar. *bicolor* (L.) Roberty, Boissiera 9: 302. 1960, comb. Inval.].— *Sorghum saccharatum* (L.) Moench var. *bicolor* (L.) Kerguélen, Lejeunia 75: 262. 1975.— Lectotype: Persia, cultivated, *Herb. Clifford 468, Holcus 1* (holo: BM*, 000647533*), designated by Davidse in Cafferty, et al. (Taxon 49: 251. 2000).— Homotypic with *H. sorghum* L. through lectotypification, see also Wiersema & Dahlberg (Taxon 56: 943. 2007).

Holcus sorghum L., Sp. Pl.: 1047. 1753.— *Andropogon sorghum* (L.) Brot., Fl. Lusit. 1: 88. 1804; Roxb., Hort. Bengal.: 7. 1814, isonym.— *Panicum frumentaceum* Salisb., Prodr. Stirp. Chap. Allerton: 18. 1796, nom. superfl.— *Sorghum vulgare* Pers., Syn. Pl. 1: 101. 1805. nom. superfl.— *Andropogon vulgaris* Raspail, Ann. Sci. Nat. (Paris) 5: 307. 1825, nom. superfl.— [*Sorghum sorghum* (L.) H. Karst., Deut. Fl.: 357, t. 189. 1881, nom. inval.].— [*Andropogon sorghum* (L.) Brot. subsp. *sativus* Hack. in A. DC., Monogr. Phan. 6: 505. 1889, nom. inval.].— [*Andropogon sorghum* L. var. *vulgaris* Hack. in A. DC., Monogr. Phan. 6: 515. 1889, nom. inval.].— *Sorghum saccharatum* (L.) Moench var. *vulgare* Kuntze, Rev. Gen. Pl. 2: 793. 1891.— [*Rhaphis sorghum* (L.) Roberty, Petite Fl. Ouest-Afr.: 403. 1954, comb. inval.].— [*Sorghum halepense* (L.) Pers. subvar. *vulgare* Roberty, Boissiera 9: 304. 1960, comb. inval.].— Lectotype: Cultivated, *Herb. Clifford 468, Holcus 1* (holo: BM, no. *000647533*), designated by Davidse in Cafferty, et al. (Taxon 49: 251. 2000).— Homotypic with *H. bicolor* L. through lectotypification, see Wiersema & Dahlberg (Taxon 56: 943. 2007).

[*Holcus saccharatus* L., Sp. Pl.: 1047. 1753, excl. syn. Bauhin, Hermann; nom. rej.].— *Sorghum saccharatum* (L.) Moench, Methodus: 207. 1794; Pers., Syn. Pl. 1: 101. 1805; Host, Annal. Univ. Centr. Ecuador 4: 48. 1809, isonyms.— *Panicum sacchariferum* Salisb., Prodr. Stirp. Chap. Allerton: 18. 1796, nom. superfl.— *Sorghum bicolor* Moench var. *saccharatum* (L.) Pers., Syn. Pl. 1:101. 1805; Mohlenbr., Ill. Fl. Illinois : 192. 1973, isonym.— *Andropogon* *saccharatus* (L.) Roxb., Hort. Bengal.: 7. 1814 ('*saccharatum*'), pro comb.; Raspail, Ann. Sci. Nat. (Paris) 5: 307. 1825, isonym.— *Andropogon sorghum* (L.) Brot. var. *saccharatus* (L.) Alef., Landw. Fl.: 313. 1866; Körn. & Wern., Handb. Getreidebau 1: 310. 1885, isonym.— *Sorghum vulgare* Pers. var. *saccharatum* Boerl., Ann. Jard. Bot. Buitenzorg 8: 69. 1890.— *Sorghum halepense* (L.) Pers. var. *saccharatum* (L.) Goiran, Nuov. Giorn. Bot. Ital., n.s. 17: 39. 1910.— *Holcus sorghum* L. var. *saccharatus* (L.) L.H. Bailey, Gent. Herb. 1: 132. 1923.— [*Sorghum halepense* (L.) Pers. subvar. *saccharatum* (L.) Roberty, Boissiera 9: 303. 1960, nom. inval.]. — Lectotype: India, not designated.

Sorghum splendidum Snowden var. *magnum* Snowden, Bull. Misc. Inform. 1935: 234. 1935.— Type: Thailand, Seiracha, *Collins 1402* (holo: K; iso: BKF!).

Andropogon saccharatus auct. non Kunth: Roxb., Hort. Bengal.: 7. 1814 ('*saccharatum*'), pro specim.; Fl. Ind. 1: 274. 1820.— *Andropogon sorghum* (L.) Brot. var. *roxburghii* Hack. in A. DC, Monogr. Phan. 6: 510. 1889; in Schum. in Engl., Pflanzenw. Ost-Afr. 5 B: 48. 1895.— *Sorghum roxburghii* (Hack.) Stapf in Prain, Fl. Trop. Afr. 9: 126. 1917.— *Sorghum vulgare* Pers. var. *roxburghii* (Hack.) Haines, Bot. Bihar Orissa 5: 1034. 1925.— Type: India Orientalis, no Roxburgh drawing present (Stapf, 1917: 127).

Andropogon sorghum (L.) Brot. subvar. *splendidus* Hack. in A. DC., Monogr. Phan. 6: 510. 1889.— *Sorghum splendidum* (Hack.) Snowden, Bull. Misc. Inform. 1935: 233. 1935.— [*Sorghum halepense* (L.) Pers. subvar. *splendidum* (Hack.) Roberty, Boissiera 9: 304. 1960, comb. inval.].— Type: Hawaii, Honolulu, *Wawra* s.n. (holo: W).

Annuals, without rhizomes. *Culms* 80-100 cm high, erect, robust, nodes glabrous. *Leaf-sheaths* 10-16 cm; *ligules* membranous, 1-2 mm long; *leaf-blades* 20-40 by 2-2.5 cm, glabrous, base rounded, apex acuminate. *Inflorescences* oblong, 14-30 cm long. *Sessile spikelets* variable, broadly obovate to subglobose, 4-5 mm long (including callus); *lower glumes* ovate, 3.5-4 by 2-3 mm, 11- or 12-nerved, leathery, light green, pubescent on the back, apex acute and hyaline, winged in the upper part of the keels; *upper glumes* ovate, 4-5 by 1.5-3 mm, 9-nerved, 1-keeled near the tip, pubescent in the upper part of the back; *lower lemmas* ovate, 4.5 by 2 mm, 2- or 3-nerved, pubescent between keel and margin; *upper lemmas* ovate, 3-4 by 2 mm, 1-nerved, apex bifid; awned or awnless, awn straight or geniculate, 1-3 mm long; *upper palea*s linear, 2.5 by 0.3 mm long, apex rounded; *lodicules* 0.5 mm long; *anthers* 1.3-2.3 mm long. *Pedicelled spikelets* reduced, 4 mm long; pedicel c. 1 mm long; *lower glumes* lanceolate, 3-3.8 by 1.5 mm, 9-nerved, apex acute and hyaline, pubescent on the back, margin hyaline; *upper glumes* lanceolate, 1.5-2 by 1 mm, hyaline, apex acute. (**Figure 5.24**, **Figure 5.34C-D**)

Thailand.— NORTHERN: Chiang Mai [Wiang Pa Pao, Ban Pa Tad, 26 Jan. 1981, *Y. Paisooksantivatana* Y 585-81 (BKF); 10 Nov. 1914, *A.F.G. Kerr* 3447 (BM)]; CENTRAL: Bangkok [Garden, 2 Sep. 1923, *A. Marcan* 1454 (BM); Phrakhanong, 31 Dec. 1961, *A. Swasdibat* 146 (BCU); Kasetsart University, 1 Dec. 1962, *C. Promsakha* s.n. (BCU); 17 Oct. 1920, A.F.G. Kerr s.n. (BM)]; Nakhon Pathom [Kasetsart University, Kamphaengsaen, 3 Jul 2006, *O. Neamsuvan* 232 (BCU)]; Lop Buri [Sorghum field, Pattananikom district, 19 Dec 2004, *O. Neamsuvan* 169 (BCU)]; SOUTH-EASTERN: Chon Buri [Seiracha, *Collins 1402* (K, BKF)];

SOUTH-WESTERN: Kanchanaburi [Bo Phloi, 3 Dec 2006, *O. Neamsuvan* 246 (BCU)]

Distribution.— Originally from E Africa, now cultivated pan(sub)tropical elsewhere.

Ecology.— Cultivated in Northern, Central, and North-Eastern Thailand

Vernacular.— Khao pang nok (ข้าวป้างนก), Khao pang hang chang (ข้าวป้างหางช้าง), Khao fang samut khodom (ข้าวฟ่างสมุทรโคดม), Khao fang hang chang (ข้าวฟ่างหางช้าง), Samut khodom (สมุทรโคดม), Mok khodom (มกโคดม), Mut khodom (มุทโคดม)

Uses.— cultivated for fodder.

2. ***Sorghum halepense*** (L.) Pers, Syn. Pl. 1: 101. 1805.— *Holcus halepensis* L., Sp. Pl. 2: 1047. 1753.— *Milium halepense* (L.) Cav., Descr. Pl.: 306. 1802.— *Blumenbachia halepensis* (L.) Koeler, Descr. Gram.: 29. 1802.— *Andropogon halepensis* (L.) Brot., Fl. Lusit. 1: 89. 1804.— [*Andropogon halepensis* (L.) Brot. var. *genuinus* Stapf in Hook. f., Fl. Brit. India 7: 183. 1896, nom. inval.].— [*Andropogon halepensis* (L.) Brot. var. *typicus* Aschers. & Graebn., Syn. Mitteleur. Fl. 2, 1: 47. 1898, nom. inval.]— [*Andropogon sorghum* (L.) Brot. subsp. *halepensis* & var. *halepensis* (L.) Hack. in A. DC., Monogr. Phan. 6: 501. 1889, incl. subvar. *genuinum* Hack., nom. inval.].— [*Rhaphis halepensis* (L.) Roberty, Petite Fl. Ouest-Afr.: 403. 1954, nom. inval.].— *Sorghum saccharatum* (L.) Moench var. *halepense* (L.) Kuntze, Rev. Gen. Pl. 3: 368. 1898.— Lectotype: Mauretania / Syria, *Herb. Linn.* 1212.7 (holo: LINN!), designated by Meikle (Fl. Cyprus 2: 1869. 1985).

[*Andropogon miliaceus* Roxb., Hort. Beng.: 7, nom. inval. (“*miliaceum*”), Fl. Ind. 1: 276. 1820.].— *Sorghum miliaceum* (Roxb.) Snowden, J. Linn. Soc. Bot. 5: 205. 1955.— Type: Cultivated in Calcutta, extant?; *Icon. Ined. 1717* (CAL, K).

Perennials, rhizomatous. *Culms* erect, up to 2 m high, nodes shortly pubescent, prop roots at lower node. *Leaf-sheaths* 12-20 cm long; *ligules* fringed, membranous, 2 mm long, collars pubescent; *leaf-blades* 20-90 by 1-3 cm, glabrous, apex long-acuminate, base tapering to obtuse. *Inflorescence* large, open, c. 10-25 cm long. *Sessile spikelets* ovate-oblong to ovate-lanceolate; *lower glumes* oblong to lanceolate, 4-5 by 2.5-3 mm, 9-nerved with distinct at upper part, distinct tessellate nerves, yellowish, shinny, pubescent on the back, apex minutely 3-dentate; *upper glumes* oblong to lanceolate, 4-5 by 2-2.5 mm, 7-nerved with distinct at upper part, 3-keeled near the tip, yellowish, pubescent on the back, apex acute; *lower lemmas* oblong, 3.5-4 by 1.1-1.5 mm, 2-nerved, glabrous, apex obtuse; *upper lemmas* ovate, c. 2.5 by 1 mm, glabrous, apex bifid, awned or awnless, awn 0-13 mm long; *upper paleas* lanceolate, 2 by 0.5 mm long, apex acute; *lodicules* 0.2-0.3 mm long; *anthers* 2 mm long. *Pedicelled spikelets* lanceolate; pedicel c. 2 mm long; *lower glumes* oblong to lanceolate, 4.5-5.5 by 1.5-2 mm, 7 nerved, 2-keeled, purplish, sparsely hairy on the back, apex acute, margin ciliolate; *upper glumes* oblong to lanceolate, convex at the back, 4-5 by 1.5-2 mm, 5-nerved, chartaceous, apex acute, margin inflexed and ciliolate; *lower lemmas* lanceolate, 4-4.5 by 1 mm, hyaline, glabrous, apex acute, margin inflexed, ciliolate; *upper lemmas* ovate, 2.5-3 by 1-1.5 mm, hyaline, glabrous, apex acute to obtuse, margin ciliolate; *upper paleas* linear, c. 2 by 0.2 mm, hyaline, glabrous, apex obtuse, margin on the upper part ciliate; *lodicules* 0.2-0.3 mm long; *anthers* 2.5 mm long. (**Figure 5.25**)

Thailand.— NORTHERN: Chiang Mai [4 Sep. 1911, *A.F.G. Kerr* 2004 (BM)]; CENTRAL: Bangkok [29 Oct. 1922, *A. Marcan* 1036 (BM)]; SOUTH-WESTERN: Kanchanaburi [Sisawat, 26 May 1987, *Y. Paisooksantivatana & P. Sangkhachand* 2074-87 (BK)].

Distribution.— Originally from the East Mediterranean, now widely introduced elsewhere.

Ecology.— Open and moist areas.

Vernacular.— Ya pong (หญ้าปง), Ya phong (หญ้าพง).

Note.— The hybrid with *S. bicolor* is *S.* × *almum* Parodi, a widespread noxious weed that might be expected in Thailand. The sessile spikelets are 2-2.8 mm wide, lower glumes 13-15-nerved, pedicelled spikelets subpersistent, which, if they do drop off, have part of the pedicel attached.

3. *Sorghum nitidum* (Vahl) Pers., Syn. Pl. 1: 101. 1805.— *Holcus nitidus* Vahl, Symb. Bot. 2: 102. 1791.— *Anatherum nitidum* (Vahl) Spreng., Syst. 1: 290. 1824.— *Andropogon nitidus* (Vahl) Kunth, Révis. Gramin. 1: 166. 1829.— *Andropogon serratus* Thunb. var. *nitidus* (Vahl) Hack. in A. DC., Monogr. Phan. 6: 521. 1889. — [*Sorghum serratum* Kuntze var. *nitidum* (Vahl) Domin, Biblioth. Bot. 85: 270. 1915, nom. inval, contra prior.].— [*Holcus fulvus* R. Br. var. *nitidus* (Vahl) Honda, Bot. Mag. (Tokyo) 40: 101. 1926, nom. inval, contra prior.].— *Andropogon amboinicus* (L.) Merr. var. *nitidus* (Vahl) Backer, Handb. Fl. Java 2: 99. 1928.— Type: India, *Koenig* s.n. (holo: ?C)

Andropogon serratus Thunb. in Murr., Syst. Veg., ed. 14: 903. May-Jun 1784; Fl. Jap.: 41. 1784.— *Andropogon laxus* Willd., Sp. Pl., ed. 4, 4: 907. 1806, nom. superfl.— *Sorghum serratum* (Thunb.) Kuntze, Rev. Gen. 2: 792. 1891, non Roem. & Schult (1817); Stapf in Gibbs, J. Linn. Soc., Bot. 42: 188. 1914, isonym.— [*Andropogon serratus* Thunb. var. *genuinus* Hack. & subvar. *parviflorus* Hack. in A. DC., Monogr. Phan. 6: 521. 1889, both nom. inval.].— [*Sorghum nitidum* (Vahl) Pers. var. *parviflorum* Ohwi, Bull. Tokyo Sci. Mus. 18: 4. 1947, nom. inval.].— [*Sorghum serratum* (Thunb.) Kuntze var. *genuinum* A. Camus, Bull. Mus. Hist. Nat. (Paris) 31: 329. 1925, nom. inval.].— *Sorghum nitidum* (Vahl) Pers. forma *aristatum* C.E. Hubb. in Hooker's Icon.: t. 3364, p. 5. 1938.— [*Sorghum nitidum* (Vahl) Pers. var. *serratum (Thunb.)* Roberty, Boissiera 9: 300. 1960, nom. inval.].— Type: *Herb. Thunberg 23910* (holo: UPS, microfiche IDC 1036).

Holcus fulvus R. Br., Prodr.: 199. 1810.— *Sorghum fulvum* (R. Br.) P. Beauv. ex Roem. & Schult, Syst. Veg. 2: 840. 1817.— *Andropogon tropicus* Spreng., Syst. Veg. 1: 287. 1825, non *Andropogon fulvus* Spreng. (1815).— *Sorghum tropicum* (Spreng.) Büse, Pl. Jungh.: 359. 1854, nom. superfl.—[*Holcus fulvus* R. Br. var. *genuinus* Honda, Bot. Mag. (Tokyo) 40: 101. 1926, nom. inval.].— Type: Australia, *R. Brown* 6191 (iso: K!).

Sorghum burmahicum Raizada, Indian Forester 83: 315. 1957.— Type: Burma, *C.E. Parkinson* 15608 (holo: DD).

Perennial, tufted, without rhizomes. *Culms* erect, or weakly geniculate below, 1.5-2 m long, nodes bearded. *Leaf-sheaths* 10-20 cm long; *ligules* membranous, ciliate on the back, 1-3 mm long; *leaf-blades* 40-60 by 0.5-1 cm, glabrous or hairy on both surfaces, base tapering, apex long-acuminate. *Inflorescence* open, lanceolate, up to 30 cm long, –racemes bearing 2-8 spikelet pairs; joints and pedicels with brown ciliate on both margins. *Sessile spikelets* elliptic to oblong, c. 3.5 mm long (including callus); callus covered by brownish hairs, brownish pubescent on the back; *lower glumes* elliptic to oblong, 3.5 by 1.2-1.5 mm, 7-nerved, brownish, brown pubescent on the back, apex acute; *upper glumes* boat-shaped, 3-4 by 1.5 mm long, 3-nerved, coriaceous and thinner above, brownish, shiny, brownish pubescent on the upper part of the back, apex acute; *lower lemmas* lanceolate, 2.5-3 by 1-1.2 mm, 2-nerved, brownish, apex acute to obtuse; *upper lemmas* obovate, 1.5-2.5 by 1-3 mm, 1-nerved, apex acute without an awn, or apex bifid with awn; awn 1.7-2 cm long, geniculate, twisted; *upper palea* absent; *lodicules* 0.2 mm long; *anthers* 2.5-3.5 mm long. *Pedicelled spikelets* oblong; callus short, covered by brownish hairs; pedicel 3 mm long, brownish hairy on both margins; *lower glumes* ovate to oblong, 3.5-3.8 by 1-1.2 mm, 7-nerved, lower part brownish, upper part light green, brownish pubescent on the back, apex acute; *upper glumes* lanceolate, 3-3.5 by 1-1.2 mm, 5-nerved, chartaceous, upper part light green, lower part brownish, glabrous to brownish hairy on lower part of the back, apex acute, margin inflexed; *lower lemmas* lanceolate, 2.8-3.2 by 0.6-1 mm, 2-nerved, hyaline, apex acute, margin inflexed and ciliolate; *upper lemmas* obovate-lanceolate, 2.5-3 by 0.5-0.7 mm, hyaline, apex acute to obtuse, margin ciliolate in the upper part; *upper paleas* absent; *anthers* 2.3 mm long. (**Figure 5.26, Figure 5.35A-C**)

Thailand.— NORTHERN: Mae Hong Son [Pai, 13 Nov. 1992, *M. Balick* and *W. Nanakorn* 3457 (C, AAU)]; Chiang Mai [Doi Suthep, 9 Nov. 1911, *A.F.G. Kerr* 2215 (K, BM); Daht Mawk Falls, north part of Doi Sutep-Pui National Park, 5 December 1989, *J.F. Maxwell* 89-1504 (L); Doi Saget, Huai Hong Khrai Royal Development Project, 8 Nov. 1993, *S. Suwannaratana* 31 (CMU, L); Doi Chiang Dao Animal Sanctuary, 15 Dec. 1990, *J.F. Maxwell* 90-1362 (L, AAU); Doi Chiang Dao, 10 Nov. 1922, *A.F.G. Kerr* 6656 (K, BM); Jawm Tong, Ban Huay Nam Kao, Yahng Krahm Subdistrict, 3 Dec. 1991, *J.F. Maxwell* 91-1084 (L, AAU); Jawm Tong, 14 Nov. 1992, *J.F. Maxwell* 92-731 (CMU, P, L); Mae Soi Valley, Jawm Tong, 5 Jan. 1991, *J.F. Maxwell* 91-49 (L, AAU); Doi Chiang Dao, 30 Dec. 1961, *K. Bunchuai* 1280 (K); Nov. 1986, *C. Phengklai & T. Smitinand* 3067 (BKF, K, AAU); Doi Suthep, 23 Dec. 1912, *A.F.G. Kerr* 2813 (K, BM); Mae Tang, 13 Nov. 1922, *A.F.G. Kerr* 6668 (K, BM); Keng Lah Et, 7 Dec. 1909, *A.F.G. Kerr* 907 (K, BM, P); along road Mae Rim-Samoeng, 12 Oct. 2001, *S. Lægaard* 21703 (K, AAU)]; Chiang Rai [Wiang Pa Pao, 24 Feb 2005, *O. Neamsuvan* 186 (BCU)]; Lampang [Mae Wa National Park, 29 Oct 2004, *O. Neamsuvan* 164 (BCU); Chae Son National Park, 19 Jan. 1914, *A.F.G. Kerr* 3112 (K); Khun Tan, 4 Sep. 1967, *M. Tagawa, K. Iwatsuki, H. Koyama, N. Fukuoka, A. Nalampoon* and *A. Chintayungkun* T-9192 (BKF, K, C); Doi Palad, 26 Sep 1967, *T. Shimizu, H. Koyama* and *A. Nalampoon* T-10838 (K); Ngao Mae Huat, 26 May 1954, *T. Smitinand* 1612 (K)]; Tak [Ban Na, 120 m alt, 10 Nov. 1959, *Pleonchit* 419 (BCU)]; Phayao [Muaeng, 13 Jul. 1931, *Put* 3993 (K, BM); Doi Luang National Park, 26 Jan. 1999, *O. Petrmitr* 428 (CMU, L)]; Phrae [Mae Yom National Park, 8 Dec. 1993, *J.F. Maxwell* 93-1454 (CMU, L); Nakhon Sawan [21 Jul. 1973, *G. Murata, N. Fukuoka* and *C. Phengklai* T-16579 (K, L); c. 10 km north-west of Nakhon Sawan, 21 Jul. 1973, *G. Murata, N. Fukuoka* and *C. Phengklai* T-16581

(BKF, L)]; Lamphun [Doi Kuhn Dahn National Park, 19 Jul. 1993, *J.F. Maxwell* 93-809 (BKF, CMU, L); Thoern, 19 Aug. 1995, *Parnell, Pendry, Jebb* and *Pooma* 95-245 (BKF, K, L, AAU, TCD)]; NORTH-EASTERN: Phetchabun [Nam Nao National Park, 2 Jan 2007, *O. Neamsuvan* 250 (BCU)]; Loei [Phu Kradueng, 16 Oct. 1954, *T. Smitinand* 2036 (K)], Nong Khai [7 December 1924, *A.F.G. Kerr* 8944 (K, BM)], Khon Kaen [Phu Khieo, 7 Nov. 1984, *G. Murata* et al. T-41625 (BKF)]; EASTERN: Nakhon Ratchasima [Pak Thong Chai, 3 Nov. 1970, *Ch. Charoenphol, K. Larsen* and *E. Warncke* 4517 (BKF, K, P, C, AAU); Hui Taleng, 21 Dec. 1928, *Put* 2178 (K, BM)]; SOUTH-EASTERN; Sa Kaeo [Banbeng, Krabinburi, 10 Nov. 1930, *A. Marcan* 2595 (K, BM, P, L)]; Chachoengsao [Ang Rue Nai, 7 Sep 2005, *O. Neamsuvan* 216 (BCU)]; CENTRAL: Saraburi [Sahm Lahn forest, 30 Jun. 1974, *J.F. Maxwell* 74-643 (L, AAU)], Lopburi [Chai Badan, 14 Dec. 1923, *A.F.G. Kerr* 8010 (BKF, K)]; SOUTH-WESTERN: Kanchanaburi [Khao Salop National Park, 18 Nov. 1970, *M. Lazarides* 7418 (BKF, K, L, C); about 17 Km north of Kanchanaburi, 17 Nov. 1970, *M. Lazarides* 7403 (BKF, K, L, C)], Phetchaburi [Bo Fai, 8 Nov. 1931, *A. Marcan* 2726 (K)], Prachuap Khiri Khan [Pranburi, 27 Nov. 1929, *Put* 2469 (K, BM); Hua Hin, 11 Nov. 1968, *A.F.G. Kerr* 16212 (K, BM)]; CENTRAL: Sukhuthai [3 May 1979, *T. Koyama, C. Phengklai, C. Niyomdham, M. Tamura, H. Okada* and *P.J. O' Connor* 15655 (AAU)]

Distribution.— Sri Lanka, Bhutan, India to SE China, S Ryu-kyu, Australia (Queensland).

Ecology.— Sunny to lightly shaded, dry or barren soil, open grass fields and scrub, savannas, teak forests, roadsides, locally abundant.

Vernacular.— Ya hang ma (หญ้าหางหมา), Ya khao niew (หญ้าข้าวเหนียว), Yaa met dum (หญ้าเม็ดดำ)

4. *Sorghum propinquum* (Kunth) Hitchc., Lingnan Sci. J. 7: 249. 1931.— *Andropogon affinis* J. Presl in C. Presl, Reliq. Haenk. 1: 343. 1830., non R. Br. (1810).— *Andropogon propinquus* Kunth, Enum. Pl. 1: 502. 1833.— *Andropogon halepensis* (L.) Brot. var. *propinquus* (Kunth) Hack., Bot. Jahrb. Syst. 6: 239. 1885.; Merr., Philipp. J. Sci. 1, Suppl. 5: 336. 1906, isonym.— *Andropogon sorghum* (L.) Brot. var. *propinquus* Hack. in A. DC., Monogr. Phan. 6: 503. 1889.— *Sorghum affine* A. Camus, Fl. Indo-Chine 7. 321. 1922., non Kuntze (1891), nom. superfl.— *Sorghum halepense* (L.) Pers. var. *propinquum* Ohwi, Bot. Mag. (Tokyo) 55: 550. 1941.— [*Sorghum halepense* (L.) Pers. subvar. *affine* Roberty, Boissiera 9: 302. 1960, comb. inval.].— *Sorghum bicolor* (L.) Moench 'race *propinquum*' J.R. Harlan & De Wet, Crop. Sci. 12: 173. 1972.— Type: *Haenke* s.n. (holo: PR).

KEY TO THE VARIETY

1. Sessile spikelet elliptic, 4-4.5 mm long ……………..…...….. a. var. *propinquum*
1. Sessile spikelet oblong, ovate-oblong, 4.5-5.5 mm long ……. b. var. *siamensis*

a. *Sorghum propinquum* var. *propinquum*

Perennials, rhizome elongated. *Culms* erect, 200-300 cm high, nodes shortly pubescent; *leaf-sheaths* 13-30 cm long; *ligules* fringed, membranous, 1.5-2 mm long, collars pubescent; *leaf-blades* 60-90 by 1-4 cm, glabrous, apex long-acuminate, base tapering to obtuse. *Inflorescence* large, open, c. 20-40 cm long, racemes 4-10 cm long. *Sessile spikelets* elliptic, c. 4-4.5 mm long (including callus); *lower glumes* ovate-oblong, c. 4 by 2.5 mm, 10-nerved, non distinct tessellate nerves, greenish yellow, pubescent on the back, apex acute; *upper glumes* ovate-oblong, 4-4.3 by 1-1.2 mm, 8-nerved, greenish yellow, pubescent, apex acute; *lower lemmas* oblong, 3.5 by 1-1.2 mm, 2-nerved, glabrous, apex acute; *upper lemmas* ovate, c. 2.5 by 1.5 mm, 1-nerved, glabrous, apex acute, awnless, margin entire; *upper paleas* lanceolate, 1.5 mm long, apex acute; *anthers* 3 mm long. *Pedicelled spikelets* 4.8-5 mm long (including callus); callus very short, covered by short hairs; pedicels c. 2 mm long; *lower glumes* ovate-lanceolate, 4.2-4.5 by 1.5 mm, 9-nerved, glabrous, apex acute, margin distally ciliolate; *upper glumes* ovate-oblong, 4.5 by 1.5 mm, 7-nerved, chartaceous, glabrous, apex mucronate, margin inflexed and ciliate; *lower lemmas* oblong, 3.5 by 1.2 mm, 2-nerved, hyaline, glabrous, apex acute, margin inflexed, ciliolate; *upper lemmas* ovate, 2.5 by 1 mm, 1-nerved, hyaline, glabrous, apex obtuse, margin ciliolate; *lower paleas* linear, 1.2 mm long, hyaline, margin distally ciliolate; *lodicules* 0.1 mm long; *anthers* 2 mm long.

Thailand.— NORTHERN: Chiangrai [Mae Sai, Doi Pha Mee, 22 Jan 1981, Y. Paisooksantiwattana 518-81(BK)]; Uttaradit [km 50 on road 11 south of Uttaradit, 30 Oct. 2001, *S. Lægaard* and *M. Norsangsri* 21886 (AAU); CENTRAL: Bangkok [Yommaratch railway station, 15 Oct. 2006, *O. Neamsuvan* 239 (BCU)]; Kamphaeng Phet [roadside from Kamphaeng Phet to Nakhon Sawan, 2 Mar. 2005, *O. Neamsuvan* 195 (BCU)]

Distribution.— S India, Sri Lanka to S China and Palau Isl.; wide-spread in Malesia, introduced elsewhere.

Ecology.— Sunny to lightly shaded, barren localities in grass jungles, thickets, teak forests.

Vernacular.— Ya phong (หญ้าพง)

b. *Sorghum propinquum* (Kunth) Hitchc. var. *siamense* (Piper) Snowden, J. Linn. Soc. London, Bot. 55: 214. 1955.— *Andropogon halepensis* (L.) Brot. var. *siamensis* Piper, Proc. Biol. Soc. Washington 28: 30. 1915.—Type: Thailand, Northern, Kamphaeng Phet, *A.F.G. Kerr* 2156 (holo: K!; iso: BM!)

This taxon differs from *S. propinquum* var. *propinquum* by its sessile spikelet is oblong or ovate-oblong and 4.5-5.5 mm long, while it is elliptic and 4-4.5 mm long in *S. propinquum* var. *propinquum*. (**Figure 5.27, Figure 5.35D**)

Thailand.— NORTHERN: Lamphun [east bank of the Ping River, Tah Sai, Wahng Sah Gahng Village, 6 Feb. 1999, *J.F. Maxwell* 99-58 (CMU, L), Uttaradit [Ban Bak Klong, Pichai, 20 Oct. 1992, *J.F. Maxwell* 92-631 (CMU, L, AAU); Sukhothai [Sawankhaloke, 24 Nov. 1969, *D.E. Parry* 10 (K); North of Sukhothai, between Sukhothai and Swankhaloke, 28 Jul. 1973, *G. Murata* T-17020 (L); roadside, 3 May 1979, *T. Koyama* et al. 15655 (BKF, AAU)], Nakhon Sawan [Pak Nam Pho, 4 Dec. 1957, *T. Smitinand* 3886 (BKF, K); 10 km north-west of Nakhon Sawan, 21 Jul.

1973, G. Murata, N. Fukuoka and C. Phengklai T-16584 (BKF, P); Ban Nong Bane, 12 Jan 82, *Y. Paisooksantiwattana* 780A-82 (BK)]; Kamphaeng Phet [11 Oct. 1911, *A.F.G. Kerr* 2156 (BM, K)]; CENTRAL: Ang Thong [behind Tawng Koong Temple, 15 Aug. 1971, *J.F. Maxwell* 71-484 (BKF, L); Bangkok [Kasetsart University, 1 Dec. 1963, *C. Promsakha* 82 (BCU)]; Chainat [Manorom, 19 Sep. 1930, *A.F.G. Kerr* 19671 (BK, K)]; Lop Buri [along road, 23 Sep. 1971, G. Murata, K. Iwatsuki and C. Phengklai T-14817 (BKF, L)], Ayutthaya [Bang Pa In, 23 Oct. 1924, *A.F.G. Kerr* 9337 (K, BK)], Bangkok [Bangkhen, 1 Sep. 1955, *K. Suvatabandhu* s.n. (BK); 25 Jul. 1920, *A.F.G. Kerr* 4358 (K, BM, C)]

Distribution.—S India, Sri Lanka, to Thailand

Notes.— Maxwell's specimens number 71-484 was identified as *S. miliaceum* but it was determined as *S. propinquum var. siamensis* by this study.

This species is very similar to *S. halepense*, which has ovate sessile spikelets and the apex of lower glume of sessile spikelet is clearly 3-denticulate, while in *S. propinquum* the sessile spikelet is ellipsoid and the apex of the lower glume is acute.

Sorghum propinquum has fully fertile hybrids with *S. bicolor* which are obnoxious weeds at least in the Philippines (De Wet, 1978) and so may be expected in Thailand.

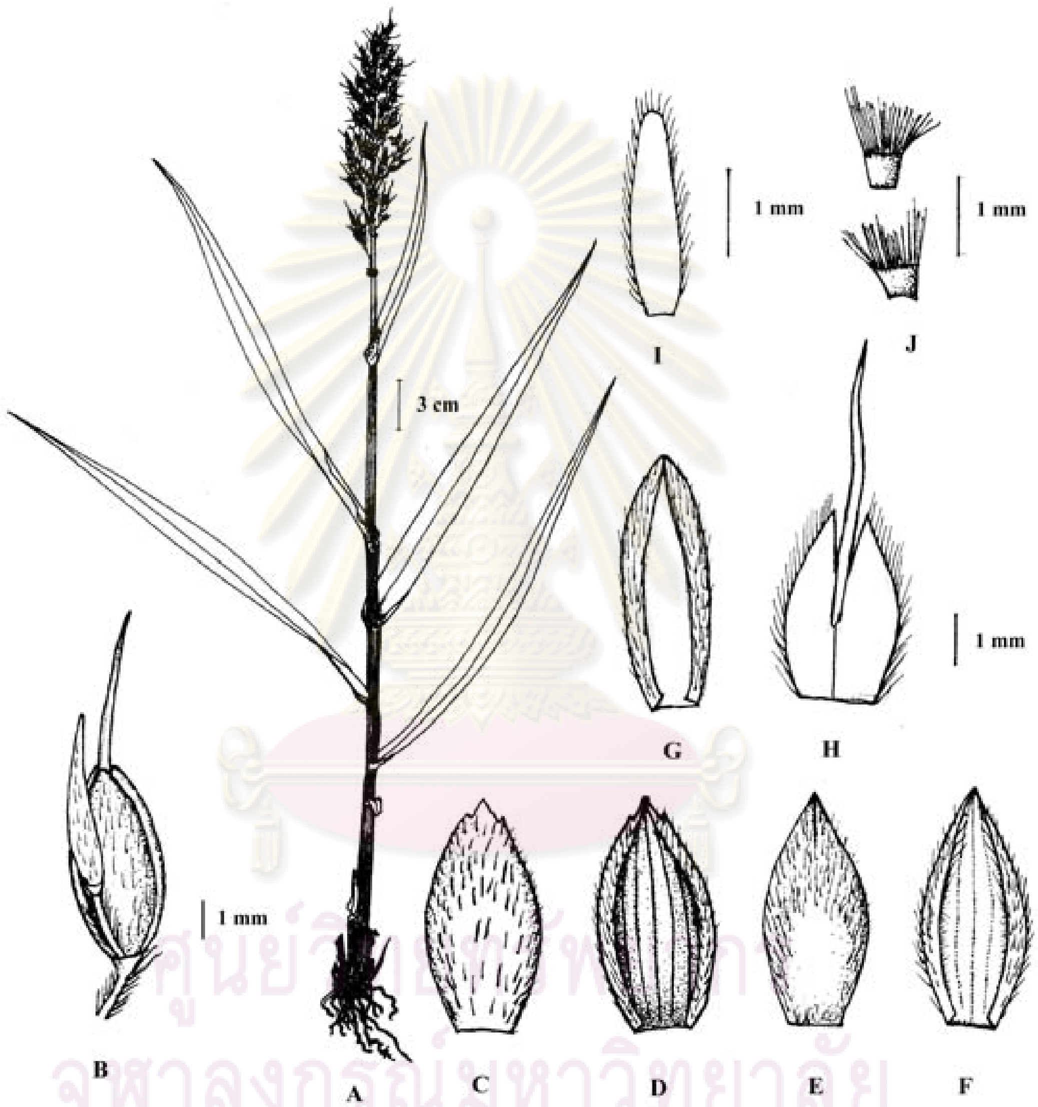

Figure 5.24 *Sorghum bicolor*: A. habit. B. spikelet pair. C.-J. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma; I. upper palea; J. *lodicules*.

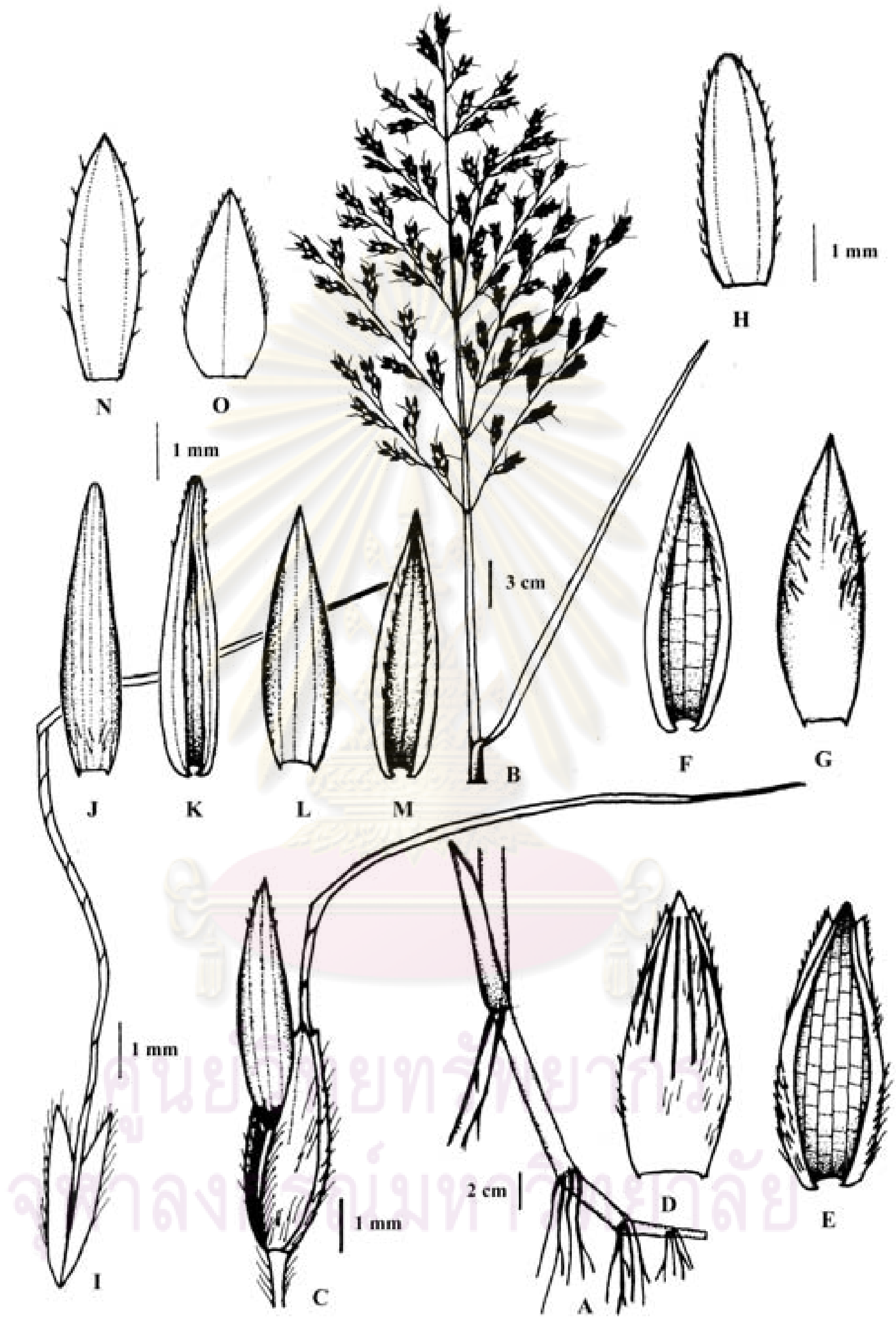

Figure 5.25 *Sorghum halepense*: A. habit. B. inflorescence. C. spikelet pair. D.-I. sessile spikelet: D.-E. lower glume; F.-G. upper glume; H. lower lemma; I. upper lemma. J.-O. pedicelled spikelet: J.-K. lower glume; L.-M. upper glume; N. lower lemma; O. upper lemma.

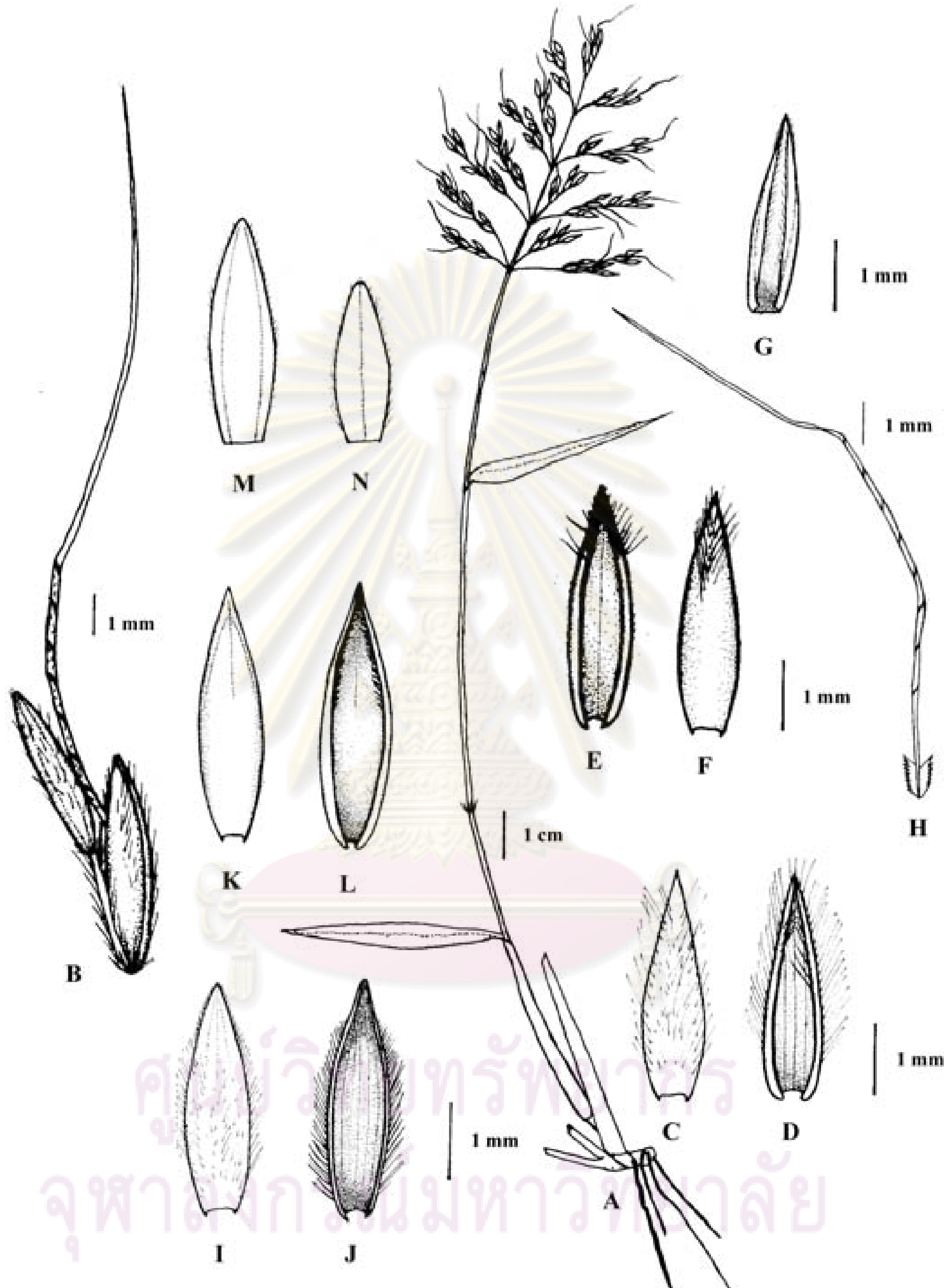

Figure 5.26 *Sorghum nitidum*: A. habit. B. spikelet pair. C.-H. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma. I.-N. pedicelled spikelet: I.-J lower glume; K.-L. upper glume; M. lower lemma; N. upper lemma

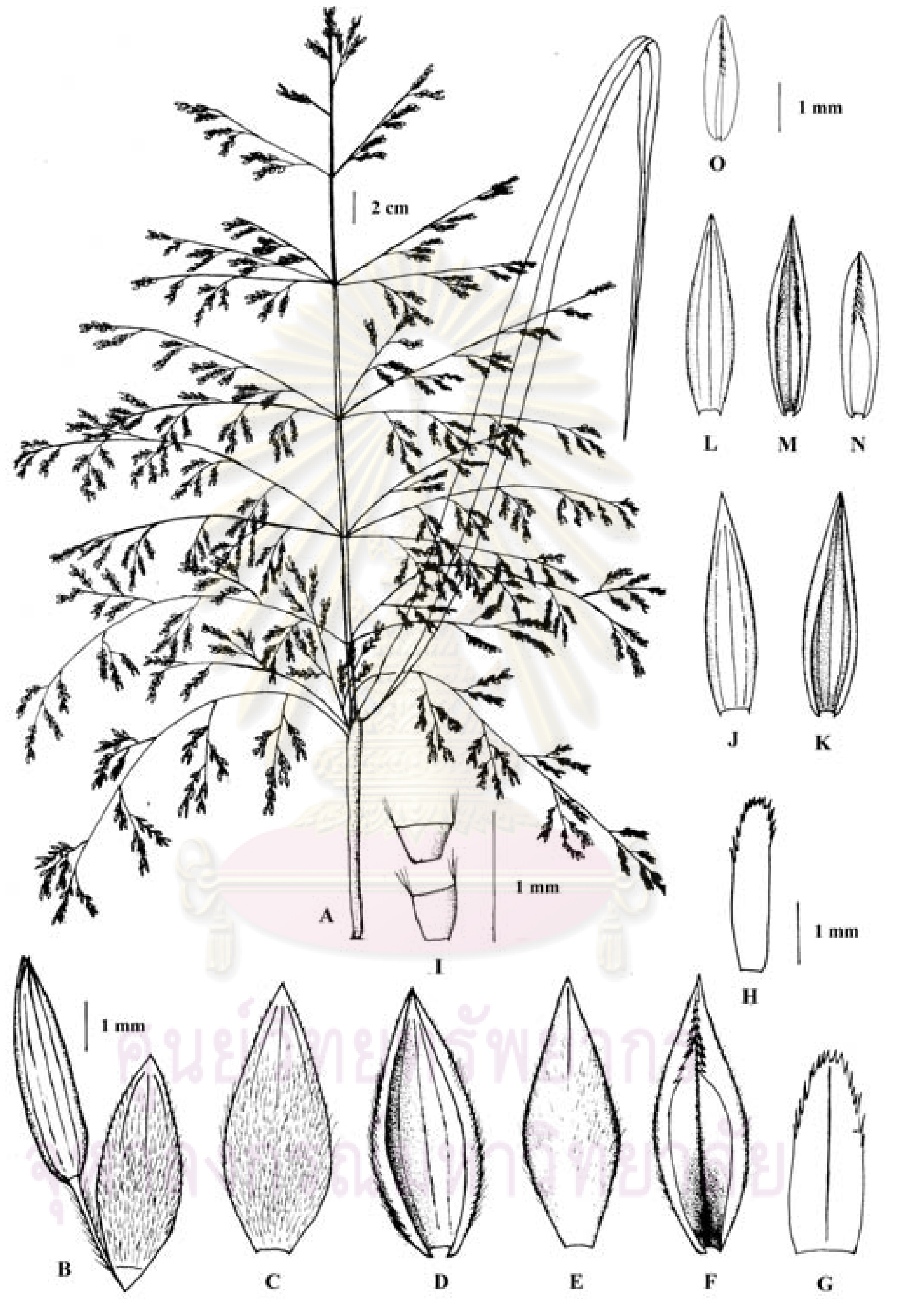

Figure 5.27 *Sorghum propinquum* var. *siamense*: A. Inflorescence. B. spikelet pair. C.-I. sessile spikelet: C.-D. lower glume; E.-F. upper glume; G. lower lemma; H. upper lemma; I. lodicules. J.-O. pedicelled spikelet: J.-K. lower glume; L.-M. upper glume; N. lower lemma; O. upper lemma.

5.4 Discussion and Conclusion

Comparison with previous works

The species enumeration of the subtribe Sorghinae in Thailand was estimated to be about 39 species in 8 genera by Nanakorn & Norsangsri (2001): *Bothriochloa* (5 species), *Capillipedium* (5 species), *Chrysopogon* (6 species), *Dichanthium* (7 species), *Hemisorghum* (1 species), *Pseudosorghum* 2 species), *Sorghum* (11 species), and *Vetiveria* (2 species). Interestingly, only 29 species (3 *Bothriochloa*, 7 *Capillipedium*, 9 *Chrysopogon*, 4 *Dichanthium*, 1 *Hemisorghum,* 1 *Pseudosorghum*, and 4 *Sorghum* were found in the present work (Table 5.1). The difference in species numbers in this subtribe is due to new taxonomic insights and consequently changes in nomenclature.

Comparison to the previous works (Table 5.1), there are 3 taxa which are additionally reported from this study, namely *Chrysopogon gryllus* subsp. *gryllus*, *Capillipedium* sp. 1 and *Capillipedium* sp. 2. Four misidentified taxa are found in this study, including *Chrysopogon nemoralis, Bothriochloa insculpta, Dichanthium polyptichum* and *Sorghum miliaeuum*. *Chrysopogon zeylanicus, Sorghum saccharatum* (synonym of *S. bicolour*) and *S. splendidum* (synonym of *S. bicolour*) were noted by Nanakorn & Norsangsri (2001), but no specimens under these names were deposited in any herbaria in Thailand nor abroad. Moreover, *D. siamensis* was a name labelled on *D. mucronulatum* sheath, but it was not published.

New species and a new record

A new recorded species was reported, *Chrysopogon gryllus* subsp. *gryllus*. It was found from 3 localities: Doi Luang National Park, Lampang; Phu Chi Fa Wildlife Reserve, Chiang Rai; Pha Taa Lern, Phuluang National Park, Loei.

Two new species from *Capillipedium* were present: *C.* sp1. from Samila beach, Songkhla and *C.* sp. 2 from Sam Lan National Park, Saraburi.

Lectotypification

Lectotypes were designated in this study for *Andropogon capilliflorus* (synonym of *Capillipedium parviflorum*) and *Hemisorghum mekongense*. In addition, *Andropogon laguroides* (=*Bothriochloa laguroides*) was selected as type species of *Andropogon* L. sect. *Amphilophis* (synonym of *Bothriochloa*)]

Ecology and Distribution

Most species inhabit in open area, except species in *Capillipedium* which both in shaddy and exposed area. Along road and open field are common habitats for all genera. By the sea is favorite for *Chrysopogon orientalis*, however it well grow in dipterocarp forest as well. *Chrysopogon festucoides*, *Chrysopogon zizanioides* and *Hemisorghum mekongense* are naturally inhabiting along river banks or swampy areas.

Considering distribution, some species are common throughout Thailand, namely *Bothriochloa bladhii*, *B. pertusa*, *Dichanthium annulatum*, *D. caricosum*, *Chrysopogon aciculatus* and *C. zizanioides*. This is because they can survive all seasons throughout years. While some species can be found in all parts of Thailand except Southern Thailand, such as the genus *Hemisorghum*, *Pseudosorghum*, *Sorghum* and most species in *Capillipedium*. This is because most grass genera are annual or perennial plants that their life cycle relates to cool temperature in winter season. In summer, seeds of annual or perennial grasses germinate or perennial grasses produce their vegetative part from rhizome and fully developed in rainy season. In the end of rainy season to winter, i.e. October to February, their flowers are produced and then die around the end of winter. Since no cool temperature in winter in Southern Thailand, so the grasses that require low temperature for flowering cannot survive here.

Some species are endemic to some area such as *Capillipedium* sp.1 endemic to Samila Beach in Songkhla Province, *Capillipedium* sp.2 endemic to rocky area in Bamboo forest in Saraburi Province, *Dichanthium mucronulatum* endemic to South-Western Thailand, *Chrysopogon lawsonii* endemic to Northern Thailand, *C. perlaxus* endemic to Chon Buri, and *Hemisorghum Mekongense* endemic to Me Khong River. This may be that these species are specific to certain habitat types.

Figure 5. 28 A.-B. *Bothriochloa bladhii*: A. habitat, B. inflorescence
C.-D. *Bothriochloa pertusa*: C. habitat, D. young inflorescence

Figure 5. 29 A. *Capillipedium assimile* inflorescence
B. *Capillipedium laoticum* inflorescence
C. *Capillipedium parviflorum* inflorescence
D. *Capillipedium sulcatum* inflorescence

Figure 5. 30 A.-B. *Chrysopogon aciculatus*: A. habitat, B. inflorescence
C.-D. *Chrysopogon fulvus*: C. habitat, D. inflorescence

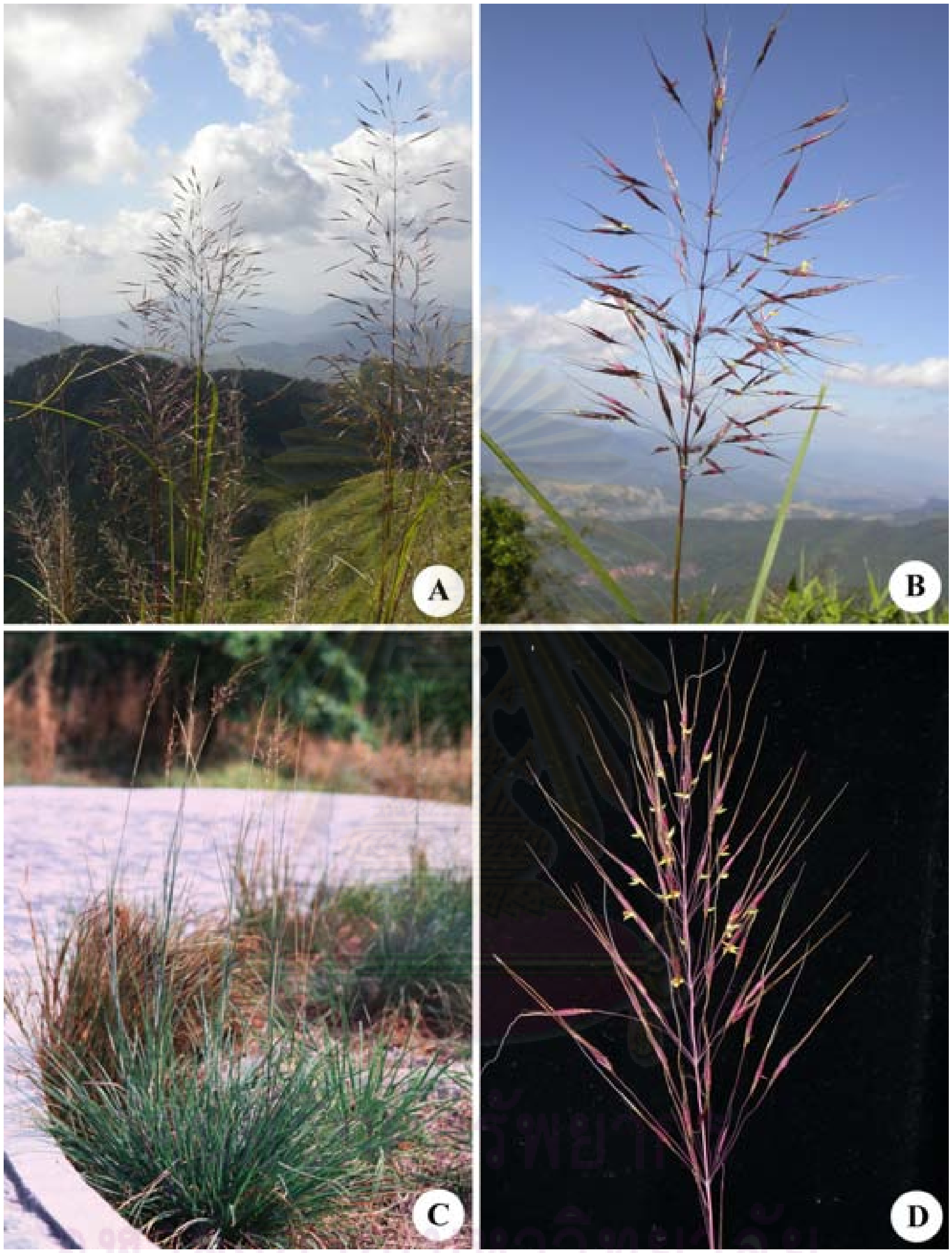

Figure 5. 31 A.-B. *Chrysopogon gryllus*: A. habitat, B. inflorescence
C.-D. *Chrysopogon orientalis*: C. habitat, D. inflorescence

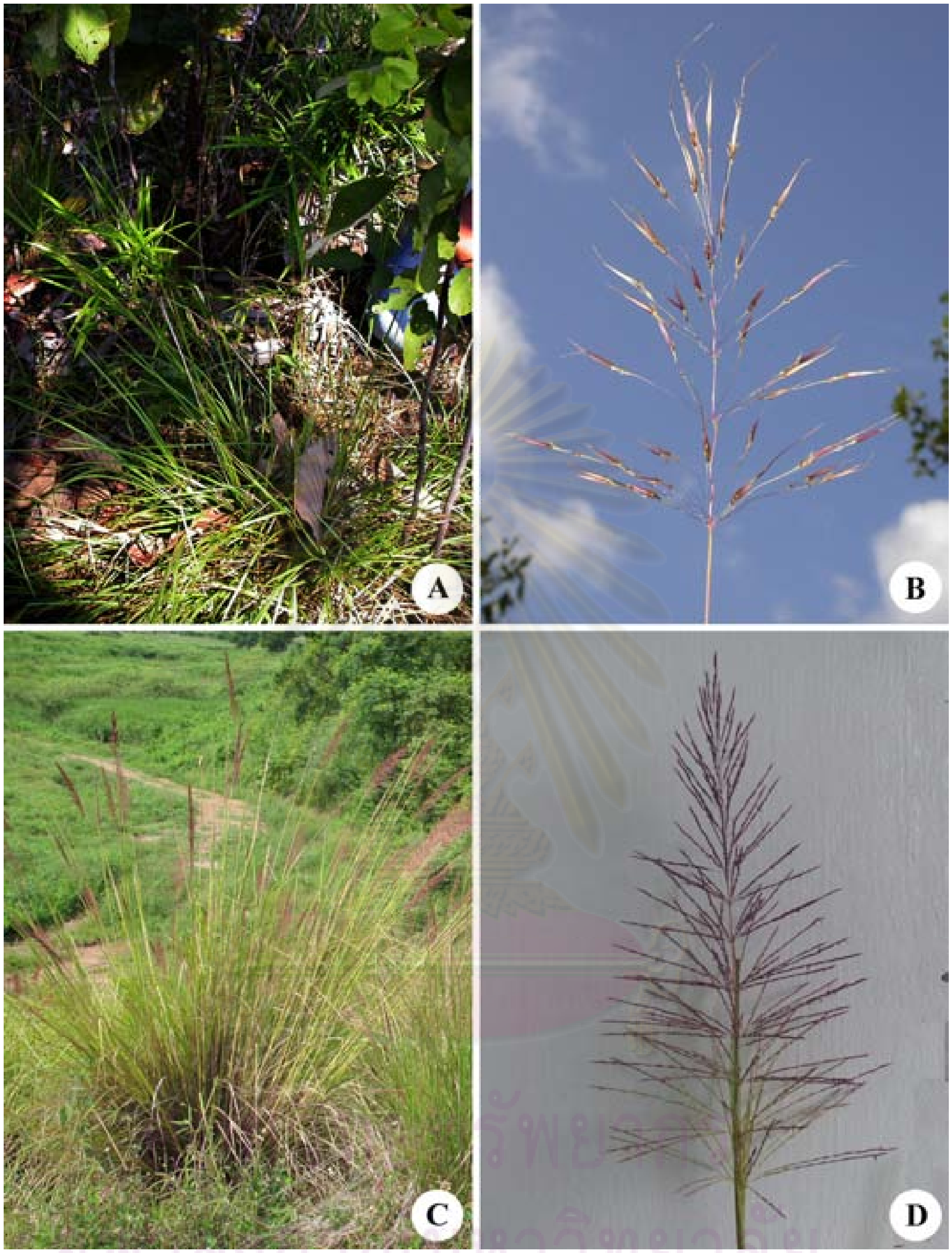

Figure 5. 32 A.-B. *Chrysopogon serrulatus*: A. inflorescence, B. a triad
C.-D. *Chrysopogon zizanioides*: C. habitat, D. inflorescence

Figure 5. 33 A.-B. *Dichanthium annulatum*: A. habit, B. inflorescence
C. *Dichanthium aristatum* inflorescence showing pubescent peduncle
D. *Dichanthium caricosum* inflorescence

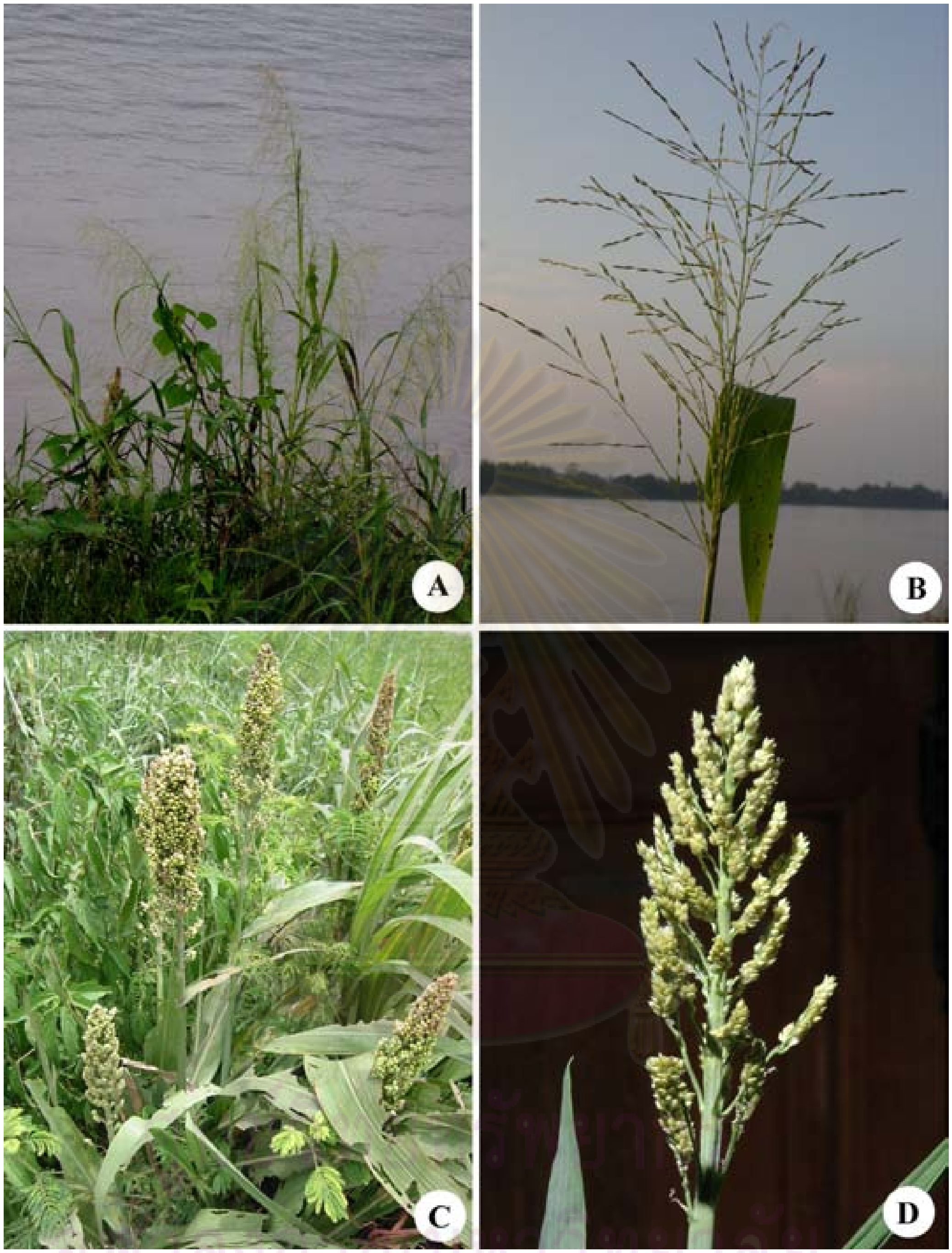

Figure 5. 34 A.-B. *Hemisorghum mekongense*: A. habitat, B. inflorescence
C.-D. *Sorghum bicolor*: C. habitat, D. inflorescence

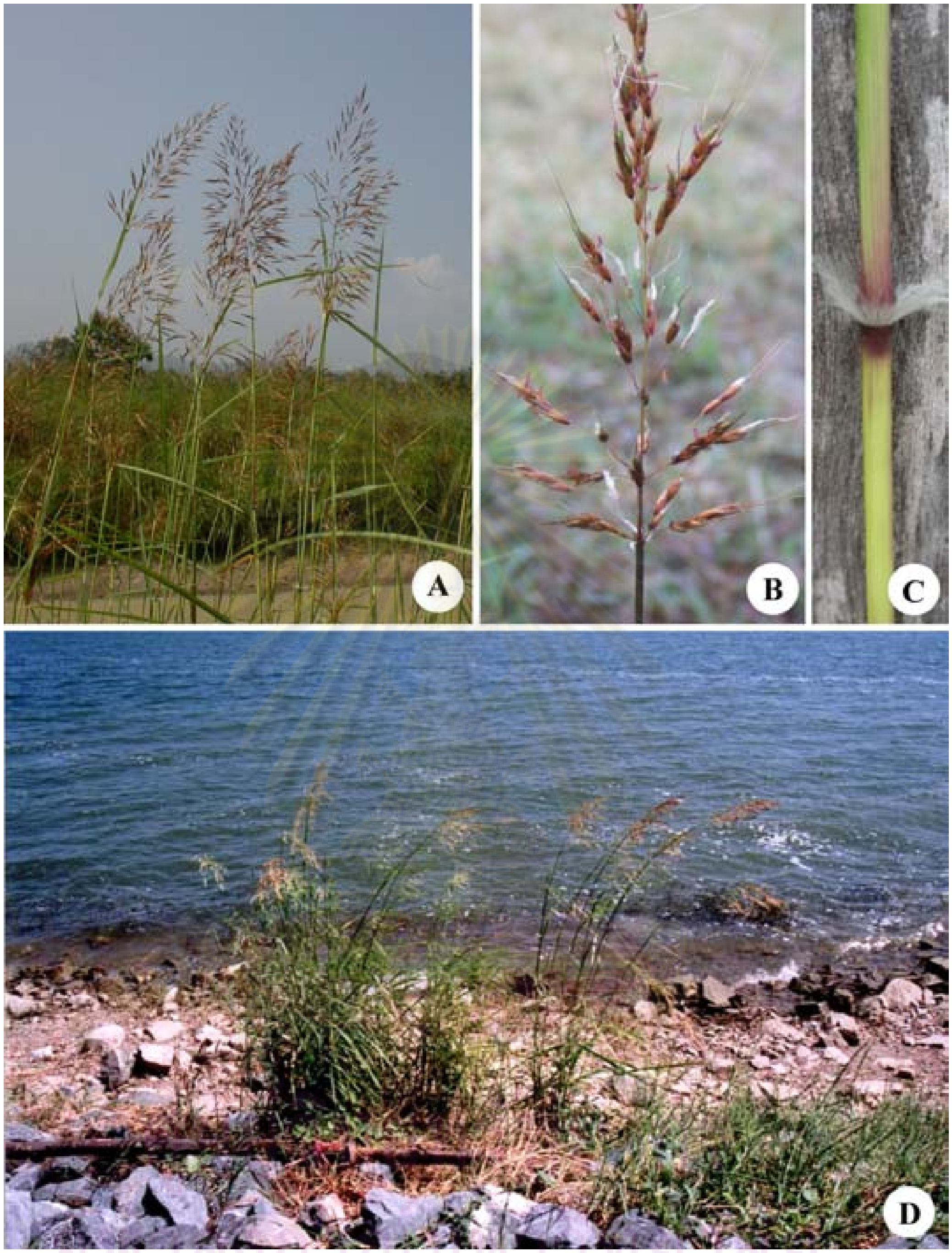

Figure 5. 35 A.-C. *Sorghum nitidum*: A. habitat, B. inflorescence, C. culm node With bearded hairs
D. *Sorghum propinquum* habitat

CHAPTER VI

GENERAL CONCLUSION

Three parts of Subtribe Sorghinae were studied: phylogeny of *Chrysopogon-Vetiveria* complex, anatomical study and taxonomic revision. Phylogeny of *Chrysopogon-Vetiveria* complex was special study with specimens represented groups around the world, while anatomical and taxonomic studies were conducted with specimens in Thailand.

In order to study phylogeny of *Chrysopogon-Vetiveria* complex, nuclear *ITS* and chloroplast *TrnL-F* genes were separately analyzed and then combined analysis was conducted. It was found that combined data seems to be more reliable because most of nodes were highly supported and well resolved. The result showed that both two genera were not monophyletic groups since *Vetiveria* were dispersed among *Chrysopogon* taxa. Therefore, these 2 genera should be included in one genus under the name *Chrysopogon*. This study agreed with morphological evidence by Veldkamp's (1999) that united them into one genus.

In addition, *C. micrantherus* showed closely related to *C. elongatus* with 100 % bootstrap support and only one base pair from *ITS* sequence and one from *trnL-F* sequence difference. Accordingly, *C. micrantherus* was proposed as a synonym of *C. elongatus* in this study.

Anatomical study was represented by 21 species found in Thailand. Many anatomical characters including short-cell, silica-bodies, prickle-hair, papillae, micro-hair, macro-hair, stamata, vascular bundle arrangement, sclerenchyma pattern, and culm anatomy were useful to classify in generic and specific level.

In addition, the arrangement pattern of short cells which alternate with costal long cells in *Chrysopogon* was also found in *Vetiveria*, while it was in rows in the rest genera. Similarly, bulliform cells that poorly developed in *Chrysopogon* were concordant to those in *Vetiveria*, whereas they were well developed in the rest genera of Sorghinae. In correspond to molecular phylogeny, these characters support the inclusion of *Vetiveria* into *Chrysopogon*, and these characters were synapomorphic for the genus.

For taxonomic revision, living plants from fields throughout Thailand as well as herbarium specimens and type specimens deposited in Thailand and abroad were examined. Twenty-nine species from seven genera were enumerated and described. Among them, they comprised *Bothriochloa* 3 species, *Capillipedium* 7 species, *Chrysopogon* 9 species, *Dichanthium* 4 species, *Hemisorghum* 1 species, *Pseudosorghum* 1 species, and *Sorghum* 4 species. However, 2 new taxa from *Capillipedium* were recorded. *Capillipedium* sp 1. was very similar to *C. sulcatum*, but it differed from *C. sulcatum* by its puberulous panicle branches and axis while glabrous in *C. sulcatum*. Another taxon was *Capillipedium* sp. 2. This was very similar to *C. laoticum*, but it differed from *C. laoticum* by its 2 types of hairs, long tubercle-based hairs and very short, non tubercle-based hairs, at panicle branches and axis, whereas only tubercle-based hairs at upper part of peduncle of raceme in *C. laoticum*. In addition, tubercle-based hairs are 5-9 mm long in *C.* sp. 2, while they are only 2-3 mm long in *C. laoticum*.

Chrysopogon. nemoralis, *C. zeylanicus*, and *D. polypticum* which previously recorded from Thailand were confirmed to be not present in Thailand in this study. However, they were recorded because of mis-identification by previous study.

Many botanical names also previously recorded from Thailand were treated as synonyms by this study. Thus, species enumeration of 39 species in Sorghinae by Na nakorn and Norsangsri (2002) were reduced to 27 species (without new taxa) in this study.

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