SYSTEMATICS OF ISCHAEMINAE AND ROTTECELLIINAE (POACEAE) IN THAILAND

Miss Paweena Traiperm

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy Program in Biological Sciences
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Chulalongkorn University
Academic Year 2007
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อนุกรมวิฐานของพืชวงศ์หญ้าอัดยอกและยาไกลตีในประเทศไทย

นางสาวปรีดา ไตรภพ

วิทยานิพนธ์เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาตรีวิทยาศาสตร์ดูษฎ์บัณฑิต
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Field of Study: Biological Sciences

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ปีนี้เราได้ศึกษาพืชที่น่าสนใจ Ischaeminae และ Rottboellinae ในประเทศไทย พบพืชจำนวน 13 ชนิด 282 ชนิด กลุ่มที่มีขนาดใหญ่ที่สุดของกลุ่ม ได้แก่กลุ่ม Ischaemum มีจำนวน 13 ชนิด 1 พืช และกลุ่ม Eremochloa มีจำนวน 11 ชนิด จำนวนนี้ได้เจริญ 1 ชนิดในป่าใหญ่ในกลุ่ม Andropogon L. คือ I. tenuifolium (A. Camus) P. Traiperm & T. Boonkerd ได้บันทึกพืชผีเสื้อ I. barbatum Retz. var. globerrimum Bor ได้เป็นชื่อที่ตั้งของ I. barbatum Retz. นอกจากนี้ยังได้บันทึกด้วยชื่อต้นแบบจำนวนห้าทางจากกลุ่ม Ischaemum คือ I. aristatum subsp. imbercatum, I. aristatus var. arfakensis, I. lacei, I. magnus และ I. macrurum พบมีต้นต้นที่กระจายเป็นครึ่งกิโลเมตรของประเทศไทย 2 แห่งๆ คือ Ischaemum huddarii Bor และ Mnesitha striata (Nees ex Steud.) Koning & Sosef. var. pubescens (Hack.) S.M. Phillips & S.L. Chen และมากกว่า 6 ชนิด ในกลุ่ม Ischaemum, Eremochloa และกลุ่ม Mnesitha อาจเป็นพืชชนิดใหม่ของโลก ได้สร้างขึ้นวิธีนักเพาะเจริญกลุ่ม ชนิดและพืชผีเสื้อ และได้จัดทำคำบรรยายลักษณะ วาดภาพลายเส้น บันทึกภาพ ข้อมูลการกระจายพันธุ์ของแต่ละชนิด

การศึกษาลักษณะและวิทยาศาสตร์ของพืชในกลุ่มเส้นผ่าตัด ได้บันทึกในและสีสันเหนือคินของพืชทั้งสองฝ่ายผีเสื้อ ได้ใช้ที่ชื่อคินและคัดตามช่วง จำนวน 25 ชนิด จาก 12 กลุ่ม พบว่าสามารถเก็บค่าและของพันธุ์ และสีสันเหนือคินได้ใช้บุคคลที่สองกลุ่มในการศึกษาได้

การวิเคราะห์สายพันธุ์ทางวิวัฒนาการของพืชจำนวน 44 ตัวอย่าง 38 แห่งๆ จากกลุ่ม มิกที่โลหิตไล่ในคลอโรฟิลล์ดีเอ็นเอ (trnL intron และ trnL-F intergenic spacer) และในไรโบโซมิดเอียนบริเวณ internal transcribed spacer (ITS) ด้วยวิธี Maximum Parsimony โดยโปรแกรม PAUP* 4.0b10 พบว่าการวิเคราะห์รวมกันของอินไล่ในไรโบโซมิดเอียน และคลอโรฟิลล์ดีเอ็นเอ แสดงความไม่ข้อต่อและพบว่าพืชทั้งสองฝ่ายผีเสื้อไม่เป็นชนิดพันธุ์เดียว (non-monophyletic) เมื่อพิจารณาสายพันธุ์ภายในสง่าผีเสื้อพบว่า กลุ่ม Ischaemum และ Mnesitha ไม่เป็นชนิดพันธุ์เดียว และสกุล Hemarthria, Hackelochloa และ Eremochloa เป็นชนิดพันธุ์เดียว (monophyletic)

สาขาวิชา วิทยาศาสตร์ชีวภาพ
ปีการศึกษา 2550

A taxonomic study of subtribes Ischaeminae and Rottboellinae in Thailand was carried out. Thirteen genera, 49 species and two infraspecific taxa are enumerated. *Ischaemum* (13 species and one infraspecific taxon) and *Eremochloa* (11 species) are the two largest genera. One new combination in *Andropogon* L.: *I. tenuifolium* (A. Camus) P. Traiperm & T. Boonkerd is made. A variety, *I. barbatum* Retz. var. *glaberrimum* Bor is treated here as a synonym of *I. barbatum* Retz. In addition, five taxa of *Ischaemum* namely, *I. aristatum* subsp. *iberbe* var. *imbricatum*, *I. aristatus* var. *arfakensis*, *I. lacinii*, *I. magnum* and *I. macrurum* are lectotypified. It was found that two taxa, i.e. *Ischaemum hubbardii* Bor and *Mnesithea striata* (Nees ex Steud.) Koning & Sosef. var. *pubescens* (Hack.) S.M. Phillips & S.L. Chen are new records. Six species in *Ischaemum*, *Eremochloa* and *Mnesithea* are new to science. Keys to the subtribes, genera and species together with descriptions, line drawings, photographs and distributional information of each species are given.

Epidermal peels and transverse sections of leaf-blades and culms were investigated in 25 species of the 12 genera from the two subtribes. It is evident that anatomical features are taxonomically useful for generic delimitation.

Phylogenetic analyses of 44 samples from 38 taxa were carried out using non-coding chloroplast DNA *trnL* intron, and *trnL*-F intergenic spacer sequence data together with nuclear ribosomal internal transcribed spacer (ITS) sequence data. Maximum Parsimony analyses were conducted using PAUP* 4.0b10. It was found that combined ITS and *trnL*-F analyses strengthen the phylogenetic signal and reveal that both subtribes are not monophyletic. The combined data also reject the monophyly of the genera *Ischaemum* and *Mnesithea* but provide evidence to show that *Hemarthria*, *Hackelochloa* and *Eremochloa* are monophyletic.
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LIST OF ABBREVIATIONS

c. or ca.  circa or circiter  about, approximately
comb. nov.  combinatio nova  new combination of name and ephithet
det.  determinavit  he determined
e.g.  exempli gratia  for example
et al.  et aliorum  and others
f.  filius or filial  son or son of
I.c.  loco citato  compare reference
ined.  ineditus  unpublished
nom. nov.  nomen novum  new name
nom. nud  nomen nudum  name published
p.p.  pro parte  partly, in part
s.l.  sensu lato  in a broad sense
sp.  species  species (singular)
sp.  species  species (plural)
ssp.  subspecies  subspecies
syn.  synonymon, synonymia  synonym, synonymy
var.  varietas  variety
viz.  videlicet  namely
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CHAPTER I

GENERAL INTRODUCTION

1.1 Introduction

The grass family, Poaceae are mostly herbs comprising one of the largest flowering plants families, with approximately 10,000 species, including in 660 to 700 genera (Clayton & Renvoize, 1986; Watson & Dallwitz, 1999). The figures are only after Compositae, Orchidaceae Leguminosae and Rubiaceae in terms of number of species. Grasses can thrive in various habitats and that they have wider geographic range than the other plant families, and can dominate various vegetation types which cover about 30% of the earth’s land surface. They are well represented throughout the world and can be found in abundance throughout tropical regions, especially Asia.

This family is the most ecologically and economically important of all plant families. Cereal crops or grains are mostly grasses cultivated for their edible grains called a caryopsis. Cereal grains are grown in greater amount and provide more energy worldwide than any other type of crop; they are therefore staple crops. They are also a rich source of carbohydrate. As food, cereals have two important advantages over roots and most food crops other than nuts. Firstly, they are relatively concentrated foods being low in water and high in reverse carbohydrates, mainly starch, and also oils. Secondly, these characteristics make them able to be stored for relatively long periods and make them more transportable than the other bulky foods such as roots. Maize, rice, wheat, oats, sorghum are among the important cereals.

Sugar cane is the source of sugar in all tropical and subtropical countries of the world. Uses of sugar cane also include the production of alcoholic drink, molasses, and ethanol for fuel. Bamboos are a special, distinctive group of grasses because most of them are woody and often very large; their culms may grow up to 40 m high in some species. Even today, bamboo is still widely used in building and scaffolding, and for utilitarian as well as artistic objects. Up to 20th century in Japan, China, Korea and much of the rest of eastern Asia, bamboo was used for virtually everything from building to cooking ware, from musical instruments to paper-making. Many grasses are definitely elegant and graceful adding structure and form to a garden such as, Miscanthus, Molina, Pennisetum, Stipa, Festuca (Russelle, 2001; Grounds, 1989).
Applications of Grasses for medicinal properties are locally specific. The British Pharmacopoeia is stated that the rhizome of *Agropyrum repens* contains triticin, dextrose, mucilage, mannitol and inositol. It is a demulcent diuretic and is used internally in the treatment of catarrhal diseases of the genitor-urinary tract, in the form of the lipid extract or decoction. A number of species belong to the genus *Cymbopogon*, produce aromatic oils which accumulate in the tissue and are obtained by stream distillation. *C. schoenanthus* is used in an infusion as a stomachic and the essential oil is said to be useful in rheumatism. *C. nardus*, the citronella grass, is used in an infusion as a stomachic and carminative. *C. citratus* is said to be a good laxative and of use as an anthelmintic. The oil is to be an excellent embrocation for chronic rheumatism, sprains and neuralgia. The stem and roots of *Saccharum*, particularly *S. officinarum*, enter into ayurvedic prescriptions as diuretic, cooling and aphrodisiac. Various parts of plant have figured in cures for snake-bite. The smoke of burning *Panicum antidotale* is used for fumigating wounds and as a disinfectant in smallpox. *Hackelochloa granularis* is prescribed internally with a little sweet oil, in cases of enlarged spleen and liver (Bor, 1960).

The sedges, Cyperaceae is a plant family that used to confuse many people with the grasses. Both are similar in having small flowers borne in bracteate clusters, in the lack of or the extreme modification of perianth segments, in being wind-pollinated, and in the dry, indehiscent, single-seeded fruit. The most apparent morphological differences between the grasses and the sedges are shown in Table 1.1.

From Table 1.1 sedges have three rows of leaves, sheaths with united edges (in contrast to the overlapping sheaths of grasses). Most stems of sedges are triangular and solid, and most leaves are entirely basal. Sedges are commonly in wet places, whereas grasses occur in a wide range of habitats. The families Poaceae and Cyperaceae have been placed in the same order (Glumiflorae, Graminales, or Poales) by many authors. These two families have also been considered close to the Liliaceae and Juncaceae (Clark & Pohl, 1996; Gould & Shaw, 1983).
Table 1.1 Morphological differences between grasses (Poaceae) and sedges (Cyperaceae) (adapted from Duistermaat, 2005; Gould & Shaw, 1983).

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<th>Grasses (Poaceae)</th>
<th>Sedges (Cyperaceae)</th>
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<tr>
<td>Culm</td>
<td>rounded to flattened, hollow</td>
<td>triangular (at least just below the inflorescence) or rounded to flattened, solid</td>
</tr>
<tr>
<td>Leaves</td>
<td>2-rank</td>
<td>3-rank</td>
</tr>
<tr>
<td>Sheath margins</td>
<td>mostly open or overlapping</td>
<td>mostly closed or fused</td>
</tr>
<tr>
<td>Ligule</td>
<td>generally present and short to long, sometimes absent</td>
<td>absent or present</td>
</tr>
<tr>
<td>Flower</td>
<td>each generally subtended by two bracts</td>
<td>each always subtended by only one bract (and a number of perianth- bristles or scales can be present as well)</td>
</tr>
<tr>
<td>Florets</td>
<td>arranged in two ranks</td>
<td>spirally arranged or in two ranks</td>
</tr>
<tr>
<td>Fruit</td>
<td>caryopsis</td>
<td>usually an achene, never a caryopsis</td>
</tr>
</tbody>
</table>

1.2 General morphology of grass (adapted from Clark & Pohl, 1996; Duistermaat, 2005; Gould & Shaw, 1983; Kucera, 1998; Wycherley & Yosof, 1974).

Habit
Grasses are herbaceous (with the exception of woody bamboos), which means that the stems are typically green and relatively soft, although fibrous, but not woody. Grasses plants may be annual or perennial vary in their duration and growth forms. The annuals grasses die after seed set and usually complete their life cycle in one year. The shoots are all alike and all produce inflorescences. However, some grasses are biennials, because their life cycle is usually about two years. The perennials produce flowering shoots accompanied by vegetative shoots; these persist for a few to many years and have an indefinite life span. Perennial grasses are loosely or densely tufted or form large spreading plants by their rhizomes or stolons.

The grass-plant consists of a root and shoot systems. The root system is fairly uniform throughout the grasses and in individual plants. The roots which emerge from
the seeds on germination are few and short-lived, but having extensive system of fibrous. Adventitious roots develops later from nodes of the stems, especially those at or below the surface of the soil. The shoot system consisting of stem, leaves and inflorescence is much diversified (Fig. 1.1).

![Diagram of grass morphological parts]

**Figure 1.1** Morphological parts of typical grass (after Wycherley & Yosof, 1974).

1.2.1 Vegetative parts

**Stem**

The aerial stems of a grass is called a culm. It is consists of solid joints or nodes separated by short or long segments, the internodes. The nodes bear the leaves and, if present, roots and branches. The internodes are generally hollow, but are solid in a few grasses. At the base of the culm, they can be very short (about as long as the nodes) resulting in a concentration of leaves, which cover all the nodes. In the upper part of the culm the internodes are elongated. The typical culm grows vertically: erect, or ascending from a geniculate base. Some culms, however, grow horizontally.
Horizontal culms that lie on the soil surface are called stolons. They are generally green and the nodes bearing roots or not and bear well-developed leaves. Culms growing horizontally beneath the soil surface are called rhizome. Rhizomes are generally whitish with rooting nodes and reduced, scale-like leaves.

**Leaves**

Grasses leaves always arise from the node, arranging in two rows along the culm, but this is often obscured due to the twisting of the sheath or the culm in side the sheath. Each leaf consists of two main parts: the lower portion is the sheath which is wrapped around the stem and the upper portion, the blade, which is hinged to the top of the sheath.

**Leaf-sheath**

The sheath is a tube around the culm with (slightly) overlapping margins. The sheath may be shorter or longer than the internode. The midrib may be raised or winged, and (minute) transverse veins may be also present. The throat or the base of the blade may have ear-shaped or triangular appendages, referred to as auricles. Auricles can be persistent or deciduous, glabrous or hairy.

**The Ligule**

At the junction of the sheath with the blade, the sheath may be extended on its inner side to form a very characteristic membranous structure called the ligule; the part outside the junction is called the collar (Fig. 1.2). The ligule, a characteristic feature of the grass family, is usually fairly constant in each species and very often serves as an important means of distinguishing between specimens of different species in their vegetative phase because of they are displays various structural modifications.

**Leaf-blades**

The leaf-blade is similar to the other monocotyledonous plants, typically linear or lanceolate, arises on the top of the sheath. It is generally flat and elongated or inrolled with more or less prominent longitudinal veins. Transverse veins are sometimes present as well.
1.2.2 Reproductive part

Inflorescences

The erect flowering stem or culm of a grass is terminated by an inflorescence. The inflorescence consists of distinct units called spikelets borne on the main axis or rachis. A few species have an inflorescence consisting of one spikelet only. However, the majority of grasses have inflorescences consisting of many spikelets, which display great variety in modifications of basic spikelet structure and in the different possible arrangements of the spikelets.

Spikelet

The spikelet is the basic unit of the inflorescence. It consists of one to several florets, each of which encloses the true flower, the whole subtended by two empty bracts called glumes. The lower (or first) and upper (or second) glumes. The glumes, rachilla, and the one to many florets together form a spikelet (Fig. 1.3). Above the empty glumes are one or more floral glumes. A floral glume are called “lemma” and “palea”. The lemma is usually the larger and is on the side away from the rachilla. The spikelets of certain grasses or groups bear awns, which are mostly solitary projections of the mid-vein of either glumes or lemmas or both. Awns vary in length,
thickness, and form (straight, geniculate, twisted, etc.) and are a useful character in identification.

![Diagram of a spikelet](image)

**Figure 1.3** A spikelet (after Wycherley & Yosof, 1974).

**Floret**

The actual floret is between the lemma and palea. There is a variety of possible conditions and arrangements of the florets. The sex organs may be aborted and the floret is then sterile. If only the stamens are present or only the pistil is developed, the floret is referred to as male or female respectively. If both sexes are functional in the same floret the condition is bisexual or perfect or hermaphrodite. The perfect flower consists of stamens and pistil (Fig. 1.4). The most common number of stamen is three, but sometimes there are as many as six (e.g. *Zizania*). The filament of the grass stamen is typically delicate and flexible. The pistil consists of feathery, usually 2-parted stigmas and a 1-seeded ovary, the latter developing as the grain or caryopsis. At the base of the ovary, there are two or rarely three scales, called lodicules. The lodicules vary in sizes, but usually rather small. There are vestigial parts of an ancestral perianth. Their function is believed to push the lemma and palea apart when the sex organs are mature.
Figure 1.4 The grass floret (after Gould & Shaw, 1983).

Caryopsis

A fertilized ovule develops within the ovary, it is enclosed with ovary wall or pericarp when mature; a single seed-fruit is called a caryopsis.

1.3 Literature reviews

1.3.1 The previous classification systems of grass family

Robert Brown (1810) was the first person who subdivided the grass family into two subfamilies, the Pooideae and Panicoideae based on differences in spikelet morphology. This primary subdivision has been used as a basis by most authors later. Brown’s concept was maintained and elaborated on by Bentham (1883), Hackel (1887), Hayek (1925) and Hubbard (1934). These botanists are among those who have made outstanding contributions to the classification of the Gramineae as a whole.

The modern foundation for the classification was established by Avdulov (1931), who introduced the use of cryptic characters, for example chromosome characteristics and linked them to morphological, anatomical features as well as the orientation and size of the first seedling leaf. It is really the turning point in the study of the grass family and launched new vistas in classification to which an increasing number of scientists are contributing (Bor, 1960). Synchronously, Prat (1936) also
used information from anatomy, physiology and geography in addition to morphology and chromosomes. The outstanding feature of classification systems initiated by Avdulov (1931) and Prat (1936) is the apparent necessity for an increased number of sub-families (Pilger, 1954; Tateoka, 1957; Jacques-Félix, 1958; Parodi, 1959; Stebbins & Crampton, 1959 and Prat, 1960). These authors have subdivided the grass family into 5 to 10 subfamilies.

In 1992, a phenetic classification of the family and comprehensive descriptions of all genera was done by Watson & Dallwitz. At more or less the same time Clayton and Renvoize (1986), using a combination of phentic methods and evolutionary classification, recognized six subfamilies, viz. Arundinoideae, Bambusoideae, Centothecoideae, Chloridoideae, Panicoideae and Pooideae, and also provided diagnostic generic descriptions for all genera of the family. So far this system of grass classification is widely accepted. Recently, a new classification of the family Poaceae has been proposed by the Grass Phylogeny Working Group (GPWG, 2000, 2001) based on molecular data. This classification recognized twelve subfamilies i.e. Anomochlooideae, Aristidoideae, Arundinoideae, Bambusoideae, Centothecoideae, Chloridoideae, Danthonioideae, Ehrhartoideae, Panicoideae, Pharoideae, Pooideae and Puelioideae.

The Andropogoneae is one of the two major tribes in the subfamily Panicoideae (Clayton & Renvoize, 1986), which includes about one-third of all grass species (Mathews et al., 2002). The grass tribe Andropogoneae is a monophyletic tribe that includes both maize (Zea may ssp. mays) and sorghum (Sorghum bicolor), two of the world’s most important crops. Clayton (1972, 1973) divided Andropogoneae into “awned” and awnless” taxa. Later, Clayton & Renvoize (1986) divided this tribe into 11 subtribes of 85 genera in the world, based largely on characters of the inflorescence. This tribe distributed throughout the tropics, particularly the savannah zone, extending into warm temperate regions. Most species of this tribe have pairs of spikelets in the inflorescence, one sessile and one on a pedicel, although in some species one or the other of these spikelets appears to be suppressed. Inflorescence form is highly variable, the members of each pair commonly dissimilar; glumes as long as the spikelet, often indurated and always firmer than the hyaline florets scales; florets two per spikelet, the lower male or barren, the upper female or bisexual; lemma of the upper floret often geniculately awned (Clayton, 1986).
In this study, two subtribes, i.e. Ischaeminae and Rottboelliinae which include about 15 genera in Thailand were studied.

The subtribes Ischaeminae and Rottboelliinae belong to the tribe Andropogoneae, which is the one of two major tribes in the subfamily Panicoideae (Clayton & Renvoize, 1986). The both subtribes in Thailand comprising of approximately 21 and 31 species, belonging to 5 genera and 10 genera, respectively. The 15 genera include *Apluda, Coelorachis, Eremochloa, Hackelochloa, Hemarthria, Ischaemum, Kerriochoa, Mnesithea, Ophiuros, Phacelurus, Rottboellia, Sehina, Thaumastochloa, Thelepon and Vossia* (Nanakorn & Norsaengsri, 2001). At present taxonomic study of the family Poaceae in Thailand is slowly carried out, though it is really needed to fulfill our knowledge for the Flora of Thailand Project. This study aims to conduct taxonomic study of the subtribes Ischaeminae and Rottboelliinae in Thailand which are still scanty known. The knowledge gain from this study will be the basis for the Grass Flora of Thailand project as well as can serve as a model for further taxonomic study in Poaceae.

1.3.2 General morphological characteristics of the subtribe Ischaeminae

The first is subtribe Ischaeminae, includes over 60 species in the tropics of both hemispheres, but mainly occur in Asia and Australia. This subtribe is recognized by a single inflorescence, paired or digitate racemes or rarely solitary racemes, these usually terminal, sometimes axillary, rarely spathate; racemes with fragile rachis and linear to obovoid internodes, without homogamous pairs. Spikelets in dissimilar pair at each node of an articulated rachis or rarely becoming solitary through the reduction of the pedicelled spikelets. Sessile spikelet bisexual, dorsally or laterally compressed and composed of 1-2-flowers. The callus blunt and fitting a truncate or shallowly hollowed internode tip; lower glume chartaceous to crustaceous, convex or concave, 2-keeled or rounded on the flanks, with or without a median groove; lower florets male, with palea; upper lemma oblong, bidentate or bifid, nearly always with a glabrous awn. The pedicelled spikelet usually are staminate or neuter flowers, perfect flower are rare. The rachis-joints and the pedicels are either slender and separate or triquetrous and confluent at the base of node into U- or V-shaped structures (Keng, 1933; Clayton & Renvoize, 1986).
This subtribe composed of 8 genera in the world but occurs only 5 genera and 21 taxa in Thailand (Table 1.2) (Clayton & Renvoise, 1986; Nanakorn & Norsaengsri, 2001).

**Table 1.2** List of genera in subtribe Ischaeminae of the World (Clayton & Renvoise, 1986) and Thailand (Nanakorn & Norsaengsri, 2001).

<table>
<thead>
<tr>
<th>Genera</th>
<th>(Clayton &amp; Renvoise, 1986)</th>
<th>(Nanakorn &amp; Norsaengsri, 2001)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <em>Ischaemum</em> L.</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>3. <em>Apluda</em> L.</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>4. <em>Kerriochloa</em> C.E. Hubbard</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>5. <em>Triplopon</em> Bor</td>
<td>✔</td>
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<tr>
<td>6. <em>Pogonachne</em> Bor</td>
<td>✔</td>
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<tr>
<td>8. <em>Andropterum</em> Stapf</td>
<td>✔</td>
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<td><strong>Total</strong></td>
<td>8</td>
<td>5</td>
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</table>

**1.3.3 General morphological characteristics of the subtribe Rottboellinae**

The subtribe Rottboellinae contains 19 genera which includes 120 species or more. This subtribe is mainly found in the tropics of the Old World, with some genera extend to tropical America (Keng, 1933). This subtribe is recognized by a single inflorescence or sometimes with digitate racemes, these terminal, axillary or spathate; racemes fragile, though sometimes tardily so and rarely tough, the internodes variously thickened or swollen, without homogamous pairs. Spikelets usually in dissimilar paired, rarely ternate through the development of two sessile spikelets or solitary through the reduction of the pedicelled spikelet at each node of an articulated rachis. Sessile spikelets are dorsally compressed, bisexual and composed of 1-2-flowers. The callus sometimes obtuse with oblique scar, more often transversely truncate and then commonly reinforced by a central peg; lower glume herbaceous to crustaceous, convex, often sculptured, mostly 2-keeled; lower floret male or barren; upper lemma narrowly ovate and entire. In each floret of the spikelet, upper lemma usually has no awn. Lodicules are truncate, retuse or toothed from one corner. The
pedicelled spikelet usually are staminate or neuter; the rachis-joints and the pedicels are mostly thickened and glabrous, they are often connivent or united to the internode and forming one or two cavities for the reception of the sessile spikelets (Keng, 1933; Clayton & Renvoze, 1986). This subtribe composed of 21 genera in the world but occur only 10 genera and 31 taxa in Thailand (Table 1.3) (Clayton & Renvoze, 1986; Nanakorn & Norsaengsri, 2001).

**Table 1.3** List of genera in subtribe Rottboelliinae of the World (Clayton & Renvoze, 1986) and Thailand (Nanakorn & Norsaengsri, 2001).

<table>
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<tr>
<th>Genera</th>
<th>(Clayton &amp; Renvoze, 1986)</th>
<th>(Nanakorn &amp; Norsaengsri, 2001)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Urelytrum Hack.</td>
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<tr>
<td>2. Loxodera Launert</td>
<td>✓</td>
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<tr>
<td>3. Eliomurus Kunth ex Willd</td>
<td>✓</td>
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<tr>
<td>4. Phacelurus Griseb.</td>
<td>✓</td>
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<td>5. Vossia Wall. &amp; Griff.</td>
<td>✓</td>
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<td>7. Lasiurus Boiss.</td>
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<td>8. Rhytachne Desv.</td>
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<td>9. Coelorachis Brongn.</td>
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<td>10. Eremochloa Büse</td>
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<td>11. Chasmospodium Stapf</td>
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<td>12. Rottboellia L. f.</td>
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<td>13. Heteropholis C.E. Hubbard</td>
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<td>14. Hackelochloa Kuntze</td>
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<td>15. Glyphochloa Clayton</td>
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<td>16. Manisuris L.</td>
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<td>17. Ophiuros Gaertn.</td>
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<td>18. Oxyrhachis Pilger</td>
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<td>19. Mnesithea Kunth</td>
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<tr>
<td>20. Ratzeburgia Kunth</td>
<td>✓</td>
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<tr>
<td>21. Thaumastochloa C.E. Hubbard</td>
<td>✓</td>
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</table>

**Total** | **21** | **10**
1.3.4 Taxonomic historical reviews of the Poaceae

Previously, taxonomic works of the Poaceae were published in many Floras by various taxonomists (Table 1.4). The first major comprehensive study of Asian Gramineae was accomplished by Sir Joseph Hooker (1897) in his Flora of the British India. Standard works by other botanists related to the Grass flora include: Flora of tropical Africa (Stapf, 1917); the Poaceae in Laos, Cambodia and Vietnam was included in Flora Générale de L' Indochine (Camus & Camus, 1922); Malay Peninsula (Ridley, 1925); Grasses of China was performed by Keng (1933); Burma by Rhind (1945); Flora of western Australia (Gardner, 1952); Notes on Malaysian Grasses (Jansen, 1953); Grasses of Ceylon (Senaratna, 1956); Grasses of Burma, Ceylon, India and Pakistan (Bor 1960); Grasses for Flora of Japan (Ohwi, 1965); Grasses of Hawai (Rotar, 1968); A manual of the Grasses of New Guinea (Henty, 1969); Flora of Malaya (Gilliland et al., 1971); Grasses in Malayan plantations (Wycherley, 1974); the Tropical Grasses of Southeast Asia (Lazarides, 1980); Flora of Pakistan (Cope, 1982); Grasses of Japan and neighbouring regions was also studied by Koyama (1987); Flora of Kerala-Grasses (Sreekumar, 1991); Flora of Ceylon (Dassanayake et al., 1994); Grasses of North-Eastern India (Shukla, 1996); the Grasses and Bamboo of India (Moulik, 1997). Recently by Duistermaat (2005) in Field Guide to the Grasses of Singapore; Flora of China (Chen et al., 2006) (Table 2.3).

1.3.5 History of Species Diversity of Poaceae in Thailand

The first taxonomic account of the family Poaceae in Thailand was prepared by Craib in 1913. He primarily reported species of Monocots in "Contribution to the Flora of Siam", which included mainly species collected by Kerr during 1907-1913. Twenty years later, Craib and Kerr published part of the Poaceae in Flora Siamensis Enumeratio. Since then all international activities were diminished due to the Second World War and the death of the authors. The Thai-Danish Botanical Projects carried over in 1957 have inspired the study on the Thai flora. Specimens collected in these expeditions were identified and species were published in Dansk Botanisk Arkiv by Bor & Larsen during 1962-1965, under the cooperation of Thai-Danish project "Studies in the Flora of Thailand" (Nanakorn, 1990).

From the last nine decades, taxonomic works on Thai grasses are rather scant. Only some accounts were reported by botanists who worked in some specific areas or

So far, the grass Flora of Thailand is rather in a slow process. It is probably due to lack of interested young botanists as well as lacking taxonomic resources such as references and type specimens. Prior to this study, little attention has been paid to the grasses of Thailand. The identification and distribution of grasses from Thailand have come from the literature of neighboring countries.
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Table 1.4 List of species in subtribes Ischaeminae and Rottboelliinae in some Floras (Cont.).
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<td><em>Mesithrea striata</em> (Nees ex Steud.) Koning &amp; Sosef</td>
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### Table 1.4 List of species in subtribes Ischaeminae and Rottboellinae in some Floras (Cont.)

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<tr>
<th>No.</th>
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<td><em>Ophiuros bombaiensis</em> Boes.</td>
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<td><em>Ophiuros megaphyllus</em> Stagg &amp; Haines</td>
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<td>71</td>
<td><em>Phacelurus tae</em> (C.B.Clarke) Clayton</td>
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<td><em>Rottboelia cochinchinensis</em> (Lour.) Clayton</td>
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<td>74</td>
<td><em>Rottboelia compressa</em> L. f</td>
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<td><em>Rottboelia exaltata</em> L. f</td>
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<td>76</td>
<td><em>Rottboelia glandulosa</em> Trin.</td>
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<td><em>Rottboelia helferi</em> Hook f</td>
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<td><em>Rottboelia longiflora</em> Hook f</td>
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<td><em>Rottboelia protensa</em> Hack</td>
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<td>81</td>
<td><em>Vassia cuspidata</em> (Roxb.) Griff</td>
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<td>82</td>
<td><em>Vassia procera</em> Wall. &amp; Griff</td>
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1.4 Objectives

1. To accomplish a taxonomic revision of the subtribe Ischaeminae and Rottboelliinae in Thailand.
2. To examine the anatomical and molecular characters of the selected groups.
3. To develop a phylogeny of the genera and species in the subtribes Ischaeminae and Rottboelliinae in Thailand based on molecular characters.

1.5 Scopes of study

The study of the subtribes Ischaeminae and Rottboelliinae in Thailand was conducted between June 2004 and August 2007, morphological ecological and distributional data of the two subtribes were obtained from field collected specimens and herbarium specimens kept at main herbaria in Thailand and Europe. Molecular biology, leaf and culm anatomy were studied.

1.6 Anticipated benefits

This research will be the basis for the Grass Flora of Thailand project. The outcome from this research could be a model for further taxonomic study in Poaceae.

1.7 Places of study

1. Department of Botany, Faculty of Science, Chulalongkorn University, Bangkok and Applied Taxonomic Research Center, Department of Biology, Faculty of Science, Khon Kaen University.
2. Main herbaria in Thailand and Europe: Department of Systematic Botany, University of Aarhus (AAU), Kasin Suvatabandhu Herbarium, Chulalongkorn University, Bangkok (BCU); Bangkok Herbarium, Department of Agriculture, Bangkok (BK), Forest Herbarium, Bangkok (BKF), British Natural History Museum Herbarium (BM), Botanical Museum, University of Copenhagen (C), Chiangmai University Herbarium (CMU), Royal Botanic Garden, Edinburgh (E), Khon Kaen University Herbarium (KKU), Royal Botanic Gardens, Kew (K), National Herbarium Netherland University of Leiden branch (L); Linnean Society Herbarium (LINN),
Prince of Songkhla University Herbarium (PSU), Queen Sirikit Botanic Gardens Herbarium (QBG), Muséum National d’Histoire Naturelle, Paris (P), Trinity College, University of Dublin (TCD) and Department of Biology Herbarium, Chiang Mai University.

3. The molecular research was undertaken at the Jodrell laboratory, Royal Botanic Gardens, Kew, Richmond, Surrey, England.
CHAPTER II

MORPHOLOGICAL STUDY

2.1 General characters of subtribes Ischaeminae and Rottboelliinae in Thailand

2.1.1 Vegetative Morphology

2.1.1.1 Habits

It was found that grasses in subtribes Ischaeminae and Rottboellia inae are having different life cycle. The annual grasses have a rooting system which is simple and produce each ascending culm which terminates with an inflorescence. While perennials having an enduring root system which may consist of a woody root-stock or being rhizomatous or stoloniferous (e.g. Ischaemum indicum, I. muticum, I. timorense, Kerriochloa siamensis, Thelepongon elegans, Eremochloa bimaculata, E. ciliaris, E. maxwellii, E. muricata, E. sp.1, Hemarthria altissima, H. compressa and H. stolonifera). In addition to the flowering culm there will be other shoots in various stages of development, some of which may not flower till the following year. Plants in both subtribes are mostly perennial grass and rarely found in annual tufted as in Ischaemum hirtum, I. rugosum, I. timorense, I. sp.1, Thelepongon elegans, Eremochloa ciliatifolia, E. lanceolata, Hackelochloa granularis, H. porifera, Hemarthria debilis and Rottboellia cochinchinesis.

2.1.1.2 Clum

Most of culms are terete, subterete (e.g. Kerriochloa siamensis, Hackelochloa granularis and H. porifera) or compressed (e.g. Hemarthria altissima, H. compressa and H. longiflora) with a glabrous internodes, usually erect which covered with a hairs on the nodes. Only some species have a glabrous node (e.g. Ischaemum hubbardii, I. magnum, I. tenuifolium, I. sp.1, Eremochloa bimaculata, E. maxwellii, E. petelottii, E. sp.2, Hemarthria altissima, H. compressa, H. pratensis, H. stolonifera and Vossia cuspidata).
2.1.1.3 Leaves
Leaves are alternate arranging in two-ranks, consisting of three distinct parts: a sheath, a blade and a ligule as follow:

**Leaf-sheaths**
The sheath forms a hollow cylinder around the culm. It is attached to the whole circumference of the node. The margins are usually free from one another. The surface of the sheath is usually ridged and often hairy or glabrous.

**The ligule**
A ligule is a small structure, situates at the junction of the sheath and the blade. It is usually an appendage arising from the inner surface of the leaves. The ligules may be a membrane, a membrane tipped with hairs or a rim of hairs.

**Leaf-blades**
The shape, size and texture of the leaves are variable. The shape can be found from narrowly linear, linear, linear-lanceolate and oblong-lanceolate to lanceolate. Leaf size ranges from small, 3–6 cm by 2–3 mm, e.g. *Eremochloa lanceolata* to large, ca. 150 by 1–1.5 cm, e.g. *Phacelurus zea*. Laminas with membranous textures have been observed in most species while coriaceous lamina are rarely found, e.g. *Ischaemum* sp.1, *Phacelurus cambogiensis* and *P. zea*. Leaf base is mostly rounded or cordate, whereas apices are commonly acute or acuminate. Leaves margins are usually entire, with an exception in *Thelepogon elegans*, having undulate margins.

2.1.2 Reproductive Morphology
2.1.2.1 Inflorescence (Figs. 2.1–2.2)
Inflorescences are always terminal in both subtribes. They may, however, be found at the end of axillary shoots shoots. The peduncle is normally teret. In general, shapes of inflorescences are having taxonomic value for identification. The determinate inflorescences can be divided in to 3 types due to differences in their lateral branches, as below:

Single spike-like racemes (Figs. 2.1A-B & 2.2A-D): The pairs of spikelets, one spikelet sessile, the other pedicelled, are attached to a joint and fall with the joint of the axis bearing it, the pedicelled spikelet falls with its pedicel. This type is
common in the all member of the genus *Selima, Eremochloa, Hackelochloa, Hemarthria, Mnesithea, Ophiuros* and *Rottboellia*. In the genus *Kerriochloa* the racemes are embraced by a spatheole.

Paired or digitate of spike-likes racemes (Figs. 2.1C-E & 2.2E): As in the single spike-likes racemes, but the inflorescence compose of paired or sometimes digitate racemes which are separated or conjugated 1-sided and interlocked back to back in a single spike. This type is common in most members of the genus *Ischaemum, Thelepogon* and *Vossia*.

Panicle (Fig. 2.1F): The inflorescence with branches, each branch is raceme, borne at intervals along the rachis. This inflorescence type is found in 3 species, i.e. *Apluda mutica, Phacelurus zeas* and *P. cambogiensis*.

**Figure 2.1** Inflorescence types of Ischaeminae: A-B. single spike-likes racemes; A. *Selima nervosum*; B. single raceme enclosed by a spatheole; C. conjugating of pairs racemes; D. separating of pairs racemes; E. digitated racemes and F. panicle inflorescence (drawn by P. Traiperm).
2.1.2.2 Spikelet (Figs. 2.3–2.4)

The spikelets of both subtribes are of two types, one is sessile and the other is pedicelled. Shape, size and a number of spikelet are taxonomic significant in identification. Three spikelets can be found in the genus Apluda or sometimes in the genus Mnesithea. Sessile spikelet of most genera is usually equal or larger than pedicel, except in the genus Sehima. The spikelets are globose in the genus Hackelochloa, while columnar or cylindrical forms are found in Hemarthria, Mnesithea, Ophiuros, Rottboellia and Vossia. The presence of pedicelled spikelet can be found in most genera, with an exception in Thelepodon, Eremochloa, Ophiuros and Mnesithea laevis.

2.1.2.3 Rachis node

The grasses in the subtribe Ischaeminae are having a slender rachis node, which is linear or oblong in shape, while thickened or swollen rachis node is found in the subtribe Rottboellinae.
2.1.2.4 Glume (Figs. 2.5–2.6)

Glume is a scale-like bract. There are two bracts at the base of grasses in these two subtribes. The first one is inserted on the rachilla just above the other and designated the lower and the upper glume. There are variously modified in size,
shape, texture, nerve number, hairiness and colour. This character is very useful
diagnostic feature for identification into species level of all taxa.

Figure 2.5 Variation of lower glume in subtribe Ischaeminae: A. Apluda mutica; B.
Ischaemum hubbardii; C-D. I. sp.2; E. Kerriochloa siamensis; F. Sehima
nervosum and G. Thelepo gon elegans (drawn by P. Traiperm).

Figure 2.6 Variation of lower glume in subtribe Rottboellinae: A. Eremochloa
eripoda; B. E. petelotii; C. E. muricata; D. Hackelochloa granularis; E.
H. porifera; F. Hemarthria altissima; G. H. stolonifera; H. Mnesithea
cancellata; I. M. glandulosa; J. M. mollicoma; K. M. striata var.
pubescens; L. Ophiuros exaltatus; M. Rottboellia cochin chinensis and
N. Vossia cuspidata (drawn by P. Traiperm).
2.1.2.5 Lemma

Lemma is a small bract, subtending the floret. It encircles the palea and also protects the reproductive organs. The characters of the lemma are very useful in classification of both subtribes.

2.1.2.6 Palea

Palea is a scale borne on the floral axis directly facing the lemma. It is usually with 2 keels, the adaxial is concave and the two flap embrace the flower.

2.1.2.7 Lodicules

The lodicules are situated at the base of palea. There are two and small to fairly large scales. Their shapes are conical.

2.1.2.8 The Androecium

The androecium consists of the stamens which is three in number. Each stamen composes of a long slender filament carrying a two-celled anther. The colour of the anther is bright yellow.

2.1.2.9 The Gynoeceum

The gynoeceum comprises of the ovary, ovule, style and stigmas. The shape of the ovary is normally elliptic and glabrous on surface, composed of 3 carpels fused together. The base of style is connected into a beak which is persistent and attached to the pericarp. The style ends in stigma, which is papillose or plumose on the surface. The colour is usually purple, except in Ischaenum muticum and I. barbatum, which is white to yellow.

2.1.2.10 Fruit

The fruit is a caryopsis; one-seeded fruit in which the seed coat is closely fused to the fruit wall. The caryopsis is popularly called a grain and is the typical fruit of the family Poaceae.
2.2 Conclusion

The characters of inflorescence and spikelet are the most two important in identification, especially in the genera level. Some additional characters, e.g., culms, leaves and habit can be of taxonomical importance and can be useful for species identification, especially in closely related collected group.
CHAPTER III

ANATOMICAL STUDY

3.1 Introduction

The subfamilies and tribes of the family Poaceae are generally distinguished by morphological characters of the spikelet and inflorescence (Clayton & Renvoize, 1986). However, it has been known more than 75 years that anatomical investigations of the grass leaf-blade have provided valuable taxonomic information. In fact, nowadays, it is generally accepted that anatomical details, especially of the leaf-blade, are not only useful in characterizing the major taxa within the family but are also an essential ingredient of any satisfactory treatment of grass taxonomy. Furthermore, in the Poaceae, with their highly specialized and reduced flowers, very fine morphological distinctions are often necessary to define differences between taxa. Anatomical data is, therefore, regarded as being of undoubted importance in the jigsaw of complete systematic evidence in this numerically large and important family (Ellis, 1976).

3.2 Literature reviews

Grass anatomy, as revealed by transverse sections, has been emphasized as a very fundamental character by Duval-Jouve (1875), who was the first to attempt to use it for systematics. The character used was the position of the bands of bulliform cells in relation to the nerves: for example, the presence of bulliform cells over the tertiary nerves in the Paniceae and Andropogoneae and the existence of bulliform cells in both upper and lower epidermis of Paniceae.

Six major groups of anatomical features in leaf-blades of the Poaceae were recognized by Brown (1958) viz, Bambusoid, Festucoid, Arundoid, Panicoid, Aristidoid and Chloridoid types. Each type has a unique shape and arrangement of mesophyll cells, sclerified cells, chlorenchyma, parenchyma and vascular bundles. The characters considered to be of phylogenetic value are presence or absence of the inner bundle sheath (endodermis); structure and function of the outer bundle sheath (parenchyma sheath) and the arrangement of the chlorenchyma cells between the
bundles. He concluded that the panicoid type is characterized by the parenchyma sheath cells developed to specialized plastids for starch storage, accompanied by a loss of starch formation by the chloroplasts of the chlorenchyma cells. Associated with this specialization in the sheath were a more regular, radial arrangement of the adjacent chlorenchyma cells and the complete elimination of the endodermis in some groups. The panicoid type is characterized in the tribe Paniceae by the retention of an endodermis on large bundles in some species of *Panicum, Tricholaena, Oplismenus, Brachiaria, Eriochloa*, and probably some other genera. Typically, however, an endodermis is lacking in this tribe. In the rosette leaves of *Panicum lindheimeri* and some species of other genera, the cells of the parenchyma sheath do not have the specialized starch plastids typical of the tribe. The chlorenchyma is, to some extent, radially arranged around the bundles, but the cells are not very long and narrow or very obviously radially arranged, as in the Chloridoideae, nor is this layer only one cell thick. There are evident air spaces among the cells of the mesophyll. In Andropogoneae there is no endodermis, the chlorenchyma is indefinitely or not at all radially arranged, and the cells are not obviously long and narrow.

Metcalfe (1955), in discussing his work on the systematic anatomy of the monocotyledons, states that in the transverse section of a grass leaf-blade both the occurrence and distribution of sclerenchyma especially in relation to the vascular bundles and the shape of the lamina are specific diagnostic characters. For the epidermal preparations, the characters that have been found to be of diagnostic value include the occurrence and distribution of large hooks or small rounded hooks, the distribution and types of epidermal papillae and the occurrence and distribution of 1-celled hairs.

Five years later, the applicable data, definitions, descriptions for the family as a whole and comparisons with any degree of assurance were greatly improved by the publication of "Anatomy of the Monocotyledons. 1. Gramineae" (Metcalfe, 1960). He arranged the descriptions of genera and species in alphabetical sequence and states that the tribe Andropogoneae has Panicoid type leaf-blades. Leaf-blades of the Panicoid type have many characters in common. From the anatomical standpoint, they are characterized by having cross to dumb-bell shaped silica-bodies over the veins; relatively long micro-hairs of which the distal cell tapers towards the apex; conspicuous to inconspicuous radiate chlorenchyma; and single or double bundle-sheaths. The double bundle-sheaths are uncommon, and when present, they are often
restricted to the large vascular bundles. Grass materials for his study included *Apluda* and *Ischaemum* from the subtribe Ischaeminae and *Eremochloa, Hackelochloa, Hemarthria, Rottboellia* and *Vossia* from the subtribe Rottboelliinae.

Ellis (1976) continued to stabilize the terminology of the grass family, and at the same time presented a classification system based on description and comparison of grass leaf anatomy as viewed in transverse section (Ellis, 1976) and the epidermis as seen in surface view (Ellis, 1979).

The diagnostic anatomical characters, together with other conservative characters, enable any grass to be consistently evaluated with reference to the core subfamily concept. This has been summarized by Ellis (1986) on the basis of the leaf anatomy, and also by Renvoize (1981), Clifford & Watson (1977) and Watson et al. (1985, 1986) (Table 3.1).

Detailed descriptions of some grass genera have been compiled by Watson & Dalwitz (1992). In their study they also listed the anatomical characters of some genera, namely *Apluda, Coelorachis, Eremochloa, Hackelochloa, Hemarthria, Ischaemum, Mnesitea, Ophiuros, Phacelurus, Rottboellia, Sehima, Thelepogon* and *Vossia*, from the two subtribes Ischaeminae and Rottboelliinae. For the genus *Kerriochloa*, they commented that the anatomical data was still missing.

Leaf-blade anatomy of 86 genera in the tribe Andropogoneae was investigated by Renvoize (1982). His results show that anatomy of the leaf blade is rather uniform, and that it is therefore possible to combine most of the observations into a single generalized description with illustrations of a few selected species.

**Epidermis**

Long cells narrowly to broadly oblong, of constant width; usually convolute-walled (80% of the genera), occasionally wave-walled; spined, papillate or smooth; contiguous, alternating with or irregularly interspersed with short cells.

Short cells solitary, often associated with a silica-containing cell.

Stomata of the lower epidermis usually in 1-2 rows (67% of the genera) occasionally up to 10 rows; of the upper epidermis often in 1-2 rows, occasionally up to 7 but often absent; of the lower surfaces usually alternate with the interstomatal cells (74% of the genera), but occasionally scattered; equal in width or slightly narrower than the interstomatal cells (Figs. 3.1 & 3.2).
<table>
<thead>
<tr>
<th>Characters</th>
<th>POOIDEAE</th>
<th>BAMBUSOIDEAE</th>
<th>ARUNDINOIDEAE</th>
<th>CHLORIDOIDEAE</th>
<th>PANICOIDEAE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MIDRIB</strong></td>
<td>median bundle only simple vasculature no adaxial parenchyma</td>
<td>keeled complex vasculature adaxial parenchyma rare</td>
<td>keeled or not simple vasculature no adaxial parenchyma rare</td>
<td>keeled or not simple vasculature adaxial parenchyma rare</td>
<td>keeled simple vasculature adaxial parenchyma common</td>
</tr>
<tr>
<td><strong>CHLORENCHYMA</strong></td>
<td>non-radiate diffuse (or compact) parenchyma cells</td>
<td>non-radiate compact (or diffuse) arm and fusoid cells</td>
<td>non-radiate compact (or diffuse) rachymorphous cells</td>
<td>strongly radiate uniform tabular cells rachymorphous cells</td>
<td>strongly or weakly radiate variable cells rachymorphous cells</td>
</tr>
<tr>
<td><strong>INTERCOSTAL LONG CELLS</strong></td>
<td>fusiform or rectangular straight walled or sinuous</td>
<td>rectangular sinuous walled</td>
<td>rectangular sinuous walled</td>
<td>rectangular sinuous walled</td>
<td>rectangular sinuous walled (rarely straight walled)</td>
</tr>
<tr>
<td><strong>STOMATA</strong></td>
<td>parallel sided guard cells sunken</td>
<td>triangular or domed guard cells flush</td>
<td>domed or triangular guard cells flush</td>
<td>triangular (rarely domed) guard cells flush</td>
<td>domed or triangular guard cells flush</td>
</tr>
<tr>
<td><strong>PAPILLAE</strong></td>
<td>absent</td>
<td>common cuticular many/cell</td>
<td>absent (rarely present)</td>
<td>common cuticular one/cell</td>
<td>common or absent inflated or cuticular one or many/cell</td>
</tr>
<tr>
<td><strong>MICROHAIRS</strong></td>
<td>absent</td>
<td>elongated, finger-like</td>
<td>elongated, finger-like</td>
<td>inflated, spherical</td>
<td>elongated, finger-like</td>
</tr>
<tr>
<td><strong>SILICA BODIES</strong></td>
<td>horizontally elongated oblong nodular</td>
<td>vertically elongated dumbbell, saddle, cross, olyroid</td>
<td>horizontally elongated square, oblong, cross, saddle, dumbbell</td>
<td>equidimensional saddle, square, angular, round, dumbbell</td>
<td>horizontally elongated dumbbell, cross, nodular</td>
</tr>
</tbody>
</table>
Subsidiary cells low- to high-domed or triangular. Silica bodies longitudinal, saddle-, cross- or dumbbell-shaped (Fig. 3.3). Micro-hairs finger like, the apical cell usually of equal length to the basal cell or longer (85% of the genera), occasionally slightly shorter (Fig. 3.4).
**Transverse section**

Leaves usually flat (77% of the genera), occasionally V-shaped or U-shaped.

Vascular bundles of different classes arranged in a single straight or slightly irregular lateral sequence. Primary bundle (midrib) solitary or with several smaller associated bundles and multiple layers of parenchyma cells below the upper epidermis. Secondary bundles round or rhomboidal, linked above and below the epidermis by small, square or oblong, often poorly developed, sclerenchymatous
girders. Sheath single, complete or incomplete above or below or both, the cells the same size as or slightly larger than the chlorenchyma cells, thick-walled. Tertiary bundles round, sclerenchymatous girders present, poorly developed or absent, sheath complete. Quaternary bundles usually present (85% of the genera) occasionally absent, circular, sclerenchymatous girders usually absent (81% of the genera) (Fig. 3.5).

![Image](image_url)

**Figure 3.5** Transverse section of *Themeda triandra* x 340 (after Renvoieze, 1982).

Chlorenchyma around all classes of vascular bundles, clearly radiate, obscurely radiate or non-radiate, never extensive; the number of cells between the bundles not exceeding four. Fusoid cells absent.

Upper epidermis flat or wavy. Lower epidermis of uniform small cells or of various sized cells. Bulliform cells on the upper epidermis often spanning the whole width of the intercostal zone, occasionally slightly less, often absent but then the epidermal cells often large. Motor cells usually absent (70% of the genera), occasionally present but seldom extensively developed.

However, a number of genera failed to conform completely to the general pattern. They represent extreme forms of the normal range of variation but do not appear to be associated with morphological trends within the tribe. These genera included *Andropterum, Apluda, Arthraxon, Bhidea, Diheteropogon, Dimeria, Eriocharis, Eulalia, Eulatiopsis, Glyphochloa, Hemarthria, Heteropogon, Imperata, Miscanthus, Mneseithia, Ophiuros, Oxylachis, Rhytachne, Saccharum, Spodiopogon, Thelephogon, Tripsacum* and *Zea* (Renvoieze, 1982).
Gould & Shaw (1983) noted that the epidermis of the culm is similar to the leaf blade, consisting mainly of rows of long-cells and short-cells, with stomata developed at intervals in some of the columns of long-cells. Hair cells of various types may also be present. Beneath the epidermis is a cortex of variable width. In the early stages of culm development, the cortex is made up of both parenchyma and sclerenchyma (fiber) cells. In young, green stems the parenchyma cells contain chloroplasts and thus are referred to as chlorenchyma cells. As the culm matures, lignification of cortical cells often continues, and one to several layers of sclerenchyma will develop immediately beneath the epidermis.

They also concluded that the culm in transverse section exhibits typical monocotyledonous stem structure. Vascular bundles of the internode may be scattered in persistent pithy ground tissue, as in Zea mays; arranged in two to several rings around a persistent central region of ground tissue, as in Bouteloua hirsuta (Fig. 3.6); or arranged in two to several rings around a central ground tissue that breaks down to form a hollow stem, as in typical Triticum aestivum (Fig. 3.7). Solid or semisolid internodes are characteristic of grasses of the Panicoideae, especially of the tribe Andropogoneae, and hollow internodes are characteristics of the Pooideae. However, the variations do occur, even within a single species.

**Figure 3.6** Transverse section of Bouteloua hirsuta culm internode showing vascular bundles arranged around the margin of a persistent central ground tissue (after Gould & Shaw, 1983).
Figure 3.7 Transverse section of *Triticum aestivum* culm internode showing large central cavity (after Gould & Shaw, 1983).

The number of xylem and phloem elements and the number of the associated fiber and parenchyma cells of the vascular bundle varies with the size of the bundle (Fig. 3.8). Often there are two protoxylem and two metaxylem vessels and a number of tracheids. At maturity one or both of the protoxylem vessels usually break down, leaving irregular cavities or lacunae. Frequently, the outer vascular bundles of the stem are in the cortical region (Gould & Shaw, 1983).

Figure 3.8 Transverse section of vascular bundle from culm of *Zea mays* (after Gould & Shaw, 1983).
3.3 Materials and methods

Living materials were collected in the fields throughout Thailand. Voucher herbarium specimens were prepared for identification purposes. The permanent slides were prepared using the paraffin methods adapted from Thammathaworn (1995) (Appendix E). The specimens were fixed in 70% FAA\(^1\) or 70% ethanol. Fully expanded leaves from the mid-culm were used, excluding the lowermost leaf and the leaf directly subtending the inflorescence. Transverse sections of culms and the midribs at median level, as well as transverse sections of the leaf-blades in the intercostals region and in the margin were obtained. The samples were dehydrated in increasing ethanol series then embedded in paraffin, sectioned with microtome at 8–16 \(\mu\)m thickness, stained in safranin and fast green, cleared with xylene and mounted in DePeX.

Epidermal preparations were made by scraping pieces of softened leaves with a safety razor blade, dehydrated in increasing ethanol series, stained in safranin, cleared with xylene and mounted in DePeX.

For each species, 15 or more sections of leaf-blades and culms were examined, the anatomical characters were observed, described and recorded photographically with an Olympus BX 51 microscope and an Olympus DP11 camera, respectively.

The leaf anatomy of each taxon was further evaluated by examination of all the anatomical characters of the leaf blade in transverse section (Ellis, 1976) and epidermis (Ellis, 1979) and used also by Metcalfe (1960).

The slides representative of each species are kept at the Kasin Suvathabhandhu Herbarium, Department of Botany, Chulalongkorn University, Bangkok (BCU) and Herbarium of Khon Kaen University, Khon Kaen, Thailand (KKU).

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\(^1\) 70% FAA (90 parts 70% EtOH; 5 parts glacial acetic acid; 5 parts 40% formaldehyde)
3.4 Results

Leaf and culm anatomy of 25 species, representing 12 genera of subtribes Ischaeminae and Rottboellinae in Thailand were described.

A. Subtribe Ischaeminae

Genus *Apluda*: 1 of 1 species was examined.

1. *A. mutica*

*Leaf surface* (Fig. 3.9A-C).

**ABAXIAL EPIDERMIS.**—Costal and intercostal zones well differentiated. *Intercostal long cells*: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls slightly thickened, slightly cuticular flanges probably developed; moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; no short cells between the adjacent long cells; no bulliform cells present on surface of the preparation examined. *Stomata*: dome-shaped subsidiary cells somewhat rounded, vertical width of the subsidiary cells smaller in relation to the horizontal length, always one row of stomata in each intercostals zone, centrally situated rows in the centre of intercostals zones; interstomatal long cells present, one cell between successive stomata, with concave ends. *Intercostal short cells*: absent. *Papillae*: absent. *Prickle hairs*: common in costal zones, overlying any vascular bundle-order, large prickles, base at least twice as long as the stomata; short barb, barb shorter than the base, point in both directions, apically and basally; one to three rows along the wholelength between all vascular bundle, rows separated by more than 5 silica bodies between successive prickles. *Micro-hairs*: bicellular, two-celled, basal and distal cells approximately equal in length; wall of distal cell thinner than wall of basal cell, apex of distal cell sharply pointed, base or attachment of basal cell: parallel-side, point of attachment small. *Macro-hairs*: absent. *Silica bodies*: dumb-bell shaped, relatively short, not elongate, present throughout the costal zones, constricted narrow central; granules present in silica bodies. *Costal short cells*: absent.
ADAXIAL EPIDERMIS.—In general, similar to the abaxial epidermis. Stomata marginally present rather rare, regular in form.

Leaf in transverse section (Fig. 3.9D-F).

Outline: blade expanded, corrugated: waves rounded, or only slightly undulating with no regular pattern associated with the vascular bundles or sometimes nearly straight, the margins round to slightly acute; no ribs or furrows present on either surface. Epidermis: bulliform cells present, regular adaxial and abaxial group; in simple fans the central cell not much larger than bundle sheath parenchyma; thickened prickles present in epidermis; usually located opposite the vascular bundles; bulbous base; barbed; papillae and macro-hairs absent. Midrib outline: present, keel conspicuous, triangular-shaped, projecting strongly from the abaxial, and slightly from the adaxial surface; one vascular bundle comprising the keel, parenchyma of small round cells surrounding or immediately adaxial to the median bundle. Midrib sclerenchyma: sclerenchyma associated with the keel; adaxial sclerenchyma strands fused forming a hypodermal band; sclerenchyma forming fairly wide abaxial girder combined with vascular bundle. Vascular bundle arrangement in the lamina: one median bundle, 10 or more third-order bundles between one second-order bundles; all bundles situated in the center of the blade. Primary-order vascular bundles: circular or round to slightly square-shaped in outline; phloem completely surrounded by thick-walled fibres; enlarged protoxylem vessel present but no lysigenous cavity; very wide vessels, width of vessels very much more than that of parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. Secondary-order vascular bundles: circular in outline; xylem and phloem easily distinguishable; bundles fairly large, similar size to the first-order bundles; sclerenchyma girder on both sides. Third-order vascular bundles: somewhat rounded in outline; usually with many small parenchyma sheath cells, vascular tissue consists of only a few vascular strands; sclerenchyma girder on both side. Intercostal sclerenchyma: crescent-shaped cap; sclerenchyma extends shortly along both abaxial and adaxial side of leaf margin. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.
Culm in transverse section (Fig. 3.9G).

Outline: circular or somewhat oval, culm 1.5-2 mm in diameter. No well-defined sclerenchyma ring present, apart from a few layers of fibres subjacent to the epidermis. Outer ground tissue consisting of sclerenchyma cells, and thin-walled cells, the walls being slightly thickened at the corners where several contiguous cells meet. Inner ground tissue consisting of large, thin-walled cells, and without pith cavity. Vascular bundles scattered, but a few from the spongy tissue at the centre of the culm, the outermost vascular bundles being smaller than the remainder.

Genus Ischaemum: 6 out of 13 species were examined.

2.1 I. hirtum

Leaf surface (Fig. 3.10A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. 
Intercostal long cells: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal, sometimes shape varies in single files: angled outwards, cells hexagonal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls slightly thickened, slightly cuticular flanges probably developed; moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: dome-shaped or low-dome shaped subsidiary cells somewhat rounded, one to five rows of stomata in each intercostals zone, interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: solitary short cells, tall and narrow in shape, vertical dimension greater than horizontal dimension, or sometimes square or rectangular in shape, smooth outline. Papillae: circular or rounded papillae as seen in surface view, small: diameter of the papillae usually less than ½ the vertical width of the long cells, more than one papillus per cell, same size and shape, unthickened, irregularly arranged present on all intercostals long cells and interstomatal longs cell. Prickle hairs: absent. Hooks: present very rare on the intercostals zone. Micro-hairs: bicellular, two-celled, basal cell only slightly shorter than the distal cell; wall of distal cell thinner than wall of basal cell, apex of distal cell slightly tapered, tapering to a round apex, base or attachment of basal cell: parallel-side, point of attachment small. Macro-hairs:
unicellular, hard, long hairs usually with thickened walls, many, usually smaller, specialized epidermal cell accompanying base of hair. Silica bodies: intermediate between cross and dumb-bell shaped, relatively short, not elongate, present one to three rows between the costal zones, constricted narrow central; granules present in silica bodies. Costal short cells: square or rectangular in shape, smooth outline, present very rare.

ADAXIAL EPIDERMIS.—Intercostal long cells: variable shape; shape varies across a single intercostals zone, hexagonal cells, or bowed outwards, inflated or rectangular cells, moderately to deeply undulating. Stomata: marginally present rather rare, regular in form. Costal short cells: tall and narrow in shape, smooth outline, present paired cells with the adjacent silica bodies.

Leaf in transverse section (Fig. 3.10D-F).

Outline: two halves of lamina curved upwards on either side of the midrib, the margins acute; no ribs or furrows present on either surface. Epidermis: bulliform cells present, arranged irregularly; epidermal cells rounded, inflated and much larger than bundle sheath cells, outer walls slightly thickened and covered by cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles absent; papillae present on abaxial side, papillae much less than half the width of cell, many per cell; macro-hairs present, constricted above bulbous base and sunken between the inflated epidermal cells, hairs very long and slender. Midrib outline: present, keel conspicuous, triangular-shaped and projection under first and second-order bundles due to sclerenchyma; many vascular bundle present in the keel, all vascular bundles abaxially arranged: three first-order bundle and smaller bundles comprise keel. Midrib sclerenchyma: sclerenchyma associated with the keel; adaxial sclerenchyma absent; sclerenchyma forming abaxial girder combined with vascular bundle. Vascular bundle arrangement in the lamina: 2-4 third-order bundles between consecutive larger bundles; all bundles situated in abaxial of the blade. Primary-order vascular bundles: round or circular in outline; phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present; width of vessels much more than that of parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. Secondary-order vascular bundles: elliptical in outline; xylem and phloem indistinguishable; sclerenchyma girder extension from bundle sheath on both
side. Third-order vascular bundles: square-shape or pentagonal in outline, surrounded by a sheath of 4-6 large parenchyma, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. Intercostal sclerenchyma: point-cap shaped of sclerenchyma at the margin, contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

Culm in transverse section (Fig. 3.10G).

Outline: circular or oval, culm 1-2 mm in diameter. Epidermis subtended by a sclerenchyma ring consisting of some 9-12 layers of fibres and assimilatory tissue bounded on the inner side, alternating with the outermost vascular bundle. Inner ground tissue consisting of many layers of large, thin-walled cells, extending to the hollow centre of the culm, center of the culm with a somewhat irregular pith cavity. Vascular bundles: the outermost vascular bundles embedded in the inner sclerenchyma ring. The other vascular bundles scattered throughout the thin-walled ground tissue.

2.2 I. hubbardii

Leaf surface (Fig. 3.11A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: shortened cells, length less than 3x longer than wide; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed; moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: dome-shaped subsidiary cells somewhat rounded or ovoid, one to four rows of stomata in each intercostals zone, separated by one or more than one file of intercostals long cells; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: tall and narrow in shape, smooth in outline, present very rare. Papillae: circular or rounded papillae as seen in surface view, large: diameter more than or equal ½ the vertical width of the long cells, more than one papillus per cell, same size and shape on individual cells but difference size in
difference cells, thick-wall, inflated, arranged in one horizontal rows, present on intercostals long cells, interstomatal longs cell and sometimes on costal long cells. *Prickle hairs:* absent. *Hooks:* absent. *Micro-hairs:* not seen. *Macro-hairs:* unicellular, hard, long hairs usually with thickened walls, many smaller specialized epidermal cell accompanying base of hair. *Silica bodies:* dumb-bell shaped, constricted, narrow central portion, present one or two rows between the costal zones; granules present in silica bodies. *Costal long cells:* narrowly than intercostals long cells.

**ADAXIAL EPIDERMIS.—** *Intercostal long cells:* short and inflated cells. *Stomata* marginally present rather rare, regular in form.

*Leaf in transverse section* (Fig. 3.11D-F).

**Outline:** two halves of lamina curved upwards on either side of the midrib, sometimes V-shaped; the margins round or acute; no ribs or furrows present on both surface. *Epidermis:* bulliform cells present on adaxial surface, arranged irregularly; epidermal cells rounded, inflated and larger than bundle sheath cells, outer walls thickened and covered by cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles absent; papillae present on abaxial side, thin-walled wide papillae scattered throughout the epidermis; macro-hairs absent. *Midrib outline:* present, keel conspicuous, triangular-shaped to slightly round; many vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. *Midrib sclerenchyma:* sclerenchyma associated with the keel; adaxial sclerenchyma absent, sclerenchyma forming abaxial girder combined with vascular bundle. *Vascular bundle arrangement in the lamina:* 10 or more third-order bundles between consecutive larger bundles; all bundles situated in abaxial of the blade. *Primary-order vascular bundles:* round or circular in outline; phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present; width of vessels much more than that of parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. *Secondary-order vascular bundles:* round or circular in outline; xylem and phloem indistinguishable; bundles fairly large, similar size to the first-order bundles; sclerenchyma girder on both side. *Third-order vascular bundles:* square-shaped or pentagonal or hexagonal in outline, surrounded by a sheath of 4-7 large parenchyma, all vascular tissue consists of only a few vascular strands; sclerenchyma girder on both side or sometimes absent. *Intercostal*
sclerenchyma: cap shaped of sclerenchyma at the margin, cap equal or less than the width of a third-order bundle, contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

Culm in transverse section (Fig. 3.11G).

Outline: somewhat circular or oval, culm 1.5-2.5 mm in diameter, intercellular air spaces present about 3 cells below the epidermis around the periphery of the culm, the outermost vascular bundle alternating with the spaces. Intercellular spaces followed on the inner side by a somewhat sinuous, continuous ring of fibres about 2-3 cells wide, the fibrous ring being bounded on the inner side by a zone of thin-walled ground tissue, extending to the hollow centre of the culm, with a somewhat circular pith cavity. The other vascular bundles scattered throughout the thin-walled ground tissue.

2.3 I. muticum

Leaf surface (Fig. 3.12A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed; moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: dome-shaped subsidiary cells somewhat rounded, vertical width of the subsidiary cells smaller in relation to the horizontal length, three to six rows of stomata in each intercostals zone, separated by more than one file of intercostals long cells; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: solitary cells, tall and narrow in shape, crenate in outline, sometimes connect to silica bodies present at only one or both end of each long cell, in 80 % of all long cells. Papillae: circular or rounded papillae as seen in surface view, large: diameter more than or equal ½ the vertical width of the long cells, more than one papillus per cell, different sizes or shape present on individual cells,
unthickened, arranged in one horizontal rows, present on intercostals long cells and interstomatal longs cell that near the stomata. *Prickle hairs*: absent. *Hooks*: present very rare in intercostals zone. *Micro-hairs*: bicellular, two-celled, basal cell only slightly shorter than the distal cell; wall of distal cell thinner than wall of basal cell, apex of distal cell slightly tapered, tapering to a round apex, base or attachment of basal cell: parallel-side, point of attachment small. *Macro-hairs*: absent. *Silica bodies*: dumb-bell shaped, constricted, narrow central portion, present one or two rows between the costal zones; granules present in silica bodies. *Costal long cells*: narrowly than intercostals long cells. *Costal short cells*: square or rectangular in shape.

**ADAXIAL EPIDERMIS.**—Costal and intercostal zones well differentiated. *Intercostal long cells*: variable shape; shape varies across a single intercostals zone, hexagonal cells, or bowed outwards, inflated or rectangular cells, moderately undulating. *Stomata* marginally present rather rare, regular in form.

*Leaf in transverse section* (Fig. 3.12D-F).

*Outline*: blade expanded, straight, the margins acute; no ribs or furrows present on either surface. *Epidermis*: bulliform cells present, fans-shaped, group of large and inflated bulliform cells, well-defined and regular on adaxial, extending over one or two vascular bundles, the central cell much larger than bundle sheath cells; outer walls thickened and covered by a distinct thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles absent; papillae present on abaxial side, papillae narrower than the epidermal cells; macro-hairs absent. *Midrib outline*: present, keel conspicuous, triangular-shaped; many vascular bundles present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. *Midrib sclerenchyma*: sclerenchyma associated with the keel; adaxial sclerenchyma strands fused forming a hypodermal band; sclerenchyma forming abaxial girder combined with vascular bundle. *Vascular bundle arrangement in the lamina*: one first-order bundle, many third-order bundles between one second-order bundles; all bundles situated in abaxial of the blade. *Primary-order vascular bundles*: round to elliptical in outline; phloem completely surrounded by thick-walled fibres; enlarged protoxylem vessel present but no lysigenous cavity; width of vessels slightly more than that of parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. *Secondary-order vascular bundles*: elliptical in outline;
xylem and phloem easily distinguishable; bundles fairly large, similar size to the first-order bundles; sclerenchyma girder on both side. Third-order vascular bundles: square-shape or pentagonal or hexagonal in outline, surrounded by a sheath of 4-7 large parenchyma, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. Intercostal sclerenchyma: point-cap shaped of sclerenchyma at the margin, contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

Culm in transverse section (Fig. 3.12G).

Outline: somewhat circular in outline, culm 1-2 mm in diameter. Epidermis subtended by a zone of 1-2 layers of fibres of small diameter and with thick walls, followed by a zone of thin-walled tissue about 4-5 cells wide, this zone being bounded internally by a sclerenchyma ring about 5-6 cells wide. Inner ground tissue consisting of many layers of large, thin-walled cells, extending to the hollow centre of the culm, center of the culm with a somewhat irregular pith cavity. Vascular bundles of the outermost circle situated at the outer or center boundary, and the next circle at the inner boundary, of the sclerenchyma ring. The other vascular bundles scattered throughout the thin-walled ground tissue.

2.4 I. rugosum

Leaf surface (Fig. 3.13A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed; deeply undulating, corrugated, wave-length short, amplitude relatively deep and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: dome-shaped or low-dome shape subsidiary cells somewhat rounded or ovoid, one to four rows of stomata in each intercostals zone, separated by one or more than one file of intercostals long cells; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: solitary cells, tall and
narrow in shape, crenate in outline, present at only one or both end of each long cell, in 80 % of all long cells. *Papillae*: absent. *Prickle hairs*: absent. *Hooks*: absent. *Micro-hairs*: bicellular, two-celled, basal cell only slightly shorter than the distal cell; wall of distal cell thinner than wall of basal cell, apex of distal cell slightly tapered, tapering to a round apex, base or attachment of basal cell: parallel-side, point of attachment small. *Macro-hairs*: unicellular, hard, short, stiff hairs usually with thickened walls, two, or sometimes one specialized epidermal cell accompanying base of hair. *Silica bodies*: dumb-bell shaped, constricted, narrow central portion, present one or two rows between the costal zones; granules present in silica bodies. *Costal long cells*: narrowly than intercostals long cells. *Costal short cells*: tall and narrow in shape, crenate in outline.

**ADAXIAL EPIDERMIS.—** *Intercostal long cells*: Basally similar to the abaxial epidermis. *Stomata*: distribution similar to the abaxial epidermis. *Papillae*: circular or rounded papillae as seen in surface view, small: diameter of the papillae usually less than ½ the vertical width of the long cells, more than one papillus per cell, same size and shape, unthickened, irregularly arranged present on 90 % of the intercostals long cells and interstomatal longs cell. *Prickle hairs*: common in costal zones, overlying any vascular bundle-order, medium prickles, base as long as or slightly longer than the stomata; long barb, barb as long as the base, point in both directions, apically and basally; one row along the wholelength between all vascular bundle, rows separated by more than 5 silica bodies between successive prickles. *Hooks*: present very rare on the intercostals zone. *Macro-hairs*: unicellular, hard, long hairs, usually with thickened walls, many smaller specialized epidermal cell accompanying base of hair. *Silica bodies*: dumb-bell shaped, constricted, narrow central portion, or sometimes nodular silica bodies, present one or two rows between the costal zones; granules present in silica bodies.

*Leaf in transverse section* (Fig. 3.13D-F).

*Outline*: lamina rolled inwards towards the adaxial surface, inrolled from one margin only; margins wrapped around each other; the margins acute; ribs and furrows present on both surface; on adaxial surface: medium furrows, a quarter to one half the leaf thickness, furrows obtuse angle, furrows between all vascular bundles; triangular ribs, apex pointed, one vascular bundle in each rib; on abaxial surface shallow and wider than the adaxial ribs, present opposite all vascular bundles. *Epidermis*: 
bulliform cells present on adaxial surface or sometimes in abaxial surface, associated with colourless cells in fan-shaped groups penetrating deeply into the mesophyll, outer walls thickened and covered by cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles absent; papillae present on adaxial side, papillae narrower than the epidermal cells, 1-many per cell or sometimes bifurcate; macro-hairs absent. Midrib outline: present, inconspicuous keel, no associated parenchyma developed, projection due to position or size of bundle and sclerenchyma on abaxial surface; one vascular bundle comprising the keel. Midrib sclerenchyma: sclerenchyma associated with the keel; sclerenchyma forming adaxial and abaxial girdler combined with vascular bundle. Vascular bundle arrangement in the lamina: 1-4 third-order bundles between consecutive larger bundles; all bundles situated in center of the blade. Primary-order vascular bundles: elliptical in outline; phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present; width of vessels much more than that of parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. Secondary-order vascular bundles: elliptical in outline; xylem and phloem indistinguishable; bundles fairly large, similar size to the first-order bundles; sclerenchyma girdler on both side. Third-order vascular bundles: pentagonal or hexagonal in outline, vertically elonged, surrounded by a sheath of 4-7 large parenchyma, all vascular tissue consists of only a few vascular strands; sclerenchyma girdler on both side or sometimes absent. Intercostal sclerenchyma: point-cap shaped of sclerenchyma at the margin, contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

Culm in transverse section (Fig. 3.13G).

Outline: circular, culm 1.5-2 mm in diameter. Epidermis subtended by a zone of 3-4 layers of sclerenchyma. Inner ground tissue consisting of 7-8 layers of large, thin-walled cells, extending to the hollow centre of the culm, center of the culm with a somewhat circular pith cavity. Vascular bundles of the outermost embedded in the center sclerenchyma ring. The other vascular bundles scattered throughout the thin-walled ground tissue.
2.5 I. tenuifolium

Leaf surface (Fig. 3.14A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. *Intercostal long cells*: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls slightly thickened, slightly cuticular flanges probably developed; moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. *Stomata*: low-dome shaped subsidiary cells ovoid, one row of stomata in each intercostals zone, rarely 2 rows, centrally situated rows in the centre of intercostals zones; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. *Intercostal short cells*: solitary short cells, tall and narrow in shape, crenate in outline, present at only one or both end of each long cell, in 80 % of all long cells. *Papillae*: absent. *Prickly hairs*: absent. *Hooks*: absent. *Micro-hairs*: only basal cell remains. *Macro-hairs*: absent. *Silica bodies*: dumb-bell shaped, elongated with rounded ends, length of central portion equal to one third of total length of the body, present throughout the costal zones; granules present in silica bodies. *Costal long cells*: narrowly than intercostals long cells.

ADAXIAL EPIDERMIS.—*Intercostal long cells*: variable shape; shape varies across a single intercostals zone, hexagonal cells, or bowed outwards, inflated or rectangular cells, slightly undulating. *Stomata* present regular in form. *Prickly hairs*: common in intercostal zones, very large prickles, base as least twice as long as the stomata; long barb, barb longer than the base, point in both directions, apically and basally.

*Leaf in transverse section* (Fig. 3.14D-F).

*Outline*: heart-shaped in outline or sometimes two halves of lamina curved upwards on either side of the midrib and inrolled in one side; the margins round or acute; ribs and furrows present on adaxial surface: slight, shallow furrows, between all vascular bundles; triangular ribs, one vascular bundle in each rib; sometimes no ribs or furrows on either side of the midrib. *Epidermis*: bulliform cells present on adaxial surface, associated with colourless cells in fan-shaped groups penetrating...
deeply into the mesophyll and abaxial side, outer walls very thickened and covered by cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles present, pointed broad prickle, base not bulbous; papillae absent on both side; macro-hairs absent. Midrib outline: present, keel conspicuous, triangular to round-shaped, three-six vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. Midrib sclerenchyma: sclerenchyma associated with the keel; sclerenchyma forming adaxial and abaxial girder combined with vascular bundle. 
Vascular bundle arrangement in the lamina: 3-8 third-order bundles between consecutive larger bundles; all bundles situated in center of the blade. Primary-order vascular bundles: round or slightly elliptical in outline; phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present; width of vessels much more than that of parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. Secondary-order vascular bundles: round to slightly elliptical in outline; xylem and phloem indistinguishable; bundles similar size to the first-order bundles; sclerenchyma girder on both side extension from bundle sheath. Third-order vascular bundles: square-shaped or pentagonal or hexagonal in outline, surrounded by a sheath of 4-7 large parenchyma, all vascular tissue consists of only a few vascular strands; sclerenchyma girder on both side or sometimes absent. Intercostal sclerenchyma: point-cap shaped of sclerenchyma at the margin, not contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

Culm in transverse section (Fig. 3.14G).

Outline: oval, culm 1.5-2 mm in diameter. Epidermis subtended by a zone of 4-5 layers of sclerenchyma. Inner ground tissue consisting of large thin-walled cells, and without pith cavity. Vascular bundles of the outermost embedded in the inner sclerenchyma ring. The other vascular bundles scattered in the peripheral part of the inner thin-walled ground tissue.

2.6 I. sp.1

Leaf surface (Fig. 3.15A-B).
ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. *Intercostal long cells*: shortened cells, length less than 3x longer than wide, or varies in shape; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed; moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; no short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. *Stomata*: dome-shaped subsidiary cells somewhat rounded, one to four rows of stomata in each intercostals zone, separated by one or more than one file of intercostals long cells; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. *Intercostal short cells*: absent. *Papillae*: circular or rounded papillae as seen in surface view, large: diameter more than or equal ¼ the vertical width of the long cells, more than one papillus per cell, same size and shape on individual cells but differrence size in difference cells, thick-wall, inflated, arranged in one horizontal rows, present on intercostals long cells, interstomatal longs cell and sometimes on costal long cells. *Prickle hairs*: absent. *Hooks*: absent. *Micro-hairs*: not seen. *Macro-hairs*: densely, unicellular, long and slender hairs usually with thickened walls, many smaller specialized epidermal cell accompanying base of hair. *Silica bodies*: dumbbell shaped, constricted, narrow central portion, present one or two rows between the costal zones; granules present in silica bodies. *Costal long cells*: absent.

ADAXIAL EPIDERMIS.—In general, similar to the abaxial epidermis. *Intercostal long cells*: short and inflated cells. *Stomata* marginally present rather rare, regular in form.

*Leaf in transverse section* (Fig. 3.15C-E).

*Outline*: two halves of lamina curved upwards on either side of the midrib, or U-shaped; the margins round or acute; no ribs or furrows present on both surface. *Epidermis*: bulliform cells present on adaxial surface, arranged irregularly; epidermal cells rounded, inflated and much larger than bundle sheath cells, outer walls very thickened and covered by cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles absent; papillae present on abaxial side, thick-walled wide papillae scattered throughout the epidermis; macro-hairs present, constricted above bulbous base and sunken between
the inflated epidermal cells, hairs long and slender. **Midrib outline:** present, keel conspicuous, triangular, sometimes inconspicuous; five vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. **Midrib sclerenchyma:** sclerenchyma associated with the keel; adaxial sclerenchyma strands forming a hypodermal band; sclerenchyma forming abaxial girder combined with vascular bundle. **Vascular bundle arrangement in the lamina:** 10 or more third-order bundles between consecutive larger bundles; all bundles situated in abaxial of the blade. **Primary-order vascular bundles:** round or circular in outline; phloem completely surrounded by thick-walled fibres; enlarged protoxylem vessel present but no lysigenous cavity; width of vessels smaller than that of parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. **Secondary-order vascular bundles:** round to slightly elliptical in outline; xylem and phloem indistinguishable; bundles similar size to the first-order bundles; sclerenchyma girder on both sides. **Third-order vascular bundles:** square-shaped or pentagonal or hexagonal in outline, surrounded by a sheath of 4-7 large parenchyma, all vascular tissue consists of only a few vascular strands; sclerenchyma girder on both side or sometimes absent. **Intercostal sclerenchyma:** cap shaped of sclerenchyma at the margin, cap more than the width of a third-order bundle, contact with the lateral bundle. **Mesophyll:** radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

**Genus Kerriochloa:** 1 of 1 species was examined.

3. **K. siamensis**

**Leaf surface** (Fig. 3.16A-C).

**ABAXIAL EPIDERMIS.**—Costal and intercostal zones well differentiated. **Intercostal long cells:** variable shape; shape varies across a single intercostals zone, hexagonal cells centrally and rectangular cells laterally; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls slightly thickened, slightly cuticular flanges probably developed; moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; sometimes adjacent with single short cells. **Stomata:** low dome-shaped, ovoid or vertical width of the subsidiary cells smaller in relation to the horizontal length, one to five rows of stomata in each intercostals zone, separated by more than one file of intercostals long
cells; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. *Intercostal short cells*: solitary cells, square or rectangular in shape, smooth walls, present at only one end of each long cell, in 20% of all long cells. *Papillae*: circular or rounded papillae as seen in surface view, large: diameter more than or equal ½ the vertical width of the long cells, one papillus per cell, unthickened, present on all intercostals long cells and interstomatal longs cell, usually centrally positioned. *Pickle hairs*: absent. *Hooks*: absent. *Micro-hairs*: not seen. *Macro-hairs*: unicellular, hard, short, stiff hairs usually with thickened walls, one specialized hemispherical epidermal cell accompanying base of hair, swollen in relation to hair thickness. *Silica bodies*: equidimensional, vertical and horizontal dimensions approximately equal, acutely angled, present throughout the costal zones; granules present in silica bodies; sometimes found transverse silica bodies tall and narrow dumb-bell shape on intercostals long cells. *Costal long cells*: bowed outwards, cells inflated, thin and smooth wall, separated by silica bodies. *Costal short cells*: absent.

**ADAXIAL EPIERMIS.**—Costal and intercostal zones well differentiated. *Intercostal long cells*: variable shape; shape varies across a single intercostals zone, hexagonal cells, or bowed outwards, inflated or rectangular cells, slightly undulating, faintly corrugated, wave-length short, amplitude shallow and frequency high. *Stomata* marginally present rather rare, regular in form. *Intercostal short cells*: solitary or paired, tall and narrow, crenate in outline, present at near leaf margins of intercostal zones only. *Hooks*: present at near leaf margins of intercostal zones only. *Micro-hairs*: bicellular, two-celled, basal and distal cells approximately equal in length; wall of distal cell thinner than wall of basal cell, apex slightly tapered, tapering to rounded apex, base or attachment of basal cell: parallel-side, point of attachment small.

*Leaf in transverse section* (Fig. 3.16D-E).

**Outline**: blade expanded, undulating gently or nearly straight, the margins round; no ribs or furrows present on either surface. *Epidermis*: bulliform cells present, arranged irregularly; epidermal cells rounded, inflated the same size or larger than bundle sheath cells; macro-hairs constricted above bulbous base and sunken between the inflated epidermal cells, hairs long and slender; papillae present on abaxial surface, thin-walled wide papillae scattered throughout the epidermis. *Midrib outline*: present, inconspicuous keel, no associated parenchyma developed, projection due to
position or size of bundle and sclerenchyma on abaxial surface; one vascular bundle
comprising the keel. *Midrib sclerenchyma*: sclerenchyma associated with the keel;
adaxial sclerenchyma strands fused forming a hypodermal band; abaxial
sclerenchyma girder combined with vascular bundle. *Vascular bundle arrangement in
the lamina*: one median bundle, 10 or more third-order bundles between one second-
order bundles; all bundles situated in the center of the blade. *Primary-order vascular
bundles*: circular or round in outline; phloem completely surrounded by thick-walled
fibres; enlarged protoxylem vessel present but no lysigenous cavity; very wide
vessels, width of vessels very much more than that of parenchyma sheath cells;
metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct.
*Secondary-order vascular bundles*: circular in outline; xylem and phloem easily
distinguishable; bundles fairly large, similar size to the first-order bundles;
sclerenchyma girder on both sides. *Third-order vascular bundles*: angular in outline;
square-shaped or pentagonal surrounded by a sheath of 4 or 5 large parenchyma cells,
vascular tissue consists of only a few vascular strands; sclerenchyma girder on both
side or only one side or absent. *Intercostal sclerenchyma*: no sclerenchyma developed
in association with the margin. *Mesophyll*: radiate chlorenchyma: radially arranged
around the vascular bundles which are often close together; single layer isodiometric.

*Culm in transverse section* (Fig. 3.16F).

*Outline*: somewhat circular, culm 1-1.5 mm in diameter. *Epidermis* subtended
by about 4-5 layers of cells with thickened, lignified walls, with a circular of small,
oval, columns of assimilatory tissue embedded in the thickened ground tissue. *Inner
ground tissue* consisting of large cells, with thin walls and wide lumina, and without
pith cavity. *Vascular bundles* of the outermost circle embedded in the layers of
thickened cells and being smaller than the remainder. The other vascular bundles
scattered in the peripheral part of the inner thin-walled ground tissue.

**Genus Sehima**: 1 of 1 species was examined.

**4. S. nervosum**

*Leaf surface* (Fig. 3.17A-C).

*ABAXIAL EPIDERMIS*.—Costal and intercostal zones well differentiated.*
*Intercostal long cells*: elongated cells, length 3x or more than 3x longer than the
width; side walls or anticlinal horizontal long walls parallel to one another, cell
rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed; deeply undulating, strongly corrugated, wave-length short, amplitude relatively deep and frequency high; no short cells between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: dome-shaped subsidiary cells somewhat rounded, vertical width of the subsidiary cells slightly smaller or nearly approximately equal in relation to the horizontal length, always one to two rows of stomata in each intercostals zone, if two: rows adjacent to one another, not separated by files of intercostals long cells; centrally situated rows in the centre furrows of intercostals zones; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: absent. Papillae: absent. Prickle hairs: common in costal zones, overlying any vascular bundle-order, medium prickles, base as long or slightly longer than the stomata; long barb, barb approximately as long or slightly shorter than the base, point in both directions, apically and basally; more than three rows along the wholelength between all vascular bundle, rows separated by one to four silica bodies between successive prickles. Hooks: present in margins of costal zones only. Micro-hairs: bicellular, two-celled, slender, basal and distal cells approximately equal in length; wall of distal cell thinner than wall of basal cell, distal cell very slender look like long caudate, angle base emerges in cells at margins of costal zones. Macro-hairs: absent. Silica bodies: dumb-bell shaped, elonged with rounded ends, length of central portion equal to one third of total length of the body, present throughout the costal zones; granules present in silica bodies. Costal short cells: alternating silica cells and costal short cells, short to square short or cork cells.

ADAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: variable shape; shape varies across a single intercostals zone, hexagonal cells centrally and rectangular cells laterally, wider cells in center of intercostals zones; sometimes adjacent with single short cells. Stomata marginally present rather rare, regular in form. Intercostal short cells: solitary, silicified silica cells containing distinct silica body or phytolith, silica body and silica cell of same or similar shape, present between 25% of successive long cells at lateral intercostals zones.
Leaf in transverse section (Fig. 3.17D-F).

Outline: blade broad wide, horizontally elongated, the margins round to slightly acute; ribs and furrows present on both surface; on adaxial surface: slight, shallow furrow less than a quarter of the leaf thickness, furrow wide and open, furrows between first-order and second-order vascular bundles, present over third-order bundles; ribs slides rounded with flat top; on abaxial surface taller than the adaxial ribs, present opposite all vascular bundles; composed of sclerenchyma in form of rounded caps on second and third-order bundles; composed of girder or strand of sclerenchyma in contact with epidermis on first-order bundles. Epidermis: bulliform cells present, fan-shaped present over third-order bundles, central cell much larger than bundle sheath parenchyma; thickened prickles present in both surface; usually located opposite the vascular bundles; papillae and macro-hairs absent. Midrib outline: present, inconspicuous keel, no associated parenchyma developed, sclerenchyma causes projection; one vascular bundle comprising the keel. Midrib sclerenchyma: sclerenchyma associated with the keel; adaxial and abaxial sclerenchyma girder combined with vascular bundle. Vascular bundle arrangement in the lamina: 4-6 first-order bundles in half lamina, 1-3 second-order bundle between first-order bundle, 1-4 third-order bundle between second-order bundle, first and second-order bundles central and third-order bundle displaced abaxially in ribs. Primary-order vascular bundles: circular or round in outline; phloem completely surrounded by thick-walled fibres; enlarged protoxylem vessel present but no lysigenous cavity; very wide vessels, width of vessels not much more than that of parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. Secondary-order vascular bundles: circular in outline; xylem and phloem easily distinguishable; bundles not large and not similar size to the first-order bundles; sclerenchyma girder on both sides. Third-order vascular bundles: rounded in outline; usually with many small parenchyma sheath cells, vascular tissue consists of only a few vascular strands; sclerenchyma cap on abaxial surface. Intercostal sclerenchyma: crescent-shaped cap; sclerenchyma extends shortly along both abaxial and adaxial side of leaf margin. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.
Culm in transverse section (Fig. 3.17G).

Outline: circular, culm 1.2-1.5 mm in diameter. Epidermis subtended by about 9-12 layers of cells with thickened, lignified walls, without a circular of small assimilatory tissue. Inner ground tissue consisting of large, thin-walled cells, and without pith cavity. Vascular bundles of the outermost circle embedded in the layers of thickened cells and being smaller than the remainder. The other vascular bundles scattered in the peripheral part of the inner thin-walled ground tissue.

Genus Thelepogon: 1 of 1 species was examined.

5. T. elegans

Leaf surface (Fig. 3.18A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: elongated cells, length 3x or more than 3x longer than the width, or sometimes with inflated cells separated the narrower cells; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls rounded if have short cells between the adjacent long cells or vertical if not; horizontal and vertical anticlinal walls slightly thickened, slightly cuticular flanges probably developed; moderately undulating, often irregular, wavelength short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: low-dome to dome shaped subsidiary cells somewhat ovoid to rounded, many or upto 18 rows of stomata in each intercostals zone, separated by more than two file of intercostals long cells; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: solitary of short cells situated between long cells, tall and narrow in shape, smooth in outline, usually connect to transverse silica bodies. Papillae: absent. Prickle hairs: absent. Hooks: present very rare in intercostals zones. Micro-hairs: bicellular, two-celled, basal cells shorter than distal cells, basal cells less than ½ the length of the distal cell; wall of distal cell thinner than wall of basal cell, slightly tapered, tapering to a rounded apex, base or attachment of basal cell: expanded base, constriction above bulbous base. Macro-hairs: unicellular, hard, short, stiff hairs usually with thickened walls, one specialized hemispherical epidermal cell accompanying base of hair. Silica bodies: transverse cross-shaped with four rounded apices of silica bodies in intercostal zones; costal zones with dumb-bell shaped, relatively short, not elongate, sometimes
intermediate between cross and dumb-bell shaped; granules present in all silica bodies. *Costal short cells*: solitary of short cells situated between long cells, tall and narrow in shape, smooth in outline, connect to silica bodies.

**ADAXIAL EPIDERMIS.**—In general, similar to the abaxial epidermis. *Intercostal long cells*: variable shape; shape varies across a single intercostals zone, hexagonal cells, or bowed outwards, inflated or rectangular cells, moderately undulating. *Stomata* no stomata visible on surface of preparation examined. *Hooks*: densely with hooks around the intercostal zones.

*Leaf in transverse section* (Fig. 3.18D-E).

**Outline**: two halves of lamina curved upwards on either side of the midrib, the margins muticus or round; no ribs or furrows present on either surface. *Epidermis*: bulliform cells present, arranged irregularly; epidermal cells rounded, inflated and larger than bundle sheath cells, outer walls thickened and covered by a distinct thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; macro-hairs constricted above bulbous base and sunken between the inflated epidermal cells, hairs long and slender; thickened prickles present in epidermis; bulbous base with short barbed; papillae absent. *Midrib outline*: present, keel conspicuous, rounded or semicircular-shaped, slightly thicker than the rest of lamina; many vascular bundles present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. *Midrib sclerenchyma*: sclerenchyma associated with the keel; adaxial sclerenchyma absent; abaxial sclerenchyma girder combined with vascular bundle. *Vascular bundle arrangement in the lamina*: one first-order bundle, 10 or more third-order bundles between one second-order bundles; all bundles situated in the center of the blade except median bundle. *Primary-order vascular bundles*: round to slightly elliptical in outline; phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels slightly larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. *Secondary-order vascular bundles*: circular in outline; xylem and phloem easily distinguishable; bundles usually fairly large, similar size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on both side. *Third-order vascular bundles*: square-shape or pentagonal or hexagonal in outline, surrounded by a sheath of 4-6 large parenchyma, all vascular tissue consists of only a
few vascular strands; no associate with sclerenchyma. *Intercostal sclerenchyma*: point-cap shaped of sclerenchyma at the margin, not in contact with the lateral bundle. *Mesophyll*: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

*Culm in transverse section* (Fig. 3.18F).

*Outline*: circular or somewhat oval, culm 2-3 mm in diameter. *Epidermis* subtended by about 1-3 layers of thin-walled cells; this zone being bounded on its inner side by a sclerenchyma ring consisting of some 6-8 layers of fibres. *Inner ground tissue* consisting of large thin-walled cells, and without pith cavity. *Vascular bundles* of the outermost circle embedded in the sclerenchyma ring, and being smaller than the next circle. The other vascular bundles scattered in the peripheral part of the inner thin-walled ground tissue.

**B. Subtribe Rottboelliiinae**

*Genus Eremochloa*: 3 out of 11 species were examined.

**6.1 E. attenuata**

*Leaf surface* (Fig. 3.19A-B).

**ABAXIAL EPIDERMIS.**—Costal and intercostal zones well differentiated. *Intercostal long cells*: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed. Moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. *Stomata*: triangular-shaped subsidiary cells, apex drawn out into a point; evagination but not containing the nucleus, one to three rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. *Intercostal short cells*: paired short cells situated between long cells: tall and narrow in shaped, crenate or irregular in outline, accompanied with hook. *Papillae*: absent. *Prickle hairs*: absent. *Hook*: present. *Micro-hairs*: bicellular, two-celled, basal cell only slightly shorter than the distal cells; wall of distal cell thinner.
than wall of basal cell, slightly tapered; tapering to a rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. **Macro-hairs:** present densely on intercostal zones, unicellular, long and slender, usually with thickened walls, many epidermal cells associated with base of macro-hairs, usually smaller, specialized epidermal cells accompanying base of hair. **Silica bodies:** dumb-bell shaped relatively short, not elongate, present usually one row over the costal zones, constricted narrow central; granules present in silica bodies.

**ADAXIAL EPIDERMIS.—** In general, similar to the abaxial epidermis but intercostals short cells and hooks absent.

*Leaf in transverse section* (Fig. 3.19C-E).

**Outline:** two halves of lamina folded toward each other on either side of the midrib formed standard V-shaped, nearly 90° to each other, the margins acute; ribs and furrows present on both surface; medium furrow, a quarter to one half of the leaf thickness, furrow wide and open, furrows between second-order vascular bundles, present over third-order bundles; ribs slides rounded with flat top. **Epidermis:** bulliform cells present, arranged in irregularly; epidermal cells rounded, inflated and slightly larger than bundle sheath cells; prickles and papillae absent; macro-hairs present, constricted above bulbous base embedded between large epidermal, hairs long and slender. **Midrib outline:** present, conspicuous keel, round V-shaped keel, bulliform cells present in adaxial epidermis above median bundle; one vascular bundle present in the keel, abaxially arranged: first-order bundle only comprise keel.

**Midrib sclerenchyma:** sclerenchyma associated with the keel; sclerenchyma forming abaxial girder and combined with vascular bundle. **Vascular bundle arrangement in the lamina:** one small first-order bundle in half lamina, 2-3 third-order bundles between second-order bundle, all bundles situated in center of the blade. **Primary-order vascular bundles:** circular or round in outline; sheath incomplete surrounding the bundle due to interruption of sclerenchyma, phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels slightly larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. **Secondary-order vascular bundles:** elliptical in outline; xylem and phloem easily distinguishable; bundles larger than size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on both side. **Third-order vascular bundles:** pentagonal or hexagonal in outline,
all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. **Intercostal sclerenchyma:** crescent-shaped of sclerenchyma at the margin, not in contact with the lateral bundle. **Mesophyll:** radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

*Culm in transverse section* (Fig. 3.19F).

**Outline:** oval, culm 1.2-1.5 mm in diameter. **Epidermis** with one layer of large thin-walled epidermal cells, and subtended by continuous zone of chlorenchyma layer. Chlorenchyma layers bounded on its inner side by a ring of sclerenchyma about 2-3 cells wide. **Inner ground tissue** consisting of large thin-walled cells, extending to the hollow centre of the culm, center of the culm with an oval pith cavity. **Vascular bundles** of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in the peripheral part of the inner thin-walled ground tissue, larger vascular bundles with sclerenchyma caps.

6.2 **E. bimaculata**

*Leaf surface* (Fig. 3.20A-C).

**ABAXIAL EPIDERMIS.—**Costal and intercostal zones well differentiated. **Intercostal long cells:** elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed. Moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. **Stomata:** high triangular-shaped subsidiary cells, apex drawn out into a point; evagination of ten containing the nucleus, one to three rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. **Intercostal short cells:** paired short cells situated between long cells: tall and narrow in shaped, crenate or irregular in outline, accompanied with transverse dumb-bell shaped silica bodies. **Papillae:** absent. **Prickle hairs:** absent. **Hook:** absent. **Micro-hairs:** bicellular, two-celled, basal cell less than ¼ the length of the distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered; tapering to a
rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. Macro-hairs: absent. Silica bodies: dumb-bell shaped relatively short, not elongate, present one or two rows over the costal zones, constricted narrow central; granules present in silica bodies.

ADAXIAL EPIDERMIS.—In general, similar to the abaxial epidermis. Stomata: one to five rows of stomata in each intercostals zone.

Leaf in transverse section (Fig. 3.20D-F).

Outline: two halves of lamina folded toward each other on either side of the midrib formed standard V-shaped, nearly 90° to each other, the margins somewhat round or slightly acute; no ribs and furrows present on both surface. Epidermis: bulliform cells present, arranged irregularly; epidermal cells rounded, inflated and slightly larger than bundle sheath cells; prickles and papillae absent; macro-hairs absent. Midrib outline: present, conspicuous keel, V-shaped or triangular keel, bulliform cells present in adaxial epidermis above median bundle; one vascular bundle present in the keel, abaxially arranged: first-order bundle only comprise keel. Midrib sclerenchyma: sclerenchyma associated with the keel; sclerenchyma forming abaxial cap and not combined with vascular bundle. Vascular bundle arrangement in the lamina: one first-order bundle in half lamina, 3-4 third-order bundles between second-order bundle, all bundles situated in center of the blade. Primary-order vascular bundles: circular or round in outline; sheath completely surrounded by parenchyma; phloem completely surrounded by thick-walled fibres; no lysigenous cavity, enlarged protoxylem vessel present, width of vessels same size of parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. Secondary-order vascular bundles: round in outline; xylem and phloem easily distinguishable; bundles large and similar size to the first-order bundles; sclerenchyma girder on both side or absent on adaxial surface. Third-order vascular bundles: square-shape or pentagonal in outline, surrounded by a sheath of 4-5 large parenchyma, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. Intercostal sclerenchyma: curved in shape with sclerenchyma extending on adaxial side, contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.
Culm in transverse section (Fig. 3.20G).

Outline: oval, sometimes flattened on one side, culm 1.5-2 mm in diameter. **Epidermis** with one layer of large thin-walled epidermal cells, and subtended by incontinuous zone of chlorenchyma layer, interrupted at intervals by intercellular air spaces present about 8 cells below the epidermis around the periphery of the culm. Chlorenchyma layers bounded on its inner side by a ring of sclerenchyma about 2-3 cells wide. **Inner ground tissue** consisting of large thin-walled or thick-walled cells, extending to the hollow centre of the culm, center of the culm with an oval pith cavity. **Vascular bundles** of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in the peripheral part of the inner thin-walled ground tissue, larger vascular bundles with sclerenchyma caps.

6.3 *E. lanceolata*

Leaf surface (Fig. 3.21A-B).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. **Intercostal long cells:** elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed. Deeply undulating, strongly corrugated, wave-length short, amplitude relatively deep and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. **Stomata:** low triangular-shaped subsidiary cells, apex drawn out into a point; evagination often containing the nucleus, two or three rows of stomata in each intercostals zone; inter stomatal long cells present, interstromatal cell between successive stomata, with concave ends. **Intercostal short cells:** paired short cells situated between long cells: tall and narrow in shaped, irregular in outline, accompanied with transverse dumb-bell shaped silica bodies. **Papillae:** absent. **Prickle hairs:** absent. **Hook:** present. **Micro-hairs:** bicellular, two-celled, basal cell only slightly shorter than the distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered; tapering to a rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. **Macro-hairs:** present at leaf margins, unicellular, slender and long, usually with thickened walls, sunken base embedded between and often below surrounding epidermal cells. **Silica bodies:** intermediate between cross and dumb-bell shaped,
relatively short, not elongate, present throughout the costal zones, constricted narrow central; granules present in silica bodies.

ADAXIAL EPIDERMIS.—In general, similar to the abaxial epidermis.

Leaf in transverse section (Fig. 3.21C-D).

Outline: two halves of lamina folded toward each other on either side of the midrib formed standard V-shaped, 45° to each other, the margins acute; no ribs and furrows present on both surface. Epidermis: bulliform cells present, arranged irregularly; epidermal cells rounded, inflated and much larger than bundle sheath cells; prickles and papillae absent; macro-hairs present, constricted above bulbous base embedded between large epidermal, hairs long and slender. Midrib outline: present, conspicuous keel, V-shaped or triangular keel, bulliform cells present in adaxial epidermis above median bundle; one vascular bundle present in the keel, abaxially arranged: first-order bundle only comprise keel. Midrib sclerenchyma: sclerenchyma associated with the keel; sclerenchyma forming abaxial girder combined with vascular bundle. Vascular bundle arrangement in the lamina: one first-order bundle in half lamina, 5-6 third-order bundle between second-order bundle, all bundles situated in center of the blade. Primary-order vascular bundles: circular or round in outline; sheath completely surrounded by parenchyma; phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels slightly larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. Secondary-order vascular bundles: round in outline; xylem and phloem easily distinguishable; bundles large and similar size to the first-order bundles; sclerenchyma girder on both side or absent on adaxial surface. Third-order vascular bundles: square-shape or pentagonal in outline, surrounded by a sheath of 4-5 large parenchyma, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. Intercostal sclerenchyma: curved in shape with sclerenchyma extending, sometimes fibres extend along both side of leaf margin. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiamic.
Culm in transverse section (Fig. 3.21E).

Outline: somewhat circular, flattened on one side, culm ca. 0.5 mm in diameter. Epidermis with one layer of large thin-walled epidermal cells, and subtended by continuous zone of chlorenchyma layers. Chlorenchyma layers bounded on its inner side by a ring of sclerenchyma about 3-4 cells wide. Inner ground tissue consisting of large thin-walled cells, extending to the hollow centre of the culm, center of the culm with an oval or irregular pith cavity. Vascular bundles of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in ground tissue.

Genus Hackelochloa: 2 out of 2 species were examined.

7.1 H. granularis

Leaf surface (Fig. 3.22A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed. Deeply undulating, strongly corrugated, wave-length short, amplitude relatively deep and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: triangular-shaped subsidiary cells, apex drawn out into a point; evagination of ten containing the nucleus, three to seven rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: paired short cells situated very rare between long cells: both are tall and narrow in shaped, crenate or irregular in outline. Papillae: absent. Prickle hairs: absent. Hook: absent. Micro-hairs: bicellular, two-celled, basal cell only slightly shorter than the distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered; tapering to a rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. Macro-hairs: present, unicellular, long and slender, usually with thickened walls, many epidermal cells associated with base of macro-hairs, usually smaller, specialized epidermal cells accompanying base of hair. Silica bodies: dumb-bell shaped relatively short, not elongate, present one or two
rows over the costal zones, constricted narrow central; granules present in silica bodies. **Costal short cells:** square or rectangular in shape with smooth walls.

**ADAXIAL EPIDERMIS.**—In general, similar to the abaxial epidermis. **Intercostal long cells:** variable shape; shape varies across a single intercostals zone. **Intercostal short cells:** solitary or paired of short cells situated between long cells: tall and narrow in shaped, smooth in outline, accompanied with transverse dumb-bell shaped silica bodies.

**Leaf in transverse section** (Fig. 3.22D-F).

**Outline:** two halves of lamina curved upwards on either side of the midrib, the margins round or acute; no ribs or furrows present on either surface. **Epidermis:** bulliform cells present, arranged irregularly; epidermal cells rounded, inflated and much larger than bundle sheath cells; outer walls slightly thickened and covered by a distinct thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles and papillae absent; macrohairs present, constricted above bulbous base embedded between large epidermal, hairs long and slender. **Midrib outline:** present, keel conspicuous, triangular-shaped; many vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. **Midrib sclerenchyma:** sclerenchyma associated with the keel; adaxial sclerenchyma forming a hypodermal band; sclerenchyma forming abaxial wide girder combined with vascular bundle. **Vascular bundle arrangement in the lamina:** one first-order bundle, 10 or more third-order bundles between one second-order bundles; all bundles situated in center of the blade. **Primary-order vascular bundles:** elliptical in outline; sheath and phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels slightly larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. **Secondary-order vascular bundles:** circular in outline; xylem and phloem easily distinguishable; bundles fairly large, similar size to the first-order bundles; sclerenchyma girder on both sides. **Third-order vascular bundles:** square-shape or pentagonal in outline, surrounded by a sheath of 4-5 large parenchyma, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. **Intercostal sclerenchyma:** small point-cap shaped of sclerenchyma at the margin, not
in contact with the lateral bundle. *Mesophyll*: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

*Culm in transverse section* (Fig. 3.22G).

*Outline*: slightly oval, flattened on one side, culm 1-1.5 mm in diameter. *Epidermis* subtended by continuous zone of chlorenchyma layers interrupted at intervals by girders of sclerenchyma connecting the vascular bundles of the outermost circle to the epidermis. Chlorenchyma layers bounded on its inner side by a not well-defined ring of sclerenchyma about 1-2 cells wide. *Ground tissue* consisting of cells with progressively thinner walls and larger diameters towards the centre of the culm, without pith cavity. *Vascular bundles* of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in the peripheral part of the inner thin-walled ground tissue, sclerenchyma girder supporting the outermost vascular bundles.

### 7.2 *H. porifera*

*Leaf in transverse section* (Fig. 3.23A-D).

*Outline*: two halves of lamina curved upwards on either side of the midrib, the margins acute; no ribs or furrows present on either surface. *Epidermis*: bulliform cells present, arranged irregularly; epidermal cells rounded, inflated and much larger than bundle sheath cells; outer walls slightly thickened and covered by a distinct thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles and papillae absent; macro-hairs present, constricted above bulbous base embedded between large epidermal, hairs long and slender. *Midrib outline*: present, keel conspicuous, triangular-shaped; five vascular bundles present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. *Midrib sclerenchyma*: sclerenchyma associated with the keel; adaxial sclerenchyma forming a hypodermal band; sclerenchyma forming abaxial wide girder combined with vascular bundle. *Vascular bundle arrangement in the lamina*: one first-order bundle, 10 or more third-order bundles between one second-order bundles; all bundles situated in center of the blade. *Primary-order vascular bundles*: round or circular in outline; sheath incomplete surrounding the bundle due to interruption of sclerenchyma, phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel
present, width of vessels larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. Secondary-order vascular bundles: somewhat round in outline; xylem and phloem easily distinguishable; bundles fairly large, similar size to the first-order bundles; sclerenchyma girders on both sides. Third-order vascular bundles: square-shape or pentagonal in outline, surrounded by a sheath of 4-5 large parenchyma, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma.

**Intercostal sclerenchyma**: point-cap shaped of sclerenchyma at the margin, not in contact with the lateral bundle. **Mesophyll**: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

*Culm in transverse section* (Fig. 3.23E).

**Outline**: slightly oval, flattened on one side, culm 3-5 mm in diameter. **Epidermis** subtended by continuous zone of chlorenchyma layers interrupted at intervals by girders of sclerenchyma connecting the vascular bundles of the outermost circle to the epidermis. Chlorenchyma layers bounded on its inner side by a ring of sclerenchyma about 4-5 cells wide. **Ground tissue** consisting of cells with progressively thinner walls and larger diameters towards the centre of the culm, without pith cavity. **Vascular bundles** of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in the inner thin-walled ground tissue, sclerenchyma girders supporting the outermost vascular bundles.

**Genus Hemarthria**: 2 out of 6 species were examined.

**8.1 H. compressa**

*Leaf surface* (Fig. 3.24A-C).

**ABAXIAL EPIDERMIS.**—Costal and intercostal zones well differentiated. **Intercostal long cells**: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed. Moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. **Stomata**: triangular-shaped subsidiary cells or low triangular, apex drawn out into a point, three
to seven rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. **Intercostal short cells:** paired short cells situated between long cells: both are tall and narrow in shaped, crenate or irregular in outline, sometimes accompanied with transverse dumb-bell shaped silica bodies. **Papillae:** absent. **Prickle hairs:** absent. **Hook:** absent. **Micro-hairs:** bicellular, two-celled, basal cell less than ½ the length of the distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered; tapering to a rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. **Macro-hairs:** absent. **Silica bodies:** intermediate between cross and dumb-bell shaped, relatively short, not elongate, present throughout the costal zones, constricted narrow central; granules present in silica bodies. **Costal short cells:** similar to intercostal short cells.

**ADAXIAL EPIDERMIS.**—In general, similar to the abaxial epidermis. **Intercostal long cells:** variable shape; shape varies across a single intercostals zone.

**Leaf in transverse section** (Fig. 3.24D-F).

**Outline:** infolded, two halves of lamina curved upwards on either side of median bundle, two arms forming an incomplete narrow ellipse, the margins acute; ribs or furrows present on adaxial surface with no regular pattern associated with the vascular bundles. **Epidermal cells:** bulliform cells present, irregular adaxial groups; outer walls thickened and covered by a thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles, papillae and macro-hairs absent. **Midrib outline:** present, keel inconspicuous, V-shaped keel, not thicker than the rest of lamina; one vascular bundle present in the keel, abaxially arranged. **Midrib sclerenchyma:** sclerenchyma associated with the keel; forming an adaxial hypodermal band, abaxial sclerenchyma girder combined with vascular bundle. **Vascular bundle arrangement in the lamina:** one first-order bundle, 6-7 third-order bundles between consecutive larger bundles; all bundles situated in the center of the blade. **Primary-order vascular bundles:** circular in outline; sheath incomplete surrounding the bundle due to interruption of sclerenchyma, phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. **Secondary-order vascular bundles:** somewhat circular
in outline; xylem and phloem easily distinguishable; bundles larger than size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on both side. Third-order vascular bundles: circular, tetragonal or pentagonal in outline, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. Intercostal sclerenchyma: point-cap shaped of sclerenchyma at the margin, not in contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

Culm in transverse section (Fig. 3.24G).

Outline: oval, culm 2-2.5 mm in diameter. Epidermis subtended by continuous zone of chlorenchyma layers interrupted at intervals by girders of sclerenchyma connecting the vascular bundles of the outermost circle to the epidermis. Chlorenchyma layers bounded on its inner side by a ring of sclerenchyma about 2-3 cells wide. Ground tissue consisting of cells with thick-walled cells, extending to the hollow centre of the culm, center of the culm with an oval pith cavity. Vascular bundles of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in the inner thick-walled ground tissue, sclerenchyma girder supporting the outermost vascular bundles.

8.2 H. pratensis

Leaf surface (Fig. 3.25A-B).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed; Deeply undulating, strongly corrugated, wave-length short, amplitude relatively deep and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: low triangular-shaped subsidiary cells, long and broadly angular subsidiary cells, vertical width of the subsidiary cells smaller in relation to the horizontal length, one to two rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short
cells: paired short cells situated between long cells: tall and narrow in shaped, crenate in outline, accompanied with transverse dumb-bell shaped silica bodies. **Papillae:** absent. **Pickle hairs:** absent. **Hook:** absent. **Micro-hairs:** bicellular, two-celled, basal cell less than ½ the length of the distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered; tapering to a rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. **Macro-hairs:** absent. **Silica bodies:** intermediate between cross and dumb-bell shaped, relatively short, not elongate, present throughout the intercostals and costal zones, constricted narrow central; granules present in silica bodies. **Costal short cells:** similar to intercostal short cells.

**ADAXIAL EPIDERMIS.**—In general, similar to the abaxial epidermis. **Macro-hairs:** unicellular, hard, long, and usually with slightly thickened walls, two specialized cells accompanying base of hair.

*Leaf in transverse section* (Fig. 3.25C-D).

**Outline:** infolded, two halves of lamina curved upwards on either side of median bundle, two arms forming an incomplete narrow ellipse, the margins acute; no ribs or furrows present on either surface. **Epidermis:** bulliform cells present, regular adaxial groups; in simple fans; outer walls thickened and covered by a thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles, papillae and macro-hairs absent. **Midrib outline:** present, keel conspicuous, rounded or U-shaped keel, much thicker than the rest of lamina; many vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. **Midrib sclerenchyma:** sclerenchyma associated with the keel; forming a thin adaxial hypodermal band, abaxial sclerenchyma girder combined with vascular bundle. **Vascular bundle arrangement in the lamina:** nine first-order bundle, 3-5 third-order bundles between consecutive larger bundles; all bundles situated in the center of the blade. **Primary-order vascular bundles:** elliptical in outline; sheath and phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. **Secondary-order vascular bundles:** somewhat circular in outline; xylem and phloem easily distinguishable; bundles smaller than size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on abaxial side. **Third-order vascular bundles:** circular or pentagonal in outline, all vascular tissue consists of only
a few vascular strands; no associate with sclerenchyma. *Intercostal sclerenchyma*: point-cap shaped of sclerenchyma at the margin, not in contact with the lateral bundle. *Mesophyll*: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiometric.

*Culm in transverse section* (Fig. 3.25E).

*Outline*: oval, culm 1.5-3 mm in diameter. *Epidermis* subtended by continuous zone of chlorenchyma layers interrupted at intervals by girders of sclerenchyma connecting the vascular bundles of the outermost circle to the epidermis. Chlorenchyma layers bounded on its inner side by a ring of sclerenchyma about 3-4 cells wide. *Ground tissue* consisting of cells with thick-walled cells, extending to the hollow centre of the culm, center of the culm with a rectangular pith cavity. *Vascular bundles* of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in the inner thick-walled ground tissue, sclerenchyma girder supporting the outermost vascular bundles.

**Genus Mnesithea: 5 out of 8 species were examined.**

**9.1 M. cancellata**

*Leaf surface* (Fig. 3.26A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. *Intercostal long cells*: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinial horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinial vertical cross-members vertical; horizontal and vertical anticlinial walls slightly thickened, slightly cuticular flanges probably developed. Slightly undulating, faintly corrugated; wave-length short, amplitude shallow and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. *Stomata*: triangular-shaped subsidiary cells, apex drawn out into a point; evagination often containing the nucleus, two to five rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. *Intercostal short cells*: solitary or paired of short cells situated between long cells: tall and narrow in shaped, smooth in outline, accompanied with transverse dumb-bell shaped silica bodies or hook cells. *Papillae*: absent. *Prickle hairs*: absent. *Hooks*: present in the intercostals zones; accompanied with short cells. *Micro-hairs*:...
long and slender, bicellular, two-celled, basal cell only slightly shorter than the distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered; tapering to a rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. **Macro-hairs**: absent. **Silica bodies**: dumb-bell shaped, relatively short, not elongate, present throughout the costal zones, constricted narrow central; granules present in silica bodies.

**ADAXIAL EPIDERMIS.** — **Intercostal long cells**: variable shape; shape varies across a single intercostals zone, hexagonal cells centrally and rectangular cells laterally, wider cells in center of intercostals zones; sometimes adjacent with single short cells. Moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. **Intercostal short cells**: paired of short cells situated between long cells: tall and narrow in shaped, irregular in outline, accompanied with hook cells.

*Leaf in transverse section* (Fig. 3.26D-F).

**Outline**: two halves of lamina curved upwards on either side of the midrib, the margins acute; no ribs or furrows present on either surface. **Epidermis**: bulliform cells present, arranged in regular groups: in simple fans-shaped; outer walls thickened and covered by a thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles, papillae and macro-hairs absent. **Midrib outline**: present, keel conspicuous, rounded or semicircular-shape, much thicker than the rest of lamina, adaxial side of keel flat; many vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. **Midrib sclerenchyma**: sclerenchyma associated with the keel; adaxial sclerenchyma forming a hypodermal band; abaxial sclerenchyma girder combined with vascular bundle. **Vascular bundle arrangement in the lamina**: one first-order bundle, 10 or more third-order bundles between one second-order bundles; all bundles situated in the central of the blade. **Primary-order vascular bundles**: somewhat circular in outline; sheath and phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels slightly larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. **Secondary-order vascular bundles**: somewhat circular in outline; xylem and phloem easily distinguishable;
bundles usually fairly large, similar size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on both side. Third-order vascular bundles: square-shaped, pentagonal or circular in outline, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. Intercostal sclerenchyma: small point-cap shaped of sclerenchyma at the margin, not in contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiamic.

Culm in transverse section (Fig. 3.26G).

Outline: circular or slightly oval, sometimes flattened on one side, culm 1.5-2.5 mm in diameter. Epidermis subtended by continuous zone of chlorenchyma layers interrupted at intervals by girders of sclerenchyma connecting the vascular bundles of the outermost circle to the epidermis. Chlorenchyma layers bounded on its inner side by a ring of sclerenchyma about 4 cells wide. Ground tissue consisting of cells with progressively thinner walls and larger diameters towards the centre of the culm, without its cavity. Vascular bundles of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundle scattered throughout the culm.

9.2 M. glandulosa

Leaf surface (Fig. 3.27A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinial horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinial vertical cross-members vertical; horizontal and vertical anticlinial walls slightly thickened, slightly cuticular flanges probably developed. Moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: triangular-shaped subsidiary cells, apex drawn out into a point; evagination often containing the nucleus, three to eight rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: solitary or paired of short cells situated between long cells: tall and narrow in shaped, smooth in outline, accompanied with transverse dumb-bell shaped silica bodies. Papillae: absent. Prickle hairs: absent. Micro-hairs:
long and slender, bicellular, two-celled, basal cell only slightly shorter than the distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered; tapering to a rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. Macro-hairs: absent. Silica bodies: dumb-bell shaped, relatively short, not elongate, present throughout the costal zones, constricted narrow central; granules present in silica bodies.

ADAXIAL EPIDERMIS.—In general, similar to the abaxial epidermis. Intercostal long cells: variable shape; shape varies across a single intercostals zone, hexagonal cells centrally and rectangular cells laterally, wider cells in center of intercostals zones; sometimes adjacent with single short cells.

Leaf in transverse section (Fig. 3.27D-F).

Outline: two halves of lamina curved upwards on either side of the midrib, the margins acute; no ribs or furrows present on either surface. Epidermis: bulliform cells present, arranged irregularly or regularly in simple fans-shaped; outer walls thickened and covered by a thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles, papillae and macro-hairs absent. Midrib outline: present, keel conspicuous, rounded or semicircular-shape, much thicker than the rest of lamina, adaxial side of keel flat; many vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. Midrib sclerenchyma: sclerenchyma associated with the keel; adaxial sclerenchyma forming a hypodermal band; abaxial sclerenchyma girder combined with vascular bundle. Vascular bundle arrangement in the lamina: one first-order bundle, 10 or more third-order bundles between one second-order bundles; all bundles situated in the abaxial of the blade. Primary-order vascular bundles: somewhat circular in outline; sheath and phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. Secondary-order vascular bundles: somewhat circular in outline; xylem and phloem easily distinguishable; bundles usually fairly large, similar size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on both side. Third-order vascular bundles: square-shaped or circular in outline, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. Intercostal
sclerenchyma: point-cap shaped of sclerenchyma at the margin, not in contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

Culm in transverse section (Fig. 3.27G).

Outline: oval, sometimes flattened on one side, culm 2.5-3.5 mm in diameter. Epidermis subtended by continuous zone of chlorenchyma layers interrupted at intervals by girders of sclerenchyma connecting the vascular bundles of the outermost circle to the epidermis. Chlorenchyma layers bounded on its inner side by a ring of sclerenchyma about 4 cells wide. Inner ground tissue consisting of large thin-walled cells, and without pith cavity. Vascular bundles of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in the peripheral part of the inner thin-walled ground tissue.

9.3 *M. laevis*

Leaf surface (Fig. 3.28A-B).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: shortened cells, length slightly greater than width or length and width approximately equal or sometimes length less than width, tall and narrow; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed; Deeply undulating, strongly corrugated, wave-length short, amplitude relatively deep and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: almost parallel-sided or intermediate between parallel-sided and very low dome-shaped subsidiary cells, vertical width of the subsidiary cells smaller in relation to the horizontal length, two to four rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: paired short cells situated between long cells: tall and narrow in shaped, irregular in outline, accompanied with transverse dumb-bell shaped silica bodies. Papillae: absent. Prickle hairs: absent. Hook: present very rare in intercostal zones. Micro-hairs: bicellular, two-celled, basal cell less than ½ the length of the distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered; tapering
to a rounded apex, emergence of base from short cell. *Macro-hairs*: absent. *Silica bodies*: transverse dumb-bell shaped, relatively short, not elongate, present throughout the intercostals and costal zones, constricted narrow central; granules present in silica bodies. *Costal short cells*: similar to intercostal short cells.

**ADAXIAL EPIDERMIS.**—In general, similar to the abaxial epidermis. *Macro-hairs*: present near leaf margins, unicellular, hard, short, stiff and usually with thickened walls, two specialized cells accompanying base of hair.

*Leaf in transverse section* (Fig. 3.28C-D).

**Outline**: two halves of lamina wided very opens V-shaped, more than 90° to each other, the margins acute; no ribs or furrows present on either surface. *Epidermis*: bulliform cells present, 1-2 rows, arranged irregularly; outer walls thickened and covered by a thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles, papillae and macro-hairs absent. *Midrib outline*: present, keel conspicuous, V-shaped keel, bulliform cells present in adaxial epidermis above median bundle; one small vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle only comprise keel. *Midrib sclerenchyma*: sclerenchyma associated with the keel; abaxial sclerenchyma girder combined with vascular bundle. *Vascular bundle arrangement in the lamina*: one first-order bundle, 4-7 third-order bundles between one second-order bundles; all bundles situated in the center of the blade. *Primary-order vascular bundles*: circular in outline; sheath incomplete surrounding the bundle due to interruption of sclerenchyma, phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. *Secondary-order vascular bundles*: elliptical in outline; xylem and phloem easily distinguishable; bundles larger than size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on both side. *Third-order vascular bundles*: circular or pentagonal in outline, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. *Intercostal sclerenchyma*: crescent-shaped of sclerenchyma at the margin, not in contact with the lateral bundle. *Mesophyll*: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.
Culm in transverse section (Fig. 3.28E).

Outline: oval, culm 1.5-2.5 mm in diameter. Epidermis subtended by continuous zone of chlorenchyma layers interrupted at intervals by girders of sclerenchyma connecting the vascular bundles of the outermost circle to the epidermis. Chlorenchyma layers bounded on its inner side by a not well-defined ring of sclerenchyma about 1-3 cells wide. Ground tissue consisting of cells with progressively thinner walls and larger diameters towards the centre of the culm, without pith cavity. Vascular bundles of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in the peripheral part of the inner thin-walled ground tissue, sclerenchyma girder supporting the outermost vascular bundles.

9.4 M. mollicoma

Leaf surface (Fig. 3.29A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls slightly thickened, slightly cuticular flanges probably developed. Moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; no bulbiform cells present on surface of the preparation examined. Stomata: triangular-shaped subsidiary cells, apex drawn out into a point; three to eight rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: tall and narrow in shaped, smooth or irregular in outline, accompanied with hook cells. Papillae: absent. Prickle hairs: absent. Micro-hairs: long and slender, bicellular, two-celled, basal cell only slightly shorter than the distal cells; wall of distal cell thinner than wall of basal cell, sharply pointed apex, base or attachment of basal cell: parallel-side, point of attachment small. Macro-hairs: present densely on intercostal zones, unicellular, long and slender, usually with thickened walls, many epidermal cells associated with base of macro-hairs, usually smaller, specialized epidermal cells accompanying base of hair. Silica bodies: dumb-bell shaped, relatively short, not elongate, present throughout the costal zones, constricted narrow central; granules
present in silica bodies. \textit{Costal short cells}: tall and narrow in shaped, smooth in outline.

\textbf{ADAXIAL EPIDERMIS}.—\textit{Intercostal long cells}: variable shape; shape varies across a single intercostals zone, hexagonal cells centrally and rectangular cells laterally, wider cells in center of intercostals zones; sometimes adjacent with single short cells.

\textit{Leaf in transverse section} (Fig. 3.29D-F).

\textit{Outline}: two halves of lamina curved upwards on either side of the midrib, the margins acute; no ribs or furrows present on either surface. \textit{Epidermis}: bulliform cells present, arranged irregularly; outer walls thickened and covered by a thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles, papillae absent; macro-hairs present, constricted above bulbous base embedded between large epidermal, hairs long and slender. \textit{Midrib outline}: present, keel conspicuous, rounded or semicircular-shape, much thicker than the rest of lamina, adaxial side of keel flat; many vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. \textit{Midrib sclerenchyma}: sclerenchyma associated with the keel; adaxial sclerenchyma forming a hypodermal band; abaxial sclerenchyma girder combined with vascular bundle. \textit{Vascular bundle arrangement in the lamina}: three first-order bundle, 10 or more third-order bundles between one second-order bundles; all bundles situated in the abaxial of the blade. \textit{Primary-order vascular bundles}: elliptical in outline; sheath and phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. \textit{Secondary-order vascular bundles}: somewhat circular in outline; xylem and phloem easily distinguishable; bundles usually fairly large, similar size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on both side. \textit{Third-order vascular bundles}: square-shaped or circular in outline, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. \textit{Intercostal sclerenchyma}: small point-cap shaped of sclerenchyma at the margin, not in contact with the lateral bundle. \textit{Mesophyll}: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiamic.
Culm in transverse section (Fig. 3.29G).

Outline: oval, sometimes flattened on one side, culm 2-2.5 mm in diameter. Epidermis subtended by continuous zone of chlorenchyma layers interrupted at intervals by girders of sclerenchyma connecting the vascular bundles of the outermost circle to the epidermis. Chlorenchyma layers bounded on its inner side by a ring of sclerenchyma about 3 cells wide. Ground tissue consisting of cells with progressively thinner walls and larger diameters towards the centre of the culm, without pith cavity. Vascular bundles of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundle embedded in the inner ground tissue.

9.5 M. sp.1
Leaf surface (Fig. 3.30A-B).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls slightly thickened, slightly cuticular flanges probably developed; slightly undulating, faintly corrugated; wave-length short, amplitude shallow and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: triangular-shaped subsidiary cells, apex drawn out into a point, up to ten rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: paired short cells situated between long cells: tall and narrow in shaped, smooth or irregular in outline, accompanied with transverse dumb-bell shaped silica bodies. Papillae: absent. Prickle hairs: absent. Micro-hairs: long and slender, bicellular, two-celled, basal cell only slightly shorter than the distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered; tapering to a rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. Macro-hairs: absent. Silica bodies: dumb-bell shaped, relatively short, not elongate, present throughout the costal zones, constricted narrow central; granules present in silica bodies. Costal short cells: similar to intercostals zones.

ADAXIAL EPIDERMIS.—In general, similar to the abaxial epidermis. Intercostal long cells: variable shape; shape varies across a single intercostals zone,
hexagonal cells centrally and rectangular cells laterally, wider cells in center of intercostals zones; sometimes adjacent with single short cells. Stomata marginally present rather rare, regular in form.

*Leaf in transverse section* (Fig. 3.30C-E).

**Outline:** two halves of lamina curved upwards on either side of the midrib, the margins acute; no ribs or furrows present on either surface. **Epidermis:** bulliform cells present, arranged irregularly; outer walls thickened and covered by a thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles, papillae and macro-hairs absent. **Midrib outline:** present, keel conspicuous, rounded or triangular-shape, much thicker than the rest of lamina, adaxial side of keel flat; many vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. **Midrib sclerenchyma:** sclerenchyma associated with the keel; adaxial sclerenchyma forming a hypodermal band; abaxial sclerenchyma girder combined with vascular bundle. **Vascular bundle arrangement in the lamina:** three first-order bundle, 8 or more third-order bundles between one second-order bundles; all bundles situated in the abaxial of the blade. **Primary-order vascular bundles:** circular in outline; sheath and phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. **Secondary-order vascular bundles:** circular in outline; xylem and phloem easily distinguishable; bundles usually fairly large, similar size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on both side. **Third-order vascular bundles:** square-shaped, pentagonal or hexagonal in outline, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. **Intercostal sclerenchyma:** point-cap shaped of sclerenchyma at the margin, not in contact with the lateral bundle. **Mesophyll:** radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

*Culm in transverse section* (Fig. 3.30F).

**Outline:** oval, sometimes flattened on one side, culm 3.5-7 mm in diameter. **Epidermis** subtended by continuous zone of chlorenchyma layers interrupted at
intervals by girders of sclerenchyma connecting the vascular bundles of the outermost circle to the epidermis. Chlorenchyma layers bounded on its inner side by a ring of sclerenchyma about 7-8 cells wide. *Inner ground tissue* consisting of large thin-walled cells, and without pith cavity. *Vascular bundles* of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in the peripheral part of the inner thin-walled ground tissue, sclerenchyma girder supporting larger vascular bundles, smaller bundles with crescentiform sclerenchyma caps.

**Genus Ophiuros:** 1 of 1 species was examined.

**10. O. exaltatus**

*Leaf surface* (Fig. 3.31A-C).

**ABAXIAL EPIDERMIS.**—Costal and intercostal zones well differentiated. *Intercostal long cells*: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls moderately thickened, cuticular flanges developed; moderately undulating, often irregular, wave-length short, amplitude variable and frequency high; short cells present between the adjacent long cells; bulliform cells present, varying in appearance with focus, inflated thin walled, rectangular in shape. *Stomata*: low dome-shaped subsidiary cells, vertical width of the subsidiary cells smaller in relation to the horizontal length, over 10 rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. *Intercostal short cells*: pairs: tall and narrow in shaped, irregular in outline, accompanied with transverse dumb-bell shaped silica bodies. *Papillae*: absent. *Prickle hairs*: absent. *Hook*: absent. *Micro-hairs*: bicellular, two-celled, basal cell less than ½ the length of the distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered; tapering to a rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. *Macro-hairs*: present at leaf margins, unicellular, hard, long, usually with thickened walls, sunken base embedded between and often below surrounding epidermal cells. *Silica bodies*: transverse dumb-bell shaped present with short cell in the intercostals zones: or intermediate between cross and dumb-bell shaped, present throughout the costal zones, constricted narrow central; granules present in silica bodies. *Costal short cells*:
pairs: tall and narrow in shaped, irregular in outline, accompanied with transverse dumb-bell shaped silica bodies.

ADAXIAL EPIDERMIS.—In general, similar to the abaxial epidermis. *Intercostal long cells:* variable shape; shape varies across a single intercostals zone, hexagonal cells, or bowed outwards, inflated or rectangular cells, slightly undulating, faintly corrugated, wave-length short, amplitude shallow and frequency high.

*Leaf in transverse section* (Fig. 3.31D-E).

Outline: two halves of lamina curved upwards on either side of the midrib formed U-shaped, tall and narrow, vertically elongated, the margins round; no ribs or furrows present on either surface. *Epidermis:* bulliform cells present, arranged irregularly; outer walls thickened and covered by a slightly thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles, papillae and macro-hairs absent. *Midrib outline:* present, keel conspicuous, rounded or semicircular-shape, much thicker than the rest of lamina, adaxial side of keel flat; many vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. *Midrib sclerenchyma:* sclerenchyma associated with the keel; adaxial sclerenchyma forming a hypodermal band; abaxial sclerenchyma girder combined with vascular bundle. *Vascular bundle arrangement in the lamina:* three first-order bundle, 9 or more third-order bundles between one second-order bundles; all bundles situated in the abaxial of the blade. *Primary-order vascular bundles:* elliptical in outline; phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. *Secondary-order vascular bundles:* elliptical in outline; xylem and phloem easily distinguishable; bundles usually fairly large, similar size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on both side. *Third-order vascular bundles:* pentagonal or hexagonal in outline, surrounded by a sheath of 5-6 large parenchyma, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. *Intercostal sclerenchyma:* point-cap shaped of sclerenchyma at the margin, sometimes relatively small, less than the width of a third order vascular bundle, not in contact with the lateral bundle. *Mesophyll:* radiate
chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

*Culm in transverse section* (Fig. 3.31F).

*Outline:* somewhat circular, culm 2-2.5 mm in diameter. *Epidermis* subtended by continuous zone of chlorenchyma layers interrupted at intervals by girders of sclerenchyma connecting the vascular bundles of the outermost circle to the epidermis. Chlorenchyma layers bounded on its inner side by a not well-defined ring of sclerenchyma about 1-3 cells wide. *Ground tissue* consisting of cells with progressively thinner walls and larger diameters towards the centre of the culm, without pith cavity. *Vascular bundles* of the outermost circle embedded in peripheral sclerenchyma ring. The other vascular bundles scattered in the inner thin-walled ground tissue.

**Genus Phacelurus:** 1 of 2 species was examined.

11. *P. zea*

*Leaf surface* (Fig. 3.32A-B).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. *Intercostal long cells:* elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls slightly thickened, slightly cuticular flanges probably developed; Deeply undulating, strongly corrugated, wave-length short, amplitude relatively deep and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. *Stomata:* low triangular subsidiary cells, long and broadly angular subsidiary cells or dome-shaped, subsidiary cells somewhat rounded, vertical width of the subsidiary cells smaller in relation to the horizontal length, often containing the nucleus, three to six rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. *Intercostal short cells:* pairs: tall and narrow in shaped, irregular in outline, accompanied with transverse dumb-bell shaped silica bodies. *Papillae:* absent. *Prickle hairs:* absent. *Hook:* present in intercostal zones. *Micro-hairs:* bicellular, two-celled, basal shorter than distal cells; wall of distal cell thinner than wall of basal cell, slightly tapered;
tapering to a rounded apex, base or attachment of basal cell: parallel-side, point of attachment small. **Macro-hairs:** absent. **Silica bodies:** dumb-bell shaped or intermediate between cross and dumb-bell shaped, relatively short, not elongate, usually accompanied by short cells, present throughout the intercostals and costal zones, constricted narrow central; granules present in silica bodies. **Costal short cells:** solitary or pairs: tall and narrow in shaped, irregular in outline, if pairs accompanied with transverse dumb-bell shaped silica bodies.

**ADAXIAL EPIDERMIS.**—In general, similar to the abaxial epidermis. **Prickle hairs:** common in costal zones, overlying any vascular bundle-order, medium prickles base as long or slightly longer than the stomata; short barb, barb shorter than the base, point to leaf apex; one to two rows along the wholelength, one row along the wholelength over all vascular bundle, rows separated silica bodies between successive prickles.

**Leaf in transverse section** (Fig. 3.32C-E).

**Outline:** two halves of lamina wide very open V-shaped, more than 90° to each other, the margins round; no ribs or furrows present on either surface. **Epidermis:** bulliform present, 1-2 rows, irregular adaxial groups; outer walls thickened and covered by a slightly thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; prickles, papillae and macro-hairs absent. **Midrib outline:** present, keel very conspicuous, elongated U-shape, very much thicker than the rest of lamina; many vascular bundle present in the keel, all vascular bundles abaxially or marginally arranged: first-order bundle and smaller bundles comprise keel. **Midrib sclerenchyma:** sclerenchyma associated with the keel; adaxial sclerenchyma forming a narrow hypodermal band and extend to colourless subepidermal parenchyma; abaxial sclerenchyma girder combined with vascular bundle. **Vascular bundle arrangement in the lamina:** one first-order bundle, 6-7 third-order bundles between one second-order bundles; all bundles situated in the center of the blade. **Primary-order vascular bundles:** circular or round in outline; phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels much larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. **Secondary-order vascular bundles:** elliptical in outline; xylem and phloem easily distinguishable; bundles usually fairly large, similar size to the first-order
bundles; bundle sheath extension forming sclerenchyma girder on both side. Third-order vascular bundles: round or slightly elliptical in outline, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. Intercostal sclerenchyma: point-cap shaped of sclerenchyma at the margin, contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

Culm in transverse section (Fig. 3.32F).

Outline: oval, flattened on one side, culm ca. 1 cm in diameter. No well defined sclerenchyma ring present, intercellular air spaces present about 3-4 cells below the epidermis around the periphery of the culm, the outermost vascular bundle alternating with the spaces. Inner ground tissue consisting of large thin-walled cells, and without pith cavity. Vascular bundle usually being accompanied by fibres. The other vascular bundle numerous and scattered in the peripheral part of the inner thin-walled ground tissue.

Genus Rotboellia: 1 of 1 species was examined.

12. R. cochinchinensis

Leaf surface (Fig. 3.33A-C).

ABAXIAL EPIDERMIS.—Costal and intercostal zones well differentiated. Intercostal long cells: elongated cells, length 3x or more than 3x longer than the width; side walls or anticlinal horizontal long walls parallel to one another, cell rectangular, square or trapezoidal; end walls or anticlinal vertical cross-members vertical; horizontal and vertical anticlinal walls slightly thickened, slightly cuticular flanges probably developed; Deeply undulating, strongly corrugated, wave-length short, amplitude relatively deep and frequency high; short cells present between the adjacent long cells; no bulliform cells present on surface of the preparation examined. Stomata: high triangular-shaped subsidiary cells, apex drawn out into a point, rarely low dome-shaped, one to four rows of stomata in each intercostals zone; interstomatal long cells present, interstomatal cell between successive stomata, with concave ends. Intercostal short cells: solitary, rarely pairs, both cells of the pair tall and narrow in shaped, irregular in outline, sometimes short cells accompanied with transverse dumbbell shaped silica bodies. Papillae: absent. Prickle hairs: present at the margins, large prickles, base at least twice as long as long as the stomata; short barb, barb shorter than the
base, point to leaf apex; one to two rows along the wholelength. **Micro-hairs**: bicellular, two-celled, only basal cell remains or visible. **Macro-hairs**: absent. **Silica bodies**: cross or dumb-bell shaped present rarely in intercostals zones; dumb-bell shaped, relatively short, not elongate, present throughout the costal zones, constricted narrow central; granules present in silica bodies. **Costal short cells**: square or rectangular in shape, sinuous or undulating walls.

ADAXIAL EPIDERMIS. — **Intercostal long cells**: variable shape; shape varies across a single intercostals zone, hexagonal cells centrally and rectangular cells laterally, wider cells in center of intercostals zones; sometimes adjacent with single short cells. **Stomata** marginally present rather rare, regular in form. **Prickle hairs**: common in costal zones, overlying any vascular bundle-order, large prickles, base at least twice as long as the stomata; short barb, barb shorter than the base, point to leaf apex; one to two rows along the whole length, one row along the wholelength over all vascular bundle, rows separated silica bodies between successive prickles. **Hook**: present in intercostal zones. **Silica bodies**: intermediate between cross and dumb-bell shaped, relatively short, not elongate, present throughout the costal zones, constricted narrow central; granules present in silica bodies.

**Leaf in transverse section** (Fig. 3.33D-F).

**Outline**: two halves of lamina folded toward each other on either side of the midrib formed standard V-shaped, 90° to each other, the margins round; nodular on adaxially surface. **Epidermis**: bulliform cells present, regular adaxial groups; in simple fans, outer walls thickened and covered by a slightly thick cuticle continuous over the epidermal cells, cuticle and cell wall less than the depth of the average epidermal cells; thickened prickles present in epidermis; usually located opposite the vascular bundles; papillae and macro-hairs absent. **Midrib outline**: present, keel conspicuous, rounded or semicircular-shape, much thicker than the rest of lamina, adaxial rib slightly developed; many vascular bundle present in the keel, all vascular bundles abaxially arranged: first-order bundle and smaller bundles comprise keel. **Midrib sclerenchyma**: sclerenchyma associated with the keel; adaxial sclerenchyma forming a hypodermal band; abaxial sclerenchyma girder combined with vascular bundle. **Vascular bundle arrangement in the lamina**: one first-order bundle, 10 or more third-order bundles between one second-order bundles; all bundles situated in the abaxial of the blade. **Primary-order vascular bundles**: elliptical or slightly angular in outline;
phloem completely surrounded by thick-walled fibres; lysigenous cavity and enlarged protoxylem vessel present, width of vessels much larger than parenchyma sheath cells; metaxylem vessels circular in T/S, distinctly thickened; inner secondary wall distinct. Secondary-order vascular bundles: elliptical in outline; xylem and phloem easily distinguishable; bundles usually fairly large, similar size to the first-order bundles; bundle sheath extension forming sclerenchyma girder on both side. Third-order vascular bundles: pentagonal or hexagonal in outline, surrounded by a sheath of 5-7 large parenchyma, all vascular tissue consists of only a few vascular strands; no associate with sclerenchyma. Intercostal sclerenchyma: point-cap shaped of sclerenchyma at the margin, not in contact with the lateral bundle. Mesophyll: radiate chlorenchyma: radially arranged around the vascular bundles which are often close together; single layer isodiametric.

Culm in transverse section

Outline: circular or flattened on one side, culm 3-7 mm in diameter. No well defined sclerenchyma ring present, sclerenchyma girders present about 2-3 cells over the outermost vascular bundle subjacent to the epidermis. Inner ground tissue consisting of large thin-walled cells, and without pith cavity. Vascular bundle of the outermost being accompanied by fibres and associated with sclerenchyma strands fused forming a hypodermal band, sclerenchyma forming fairly wide girder combined with vascular bundle. The other vascular bundle numerous and scattered throughout the culm.

3.5 Discussion and conclusion

Leaf surfaces

From Table 3.4, it can be concluded that the intercostal long cells are mostly elongated cells of rectangular, square or trapezoidal shape with slightly to deeply undulating walls, except in Mnsethea laevis having a shortened cell with deeply sinuous walls. Renvoize (1982) noted that the genus Mnsethea has long cell walls exceptionally deeply convolute; very shallow stomatal subsidiary cells and transverse silica bodies. In this study only M. laevis agreed with the study by Renvoize. In contrast, the other species of Mnsethea have a slightly to moderately sinuous wall and dome or triangular-shaped subsidiary cells (Table 3.5). Gould & Shaw (1983) stated that significant differences in long cell structure exist among genera and even
among species of the same genus. The basic types of long cells have proved very useful for broad surveys of the grasses (Metcalf, 1960), but they are not adequate for all purposes since there are many intermediates and variants. For detailed studies of limited numbers of species, it may be necessary to introduce some additional types for descriptive purposes (Ellis, 1979).

In this study the transverse silica bodies can be found in all species of *Mnesithea* (Table 3.5).

The above descriptions indicate that *O. exaltatus* is the most definitely related to *Mnesithea* species, because of similarities in leaf and culm structure. These two species are also closely related morphologically, because both species have cylindrical racemes, sessile spikelets dorsally compressed and sunken in the hollow of rachis internode. Considering these morphological and leaf and culm anatomical features, *O. exaltatus* seems to be closer to the species of *Mnesithea* than *M. laevis* (Table 3.4 and 3.5).

Because of the information given above, the system proposed by Veldkamp et al. (1986) that sunk all *Coelorachis* species into the genus *Mnesithea*, is probably not acceptable.

The stomata of all genera are confined to the intercostal zones, especially in abaxial surfaces. The paracytic type cells are recognized as a grass type (Dahlgren et al., 1985), characterized by low- or tall-dome or triangular-shaped subsidiary cells; rarely (as in *M. laevis*) the subsidiary cells are almost parallel-sided or intermediate between parallel-sided and low dome-shaped. However, stomata of more than one type may occur together in a single leaf and the shape can be somewhat intermediate in certain species. Renvoize (1982) observed stomata of more than 10 rows across the intercostal zone of the lower epidermis in genera *Hemarthria*, *Ophiuros* and *Thelepanon*, while this study found one to seven rows in *Hemarthria*, more than 10 rows in *Ophiuros* and up to 18 rows in *Thelepanon*. Ellis (1979) suggested that the number of bands and rows of stomata in each intercostal zone vary not only from one species to another but also in different parts of a single leaf blade or in leaves taken from different levels of the same plant.

It is an important to note that the papillae are a good diagnostic character for dividing the genera in the subtribe Ischaeminae into 2 main groups. A papilla per cell occurs in *Kerriochloa*, while papillae occur in *Ischaenum* but they are absent in *Apluda, Sehima* and *Thelepanon*. However, some species in the genus *Ischaenum*
fail to conform completely to the general pattern; namely absent papillae and culm without a central cavity in *Ischaemum tenuifolium* (Table 3.3). It appears to be associated with morphological trends within the genera, *I. tenuifolium* should be separated and placed in another subtribe. Papillae are absent in all genera of Rottboelliiinae.

Prickles are common in the genera *Apluda* and *Sehima*. The latter genus showed the distinctness of ribs and furrows on both surfaces. This character also appears in *Ischaemum rugosum* but it is completely different from *Sehima* in degree and shape of ribs and furrows and the masses of sclerenchymatous cells below the epidermis. The ribs slightly rounded with flat top and the furrow wide and open in genus *Sehima* while triangular ribs and furrows are obtuse in *I. rugosum*. In some grass species which grow on dry places (xerophytic grass species) the prickles from adjacent costal zones overly the intervening intercostal zone. These interlocking prickles serve to protect the underlying stomatal groove. This type of situation is only found in leaves with narrow, relatively deep furrows as well as ribs especially on the adaxial surface (Ellis, 1979). Those characters are found in genus *Sehima*.

Most genera in Rottboelliiinae do not have prickles on the leaf surface, except in the genus *Rottboellia*, where the prickles are present on both sides and very common in costal zones on adaxial surface, overlying any vascular bundle-order. The large prickles point to the leaf apex; their base is at least twice as long as the stomata; the barb is shorter than the base, and occurs one to two rows along the whole length separated with silica bodies.

Ribs and furrows can be found in some species of some genera in Rottboelliiinae, such as *Eremochloa bimaculata*, *Hemarthria compressa* and *Rottboellia cochinchinensis*, while in the other genera these ribs and furrows are absent.

Bicellular micro-hairs have been detected in most of the studied species except, *Ischaemum hubbardii*, *I. tenuifolium* and *I. sp.1*. The micro-hairs of these species probably were damaged or destroyed during the slide preparation. Although the micro-hairs vary in the ratio of length to width or in the ratio of the length of the upper cell to that of the lower cell, they are uniformly included among the so-called panicoid micro-hairs or rod-like micro-hairs (Tateoka et al., 1959). This observation agrees with Metcalfe (1960).
The shape of silica bodies on the nerves is variable. In most species the bodies are dumb-bell shaped or intermediate between dumb-bell and cross-shaped, relatively short, not elongate. According to the investigation of Renvoize (1982), he found aberrant features in some genera in Andropogoneae that could not be combined into a single generalized description. The present study supports his conclusions. The silica bodies in all genera are cross-shaped, dumb-bell or intermediate between cross and dumb-bell shaped, except in the genus *Apluda* where the silica bodies are nodular.

**Leaf in transverse section**

The character which is useful for initial identification of the leaf in transverse section is the outline of the leaf-blade. An expanded lamina with a nearly straight line occurred in all genera in subtribe Ischaeminae, except in genus *Thelepodon* and some species of the genus *Ischaemum*. The leaf-blade is folded or V-shaped is found in genus *Eremochloa* and *Hemarthria*, while two halves of lamina folded toward each other on either side of the midrib are found in genus *Hackelochloa*, *Mnesithea*, *Ophiurus*, *Phacelurus* and *Rottboellia*. However, the degree of infolding or inrolling varies with the environment conditions and thus is not of much value diagnostically (Metcalf, 1960).

The arrangement of the bulliform cells can be recognized in the subtribes Ischaeminae and Rottboelliiinae in two main groups; the first group has bulliform cells arranged in irregular groups and the second group has bulliform cells arranged in fan-shaped groups. The first group composed of *Kerriochloa* and *Thelepodon* in Ischaeminae and *Eremochloa*, *Hackelochloa*, *Ophiurus* and *Phacelurus* in Rottboelliiinae, while the second group comprised of *Apluda*, *Ischaemum* and *Sehima* in subtribe Ischaeminae and *Hemarthria*, *Mnesithea* and *Rottboellia* in subtribe Rottboelliiinae.

The midrib of *Thelepodon* is usually composed of a few vascular bundles, keel conspicuous, rounded or semicircular-shaped because of sclerenchymatous cells which make masses below the upper epidermis and above the lower epidermis, one or a few rows of colorless parenchyma below the upper epidermis and chlorenchyma surround the small vascular bundles. In contrast, the midrib of *Kerriochloa* and *Sehima* are arranged in a straight or somewhat uneven row, in which a large bundle is situated in the center and a few small bundles are placed on both sides of it. Keel is inconspicuous, not associated with developed parenchyma, the projection due to
position or size of bundle and sclerenchyma on abaxial surface. The conspicuous keels occurred in all genera and species in Rottboellinae, but they do vary in shape from V-shaped, triangular, rounded, semicircular, U-shaped to elongated U-shaped. Five to many of small and large vascular bundles are situated in the midrib, except in genus *Eremochloa*, *Hemarthria compressa* and *Mnesithea laevis* which have only one vascular bundle at the center. Metcalfe (1955) has suggested that the anatomical midrib traits can be used for classifying grass species to some extent, and the results described above support his suggestion.

It was found that all genera of both subtribes having a radiate chlorenchyma which is radially arranged around the vascular bundles and often close together; single layer isodiametric. To be in line with Renvoize (1982), all the investigated genera have a single layer and composed of relatively thick-walled cells.

**Culm in transverse section**

Intercellular air spaces can be observed below the epidermis in some species and some genera of both subtribes viz, *Ischaemum hubbardi*, *Eremochloa bimaculata* and *Phacelurus zea*.

The genus *Ischaemum* from the subtribe Ischaeminae and genus *Eremochloa* and *Hemarthria* form the subtribe Rottboellinae are the genera that have a pith cavity. All genera are found in wet habitats. Gould & Shaw (1983) noted that culms of a number of grasses, especially those adapted to aquatic or marshy habitats, also have other cavities and air chambers. McClure (1963) has used the air canals of the rhizomes of *Arundinaria tecta* as a taxonomic character in the separation of this species from *A. gigantean*.

This anatomical feature does not support the separation of the two subtribes, Ischaeminae and Rottboellinae in this study. Neither nor the morphological classification system proposed by Clayton & Renvoize (1986).

The results from this study suggested that some anatomical characters have considerable taxonomic values in separating the related genera in the subtribes Ischaeminae and Rottboellinae of Thai grass. The significant characters include leaf blade outline, ribs and furrows on both surfaces, bulliform cells, midrib and keel, number of vascular bundles in the keels, shape of sclerenchyma at margins, intercostal long cells, papillae, prickles, macro-hairs, silica bodies, culm outline and central cavity in ground tissue of culm. Table 3.2 and 3.4 show that certain characters have
been found useful in determining species in these two subtribes. This finding is in agreement with Metcalfe (1960), Renvoize (1982) and Watson & Dallwitz (1992) who studied the leaf blades with light microscopes (LM) and concluded that anatomical characters of leaf blades were significant for grass identification. However, this study show more apparent variations between the genera and described some useful characters of culms which have not been reported in most genera previously. In addition, the genus *Kerriochloa* is studied here for the first time.

However, in some genera only one species was available and investigated, so the output features may not represent the typical characteristics of the whole genus. Though the anatomy features alone are insufficient for the delineation in some genera, in general, we consider that those features have considerable systematic value and giving additional support for the species distinction. However, like all other taxonomic evidences, anatomical characters must be interpreted with caution.
Table 3.2 Comparative anatomical features of genera in subtribe Ischaeminae.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Apluda</th>
<th>Ischaemum</th>
<th>Kerriochoa</th>
<th>Sehima</th>
<th>Thelepogon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf anatomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf blade outline</td>
<td>blade expanded, slightly undulating or nearly straight</td>
<td>blade expanded or straight or two halves of lamina curved upwards on either side of the midrib or rolled</td>
<td>blade expanded, undulating gently or nearly straight</td>
<td>blade broad wide, horizontally elongated</td>
<td>two halves of lamina curved upwards on either side of the midrib</td>
</tr>
<tr>
<td>Adaxial ribs and furrows</td>
<td>absent</td>
<td>present or absent</td>
<td>absent</td>
<td>present</td>
<td>absent</td>
</tr>
<tr>
<td>Abaxial ribs and furrows</td>
<td>absent</td>
<td>present or absent</td>
<td>absent</td>
<td>present</td>
<td>absent</td>
</tr>
<tr>
<td>Bulliform cells</td>
<td>simple fans</td>
<td>fans-shaped or arranged in irregular groups</td>
<td>arranged in irregular groups</td>
<td>fans-shaped</td>
<td>arranged in irregular groups</td>
</tr>
<tr>
<td>Midrib</td>
<td>conspicuous, triangular-shaped</td>
<td>conspicuous, triangular-shaped or inconspicuous keel (rare)</td>
<td>inconspicuous</td>
<td>inconspicuous</td>
<td>conspicuous, rounded or semicircular-shaped</td>
</tr>
<tr>
<td>Number of vascular bundles in keel</td>
<td>one</td>
<td>one to many</td>
<td>one</td>
<td>one</td>
<td>many</td>
</tr>
<tr>
<td>Sclerenchyma at margins</td>
<td>crescent-cap shaped</td>
<td>point-cap or cap shaped</td>
<td>absent</td>
<td>crescent-cap shaped</td>
<td>point-cap shaped</td>
</tr>
<tr>
<td>Abaxial intercostal long cells</td>
<td>elongated cells, moderately undulating</td>
<td>elongated or shortened cells or variable in shape, deeply or moderately undulating</td>
<td>variable shape, moderately undulating</td>
<td>elongated cells, deeply undulating</td>
<td>elongated cells, moderately undulating</td>
</tr>
<tr>
<td>Abaxial intercostal short cells</td>
<td>absent</td>
<td>present (solitary)</td>
<td>present (solitary)</td>
<td>absent</td>
<td>present (solitary)</td>
</tr>
<tr>
<td>Papillae</td>
<td>absent</td>
<td>more than one papilla per cell on abaxial or adaxial surface, absent in <em>I. tenuefolium</em></td>
<td>one papilla per cell on abaxial surface</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td>Abaxial prickles</td>
<td>present (common)</td>
<td>absent</td>
<td>absent</td>
<td>present (common)</td>
<td>absent</td>
</tr>
<tr>
<td>Abaxial macro-hairs</td>
<td>absent</td>
<td>present or absent</td>
<td>present</td>
<td>absent</td>
<td>present</td>
</tr>
<tr>
<td>Abaxial silica bodies</td>
<td>nodular</td>
<td>dumb-bell or intermediate between cross and dumb-bell shaped</td>
<td>cross-shaped</td>
<td>dumb-bell shaped</td>
<td>cross, dumb-bell or intermediate between cross and dumb-bell shaped</td>
</tr>
<tr>
<td>Abaxial costal short cells</td>
<td>absent</td>
<td>present</td>
<td>absent</td>
<td>present</td>
<td>present</td>
</tr>
<tr>
<td>Culm anatomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culm outline, diameter (mm)</td>
<td>circular, 1.2-1.5</td>
<td>circular or oval, 1-2</td>
<td>somewhat circular, 1-1.5</td>
<td>circular, 1.2-1.5</td>
<td>circular or somewhat oval, 2-3</td>
</tr>
<tr>
<td>Pith cavity</td>
<td>absent</td>
<td>present, except <em>I. tenuefolium</em></td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
</tr>
</tbody>
</table>
Table 3.3 The main anatomical differences separating the species in the genus *Ischaemum*.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Genus</th>
<th><em>I. hirtum</em></th>
<th><em>I. hubbardii</em></th>
<th><em>I. muticum</em></th>
<th><em>I. rugosum</em></th>
<th><em>I. tenuifolium</em></th>
<th><em>I. sp.1</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leaf anatomy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midrib</td>
<td></td>
<td>conspicuous, triangular-shaped</td>
<td>conspicuous, triangular-shaped to slightly round</td>
<td>conspicuous, triangular-shaped</td>
<td>inconspicuous</td>
<td>conspicuous triangular to round-shaped</td>
<td>conspicuous or inconspicuous, triangular-shaped</td>
</tr>
<tr>
<td>Ribs and furrows</td>
<td></td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>present on both surfaces</td>
<td>present on adaxial surface</td>
<td>absent</td>
</tr>
<tr>
<td>Number of vascular bundles in the keel</td>
<td></td>
<td>&gt; 6</td>
<td>&gt; 6</td>
<td>&gt; 6</td>
<td>1</td>
<td>3-6</td>
<td>5</td>
</tr>
<tr>
<td>Papillae</td>
<td></td>
<td>present on abaxial surface</td>
<td>present on abaxial surface</td>
<td>present on abaxial surface</td>
<td>present on adaxial surface</td>
<td>absent</td>
<td>present on abaxial surface</td>
</tr>
<tr>
<td>Macro-hairs</td>
<td></td>
<td>present</td>
<td>present</td>
<td>absent</td>
<td>present</td>
<td>absent</td>
<td>present</td>
</tr>
<tr>
<td><strong>Culm anatomy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pith cavity</td>
<td></td>
<td>present, somewhat irregular-shaped</td>
<td>present, somewhat circular-shaped</td>
<td>present, somewhat irregular-shaped</td>
<td>present, somewhat circular-shaped</td>
<td>absent</td>
<td>not seen</td>
</tr>
<tr>
<td>Characters</td>
<td>Genus</td>
<td>Eremochloa</td>
<td>Hackelochloa</td>
<td>Hemarthria</td>
<td>Mnesithea</td>
<td>Ophiuros</td>
<td>Phacelurus</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>------------</td>
<td>-------------</td>
<td>-----------</td>
<td>----------</td>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>Leaf blade outline</td>
<td></td>
<td>two halves of lamina curved upwards on either side of the midrib</td>
<td>infolded, two halves of lamina curved upwards on either side of median bundle, two arms forming an incomplete narrow ellipse</td>
<td>two halves of lamina curved upwards on either side of the midrib or open V-shaped</td>
<td>two halves of lamina curved upwards on either side of the midrib or open V-shaped, more than 90° to each other</td>
<td>two halves of lamina folded toward each other on either side of the midrib formed U-shaped, tall and narrow</td>
<td>two halves of lamina folded toward each other on either side of the midrib formed standard V-shaped, 90° to each other</td>
</tr>
<tr>
<td>Ribs and furrows</td>
<td></td>
<td>absent, except <em>E. attenuata</em>, present on both surface, a quarter to one half of the leaf thickness</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>nodular on adaxial surface</td>
</tr>
<tr>
<td>Bulliform cells</td>
<td></td>
<td>arranged in irregular groups</td>
<td>simple fans or arranged in irregular groups</td>
<td>simple fans or arranged in irregular groups</td>
<td>arranged in irregular groups</td>
<td>arranged in irregular groups</td>
<td>simple fans</td>
</tr>
<tr>
<td>Midrib</td>
<td></td>
<td>conspicuous, rounded, triangular or v-shaped</td>
<td>conspicuous, rounded or U-shaped or inconspicuous</td>
<td>conspicuous, V-shaped, triangular, rounded or semicircular-shaped</td>
<td>conspicuous, rounded or semicircular-shaped</td>
<td>very conspicuous, elongated U-shaped</td>
<td>conspicuous, rounded or semicircular-shaped</td>
</tr>
<tr>
<td>Number of vascular bundles in keel</td>
<td></td>
<td>1</td>
<td>1 to &gt;6</td>
<td>1 to &gt;6</td>
<td>&gt;6</td>
<td>&gt;6</td>
<td>&gt;5</td>
</tr>
<tr>
<td>Sclerenchyma at margins</td>
<td></td>
<td>curved or crescent-shaped</td>
<td>point-cap shaped</td>
<td>point-cap shaped except, crescent-shaped in <em>M. laris</em></td>
<td>point-cap shaped</td>
<td>point-cap shaped</td>
<td>point-cap shaped</td>
</tr>
<tr>
<td>Abaxial intercostal long cells</td>
<td></td>
<td>elongated cells, moderately to deeply undulating</td>
<td>elongated cells, deeply undulating</td>
<td>elongated cells, slightly to deeply undulating</td>
<td>elongated cells, moderately undulating</td>
<td>elongated cells, deeply undulating</td>
<td>elongated cells, deeply undulating</td>
</tr>
<tr>
<td>Abaxial intercostal short cells</td>
<td></td>
<td>paired</td>
<td>paired</td>
<td>paired</td>
<td>solitary or paired</td>
<td>paired</td>
<td>solitary, rarely paired</td>
</tr>
<tr>
<td>Papillae</td>
<td></td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td>Prickles</td>
<td></td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td>Macro-hairs</td>
<td></td>
<td>present or absent</td>
<td>present</td>
<td>present or absent</td>
<td>present</td>
<td>absent</td>
<td>Absent</td>
</tr>
<tr>
<td>Abaxial silica bodies</td>
<td></td>
<td>dumb-bell or intermediate between cross and dumb-bell shaped, relatively short, not elongate</td>
<td>intermediate between cross and dumb-bell shaped, relatively short, not elongate</td>
<td>dumb-bell or transverse dumb-bell shaped, relatively short, not elongate</td>
<td>intermediate between cross and dumb-bell shaped, constricted narrow central</td>
<td>dumb-bell or intermediate between cross and dumb-bell shaped, relatively short, not elongate</td>
<td>dumb-bell shaped, relatively short, not elongate</td>
</tr>
<tr>
<td>Culm anatomy</td>
<td></td>
<td>oval or circular, 0.5-2</td>
<td>slightly oval, 1-5</td>
<td>oval, 1-5</td>
<td>circular to oval, 1.5-7</td>
<td>somewhat circular, 2-2.5</td>
<td>oval, ca. 10</td>
</tr>
<tr>
<td>Culm outline, diameter (mm)</td>
<td></td>
<td>oval or circular</td>
<td>oval</td>
<td>oval, 1.5-3</td>
<td>circular to oval, 1.5-7</td>
<td>somewhat circular, 2-2.5</td>
<td>oval, ca. 10</td>
</tr>
<tr>
<td>Pith cavity</td>
<td></td>
<td>present, oval or irregular-shaped</td>
<td>absent</td>
<td>present, oval or rectangular-shaped</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Characters</td>
<td>Genus</td>
<td>\textit{M. cancellata}</td>
<td>\textit{M. glandulosa}</td>
<td>\textit{M. laevis}</td>
<td>\textit{M. mollicoma}</td>
<td>\textit{M. sp.1}</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
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<td>---------------------------------------------</td>
<td>-----------------------------------------</td>
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<td></td>
</tr>
<tr>
<td><strong>Leaf anatomy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf blade outline</td>
<td></td>
<td>two halves of lamina curved upwards on either side of the midrib</td>
<td>two halves of lamina curved upwards on either side of the midrib</td>
<td>two halves of lamina wide very open V-shaped, more than 90°</td>
<td>two halves of lamina curved upwards on either side of the midrib</td>
<td>two halves of lamina curved upwards on either side of the midrib</td>
<td></td>
</tr>
<tr>
<td>Midrib</td>
<td></td>
<td>conspicuous, rounded or semicircular-shaped</td>
<td>conspicuous, rounded or semicircular-shaped</td>
<td>conspicuous, V-shaped - shaped</td>
<td>conspicuous, rounded or semicircular-shaped</td>
<td>conspicuous, rounded or triangular-shaped</td>
<td></td>
</tr>
<tr>
<td>Number of vascular bundles in keel</td>
<td>&gt; 6</td>
<td>&gt; 6</td>
<td>1</td>
<td>&gt; 6</td>
<td>&gt; 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sclerenchyma at margins</td>
<td></td>
<td>point-cap shaped</td>
<td>point-cap shaped</td>
<td>crescent-shaped</td>
<td>point-cap shaped</td>
<td>point-cap shaped</td>
<td></td>
</tr>
<tr>
<td>Abaxial intercostal long cells</td>
<td>elongated cells, slightly undulating</td>
<td>elongated cells, moderately undulating</td>
<td>shortened cells, deeply undulating</td>
<td>elongated cells, moderately undulating</td>
<td>elongated cells, slightly undulating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abaxial intercostal short cells</td>
<td>solitary or paired</td>
<td>Solitary or paired</td>
<td>paired</td>
<td>solitary or paired</td>
<td>paired</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomata</td>
<td></td>
<td>triangular-shaped, subsidiary cells</td>
<td>triangular-shaped, subsidiary cells</td>
<td>almost parallel-sided or intermediate between parallel-sided and low dome-shaped subsidiary cells</td>
<td>triangular-shaped, subsidiary cells</td>
<td>triangular-shaped, subsidiary cells</td>
<td></td>
</tr>
<tr>
<td>Abaxial silica bodies</td>
<td></td>
<td>dumb-bell shaped, relatively short, not elongate</td>
<td>dumb-bell shaped, relatively short, not elongate</td>
<td>transverse dumb-bell, relatively short, not elongate</td>
<td>dumb-bell shaped, relatively short, not elongate</td>
<td>dumb-bell shaped, relatively short, not elongate</td>
<td></td>
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<tr>
<td><strong>Culm anatomy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Culm outline and width</td>
<td>circular or slightly oval, 1.5-2.5</td>
<td>oval, 2.5-3.5</td>
<td>oval, 1.5-2.5</td>
<td>oval, 2-2.5</td>
<td>oval, 3.5-7</td>
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</table>
Figure 3.9 Leaf and culm anatomy of *Apluda mutica* (*P. Traiperm* 152 and 321): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. (SB= silica bodies; MH= micro-hairs; S=stomata; Pr=prickles; lc=long cells) Scale bar in μm.
Figure 3.10 Leaf and culm anatomy of *Ischaemum hirtum* (*P. Traiperm* 171): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. (P=papillae) Scale bar in μm.
Figure 3.11 Leaf and culm anatomy of *Ischaemum hubbardii* (*P. Traiperm* 308): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.
Figure 3.12 Leaf and culm anatomy of *Ischaemum muticum* (P. Traiperm 138 and 199): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. (SB=silica bodies) Scale bar in μm.
Figure 3.13 Leaf and culm anatomy of *Ischaemum rugosum* (P. Traiperm 127 and 293): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. (MH=micro-hairs; Pr=prickles) Scale bar in μm.
Figure 3.14 Leaf and culm anatomy of *Ischaemum tenuifolium* (P. Traiperm 233 and 287): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.
Figure 3.15 Leaf anatomy of *Ischaemum* sp.1 (*P. Traiperm* 327): A. abaxial epidermis, B. adaxial epidermis, C-E. x.s. leaf. Scale bar in µm.
Figure 3.16 Leaf and culm anatomy of *Kerriochloa siamensis* (P. Traiperm 235): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-E. x.s. leaf, F. x.s. culm. Scale bar in µm.
**Figure 3.17** Leaf and culm anatomy of *Sehima nervosum* (P. Traiperm 170 and 323):

A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.
Figure 3.18 Leaf and culm anatomy of *Thelepogon elegans* (P. Traiperm 276): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-E. x.s. leaf, F. x.s. culm. Scale bar in µm.
Figure 3.19 Leaf and culm anatomy of *Eremochloa attenuata* (P. Traiperm 162): A. abaxial epidermis, B. adaxial epidermis, C-E. x.s. leaf, F. x.s. culm. Scale bar in μm.
Figure 3.20 Leaf and culm anatomy of *Eremochloa bimaculata* (*P. Traiperm* 116): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.
Figure 3.21 Leaf and culm anatomy of *Eremochloa lanceolata* (P. Traiperm 242): A. abaxial epidermis, B. adaxial epidermis, C-D. x.s. leaf, E. x.s. culm. Scale bar in μm.
Figure 3.22 Leaf and culm anatomy of Hackelochloa granularis (P. Traiperm 303):
A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf,
G. x.s. culm. Scale bar in μm.
Figure 3.23 Leaf and culm anatomy of *Hackelochloa porifera* (*P. Traiperm* 311): A-D. x.s. leaf, E. x.s. culm. Scale bar in µm.
Figure 3.24 Leaf and culm anatomy of *Hemarthria compressa* (P. Traiperm 187): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in µm.
Figure 3.25 Leaf and culm anatomy of *Hemarthria pratensis* (P. Traiperm 158): A. abaxial epidermis, B. adaxial epidermis, C-D. x.s. leaf, E. x.s. culm. Scale bar in µm.
Figure 3.26 Leaf and culm anatomy of *Mnesithea cancellata* (*P. Traiperm* 161 and 183): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.
Figure 3.27 Leaf and culm anatomy of *Mnesithea glandulosa* (P. Traiperm 139): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. (MH=micro-hairs; sc=short cells) Scale bar in µm.
Figure 3.28 Leaf and culm anatomy of *Mnesithea laevis* (P. Traiperm 307): A. abaxial epidermis, B. adaxial epidermis, C-D. x.s. leaf, E. x.s. culm. Scale bar in μm.
Figure 3.29 Leaf and culm anatomy of *Mnjesithea mollicoma* (*P. Traiper* 131): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.
Figure 3.30 Leaf and culm anatomy of *Mnesithea* sp.1 (*P. Traiperm* 347): A. abaxial epidermis, B. adaxial epidermis, C-E. x.s. leaf, F. x.s. culm. Scale bar in \( \mu m \).
Figure 3.31 Leaf and culm anatomy of *Ophiuros exaltatus* (P. Traiperm 186): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-E. x.s. leaf, F. x.s. culm. Scale bar in μm.
Figure 3.32 Leaf and culm anatomy of *Phacelurus zea* (*P. Traiperm* 222): A. abaxial epidermis, B. adaxial epidermis, C-E. x.s. leaf, F. x.s. culm. Scale bar in μm.
Figure 3.33 Leaf anatomy of *Rottboellia cochinchinensis* (P. Traiperm 133): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf. Scale bar in µm.
CHAPTER IV

MOLECULAR STUDY

4.1 Introduction

Molecular data have had a profound impact on the field in plant systematics. Previously, the majority of data used in plant molecular phylogenetic studies mostly derives from chloroplast DNA and nuclear rDNA (Small et al., 2004). Phylogenetic reconstruction in the grass family, Poaceae have ongoing early in this century with proposed evolutionary hypotheses based on assessment of existing knowledge of grasses (e.g. Bew, 1929; Hubbard, 1948; Prat, 1960; Stebbins, 1956, 1982; Clayton, 1981; Tsvelev, 1983). Recently, molecular information has provided the basis for phylogenetic hypotheses in grasses at the subfamily and tribe levels. DNA sequence data are now commonly used to resolve problems which taxonomists have different opinion on relationships when using traditional characters. These molecular studies were based on information from chloroplast DNA (cpDNA) restriction sites and DNA sequencing of the trnL-F and the ITS region of the subtribes Ischaeminae and Rottboelliinae that have never been conducted earlier. Therefore, the analyses will provide the DNA sequence data of both subtribes in Thailand, which can be serve as a basis for further work in grass systematic.

4.1.1 Chloroplast genome

Noncoding sequences of the chloroplast genome are a primary source of data for molecular systematic, phylogeographic, and population genetic studies in plants. The chloroplast genomes from higher plants typically range in size from 120 to 170 kilobase pairs (kb), and there is a relatively high degree of conservation in size, structure, gene content, and linear order of the genes in land plants. Chloroplast (cp-)DNA genome is a circular molecule and subdivided into two single-copy regions, the large single copy (LSC) region and small single copy (SSC) region, which are separated by inverted repeats. The LSC region is slightly less conserved in sequence than the rest of the chloroplast genome (Clegg, Lear & Golenberg, 1991) (Fig. 4.1). Previous studies have suggested that the inverted repeat regions accumulate point mutations slower than the single-copy regions (Curtis & Clegg, 1984; Wolfe et al.,
1987; Wolfe, 1991; Gaut, 1998). Perry and Wolfe (2002) showed that the nucleotide substitution rate is 2.3 times higher in the single-copy regions relatively to the inverted repeats. Because of the inverted repeats evolve at relatively slower rate and the first adopted chloroplast regions (e.g., rbcL, atpB, trnL-F) are located in the LSC, most plant researchers using molecular tools have focused on the single-copy regions. The use of non-coding chloroplast DNA sequences to generate plant phylogenies began in the early 1990s with the seminal publications of Taberlet et al. (1991), Clegg et al. (1994), Morton and Clegg (1993), and Gielly and Tabelet (1994).

Figure 4.1 Physical and gene map of the green algae *Nephroselmis* chloroplast genome, showing the typical structural arrangement found in land plants. Genes located on the inside of the map are transcribed counter clockwise, and genes on the outside are transcribed clockwise. The inner circle shows where the Small Single-Copy region (SSC), Large Single Copy region (LSC) and Inverted Repeats (IR) are located (adapted from Turmel et al., 1999).
The cpDNA trnT-L-F region consists of three non-coding regions (Fig. 4.2): firstly is an intergenic spacer between trnT (UGU) and the trnL (UAA) 5’ exon, second is the trnL (UAA) intron and the last region is another intergenic spacer between the trnL (UAA) 3’ exon and trnF (GAA) (Taberlet et al., 1991). In particular the trnL intron and trnL-F spacer (collective, the trnL-F region) has become one of the most widely used chloroplast markers for phylogenetic analysis in plants (Quandt et al., 2004) due to their easily to amplified and their small size, with the trnL intron ranging from 350 to 600 bp and the trnL-F spacer ranging from approximately 129 to 350 bp (Soltis & Soltis, 1998). However, the different portions of the cpDNA evolve at different rates, which result in a wide range of possibilities for resolving relationships from species and genus level to family and even higher taxonomic levels but limit its applicability among closely related species and populations (Soltis & Soltis, 1998).

![Figure 4.2 Organisation of three non-coding regions of cpDNA. Tips of arrows indicate 3’ ends of the primers (adapted from Taberlet et al., 1991).](image)

4.1.2 Nuclear sequences

Nuclear ribosomal DNA (nrDNA) is organized as individual chromosomal units that are repeated thousands of times in most of the higher plant genomes. Each repeat contains a transcribed region, which is separated from the adjacent repeat by a long non-transcribed intergenic spacer (IGS) (Hamby & Zimmer, 1992). Within the transcribed region are three conserved ribosomal RNA regions and the two non-coding spacer regions. The conserved regions, comprising the ribosomal RNA gene
(Fig. 4.3), are arranged in 5'-18S-5.8S-26S-3' order with the ITS spacers (designated as ITS1 and ITS2) flanking the 5.8S region, an evolutionary highly conserved sequence. In addition, an external transcribed spacer region (ETS) is situated at the beginning of the 5' end of the transcribed unit.

The occurrence of high nucleotide variability in combination with low length variation found in both of the internal transcribed spacer regions (ITS1 and ITS2), suggested that this part of the rDNA gene could be used in reconstructing phylogenies within plant genera. Therefore, sequences could be readily aligned across related species and yet would contain sufficient variations for resolution of phylogeny (Baldwin et al., 1995).

**Figure 4.3** Organisation of a repeat unit of nrDNA showing the ITS, ETS, 18S, 5.8S and 26S regions. Arrows indicate the orientation and approximate position of primer sites. Primer names and sequences are from Sun et al. (1994) (adapted from Baldwin et al., 1995).

It has been relatively easy to develop primers for the amplification of the ITS region because it is flanked by the highly conserved regions 18S and 26S and the set of primers designed by White et al. (1990) has been used successfully for amplification across a wide range of plant families. Together with the rest of the nrDNA gene, ITS undergoes rapid concerted evolution, such that all members of the gene family exhibit the same sequence within an individual (Amheim, 1983) via
unequal crossing over and gene conservation. Its small size (less than 800 bp) makes it particularly appropriate for direct sequencing amplified DNA obtained from PCR. The ITS sequences have proven to be a valuable source of characters to address phylogenetic relationships among closely related species in different plant families (Francisco-Ortega et al., 2001) and also have a powerful in revealing hybridization and reticulate evolution (Sang, Crawford & Stuessy, 1997).

4.2 Literature reviews

The molecular phylogenetic information available for the family has been summarized by Linder and Kellogg (1995). They concluded that the evidence gathered till now points to a monophyletic Panicoideae sister to the Centothecoideae. The monophyly of the Andropogonoeae is also very well supported, but no conclusions can be reached as to the status of the rest of the tribes.

Clayton (1972, 1973) divided Andropogoneae into “awned” and “awnless” taxa. Later, Clayton & Renvoize (1986) divided the tribe into 11 subtribes, based largely on characters of the inflorescence.

Kellogg & Watson (1993) undertook a phylogenetic analysis of morphological characters for all genera of Andropogoneae. They found that the distinction between awned and awnless taxa was largely supported but most of the subtribes defined by Clayton & Renvoize (1986) were polyphyletic.

Spangler et al. (1999) using cpDNA from gene ndhF sequences to estimate the phylogeny of the tribe Andropogoneae. The investigations showed that subtribal designations are not informative due to the lack of resolution between clades in the strict consensus tree. However, there are well-supported clades in the tribe, including three Sorghum lineages and a “core” Andropogoneae clade, even though relationships among clades are poorly supported. A preliminary assessment of the generic limits of the genus Sorghum indicated a paraphyletic group, including the genera Cleistachne, Miscanthus, and a species of Microstegium. They have proposed subtribe Sorginae which included Sorghum, Sorghastrum, Cleistachne, Bothriochloa, Capillipedium, Dichanthium and Chrysopogon and does not form a monophyletic group.

Kellogg (2000) suggested that both molecular and morphological data supported the monophyly of the Andropogoneae. The characters that correlated with the origin of the traditional Andropogoneae are presence of a disarticulating rachis
and differentiation of the spikelets of a pair. Within the tribe, there is variation in
presence of distinctive cells in the mesophyll, formation of branch complexes on the
upper part of the culm (the anthotagma), timing of inflorescence branching, sex
expression of spikelets, induration of glumes, and formation of awns. However, the
different states of these characters do not correlate with the molecular phylogeny.
Hence, the subtribes of Andropogoneae are polyphyletic.

Mathews et al. (2002) added newly collected data from phytochrome B to the
data from the other two genes (GBSSI and ndhF) in previous studies (Mathews et al.,
1995). The phylogeny shows a single origin of a disarticulating rachis, which is a
synapomorphy for the tribe. The combined data reject the monophyly of subtribes
Andropogoninae and Anthistirinae and provided evidence that subtribes Sorghinae,
Saccharinae, and Rottboelliinae are paraphyletic or polyphyletic. A Chionachne and
Phcelurus are shown to diverge early in the history of the tribe.

In this study, nucleotide sequences data from taxa of subtribes Ischaeminae
and Rottboelliinae are cladistically analysed using outgroup comparison to produce a
rooted phylogenetic hypothesis for the two subtribes. The sequence data (both
substitution and insertion and deletion characters) are from regions of the taxa’s
chloroplast (cpDNA) and nuclear ribosomal DNA (nrDNA). In the cpDNA, the
\textit{trnL-trnF} region (composed of the \textit{trnL} (UAA) intron, the \textit{trnL} (UAA) 3’ exon, and the
intergenic spacer between the \textit{trnL} (UAA) 3’ exon and \textit{trnF} (GAA)) was chosen
because it has proved to be phylogenetically informative at the infra-and inter-generic
levels of the other taxa (Gielly & Taberlet, 1994; Gielly et al., 1996). Similarly, the
Internal Transcribed Spacer (ITS) region of nrDNA (composed of the spacers
between the 18S and 5.8S genes (ITS1) and the 5.8S and 26S genes (ITS2) was
chosen for its informativeness elsewhere at those levels (Baldwin et al., 1995).

The ITS regions has been investigated extensively and has been successfully
used to resolve phylogenetic relationships at various levels. This includes studies of
various genera such as \textit{Brachisia} and \textit{Urochloa} (González & Morton, 2005);
\textit{Bouteloua} (Columbus et al., 1998, 2000); \textit{Chloris} (Alice et al., 2000); \textit{Deschampsia}
(Chiapella, 2007); \textit{Deschampsia Antarctica} (Fernández Souto et al., 2006); \textit{Eleusine}
(Neves et al., 2005); \textit{Elymus} (Liu et al., 2006); \textit{Hordeum} (Blattner, 2004); \textit{Paspalum}
(Souza-Chies & Essi, 2007); \textit{Schizostachyum} and its allies (Yang, Peng & Li, 2007);
\textit{Spartina} (Baumel et al., 2001); \textit{Sporobolus} (Ortiz-Diaz & Culham, 2000) and
\textit{Sporobolus indicus} complex (Shrestha et al., 2003). Studies have also been conducted
on a related group of grasses known as the Festucoid grass (Catalán et al., 2004); Stipoid grasses (Jacobs et al., 2000); Chloridoid grasses (Roodt-Wilding & Spies, 2006); the Chloridoid tribe Triodieae (Mant et al., 2000); the Panicoid tribe Androponeae (Hodkinson et al., 2002b); the Pooid tribes Aveneae (Grebenstein et al., 1998) and Triticeae (Hsiao et al., 1995a). The ITS regions has also been used to a lesser extent to investigate subfamily relationships in the Arundinoideae (Hsiao et al., 1998); tribe Danthonieae by Barker et al., 2000 in a combined analysis of morphology and rpoC2, rbcL and ITS sequence data and the Pooidaeae (Hsiao et al., 1994, 1995b). The phylogeny of the entire grass family (Hsiao et al., 1999) was also investigated using ITS.

In Poaceae the trnL-F regions has been also used in many levels such as Poa jemtlandica (Brysting et al., 2000); Spartina anglica (Baumel et al., 2001); Axonopus (Gomez-Martinez & Culham, 1997); Bouteloua (Columbus et al., 2000); Chloridoid grasses (Roodt-Wilding & Spies, 2006); Deschampsia (Chiapella, 2007); Elymus (Liu et al., 2006); Festucoid grass of subtribe Loliinae (Catalán et al., 2004); Miscanthus (Hodkinson et al., 2002a); Paspalum (Souza-Chies & Essi, 2007); Spartina (Ferris et al., 1997); the Panicoid tribes Andropogoneae (Hodkinson et al., 2002b); Paniceae (Gomez-Martinez & Culham, 2000; Doust & Kellogg, 2002); the Pooid tribe Triticeae (Mason-Gamer et al., 2002) and trnL-F has also demonstrated its suitability for clarifying the systematic problems in the Gramineae (Neves et al., 2005).

Separate analyses were conducted and the data sets were then combined for combined analyses. It was decided to combine the two regions in many studies in recent years have indicated that combined molecular data sets that utilize different levels of variation (as provide by ITS and trnL-F) provide resolution at different levels of the cladogram and, therefore, phylogenetic resolution and bootstrap values are improved by combining separate data sets (Chase & Cox, 1998; Soltis & Soltis, 1998; Whitten et al., 2000).

4.3 Material and methods

4.3.1 Taxon sampling and ingroup selection

Forty-two taxa representing 12 genera of subtribes Ischaeminae and Rottboellinae were sampled. The species were chosen to represent variation within each genus. At least 10% of the species in each genus were included to avoid any excess heterogeneity in rates of molecular evolution that may be found. The
remaining one genus in subtribe Rottboellinae, as circumscribed by Nanakorn & Norsaengsri (2001), i.e. *Vossia* Wall. & Griff. is a monotypic genus could not be included owing to lack of material.

Field collected leaves and vouchers were collected between June 2004 and August 2007. All materials were preserved in silica gel.

### 4.3.2 DNA extractions

Total genomic DNA was extracted from 0.3 g of leaves from individual plants preserved in silica gel or 0.2 g of leaf material from herbarium specimens using the modified CTAB (hexadechltrimethylammonium bromide) method of Doyle & Doyle (1987) and precipitated in isopropanol. The crude total genomic DNA was purified using the QIAquick PCR Purification kit, namely Spin column Technique and DNA levels were checked on the 1% agarose gel, and stored at -20°C or -80°C (Appendix E).

### 4.3.3 Amplification of target DNA regions

The nrDNA internal transcribed spacer region (ITS) and further sequencing was amplified with Polymerase Chain Reaction (PCR) using both the external primers AB101F (5'-ACG AAT TCA TGG TCC GGT GAA GTG TTC TCC G-3'), AB102R (5'-TAG AAT TCC CCG GTT CGC TCG CCG TTA C-3') and internal pair primers ITS 2 (5'-GCT GCG TCC TTC TTC ATC GAT GC-3'), ITS 3 (5'-GCA TCG ATG AAG AAC GCA GC-3') (Sun et al., 1994). The PCR reactions were carried out in a total volume of 25 μl. Each reaction consisted of 1 μl cellular DNA, 0.5 μl dNTP (10 mM), 1.5 μl MgCl₂ (50 mM), 0.5 μl of each primer (100 ng/μl), 2.5 μl 10X Buffer, 2.5 μl BSA, 0.5 μl DMSO, and 0.5 μl *Taq* polymerase. Strong denaturing reaction conditions were needed because of the high GC (guanine-cytosine) content of ITS region and the presence of secondary structure (Bucker & Holtsford, 1996). This was achieved by the addition of DMSO, which reduces strand reannealing (Winship, 1989; Varadaraj & Skinner, 1994). Buckler et al. (1997) also suggested that the addition of DMSO would prevent the preferential amplification of pseudogenes. These might be preferentially amplified due to low secondary structure stability. The reactions were carried out using a GeneAmp PCR System 9700 thermocycler. The thermal cycling were run on following the program comprised of 30 cycles, 2 min
premelt at 94°C, 1 min denaturation at 94°C, 1 min annealing at 48°C, 1.30 min extension at 72°C and 4 min final extension at 4°C.

Table 4.1 List of primers used for amplification and sequencing.

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<th>Marker</th>
<th>Name</th>
<th>Sequence</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
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<td>5’-ACGAATTCTATGTCCTCAGAGATCGTTCG-3’</td>
<td>Sun et al., 1994</td>
</tr>
<tr>
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<td>reverse</td>
<td>5’-GCTGCGTCTTCATCGATGC-3’</td>
<td>Sun et al., 1994</td>
</tr>
<tr>
<td>ITS2</td>
<td>forward</td>
<td>5’-GCATCGATGAAGAACGACGC-3’</td>
<td>Sun et al., 1994</td>
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<td>reverse</td>
<td>5’-TATAATTCCTCCGTTGCTCAGGCGGGA-3’</td>
<td>Sun et al., 1994</td>
</tr>
<tr>
<td>trnL-F</td>
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<td>5’-CGAAATCGTAGACGCTACG-3’</td>
<td>Taberlet et al., 1991</td>
</tr>
<tr>
<td></td>
<td>reverse</td>
<td>5’-GGGATAGAGGACTGAAC-3’</td>
<td>Taberlet et al., 1991</td>
</tr>
<tr>
<td></td>
<td>forward</td>
<td>5’-GGTTCAAGTCTCCCCTTATCCC-3’</td>
<td>Taberlet et al., 1991</td>
</tr>
<tr>
<td></td>
<td>reverse</td>
<td>5’-AAATTGAACCTGGTAGACGACG-3’</td>
<td>Taberlet et al., 1991</td>
</tr>
</tbody>
</table>

The non-coding regions of cpDNA were PCR amplified using primers ‘c’ (5’-CGA AAT CGG TAG ACG CTA CG-3’) and ‘d’ (5’-GGG ATG AGA GGG ACT TGA AC-3’) for the trnL intron, and primers ‘e’ (5’-GGT TCA AGT CCC TCT ATC CC-3’) and ‘f’ (5’-AAT TGA ACT GGT GGT GAC ACG AG-3’) for the trnL-F intergenic spacer (Taberlet et al., 1991). The PCR reactions were carried out in a total volume of 25 μl. Each reaction consisted of 1 μl DNA, 0.5 μl dNTP (10 mM), 2.5 μl MgCl₂ (50 mM), 0.5 μl of each primer (100ng/μl), 2.5 μl Buffer, 2.5 μl BSA and 0.5 μl Taq polymerase. The thermal cycling were run on following the program comprised 30 cycles, 2 min premelt at 94°C, 1 min denaturation at 94°C, 1 min annealing at 50°C, 1.30 min extension at 72°C and 4 min final extension at 4°C.

Three to five μl of each PCR product for both the nuclear and chloroplast regions were run on a 1% agarose gel placed in 1X TAE (Tris-Acetic acid-EDTA) buffer. Amplified products were purified using Magic mini-columns (Promega, Southampton, Hampshire, UK) or QIAquick columns (Qiagen, Crawley, West Sussex, UK), protocols were provided by manufacturers of the minicolumns (Appendix E). Cleaned PCR products were stored at -20°C after checking the DNA level on the 1% agarose gel.
4.3.4 Cycle Sequencing

The sequencing primers for both regions were the same primers used for the amplification in PCR. The cycle sequencing profile was as follows: rapid thermal ramp to 96°C followed by 96°C for 10 s, 50°C for 5 s, and 60°C for 4 min, performed for 26 cycles and held at 4°C. Sequencing of the PCR products was carried out using cycle sequencing with ABI Big Dye terminators run on an ABI 377A automatic sequencer (according to the manufacturer’s protocols; Perkin-Elmer Applied Biosystems, Inc., Warrington, Cheshire, UK) at Jodrell Laboratory, the Royal Botanic Gardens, Kew, UK.

4.3.5 Sequence assembly and alignment

Automated sequence output files were edited and assembled using Sequence Navigator and AutoAssembler (Applied Biosystems Inc.). Sequences of both regions were unambiguously aligned by visual inspection. The final aligned matrix has 818 characters of ITS region and 1,211 characters of *trnL*-F region. The alignments were directly submitted to parsimony analysis.

4.3.6 Outgroup selection

Outgroup taxa represented different degrees of relatedness to subtribe Ischaeminae and Rottboelliinae: *Eragrostis biflora* and *Cenotheca lappacea* from the broader subfamily Chloridoideae and Centothecoideae, respectively.

4.3.7 Phylogenetic analyses

Heuristic parsimony analyses of the aligned sequence matrix was performed using PAUP* 4.0b10 software (Swofford, 1998) on a Macintosh G4. All characters were unordered and equally weighted (Fitch parsimony; Fitch, 1971) and individual gap positions were treated as missing data. Most-parsimonious trees were obtained using 1000 replicates of random taxon addition with equal weights and tree-bisection-reconnection (TBR) branch-swapping, with MULTREES in effect, but holding only one tree per step and saving no more than 100 trees per replicate to minimize time swapping on suboptimal trees. Internal support was assessed using 1000 bootstrap replicates with TBR swapping and simple addition of taxa, retaining groups with frequencies above 50% in the bootstrap consensus tree. The following categories were used to describe levels of bootstrap support: weak = 50–74%; moderate = 75–84%;
and strong 85–100% (Simpson et al., 2003.). Also computed using PAUP* were the strict consensus trees, consistency index (CI) retention index (RI) and rescaled consistency index (RC). All resulting trees were rooted using both species of *Eragrostis biflora* (subfamily Chloridoideae) and *Centotheca lappacea* (subfamily Centothecoideae) as the outgroups.

### 4.4 Results

Sampling was designed to include 12 genera of the two subtribes in Thailand and one sequences of outgroup taxa (*Eragrostis biflora*) was taken from GenBank.

#### 4.4.1 ITS region

The length of ITS1 ranged from 215 (*Ischaemum indicum* 1) to 403 bp (*Apluda mutica*) and ITS2 from 283 (*Hemarthria pratensis*) to 465 (*Ischaemum barbatum* 1) bp. Aligned sequences of the entire region of 44 specimens (42 ingroup and 2 outgroup specimens) consist of 818 characters. For the entire region, 113 characters (16.10%) were potentially parsimony-informative and 93 were variable. The heuristic search with ITS data produced 199 trees with the tree length of 475 steps, a consistency index (CI) = 0.6253, a retention index (RI) = 0.7367 and a rescaled consistency index (RC) = 0.4606. One of these trees with bootstrap values is shown in Fig. 4.4.

The subtribes Ischaeminae and Rottboellinae are resolved as a polyphyletic and paraphyletic, respectively with poor bootstrap support. Within both subtribes, there are five major clades as well supported:

- **Clade A**: Formed by all the *Ischaemum* species plus *Kerriochloa siamensis*, except *Ischaemum tenuifolium*.

- **Clade B**: Consisted of seven genera with poor bootstrap: *Mnesithea, Hackelochloa, Hemarthria, Ophiuros, Thelepodon, Rottboellia* and *Phacelurus*.

- **Clade C**: *Mnesithea laevis* as a sister to taxa in genus *Eremochloa* but with poor bootstrap support (<50%). Resolution is strong and fully supported (100%) monophyletic group for internal node of the genus *Eremochloa*.

Three basal lineages, the single taxon *Apluda mutica* in clade E, with poor bootstrap support, a clade D (<50% bootstrap support), which include *Ischaemum tenuifolium* and *Sehima nervosum*. 
4.4.2 \textit{trnL}-F region

The length of the \textit{trnL} intron from 498 (\textit{Sehima nervosum}) to 531 bp (\textit{Ischaemum hirtum}) and the \textit{trnL}-F spacer from 381 (\textit{Mnesithea mollicoma}) to 615 bp (\textit{Ischaemum barbatum} 2). Aligned sequences of the entire \textit{trnL}-F region of 44 specimens (42 ingroup and 2 outgroup specimens) consist of 1,211 characters. For the entire region 61 characters (7.15\%) were potentially parsimony-informative and 53 were variable. Parsimony analysis excluding the coded gaps, resulted in 95 equally most parsimonious trees (tree length = 140 steps; CI = 0.8857; RI = 0.9797; RC = 0.8677). One of these trees with bootstrap values is shown in Fig. 4.5.

The analysis showed the polyphyly of both subtribes with weak to high support. Within both subtribes, there are two major clades.

Clade A: Formed by all taxa in genus \textit{Ischaemum}, \textit{Hemarthria}, \textit{Rottboellia cochichinensis}, \textit{Mnesithea laevis} and unresolved at its base as form a polytomy of several lineages with a weakly bootstrap support (57\%).

Clade B: This clade consisted of the genera \textit{Eremochloa}, \textit{Ophiuros}, \textit{Mnesithea}, \textit{Hackelochloa} and \textit{Apluda} with a strongly bootstrap support (100\%). The analysis showed that the genus \textit{Eremochloa} is a mophyletic as same as the analysis of ITS data.

4.4.3 Combined analysis

Because of the two regions investigated produced poorly identical results. Therefore, the sequence data of ITS and \textit{trnL}-F were combined for additional analysis.

After alignment, the combined data matrix consisted of 2,029 characters. With indel information included the matrix consisted of 1,555 characters, of which 174 (11.19\%) were parsimony-informative and 146 were variable. Analysis of this combined matrix resulted in 4 equally most parsimonious cladograms with a tree length of 632 steps, CI of 0.6661, RI of 0.8559 and RC of 0.5701. Although some polytomies are present. One of these trees with bootstrap values is shown in Fig. 4.6.

Both subtribes form a polyphyletic group with a weakly bootstrap support 53\% and 52\%, respectively, which composed of two main clades:

Hemarthria and Phcelurus zea, which was recognized as a sister taxon to the remaining of this clade.

Clade B: Consisted of the genera in subtribe Rottboelliinae: Mnesithea, Hackelochloa, Ophiuros and Emerochloa except Apluda mutica, which is from the subtribe Ischaeminae. Well supported internal nodes were formed in this analysis.

Table 4.2 Values and statistics from PAUP* analyses of separate and combined data sets.

<table>
<thead>
<tr>
<th>Sequence characteristic</th>
<th>Combined ITS &amp; trnL-F</th>
<th>ITS</th>
<th>trnL-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of characters</td>
<td>1,555</td>
<td>702</td>
<td>853</td>
</tr>
<tr>
<td>Invariant characters</td>
<td>1,235</td>
<td>496</td>
<td>739</td>
</tr>
<tr>
<td>Uninformative variable characters</td>
<td>146</td>
<td>93</td>
<td>53</td>
</tr>
<tr>
<td>Parsimony-informative variable characters</td>
<td>174</td>
<td>113</td>
<td>61</td>
</tr>
<tr>
<td>Consistency index (CI)</td>
<td>0.6661</td>
<td>0.6253</td>
<td>0.8857</td>
</tr>
<tr>
<td>Retention index (RI)</td>
<td>0.8559</td>
<td>0.7367</td>
<td>0.9797</td>
</tr>
<tr>
<td>Rescaled consistency index (RC)</td>
<td>0.5701</td>
<td>0.4606</td>
<td>0.8677</td>
</tr>
<tr>
<td>Maximum parsimony tree length</td>
<td>632</td>
<td>475</td>
<td>140</td>
</tr>
<tr>
<td>Number of trees</td>
<td>4</td>
<td>199</td>
<td>95</td>
</tr>
</tbody>
</table>

4.5 Discussion and conclusion

This study presents the first molecular phylogenetic hypothesis of the relationships among species and genera of the subtribes Ischaeminae and Rottboelliinae. The data sets of the DNA sequences of chloroplast DNA (trnL-F region) and the nuclear ribosomal internal transcribed spacer regions (ITS) were analyzed separately before being combined into a single data set. The analysis shows that the combined tree exhibits the best phylogenetic reconstruction of both subtribes, but the analysis of trnL-F resulted in phylogenies with highest retention index (RI). Two main lineages can be identified as identical to the analysis of trnL-F data (clades A and B; Fig. 4.6), while the analysis of ITS provides evidence for phylogenetic examination of closely related taxa. Recent studies have indicated that the use of non-
coding chloroplast regions may only be useful at intergeneric but not intrageneric levels due to a lack of informative sequence variation (Roodt-Wilding & Spies, 2006). This was seen in this study with the *trnL*-F region providing resolution among, but not within, genera in both subtribes.

The results show that the subtribes Ischaeminae and Rottboelliinae are polyphyletic. Previous studies using phytochrome B, GBSSI and *ndhF* also concluded that both subtribes are polyphyletic (Mathews et al., 2002). Kellogg & Watson (1993), using morphological data, placed *Ischaemum* and its sister *Digasstrium* a sister to many genera of Rottboelliinae, whereas they considered *Apluda* a sister to *Apocopsis*. The *ndhF* phylogeny (Spangler et al., 1999; Spangler, 2000) also places *Ischaemum* as an early diverging branch, whereas *Apluda* is part of the “core” Andropogoneae. Hence, these two groups of subtribes do not support the subtribal designations of Clayton & Renvoize (1986).

**Implications for Classification**

*Ischaemum* L.

Resolution within the *Ischaemum* clade is moderate to high (most subclades having of bootstrap support (≥78%) showing that *Ischaemum* is paraphyletic. The *Ischaemum* clade also contains three morphologically very similar genera, *Mnesithea*, *Sehima* and *Kerrioehloa*. The species *Ischaemum tenuifolium* forms a subclade separate from the other species in the genus, but with weak support. The division of *Ischaemum* into sections, proposed by Clayton & Renvoize (1986), is supported by the present molecular study. The ITS, *trnL*-F and combined trees divide the genus into three major subclades that correspond to the morphology of the lower glume of the sessile spikelet. In the combined tree, subclade I, with a strong bootstrap support of 98%, comprises all taxa which share the character of an entirely sessile lower glume. Subclade IV is formed by the group of taxa which have nodules on the sessile lower glume, with a robust bootstrap support of 99%.

Subclades II and III are derived from species of four different genera, *Ischaemum tenuifolium*, *Mnesithea laevis*, *Sehima nervosum* and *Kerrioehloa siamensis*, all of which are now placed in the genus *Ischaemum*. *K. siamensis* is a sister to the remainder of this subclade, with poor bootstrap support, indicating that this group is closely related to the genus *Ischaemum*. This result is in agreement with
Clayton & Renvoize (1986), who suggested that *Kerriochloa* is related to *Ischaemum*, particularly *I. decumnens*.

All the three analyses supported the segregation of *Ischaemum tenuifolium* from the genus *Ischaemum*. This finding is also supported by the taxonomic treatments (chapter V) that moved *I. tenuifolium* to the genus *Andropogon* and Clayton & Renvoize (1986) who noted that the genus *Ischaemum* is often quite difficult to distinguish from *Andropogon*. Unfortunately, the genus *Andropogon* is not sampled here. The two genera are circumscribed on the basis of their difference in inflorescences and lower glume of the sessile spikelet characters, with the *Ischaemum* defined by 2 rarely digitate racemes that carry a spikelet with convex or flattened lower glume, whereas the *Andropogon* species are characterized by having 3–7 racemes with a concave lower glume (Clayton & Renvoize, 1986). The leaf-blades anatomical study in chapter II concluded that papillae are present in all members of *Ischaemum*, except in *I. tenuifolium*, which shows that this species is distinct from the other species in the genus. These results confirm the conclusion of Watson & Dallwitz (1992), who stated that many of the core Andropogoneae have a single oblique papilla on each of the intercostal cells, overlying the stomata. Of the genera included in their study, *Andropogon* and *Schizachyrium* lack such papillae. Both genera include a large number of species, and *Andropogon* is likely to be polyphyletic (Mathews et al., 2002); future studies will thus have to investigate more species of each genus to test the connection demonstrated here.

However, the relationships within some of the taxa in the genus *Ischaemum*, namely, *I. sp.1*, *I. sp.2*, *I. barbatum* complex and *I. indicum* complex are unresolved; there is still a low resolution between the subclades of *Ischaemum* as they were arranged in a polytomy.

**Hemarthria R. Br. & Phazelurus Griseb.**

Most of the generic groupings including more than one species are well supported. This includes, for example, the genus *Hemarthria* which forms well supported lineages (≥98%) in all analyses, which shows that the genus *Hemarthria* is monophylic. The generic status of *Hemarthria* is clearly justified and its close relationship to *Phazelurus zea* (combined tree) is also evident with a weak bootstrap support of 53%. This is in agreement with Clayton & Renvoize (1986), who stated
that the fused pedicel and basic chromosome number of 9 are evidence that *Hemarthria* is more closely related to *Phacelurus* than to *Heteropollis*.

*Hemarthria compressa* is a sister to *H. pratensis* with a 100% bootstrap support in combined and ITS trees and a 98% bootstrap support in *trnL-F* tree. The morphology of the two taxa is also clearly different; they are distinguished by leaf-blades and joints. In *H. compressa*, the leaf-blade is not deciduous and the joints are not long cuneate, in contrast to the deciduous leaf-blades and long cuneate joints in *H. pratensis* (Van Den Heuvel & Veldkamp, 2000).

Placement of *Phacelurus zea* (bootstrap support 53%) as sister to clade A (group of *Ischaemum*) is consistent with Clayton & Renvoize (1986), who pointed out that the two genera are clearly related. In practice, there is not much difficulty in distinguishing it from *Ischaemum*, but it is sometime quite hard to find unequivocal diagnostic characters.

**Mnesithea Kunth**

The results presented here show that the taxa *Ischaemum tenuifolium*, *Mnesithea laevis*, *Sehima nervosum* and *Kerriochloa siamensis* are nested within *Ischaemum*, although this subclade is not strongly bootstrap supported (<50%). *Kerriochloa siamensis* appears to be a sister to the other members of both subclades. Clayton & Renvoize (1986) proposed that the genus *Mnesithea* has only one species: *M. laevis*, and retained *Coelorachis* as distinct genus. The genus *Coelorachis* differs from the other genera by a free pedicel and a pedicelled spikelet. A re-assessment of the generic limits of *Mnesithea* sensu lato by Veldkamp et al. (1986) acknowledged the addition of *Coelorachis* in to *Mnesithea*, because several species of *Coelorachis* have the lower part of pedicel completely fused to the rachis node. The pedicelled spikelet varies from well developed to minute vestige, and its absence in traditional *Mnesithea* is therefore not enough to conserve the genus (Veldkamp et al., 1986). The results of this molecular study seem to conflict with the results of the morphological study in chapter II and the investigation by Veldkamp et al. (1986), who included all members of *Coelorachis* into *Mnesithea*. A majority of the *Mnesithea* species (*Coelorachis* sensu Clayton & Renvoize, 1986) form a group in a subclade VIII which is distinctly related to *Hackelochloa* and *Ophiuros*, however with a weak bootstrap support of 61%. The arguments mentioned above clearly show that this genus is problematic and should be studied more in details.
The species *Mnesithea glandulosa* is segregated from most other species in the genus and appears to be basal-most to all others of this group with a weak bootstrap support of 61%; correlated with a distinct morphological character; a lateral hook on the lower glume of the sessile spikelet, which is a characteristic of *Eremochloa*. In 1986, Clayton & Renvoize depicted the genus *Eremochloa* as derived from *Coelorachis* (=*Mnesithea*).

Within the remaining *Mnesithea* are three subclades with a week bootstrap support less than 50%. The first topology, with a 63% bootstrap support, suggested that *M. heferi* is sister to *M. mollicoma*, sharing the pubescence leaf surface. The second topology is one of the strongest (100% bootstrap support) supported in both ITS and combined analyses: *M. striata* var. *striata* and *M. striata* var. *pubescens*. Therefore, *M. striata* var. *pubescens* might be the same species as *M. striata* var. *striata*. However, the two subspecies can be distinguished by the culm and leaf-blade, which are covered in hairs in var. *pubescens*, whereas glabrous in var. *striata* (Hackel, 1889). The last topology confirmed that *M. cancellata* is sister to *M. sp.1* with a weak bootstrap support of 52%. In this study most materials of *M. sp.1* were previously identified as *M. striata*. *M. sp.1* is different from *M. striata* by having an oblong lower glume of the sessile spikelet, indurate, 5–5.5 by 1.2–1.5 mm; an apex with unequal wings; 7–8 longitudinal rows of small pits between the nerves of the back; and margins at base puberulous. *M. striata* has an ovate lower glume of the sessile spikelet, indurate, 4.5–5 by ca. 1.5 mm; an apex with 2 apical wings; and a continuous ridge along the length and interrupted by tubercles or tubercle-based hairs on the back, or glabrous. Hence, the molecular as well as morphological evidences indicated that *M. sp.1* should be proposed as a new species in the genus *Mnesithea*.

*Hackelochloa Kuntze*

A subclade VIII grouping (Fig. 4.6) comprises of *Mnesithea, Hackelochloa, Ophiuros* with *Mnesithea glandulosa* being a sister of this group. The small genus *Hackelochloa*, represented in this study by a couple of species, is determined as monophyletic group but with a weak bootstrap support. Further sampling of these two taxa is required in order to confirm their monophyly. From the combined analysis it revealed that *Hackelochloa* is closer to *Ophiuros* than to *Mnesithea*; however with a poor bootstrap support less than 50%. The molecular results from this study are
contrary to Veldkamp, et al. (1986) who treated Hackelochloa as a synonym of Mnesithea.

Hackelochloa granularis and H. porifera are morphologically similar and have been grouped together previously (Veldkamp, et al. 1986). In contrast, the morphological study separates the two taxa by the difference in size and sculpture on the lower glume. While the trnL-F tree (Fig. 4.5) shows that H. granularis and H. porifera are in the same clade, but with 79% bootstrap support, and both having a globose lower glume. Therefore, the two species are not identical. This is in agreement with Bor (1960), who stated that H. porifera differed from H. granularis by its larger spikelets and a more pronounced sculpture on the lower glume of the sessile spikelet.

Eremochloa Buse

The results of all phylogenetic analyses presented here provide broadly consistent estimates of the phylogeny of Eremochloa. The genus Eremochloa comprises of a monophyletic group, with Apluda (represented by A. mutica) as sister group to the genus, with a strongest bootstrap support (100%). According to Buitenhuis & Veldkamp (2001), this genus is recognized by a single spike-like raceme and a submarginally pectinate lower glume. Clayton (1973), in a numerical analysis of awnless genera of the Andropogoneae, found Eremochloa in the Coelorachidaeae close to Rhytachne (not sampled here).

The genus Eremochloa can be divided into two main groups with a strongest bootstrap support (100%), however no obvious morphological character supports this division. The first group is composed of E. bimaculata, E. maxwellii, E. ciliatifolia and E. attenuata as a sister of this group with a 99% bootstrap support. The second group is formed by E. ciliaris, E. eriopoda, E. lanceolata and E. sp.1 as a sister of this group with 64% bootstrap support.

The morphological study shows that Eremochloa sp.1 is very closely related to E. maxwellii but differs in having an obovate and long cordate pedicel, in contrast to the obliquely-lanceolate pedicel in E. maxwellii. The species is found in north-eastern Thailand. The present molecular study confirmed that E. sp.1 should be a new species, but not a variety of E. maxwellii.
Apulda L.

The strong support for the clade containing Eremochloa and Apulda is one of a surprised result produced by this molecular study, since there are no obvious morphological characters that unite the two genera. Apulda is separated from Eremochloa, so the closed relationship of the two genera might have been predicted.

Although not all genera and species in the subtribes Ischaeminae and Rottboelliinae were included in this analysis, the results observed here indicate the phylogenetic trends in both subtribes in Thailand. Additional taxonomic sampling in the future will result in better resolution of the relationships. Moreover, more gene regions and more samples from various geographic regions should be included in further studies in order to define the relationships among taxa in both subtribes.
Figure 4.4 One of 199 equally most parsimonious trees of ITS region of the subtribes Ischaeminae and Rottboelliiinae and outgroup taxa with a length of 475, CI of 0.63 and RI of 0.74. Branch lengths obtained using sequences are indicated above branches, bootstrap percentage values >50% are indicated below branches. Arrows show clades recovered in the strict consensus tree.
Figure 4.5 One of 95 equally most parsimonious trees of \textit{trnL} intron and the \textit{trnL}-\textit{F} spacer of the subtribes Ischaeminae and Rottboelliiinae and outgroup taxa, with a length of 140, CI of 0.89 and RI of 0.98. Branch lengths obtained using sequences are indicated above branches, bootstrap percentage values >50\% are indicated below branches. Arrows show clades recovered in the strict consensus tree.
Figure 4.6 One of 4 equally most parsimonious trees of ITS region and trnL intron and the trnL-F spacer of the subtribes Ischaeminae and Rottboelliinae and outgroup taxa, with a length of 632, CI of 0.67 and RI of 0.86. Branch lengths obtained using sequences are indicated above branches, bootstrap percentage values $>50\%$ are indicated below branches. Arrows show clades recovered in the strict consensus tree.
CHAPTER V

TAXONOMIC TREATMENT

5.1 Materials and methods

5.1.1 Plant materials

Grass specimens of the subtribe Ischaeminae and the subtribe Rottboellinae were studied from existing herbarium specimens deposited at the Department of Systematic Botany, University of Aarhus (AAU); Kasin Suvathabhandhu Herbarium, Department of Botany, Chulalongkorn University, Bangkok (BCU); Herbarium, Botanical Section, Department of Agriculture, Bangkok, Forest Herbarium (BK); National Park, Wildlife and Plant Conservation Department, Bangkok (BKF); British Natural History Museum Herbarium (BM); Botanical Museum, University of Copenhagen (C); Chiang Mai University Herbarium (CMU); Royal Botanic Garden, Edinburgh (E); Royal Botanic Gardens, Kew (K); Khon Kaen University Herbarium (KKU); National Herbarium Netherland University of Leiden branch (L); Linnean Society Herbarium (LINN); Muséum National d’Histoire Naturelle, Paris (P); Prince of Songkhla University Herbarium (PSU); Queen Sirikit Botanic Gardens, Herbarium (QBG); Department of Biology Herbarium, Chiang Mai University and Trinity College, University of Dublin (TCD).

Addition collections of grass specimens also collected from their natural habitats from various localities throughout Thailand. Specimens were collected using standard procedures for herbarium materials (Bridson & Forman, 1999).

5.1.2 Specimen determination

Determinations of the collected specimens were based on the existing keys available from Floras or manuals of neighboring countries. Then the identifications were confirmed by comparing with the type specimens.

5.1.3 Classification

In this work, genera have been arranged according to the Clayton & Renvoise classification (1986).
5.1.4 Taxonomic treatments

Taxonomic treatments of genera and species in the subtribe Ischaeminae and Rottboelliiinae were based mainly on morphological data. Each genus and species were described and illustrated. Keys to subtribes, genera and species were constructed. Ecological and geographical data of each species were noted.

5.2 Results

According to the examination of plant collections from the herbarium and addition collections in the fields in Thailand during July 2004-July 2006, 18 taxa in subtribe Ischaeminae and 33 in Rottboelliiinae are enumerated.

KEY TO THE SUBTRIBES

1. Rachis internodes and pedicels slender, sometimes thickening upwards, upper lemma awned
   A. Ischaeminae

1. Rachis internodes and pedicels stout, thickening upwards; upper lemma awnless
   B. Rottboelliiinae

A. ISCHAEMINA

Presl, Rel. Haenk. 1: 328. 1830.

Perennial or annual. Inflorescence of single, paired or digitate racemes, theses usually terminal, sometimes axillary, rarely spathe; racemes with slender and fragile rachis. Spikelets paired (except Apluda), dissimilar. Sessile spikelet bisexual, dorsally or laterally compressed; lower glume chartaceous to crustaceous, convex or concave, 2-kleeled or rounded on the flanks, with or without a median groove; lower floret male, with palea; upper lemma oblong, bidentate or bifid, nearly always with a glabrous awn. Pedicelled spikelet variable.

About 8 genera, distributed throughout the tropics, 5 genera, 17 species and 1 infraspecific taxa in Thailand.
KEY TO THE GENERA

1. Pedicelled spikelet absent

5. Thelepogon

1. Pedicelled spikelet present

2. Spikelet 3; subtended by cymbiform spathe; 1 sessile and 2 pedicelled spikelet

1. Apluda

2. Spikelet 2; not subtended by cymbiform spathe; 1 sessile and the other one pedicelled spikelet

3. Ischaemum

3. Racemes usually 2 or more

3. Racemes single

4. Inflorescence subtended by a linear spatheole which enclosed, sessile spikelets laterally compressed, pedicelled spikelet smaller than sessile spikelet

2. Kerriochloa

4. Inflorescence not enclosed by spatheole, sessile spikelets dorsally compressed, pedicelled spikelet larger than sessile spikelet

4. Sehima

1. APLUDA

L., Sp. Pl. 1: 82. 1753.—Type species: A. mutica L.


This genus comprises probably only one polymorphic highly variable species, which is very common throughout Southeast Asia, India and Ceylon. Typical found in partly shaded to mostly open places in deciduous forest.

*A. varia* Hack. in DC., Monogr. Phan. 6: 196. 1889.—Type: Wall. Cat. no. 8760, 8761 (K).

Perennial grass. *Clumps* hard, solid 50–150 m tall or more, glabrous. *Leaf-sheaths* tight, 4.5–7 cm long, grooved, glabrous. *Ligules* membranous, 1.5–2 mm long. *Leaf-blades* linear, up to 1.5 by 30 cm, strigose on both surfaces, base attenuate, apex acuminate. *Inflorescence* consiting of numerous racemes, 3 spikelets subtended by cymbiform spathes with long aristate at the apex, the lower most with an inflated joint. *Sessile spikelet* 1, perfect, laterally compressed. *Glumes*; lower glume oblong-lanceolate, 4–6 mm long, 11–13-nerved, coriaceous, adaxial surface scaberulous, margins thin, hyaline and folded, awnless; upper glume asymmetrically boat-shaped, 4–5 mm long, 6–7-nerved, margins folded, apex acute to acuminate, awnless. *Lower floret* sterile; lemma 4–5 mm long, 5-nerved, hyaline apex acuminate, awnless; palea boat-shaped, 2-nerved, hyaline. *Upper floret* perfect; lemma boat-shaped 3.5–4 mm long, expanded below the middle, hyaline, awn or awnless; palea lanceolate, 2-nerved, hyaline, acuminate. *Pedicelled spikelet* 2; one with only flattened pedicel and solitary glume, the other one with oblong pedicel, 3–3.5 mm long, flattened, glabrous. *Glumes*: lower glume oblong-ovate, 4–4.5 mm long, 11–12-nerved, papyraceous, acute; upper glume boat-shaped, ca. 4 mm long, 10–11-nerved, chartaceous, expanded margin, acute. *Lower floret* neutral; lemma ovate, 4–4.5 mm long, 3-nerved, hyaline, marginal winged; palea hyaline, 3.5–4 mm, 2-nerved. *Upper floret*; lemma boat-shaped, 3–3.5 mm long, 5-nerved, hyaline, acute; palea boat-shaped, 2–2.5 mm long, 2-nerved, hyaline. *Lodicules* cuneate, ca. 0.25 mm long. *Anthers* yellow, ca. 2 mm long. *Ovary* fusiform, 1–1.5 mm long. *Stigma* brown (Figs. 5.1 & 5.27A).

Oct. 1956, *T. Smitinand* 3544 (BKF); 4 Nov. 1958, *Dee* 1186 (BKF));

**PENINSULAR**: Chumphon [Khao Num-Ma-Prou, Toung Kae, 1 Jan. 1974, *S. Sutheesorn* 2816 (BK)], Surat Thani [Khao Nam Ron (hot springs), Chaiya, 5 Feb. 1987, *J.F. Maxwell* 87-149 (AAU, BKF, CMU, E, L, P)].

**Distribution.**— Worldwide.

**Ecology.**— Partly shaded to mostly open places in deciduous forest, up to 2,000 m altitude. Flowering in August to May.

**Vernacular.**— Ya kom bang (นุ้ยกบัง) (General); Ya phi (นุ้ยฟี) (Krung Thep Maha Nakhon); Ya phrik phran (นุ้ยพริกพราว) (Ang Thong).

**Notes.**— This species has 3 spikelets subtended by cymbiform spathe with long aristate at the apex. It is variable in the development of the awn of the upper lemma.

**Uses.**— The young plant is used as a fodder (Gilliland, 1971).
Figure 5.1 *Apluda mutica*: A. plant; B. inflorescence; C. three of spikelets subtended by cymbiform spathes; D. spatheole; E-F. two views of three spikelet; G. lower glume of sessile spikelet; H. upper glume of sessile spikelet; I. pedicelled spikelet; J. pedicel of sessile spikelet. All line drawings were drawn by P. Traiperm from *P. Traiperm* 152.
2. ISCHAEMUM

L., Sp. Pl. 2: 1049. 1753.—Type species: *I. muticum* L.

*Ischaemum*.

*Colladoa* Cav., Iter. Pl. 5: 37. 1799.—Type species: *C. distachia* Cav. (= *I. rugosum*).

*Meoschium* P.Beauv., Ess. Agrost.: 111. 1812.—Type species: *M. aristatum* (L.) P.Beauv.


*Argopogon* Mimeur in Rev. Bot. Appl. 31: 211. 1951.—Type species: *A. vuilletii* Mimeur (= *I. fasciculatum*).

Perennial or annual. *Inflorescence* terminal and axillary, of paired or sometimes digitate racemes, separated or conjugated 1-sided and interlocked back to back in a single spike, exserted but sometimes embraced by a spatheole; internodes and pedicels linear to obovoid, usually exposed on the back of the raceme as a U- or V-shaped segment. *Sessile spikelet* compressed; lower glume chartaceous to coriaceous, convex, 2-keeled or rounded on flanks, often rugose, sometimes winged, entire or bilobed; upper glume with or without an awn; upper lemma awnless in *I. indicum* and *I. magnum*. *Pedicelled spikelet* as large as the sessile, dorsally or laterally compressed, often asymmetrical, occasionally bisexual with the upper lemma weakly awned.

A genus of about 70 species in the Old World tropics, mainly in Asia, but a few species in tropical America; 13 species and 1 infraspecific level occur in Thailand. *Ischaemum* is a difficult genus reaching its greatest complexity in Southeast Asia and biosystematic work on the genus badly is needed.

*I. angustifolium* Hack., *I. fieldingianum* Rendle and *I. mangaluricum* (Hack.) Stapf ex Fisher have been reported from Thailand (see Nanakorn & Norsaengsri 2001) but no herbarium specimens are available for confirmation.
KEY TO THE SPECIES

1. Spikelets awnless, awn imperfect, not kneeed, rarely 1 cm long or with a weak awn hardly exerted from the glumes

2. Lower glume oblong on the lower part, upper part oblique foliose and acute at the apex, slightly winged along the upper margins; racemes 9–15 cm long
   7. I. magnum

2. Lower glume ovate, winged above the middle, racemes 2.5–3.5 cm long
   8. I. muticum

1. Spikelets distinctly awned

3. Lower glume of sessile spikelet coarsely ridged across the back or with nodules along the margins

4. Lower glume of sessile spikelet coarsely ridged across the back with 4–7 ridges
   9. I. rugosum

4. Lower glume of sessile spikelet coarsely ridged with nodules along the margins

5. Lower glume of sessile spikelet indurate below, without nerve

6. Pedicelled spikelet as long as the sessile one, lower glume with 2-3 transverse ridges or nodules at each edge
   1. I. barbatum

6. Pedicelled spikelet shorter than the sessile one, lower glume with 4-7 transverse ridges or nodules at each edge
   9. I. rugosum

5. Lower glume of sessile spikelet subcoriaceous, with 10–14 distinct nerve

7. Back of the lower glume of sessile spikelet glabrous
   4. I. hubbardii

7. Back of the lower glume of sessile spikelet hairy
   12. I. sp.1

3. Lower glume of sessile spikelet not coarsely ridged across the back or with nodules along the margins

8. Plant often with 3 racemes
   10. I. tenuifolium

8. Plant normally with 2 racemes

9. Lower glume of sessile spikelet without winged
   11. I. timorense

9. Lower glume of sessile spikelet with conspicuously winged

10. Back of the lower glume of the sessile spikelet glabrous
   2. I. hansenii

11. Inflorescences raceme, conjugated
   5. I. indicum

11. Inflorescences digitately raceme, separated
10. Back of the lower glume of the sessile spikelet slightly hairy to densely hairy

12. Leaf blade pilose without tubercle-based hair

13. Lower glume of the sessile spikelet with distinctly 2-apical wings

5. *I. indicum*

13. Lower glume of the sessile spikelet with narrowly fringed wings along the upper margins

3. *I. hirtum*

12. Leaf blade glabrous or with tubercle-based hairs at least in the lower part

14. Leaf blade pilose with tubercle-based hairs on both surfaces

6. *I. lacei*

14. Leaf blade glabrous on both surfaces, pilose with tubercle-based hairs on the lower surface

13. *I. sp.2*

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**1. Ischaemum barbatum** Retz., Observ. Bot. 6: 35. 1791.— Type: Indonesia, Java, D. Wennerberg s.n. (not seen).

*I. barbatum* Retz. var. *glaberrimum* Bor in Dansk Bot. Arkiv (20) 2: 174. 1962. *syn. nov.*— Type: Thailand, Chiang Mai: Doi Suthep, common in a bog, alt. 1000 m, 14 April 1958, Th. Sørensen, K. Larsen & B. Hansen 2709 (holotype K!, isotypes BK!, C!, E!).


KEY TO THE VARIETIES

1. Raceme glabrous
   a. var. barbatum
1. Raceme hairy
   b. var. lodiculare

a. var. barbatum

Perennial. *Culms* erect somewhat prostrate, terete, up to 1 m tall, internodes glabrous, nodes glabrous or slightly pilose. *Leaf-sheaths* loose and overlapping below, glabrous or with pilose hairs or densely appressed hairs. *Ligules* prominently membranous, 1–4 mm long, glabrous or pilose outside. *Leaf-blades* narrowly linear to linear-lanceolate up to 20 by 0.5–1.5 cm, glabrous to pilose on both surfaces, rounded or subcordate or abruptly narrowed at the base, apex acute to acuminate. *Inflorescence* racemose on terminal or axillary, 5–11 cm long, conjugate with 2 racemes, rachis internodes oblong, 3–6 mm long, tough, pilose along the angles, nodes with a ring of long cilia, callus triangular, blunt ca. 1.5 mm long, pilose at base. *Sessile spikelet* dorsally compressed. *Glumes*; lower glume varying in size and shape, oblique-oblong, 5.5–8 by 1.5–2 mm, upper part foliaceous, indurate below, not nervured, with 2–3 transverse ridges or nodules at each edge and rarely extending horizontally to meet across the back of the glumes, glabrous on the back, asymmetrically with 2 small fringed marginal wings on the 1/3 of the upper, submarginally keeled towards the apex, keels unequally and narrowly winged, wing widest on side away from pedicelled spikelet; upper glume folded, 5–7.5 by ca. 1 mm, scabrous keeled on the back of the nerve, glabrous on the back or villous. *Lower floret*; lemma oblong-acute, 4.5–7 by ca. 1 mm, hyaline, margins slightly folded, upper margins ciliate; palea oblong-acute, 3–6.5 by ca. 1 mm, hyaline, folded. *Upper floret*; lemmas 3.5–5 mm long, hyaline, bifid, geniculately awned from sinus, awn twisted, 18–25 mm; upper palea oblong, 3–4.5 mm long, hyaline, folded. *Pedicelled spikelet*: pedicels triangular-shaped, 2.5–3 mm long, pilose along the angles. *Glumes*; lower glume oblong, 4.5–7 by 1.5–2 mm, upper foliaceous and many nervured, apex with a wide fringed wing its whole length on one side, indurate below; upper glume boat-shaped, 4.5–6.5 mm long, 1-keeled along the back, keel scabrous, glabrous on the back or pilose on the lower part, apex acute. *Lower floret*; lemma oblong-acute, 4–6 by ca. 1 mm, hyaline, folded; palea oblong-acute, 3.5–5.5 by ca. 0.8 mm, hyaline, folded. *Anthers ca. 2.5
mm long. *Upper floret*; lemma boat-shaped, 4–5 by ca. 0.8 mm, hyaline, folded, apex acute; palea oblong-obtuse, 3–4 by ca. 0.8 mm, hyaline, folded (Fig. 5.27B. & C).


**Distribution.**— India and Southeast Asia.
Ecology.—Tufted grass common in paddy fields and wet places, up to 1500 m altitude. Flowering throughout the year.

Vernacular.—Ya yon hu (พืชหัวหยัก) (Peninsular); Ya wai (พืชไม้) (Trat); Ya hang khang (พืชหัวลิง) (Loei); Ya daeng (พืชแดง), Ya wai dang (พืชไม้แดง) (Narathiwat).

Notes.—This is a widespread and polymorphic species, to which many specific and infraspecific names have been applied. Variation depends mainly on the degree of hairiness of the leaves and spikelets and the number and prominence of the nodules and ridges on the sessile spikelet. In extreme cases the ridges are particularly well-developed and approach the condition in *I. rugosum*, but such plants can be recognised as *I. barbatum* by their more robust, perennial habit and more oblong sessile spikelets.

**b. var. lodiculare** (Nees) Jansen, Reinwardtia 2: 294. 1953.


*I. aristatum* subsp. *barbatum* var. *lodiculare* (Nees) Hack. in DC., Monogr. Phan. 6: 205. 1889.—Type: China, Cap Syng-Moon (Meyen); Hong-Kong (*Hance* 1257); Futschan-yen (ex Debeaux) (not seen).

Spikelets with long, white hairs. Joints of the racemes ciliate on all the sides. Sheaths usually long-hirsute, nodes bearded (Fig. 5.27D).


**Distribution.**— Southeast Asia.

**Ecology.**— In open grassy pine forest or in open area, at 50-1,300 m altitude. Flowering in June to March.

**Notes.**— This is a very distinctive variety. The inflorescence is suffused with purple and covered with long white hairs.

2. *Ischaemum hansenii* Bor, Dansk Bot. Arkiv (23) 4: 470. 1968.— Type: Thailand, Trang, Ko Talibong, B. Hansen & T. Smitinand 12198 (holotype K!, isotypes BKF!, C!, L!).

Perennial. **Culms** 20–25 cm, creeping or somewhat prostrate, culm glabrous, node glabrous or ciliolate. **Leaf-sheaths** loose, 2–3 cm long, glabrous. **Ligules**, membranous with ciliate margin, 0.8–1 mm long, brownish. **Leaf-blades** lanceolate, 3-7 by 0.6–0.9 cm, acute at the apex, glabrous on both surfaces. **Inflorescences** racemes, terminal, 2.5–4.5 cm long, conjugate not separating into 2 racemes when mature, rachis internodes triangular-shaped, **ca.** 5 by 1 mm, pilose on keel, nodes with a ring of long cilia, callus **ca.** 1 mm long, glabrous. **Sessile spikelet;** lower glume elliptic, 5.5–6 by 2–2.5 mm, indurated below, 2-apical wings and along the upper margins, wings scabrous, glabrous on the back, folded, lower glume apex dentate; upper glume boat-shaped, **ca.** 7 by 1.2 mm, acuminate, keeled along the upper back, keeled scabrous, upper margins ciliate. **Lower floret;** lemma lanceolate, **ca.** 5 by 1 mm, upper margins folded, margins ciliate; lower elliptic, **ca.** 5 by 1 mm, margins
folded, upper margins long ciliate; upper lemma *ca.* 4.5 by 1 mm, bifid, awned from sinus, twisted column, 12–15 mm long, upper margins ciliate; palea lanceolate, *ca.* 5 by 0.8 mm, hyaline, slightly folded, margins ciliate. *Ovary* ellipsoid, *ca.* 1.5 mm long. *Pedicelled spikelets* laterally compressed. *Pedicels* triangular shaped, *ca.* 4 by 1 mm, pilose along keel. *Glumes;* lower glume oblique-lanceolate, plicate, *ca.* 6 by 1 mm, indurate and convex below, margins scabrous, wing on keel, keel scabrous, glabrous on the back; upper glume boat-shaped, *ca.* 6 by 1 mm, acuminate, keel along the upper back, keel scabrous, margins ciliate. *Lower floret;* lemma boat-shaped or ovate, *ca.* 5 by 1 mm, hyaline, upper margins ciliate; palea lanceolate, *ca.* 5 by 0.8 mm, hyaline, slightly folded, upper margins ciliate. *Lodicules* cuneate, *ca.* 0.5 mm long. *Anthers* 3, *ca.* 2.5 mm long, yellow. *Upper floret;* lemma, *ca.* 4 by 1 mm, bifid, awned from sinus, twisted, 13–15 mm long, upper margins ciliate; palea lanceolate, *ca.* 4.5 by 0.8 mm, hyaline, slightly folded (Fig. 5.28A-C).


**Distribution.**— Endemic to Thailand.

**Ecology.**— Creeping on rocks by the sea, at sea level. Flowering in November.

**Notes.**— Known only from the type specimen. I can not be collected even in their original locality.

3. **Ischaemum hirtum** Hack. in DC. Monog. Phan 6.: 1889. 228.—Type: India, Khasia, *J.D. Hooker & T. Thomson* 1937 (holotype K!).

Annual, tufted. *Culms* erect, terete, 45–70 cm tall, nodes ciliate, internodes glabrous. *Leaf-sheaths* tight, 4–6 cm long, glabrous to pilose. *Ligules*, membranous, 1–2 mm long. *Leaf-blades* linear, 8–15 by 0.4–0.6 cm, pilose on both surfaces, margins scabrous, base tapering, acute at the apex. *Inflorescences* racemes, terminal and axillary, 4–6 cm long, separating into 2 racemes, rachis internodes oblong, triangular or quadrangular in transverse, 3–4 mm long, hairy along the angles, nodes with a ring of long cilia, hairs up to 3 mm long, callus 1–1.3 mm long. *Sessile spikelet;* lower glume 5–5.5 mm long, 9–10-nerved, pilose on the back, upper margins scabrous, expanded at base, marginals nerved prolonged form 2 points, narrowly
fringed wings along the upper margins; upper glume boat-shaped, 6.5–7 mm long, midnerve extended to long tail, scabrous wing along tail, glabrous on the back, upper margins ciliate. Lower floret; lemma ca. 5 mm long, plicate, scabrous along marginal keel; palea ca. 5 mm long, hyaline, slightly folded, upper margins ciliate. Lodicules ca. 0.5 mm long. Anthers yellow, ca. 2 mm long. Upper floret; lemmas boat-shaped, ca. 5 mm long, hyaline, bifid, twisted awn from sinus, 8–10 mm long; palea lanceolate, ca. 5 mm long, hyaline, slightly folded, upper margins ciliate. Ovary narrowly ovate, 1.5–2 mm long. Pedicelled spikelets; pedicels triangular, 3–4 mm long, hairy along the angles. Glumes; lower glume plicate, 5–5.5 mm long, scabrous wing along keel, pilose, upper margins ciliate; upper glume folded, 5.5–6 mm long, keeled along mid-nerved and prolonged in to long tail, upper margins ciliate. Lower floret; lemma ca. 5 mm long, hyaline, folded, upper margins ciliate; palea 4.5–5 mm long, hyaline, folded, upper margins ciliate. Anthers yellow, ca. 2 mm long. Upper floret; lemma ca. 4 mm long, bifid, hyaline, folded, twisted awn from sinus, 7–10 mm long; palea narrow, ca. 5 mm long, apex with tail, scabrous, hyaline (Fig. 5.28D–F).


**Distribution.**—India and Thailand.

**Ecology.**—Along river banks or near stream, at 50-1300 m altitude. Flowering between November and December.

**Notes.**—The distribution has a curious disjunction between India and Thailand. This species should occur somewhere in upper Myanmar. However, there still scanty available taxonomic data of this plant group from this country.

4. *Ischaemum hubbardii* Bor in Indian Forest Rec., n.s. Bot. 1: 98. 1938.—Type: India: Assam, fairly common in the Khasia and Jaintia hills, alt. 4,000-5,000 m, *N.L. Bor* 2264 (holotype K!).
Perennial, densely tussocking grass. *Culms* slender, terete, 25–60 cm tall, internodes and nodes glabrous. *Leaf-sheaths* tight, 4–7 cm long, glabrous or slightly pilose, margins thin. *Ligules*, long membranous 3.5–5 mm long, glabrous. *Leaf-blades* lanceolate, 5–15 by 0.3–1 cm, tuberculate pilose on both surfaces, margins scabrous, apex acute. *Inflorescences* raceme, terminal, 3–5 cm long, conjugated with 2 racemes, rachis internodes oblong 6–6.5 by ca. 0.1 mm, triangular in transverse section, pilose along central keel, nodes with a ring of long cilia, callus ca. 1 mm long, glabrous. *Sessile spikelet*; lower glume oblong, 6.5–8 by 1.5–1.8 mm, distinctly 10–14-nerved, subcoriaceous, transverse humped along the lower 1/3, glabrous on back, unequally narrowly laterally winged above, wing scabrous; upper glume boat-shaped, 8–9 mm by 1.8–2.2 mm, keeled, scabrous, margins ciliate, apex acuminate, with a small wing at the apex. *Lower floret*; lemma lanceolate, 7–7.5 by ca. 1.5 mm, hyaline, slightly folded, upper margins ciliate; palea elliptic, 5.5–6 by ca. 1.5 mm, hyaline, folded, apex muticous. *Upper floret*; lemmas ca. 7 mm long, bifid, geniculately awned from sinus, awn twisted, 18–25 mm; palea ovate, ca. 5 by 1.3 mm, apex acute, hyaline. *Lodicules* cuneate, 1–1.2 mm long. *Pedicelled spikelets*; pedicels 5.5–6 by ca. 1 mm, pilose along central keel. *Glumes*; lower glume obliquely-oblong, 7–7.5 by 2.7–3 mm, 6–8-nerved, with 2 subequal wings along whole length of the margins, glabrous on back, margins folded, apex bifid; upper glume boat-shaped, 7–8 by 1.5 mm, keeled along the upper of mid-nerve, scabrous on keel. *Lower floret*; lemma lanceolate, ca. 6 by 1.2 mm, hyaline, folded, glabrous, apex acute; palea oblong, ca. 5 by 0.8 mm, apex acute, hyaline, slightly folded. *Anthers ca. 3 mm long. Upper floret*; lemma ovate, ca. 5.5–6.5 by 0.9–1.4 mm, apex acute, hyaline, folded; palea oblong, ca. 4.5–6 by 0.8–1.2 mm, apex rounded, hyaline, slightly folded. *Caryopsis* ellipsoid, ca. 3 mm long (Figs. 5.2 & 5.29A. & B).


**Distribution.**— India.

**Ecology.**— Common along Kio Mae Pan nature trail or in lawn near pagoda, alt. 1,950-2,350 m. Flowering between October and November.
Notes.—*I. hubbardii* is characterized by its tuberculate-pilose leaves together with a lower glume that has 10–14 distinct nerves, and transverse hump on the lower 1/3 of the glume, which is glabrous on the back. It is similar to *I. indicum* (Houtt.) Merr. in having glabrous surface on the back of the lower glume of sessile spikelets but differs in having the unequal narrowly lateral wings above and hairs on both surfaces of the leaf-blades. The lower glume of the sessile spikelet in the Thai specimens has a transverse, nearly flat hump on the lower 1/3 of the glume whereas the hump is slightly convex on the back of the type specimen from India.


Perennial, rhizomatous. *Culms* slender, erect, up to 1 m tall, rooting at the lower nodes, internodes glabrous, terete, nodes pilose. *Leaf-sheaths* nearly tight, 5-11 cm long, glabrous but pilose or with tubercle-based hairs at margins especially near ligule or rarely pubescent on surface. *Ligules* membranous, 1–2 mm long. *Leaf-blades* 7–25 by 0.4–1.2 cm, pilose or pubescent on both surfaces, margins scabrous, base rounded, sometimes abruptly narrow. *Inflorescences* digitate, separating into 2 racemes or v-shaped, terminal, 4–9 cm long, rachis internodes oblong, pilose along the angles, nodes hirsute; callus 1.5–2 mm long, at base. *Sessile spikelet*; lower glume oblong, 4–6 mm long, many nerved, coriaceous, indurate and expanded below, upper foliaceous, bifid, distinctly 2-apical winged at the apex, sometimes lateral nerve prolonged form short caudate, glabrous on the back, margins folded; upper glume boat-shaped, 6–8 mm long, scabrous winged on keel, 5-nerved, midnerved prolonged form tail, glabrous on the back, sometimes pilose, margins folded, upper margins ciliate. *Lower floret*; lemma 4–5 mm long, hyaline, folded; paleas 4–5 mm long, plicate, margins ciliate. *Upper floret*; lemma folded, 4–4.5 mm long, hyaline, bifid, geniculately awned from sinus, awn twisted, 15–18 mm long, margins ciliate; palea lanceolate, 3.5–4 mm long, plicate, 2-nerved, hyaline. *Pedicelled spikelets* laterally compressed. *Pedicels* rachis internode like but shorter. *Glumes*; lower glume 4–6 mm long, folded, scabrous winged on keel, apex short caudate, glabrous on the back or pilose; upper glume boat-shaped, 4–6.5 mm long, short tail, margins long ciliate, pilose on the back, winged on keel. *Lower florets* and upper florets same as the sessile spikelet (Fig. 5.29C-E).

Distribution.— India to Japan, S to Malaysia, Australia.

Ecology.— Lawns, roadsides, open places, paddy fields or wet places up to 1,950 m altitude. Flowering between September and April.

Notes.— The extreme variations of hairiness and apical wings in lower glume of the sessile spikelet are certainly distinct; however, they are connected by a complete series of intermediates. It seems better not to divide this species into a
number of microspecies, but to wait until a monographic study of the whole genus should finally clear the difficulties.


Perennial. **Culms** slender, erect, up to 1 m tall, rooting at the lower nodes, internodes glabrous, terete, nodes ciliate. **Leaf-sheaths** nearly tight, 3.5–6 cm long, pilose with tubercle-based hairs. **Ligules** membranous, 1.5–2 mm long. **Leaf-blades** lanceolate, 5–14 by 0.7–1.2 cm, pilose with tubercle-based hairs on both surfaces, margins scabrous, base rounded. **Inflorescences** digitate, separating into 2 racemes or V-shaped, terminal, 3–7 cm long, rachis internodes oblong, pilose along the angles, nodes hirsute; callus 0.5–1 mm long, at base. **Sessile spikelet**; lower glume oblong, 4–4.5 mm long, coriaceous, indurate and expanded below, upper foliose, pilose on the upper back, margins folded, apex bifid, 2-obliquely narrowly lateral winged above, wing scabrous or sometime wingless; upper glume boat-shaped, 6–6.5 mm long, scabrous winged on keel, glabrous on the back, apex slightly caudate. **Lower floret**; lemma oblong, 5.5–6 mm long, hyaline, upper margins ciliate; palea 5–5.5 mm long, hyaline, margins folded and ciliate. **Upper floret** lemma 4.5–5 mm long, hyaline, margins ciliate, apex bifid, geniculately awned from sinus, awn twisted, 11–12 mm long; upper palea lanceolate, 4.5–5 mm long, hyaline. **Pedicelled spikelets** laterally compressed. **Pedicels** look-like rachis internode. **Glumes**; lower glume 4.5–5 mm long, margins folded, expanded at base, scabrous winged on keeled, apex acute, slightly pilose on the back; upper glume boat-shaped, 5.5–6.5 mm long, margins folded, slightly pilose on the above. **Lower florets** and upper florets same as sessile spikelet (Fig. 5.30A. & B).

**Thailand.**— NORTHERN: Chiang Mai [Doi Nang Ka, 4 Nov. 1930, Put 3356 (BK, BM, K)].

**Distribution.**— India to Burma.

**Ecology.**— Not recorded. Flowering in November.
Notes.—This species differs from *I. hubbardii* in having smooth lower glume of the sessile spikelet, while the lower glume of *I. hubbardii* coarsely ridge with nodules along the margins.

The original description cited the collection of *J.H. Lace* 5627 and *R.N. Parker* s.n.. Therefore, *J.H. Lace* 5627 kept at K is selected as the lectotype because it is the best preserved specimen.

7. *Ischaemum magnum* Rendle, J. Bot. 32. 102. 1894.—Type: Singapore, Blakan Mate, October 1892, *J.B. Feilding* s.n. (lectotype BM!, selected here, isolectotype K!).


Perennial, tufted. *Culms* erect, robust, up to 2 m tall, nodes and internodes glabrous. *Leaf-sheaths* loose, 11–14 cm long, glabrous. *Ligules* membranous *ca.* 1 mm long. *Leaf-blades* lanceolate-acute, 13–40 cm by 1.3–3 mm, glabrous on both surfaces, margins scabrous, base cordate. *Inflorescences* composed of racemes, digitate racemes, 2–4 racemes, 9–15 cm long, rachis internodes clavate, *ca.* 8.5 by 2 mm, glabrous, callus cupuliform, *ca.* 1 mm long, glabrous. *Sessile spikelet*; lower glume oblong on the lower part, upper part obliquely foliaceous 10–11 by *ca.* 2 mm, margins folded, glabrous on the back, acute at the apex, slightly winged along the upper margins, wing scabrous; upper glume boat-shaped, 9–10 by *ca.* 1.5 mm, scabrous along margins, keeled on the back, apex acute. *Lower floret*; lemma slightly boat-shaped, 8.5–9 mm long, hyaline, margins folded, scabrous along upper margins, apex acute; palea 8–8.5 mm long, hyaline, margins folded, scabrous along margins and apex. *Upper floret*; lemma *ca.* 7 by 0.8 mm, hyaline, slightly folded; palea boat-shaped, 9–9.5 by *ca.* 1.5 mm, hyaline, margins ciliate, acuminate. *Ovary* elliptic, *ca.* 2 mm long. *Pedicelled spikelet*; pedicels glume *ca.* 10 by 2.5 mm, with 2 subequal wings, longer wing along margins, margins scabrous, the smaller wing only on the apex, glabrous on the back; upper glume boat-shaped or lanceolate, 9–9.5 by 1.8 mm, keeled along the back, scabrous along keel, apex acute. *Lower floret*; lemma lanceolate, *ca.* 9 by 2 mm, hyaline, folded, glabrous; palea elliptic, *ca.* 8 by 1.2 mm, hyaline, folded, acute. *Upper floret*; lemma linear, *ca.* 6.5 by 0.5 mm, hyaline folded; palea linear-lanceolate, *ca.* 8.5 by 1 mm, hyaline, folded, acute (Fig. 5.30C-E).

Distribution.— Burma to Borneo.

Ecology.— Margin of rivers, canals and lakes, 0-280 m altitude. Flowering in September to May.

Notes.— *Ischaemum magnum* is similar to *I. barbatum*, but differs in having no awn while the distinctly awns in *I. barbatum*. For the type of *I. magnum*, the original description referred to the collection *J.B. Feilding* s.n. A duplicate deposited at BM is selected as the lectotype because it is the best preserved specimen.


Perennial. **Culms** stoloniferous, long-creeping, stolon internodes up to 10 cm, erect, glabrous. **Leaf-sheaths** loose, 2–3 mm long, glabrous to slightly pilose, ciliate along margins. **Ligules** membranous, ca. 1 mm long, pale brown. **Leaf-blades** linear to linear-lanceolate, 2.5–6 by 4–8 mm, glabrous above, strigillose along their margins, slightly cordate to rounded at the base, acuminate at the apex. **Inflorescences** racemes, terminal, exserted with two closely appressed racemes, 2.5–3.5 cm long. **Sessile spikelet**; lower glume ovate, 7–7.5 by ca. 3 mm, coriaceous, yellowish, glabrous, winged above the middle; upper glume boat-shaped or ovate, 7–8 by ca. 2.5 mm, keeled in the upper half, glabrous, fringed on the upper margins, apex acute. **Lower floret** staminate; lemma ovate-acute, 6–6.5 mm long, 3-nerved, hyaline, hairy above margins; palea 6–6.5 mm long, subcoriaceous, enfolded, 2-fringe keeled on both margins. **Anther** ca. 3 mm long, yellow. **Stigmas** whitish. **Upper floret** hermaphrodite;
lemma ovate, ca. 7 mm long, subcoriaceous, enfolded, bifid at the tip, awnless, fringe on marginal winged; palaec ca. 6 mm long, hyaline, margins narrowly inflexed in the upper part. Anthers ca. 3 mm long, yellow. Stigmas whitish. Pedicelled spikelet; pedicels ca. 5 mm long, similar in structure and pubescence to the rachis. Glumes; lower glume ovate-acute, ca. 6 mm long, subcoriaceous, enfolded, glabrous; upper glume ovate or boat-shaped, subchartaceous, asymmetrically, 1-fringe keeled on the upper part, enfolded, glabrous, apex acute. Lower floret staminate; lemma ca. 6 mm long, chartaceous, enfolded, glabrous 2-winged above; palea ovate-acute, 5.5–6 mm long, subchartaceous, enfolded. Anthers 2.5–3 mm long, yellow. Stigmas whitish. Upper floret hermaphrodite; lemma narrowly ovate-acute, ca. 6 mm long, hyaline, enfolded; palea linear, ca. 5 mm long, hyaline. Lodicules truncate. Anthers 2.5–3 mm long, yellow. Stigmas whitish (Fig. 5.31A. & B).


**Distribution.**— Worldwide.

**Ecology.**— Creeping grass, common along road to seashore, at sea level. Flowering throughout the year.

**Vernacular.**— Ya wai tham (ไวย่าทาม) (Trat).

**Notes.**— It is readily distinguished from the other species of *Ischaemum* by the short inflorescence with whitish stigmas sticking out laterally and awnless upper lemma.

9. **Ischaemum rugosum** Salisb., Icon. Stirp. Rar.: 1, t.1. 1791.— Type: India, Orissa, *Koenig* s.n. (holotype BM!, isotype K!).

Annual, tufted, caespitose. *Culms* usually erect somewhat prostrate, 30–120 cm tall, culm glabrous, ciliolate at node. *Leaf-sheaths* loose, 10–12 cm long, pilose hairs 1–1.5 mm long. *Ligules* membranous, 3–3.5 mm long, brownish. *Leaf-blades* lanceolate, 10–30 by 1–1.3 cm, lower blades narrowed gradually to the base, upper blades abruptly rounded, margins scabrous, surface pilose, base densely hairy, acuminate at the apex. *Inflorescences* racemes, terminal, 6–10 cm long, conjugate when young, and separating into 2 racemes when mature, rachis internodes 3.5–4.5 mm long, fragile, thickened upwards, long pilose on the central keel, nodes with a ring of long cilia, callus short, *ca.* 0.8 mm long, glabrous. *Sessile spikelet* oblong-ovate, 5 mm long. *Glumes*; lower glume oblong-ovate, 5–5.5 by 2–2.5 mm, indurated
and coarsely ridged with 4–7 ridges for the lower part, many nerved above and margins narrowly inflexed, keeled towards the asymmetric apex, 2-obliquely lateral winged at the apex, ciliolate rounded at the apex; upper glume narrowly ovate, 4.5–5 mm long, keeled along the back with a hump slightly above the middle, margins ciliolated on the upper part, apex acute. Lower floret; lemma elliptic, ca. 4.5 by 1 mm, hyaline slightly folded, margins scabrous, apex muticous; palea narrowly ovate, ca. 4.5 by 1 mm, hyaline, folded, margins ciliate, apex acute. Ovary elliptic, ca. 2 mm long. Upper floret; lemmas narrow, ca. 4 mm long, bifid, geniculately awned from sinus, awn twisted, 15–20 mm; palea ovate-acute, ca. 3.5 by 0.8 mm, hyaline, upper margins scabrous. Pedicelled spikelets; pedicels triangular, ca. 1.5 mm long, pilose along keel. Glumes; lower glume oblique-ovate, ca. 2–5 by 2 mm, indurate below, upper foliose and many nerved, subequal winged along margins, wings scabrous, 2–3 transverse nodule at each edge; upper glume boat-shaped, ca. 5 by 1 mm, keeled along the back, keel scabrous, lower margins entire, upper margins scabrous, apex acute. Lower floret; lemma lanceolate, ca. 4.5 by 1 mm, hyaline, folded, glabrous, apex acute; palea elliptic-acute, ca. 3.5 by 0.8 mm, hyaline, folded. Upper floret; lemma linear, ca. 3.5 by 0.5 mm, hyaline, slightly folded, awned from the apex, awn scabrous, ca. 4 mm long; palea elliptic-muticous, ca. 2 by 0.7 mm, hyaline, slightly folded. Caryopsis ellipsoid, ca. 2 mm long (Fig. 5.31C-E).


**Distribution.**—Worldwide.

**Ecology.**—Very common in paddy fields, roadsides, up to 1800 m altitude. Flowering in April to January.

**Vernacular.**—Ka dueai nu (ก้าดูไก่นุ), Ya kraduk kai (ก้าดูไก่) (Chai Nat);
Ya daeng (ก้าแดง), Ya nok si chomphu (ก้าไม่ซึ่งขอมพู) (Krung Thep Maha Nakhon); Ya phraek daeng (ก้าพร้ากแกม) (Ang Thong); Wrinkle duck-beat.

**Notes.**—*Ischaemum rugosum* is similar to *I. barbatum* in a number and shape of transverse ridge, but differs in having an indurate yellowish-green lower glume below, greenish on the upper, while brownish or reddish lower glume in *I. barbatum*. 

Perennial, tufted. **Culms** erect up to 1.5 m tall, terete, internodes glabrous, nodes glabrous. **Leaf-sheaths** tight, up to 15 cm long, glabrous. **Ligules** ciliate, ca. 1 mm long. **Leaf-blades** up to 50 cm by 0.3–0.5 mm, upper surface pruinose and slightly pilose, lower surface glabrous, margins scabrous and involute. **Inflorescences** digitate racemes, 3–7 racemes, 6–12 cm long, rachis internodes clavate, 3–3.5 by ca. 1 mm, pilose along the angles, nodes long ciliate, hairs up to 4 mm long. **Sessile spikelet**; lower glume lanceolate, 3.5–4.5 mm long, 2-nerved, subcoriaceous, scabrous on the upper nerve, concave along the length, margins folded and ciliate on the upper, apex bifid; upper glume lanceolate, plicate or narrowly boat-shaped, 8–9 mm long, subcoriaceous, keel along the back, prolonged from awned, pilose on upper keeled and upper margins. **Lower floret**; lemma ca. 3 mm long, hyaline, folded, upper margins ciliate; palea absent. **Upper floret**; lemmas ca. 4 mm long, bifid, twisted awn from sinus, 15–20 mm long; upper palea 2.5–3 mm long, hyaline, expanded at base, upper margins ciliate. **Pedicelled spikelet** dissimilar to the sessile spikelet. **Pedicels** clavate, 2.5–3 mm long, pilose along the angles. **Glumes**; lower glume lanceolate, 3–3.5 by ca. 1 mm, 2-nerved, subcoriaceous on each margin, scabrous; upper glume boat-shaped, 3–4.5 mm long, scabrous keel along the back, sometime prolonged from awn. **Lower floret**; lemma oblong, ca. 3 mm long, hyaline, sometime absent; palea absent. **Upper floret**; lemma hyaline, ca. 3 mm long, bifid, twisted awn from sinus, 10–12.5 mm long; palea ca. 2.5 mm long, expanded at base.


**Distribution.**—Indo-China.

**Ecology.**—Secondary grasslands or in dipterocarp forests, Dense tussock, up to 130 m altitude. Flowering in October to December.
Notes.— *I. tenuifolium* is distinct with a pruinose on the upper surface of lamina. This species proved that indeed it belongs in *Andropogon*. So, I place *I. tenuifolium* under *Andropogon*, not *Ischaemum*.


Annual, rhizomatous, long creeping. *Culms* erect, 20–45 cm tall, rooting from the lower nodes, nodes slightly to densely long ciliate, internodes glabrous. *Leaf-sheaths* tight, 3–7 cm long, glabrous or sometimes pilose on both margins. *Ligules* ciliate or membranous with ciliate margins, 1–1.3 mm long. *Leaf-blades* lanceolate, 2–9 by 0.5–1.2 cm, pilose on both surfaces, margins scabrous, acute at the apex. *Inflorescences* racemes on terminal, 2.5–6 cm long, separating into 2 racemes, rachis internodes triangular, 2.5–3 mm long, hairy along the angles, nodes long ciliate, hairs up to 2 mm long, callus 0.3–1 mm long. *Sessile spikelet*; lower glume ovate-bifid, like boat-shaped, foliar, 3–4 mm long, 6–8-nerved folded, outer nerves prolonged form 2 points, wingless, glabrous on the back or pilose on the upper part or scabrous along nerves, margins scabrous; upper glume boat-shaped, 4.5–7 mm long, 5–6-nerved, apex with a long scabrous tail which prolonged from the mid nervet, tail 1–3 mm long, wing on the upper back, upper margins ciliate, lower glabrous. Lower floret; lemma *ca.* 3 mm long, 2-nerved and scabrous along nerve, margins plicate and ciliate; palea *ca.* 3 mm long, 1-nerved, hyaline, folded, ciliate along margins, thinner than lemmas. *Upper floret*; lemmas 2–2.5 mm long, hyaline, apex bifid, geniculately awned from sinus, awn twisted, 12–15 mm, margins ciliate, folded; palea lanceolate, 3–3.5 mm long, hyaline, slightly folded, upper margins ciliate. *Lodicules* cuneate. *Anthers* *ca.* 1.5 mm long. *Pedicelled spikelets*; pedicels triangular shaped, 1.5–3 mm long, hairy along the angles. *Glumes*; lower glume boat-shaped, 3–4 mm long, slightly winged on keel, midnerved prolonged into long tail, scabrous along nerved, sometime pilose on the back, upper margins ciliate; upper glume boat-shaped, 4–4.5 mm long, scabrous along mid-nerve and pilose on the upper back, upper margins ciliate, apex
with long tail. Lower floret; lemma 2.5–3 mm long, 2–nerved, scabrous along nerve, margins ciliate; palea 2.5–3.5 mm long, 1-nerved, hyaline, slightly folded, upper margins ciliate. Upper floret; lemma boat-shaped, ca. 2 mm long, hyaline, bised, geniculately awned from sinus, awn twisted, 8–10 mm long; palea ca. 2.5 mm long, hyaline, slightly folded, upper margins ciliate. Anthers, ca. 2 mm long, yellow. Stigmas purplish. Caryopsis ellipsoid, ca. 1-1.2 mm long (Fig. 5.32A-C).


Distribution.—Africa, China, India, Indo-China, Malesia, South America, Northern South America, and western South America.

Ecology.—Very common along roadsides, near stream in savannah, weed in partly shaded area or in evergreen forest up to 1,500 m altitude. Flowering in November to March.

Notes.—Ischaemum timorense differs from I. indicum in normally having the lower glume wingless whereas the distinct wing in I. indicum, however intermediates wing do occur in some specimens.
Two collections, *H.N. Ridley* 10013 and *Hullett* s.n. were mentioned in the original description. *H.N. Ridley* 10013 kept at K is chosen as the lectotype because it is well preserved.

12. *Ischaemum* sp.1

Annual, tufted, caespitose. *Culms* erect, sometime prostrate, slender, terete, 25–45 cm tall, internodes and nodes glabrous. *Leaf-sheaths* loose, 3–5 cm long; glabrous, margins thin. *Ligules* long membranous, 2–2.5 mm long, glabrous. *Leaf-blades* 4.5–8.5 by 0.5–0.8 cm, pubescent on both surfaces, recurved, margins folded, base tapering, acute at the apex. *Inflorescences* racemes, terminal, 5–6 cm long, conjugate with 2 racemes, rachis internodes triangular, 3.5–4 mm long, pilose along keel, nodes with a ring of cilia, callus *ca.* 1.5 mm long. *Sessile spikelet*; lower glume oblong, 6.5–7 by 1.5–2 mm, pilose on the back, margins nearly smooth or with one marginal nodule at each edge, apex bifid with 2 subequal apical wings, wings scabrous; upper glume boat-shaped, 7–7.5 by *ca.* 1 mm, keeled along the back, wing on the upper keel, wing scabrous, margins ciliate. *Lower floret*; lemma lanceolate, 5.5–6 by *ca.* 1 mm, hyaline, slightly folded, upper margins ciliate, apex muticous; palea elliptic, *ca.* 5 by 0.8–1 mm, hyaline, slightly folded, upper margins ciliate, apex muticous. *Lodicules* cuneate, *ca.* 0.8 mm long. *Anthers* *ca.* 2 mm long. *Upper floret*; lemmas 4–5 mm long, hyaline, folded, apex bifid with geniculately awned from sinus, awn twisted, 18–20 mm long, upper margins ciliate; palea oblong-muticous, *ca.* 4 by 0.8 mm, hyaline. *Lodicules* cuneate, *ca.* 1 mm long. *Anthers* *ca.* 2 mm long. *Pedicelled spikelets*; pedicels clavate, 4–4.5 mm long, pilose along keel. *Glumes*; lower glume oblong-ovate, *ca.* 6 by 1.5 mm, with 2 subequal wings along margins, wing scabrous, pilose on the back, margins folded, apex bifid; upper glume boat-shaped, *ca.* 6.5 by 1 mm, pilose on the back, margins ciliate. *Lower floret*; lemma lanceolate-acute, *ca.* 5 by 1 mm, hyaline, slightly folded, upper margins ciliate; palea oblong-muticous, *ca.* 3 by 0.7 mm, hyaline. *Upper floret*; lemma *ca.* 4 by 1 mm, hyaline, slightly folded; palea *ca.* 3 by 0.5 mm, hyaline. *Anthers* *ca.* 2 mm long (Figs. 5.3 & 5.32D. & E).

Distribution.—Endemic to Thailand.

Ecology.—Growing on an open ground in evergreen forest on high mountain up to 1,450 m altitude. Flowering in December to March.

Notes.—*Ischaemum* sp.1 resembles to *I. barbatum* in the lower glume of the sessile spikelet. However, the latter is easily distinguished by its coarsely ridge more than one across the back or with 2 or more nodules along the margins. *I. sp.1* has pubescent on both surfaces of the leaf, margins recurved or folded, while *I. barbatum* flattened leaf-blade, which glabrous to pilose on both surfaces.

13. *Ischaemum* sp.2

Perennial, tufted. *Culms* erect, terete, up to 1 m tall, nodes with long ciliate, internodes glabrous. *Leaf-sheaths* nearly tight, 5.5–10 cm long, glabrous below, upper pilose with tubercle-based hairs especially near the junction of leaf-blades and leaf-sheaths. *Ligules* prominently membranous 1.5–2 mm long. *Leaf-blades* 8–25 by 0.6–0.8 cm, glabrous on both surface, pilose with tubercle-based hairs below, margins scabrous, sometimes with tubercle-based hairs below, acute at the apex. *Inflorescences* racemes, V-shaped, terminal, 7.5–10 cm long, separating into 2–3 racemes, rachis internodes oblong, *ca.* 3 mm long, pilose along the angles, nodes hirsute, callus *ca.* 1 mm long. *Sessile spikelet*; lower glume oblong, 5–6.5 mm long, 4–6-nerved, expanded and indurate, upper foliaceous, hirsute on the back, apex bifid with 2-apical wing, wings scabrous, marginals nerves prolonged form 2 long tail at the apex; upper glume boat-shaped, 8–9 mm long, subcoriaceous, scabrous winged on keel, keeled prolonged from long tail, pilose on the upper back, upper margins ciliate. *Lower floret*; lemma, *ca.* 5 mm long, 1-nerved, chartaceous, upper margins ciliate; palea *ca.* 5 mm long, 2-nerved and plicate on each margins, upper margins ciliate. *Anthers* yellow, *ca.* 2.5 mm long. *Upper floret*; lemmas boat-shaped, *ca.* 5 mm long, hyaline, apex bifid with geniculately awned from sinus, awn twisted, 18–20 mm long, upper margins ciliate; palea narrow, *ca.* 5 mm long, hyaline. *Pedicelled spikelets*; pedicels clavate, *ca.* 3 mm long, pilose along the angles. *Glumes*; lower glume folded, 7–8 mm long, scabrous wing along keel, awn from mid-nerve, hirsute on the back; upper glume folded, narrower than the lower glume, 7–8 mm long, scabrous winged on keel, awn from mid-nerved, hirsute on the back, ciliate along margins. *Lower floret*; lemma folded, 3.5–4.5 mm long, 1-nerved, chartaceous, upper margins ciliate;
palea 3.5–4.5 mm long, 2-nerved and plicate on each margins, upper margins ciliate. Anthers yellow, 1.8–2.5 mm long. Upper floret; lemma boat-shaped, 4.5–5 mm long, upper margins ciliate, bifid, geniculatey awned from sinus, awn twisted, 15–18 mm long; palea narrowly lanceolate, 3.5–4.2 mm long, hyaline (Fig. 5.4).


Distribution.— Endemic to Thailand.

Ecology.— Savannah or in wet places up to 600 m altitude. Flowering in November to March.

Notes.— This species resembles to I.lacei, but it is distinguished by its glabrous leaf blade, while pilose with tubercle-based hairs on both surfaces of the leaf in I. lacei.
Figure 5.2 *Ischaemum hubbardii*: A. plant; B. spikelet pair; C-H. sessile spikelet: C. lower glume, D. upper glume, E. lower lemma, F. lower palea, G. upper lemma, H. upper palea; I-N pedicelled spikelet: I. lower glume, J. upper glume, K. lower lemma, L. lower palea, M. upper lemma, N. upper palea. All line drawings were drawn by P. Traiperm from *P. Traiperm* 308.
**Figure 5.3** *Ischaemum* sp.1: A. plant; B. spikelet pair; C-E. sessile spikelet: C. & D. lower glume (two views), E. upper glume; F. lower glume of pedicelled spikelet. All line drawings were drawn by P. Traiperm from *P. Traiperm* 327.
Figure 5.4 *Ischaemum* sp.2: A. habit; B-D. sessile spikelet: B. & C. two views of the lower glume, D. upper glume, E. upper glume of pedicelled spikelet. All line drawings were drawn by P. Traiperm from *P. Traiperm* 149.
3. KERROCHLOA

C.E. Hubbard in Hook., Jc. Pl. 35: t. 3494. 1951.—Type species: *K. siamensis* C.E. Hubbard.


A genus of one species only in Thailand and Vietnam.


Perennial, stoloniferous. *Culms* decumbent, 30–50 cm long, subterete, glabrous. *Leaf-sheath* loose, 2.5–4 cm long, glabrous or slightly villous, margins ciliate. *Ligules* membranous, *ca.* 1.5–2 mm long. *Leaf-blades* lanceolate, 2.5–8 by 0.7–1.3 cm, chartaceous, glabrous on both surfaces, margins scabrous or slightly pilose hairs, base cordate, apex acute. *Inflorescence* a single raceme, 5–8 cm long, subtended by a linear spatheole which enclosed; rachis fragile at the nodes, flattened, rachis internodes cuneate, *ca.* 4 mm long, margins villous; spikelets in pairs. *Sessile spikelets* laterally compressed. *Glumes*; lower glume lanceolate and boat-shaped, 6–6.5 by *ca.* 1.5 mm, 5–nerved, chartaceous, keel on 1/3 on the upper part of the back, villous on the lower half part; upper glume ovate, complicate, *ca.* 6 by 2.5 mm, 3-nerved, chartaceous, bifid at the apex and awned from sinus, awn 8–9 mm long, margins of the upper glume, ciliate 1-keeled on the back, keel scabrous. *Lower floret*
sterile; lemma ob lanceolate, _ca._ 6 by 0.8 mm, 3-nerved, membranous, upper margins ciliate; palea lanceolate, _ca._ 5 by 0.7 mm, membranous, 2-nerved, apex acute, upper margins ciliate. **Ovary** cylindrical, 1 mm long. **Upper florets** fertile; lemma oblong, _ca._ 3.5 mm long, 3-nerved, hyaline, margins ciliate, hairy above, apex bifid, incised, 0.4 of lemma length, awn from sinus, geniculate, 28–35 mm long; with twisted column; palea lanceolate, _ca._ 3 mm long, 3-nerved, hyaline. **Lodicules** cuneate, _ca._ 0.5 mm long. **Anthers** 3, yellow, 3–4 mm long. **Pedicelled spikelet** sterile, smaller than sessile spikelet; composed of only one glume, lanceolate, _ca._ 2 mm long, villous. **Pedicels** ob lanceolate, villous on both margins, apex curved. **Caryopsis** elliptic, _ca._ 1.5 mm long (Figs. 5.5 & 5.33A. & B).


**Distribution.**— Vietnam.

**Ecology.**— Creeping over the rocks or in open sandy soil, at 140-600 m altitude. Flowering between October and December.

**Notes.**— _Kerriochloa siamensis_ is easily recognized by a laterally compressed sessile spikelets and a linear spatheole, which are enclosed the inflorescence.
Figure 5.5 *Kerriochloa siamensis*: A. plant; B. inflorescence; C. spikelet pair; D-F. sessile spikelet: D. sessile spikelet, E. lower glume, F. upper glume; G. pedicelled spikelet. All line drawings were drawn by P. Traiperm from *P. Traiperm* 235.
4. SEHIMA

Forssk., Fl. Aegypt.-Arab.: 178. 1775.— Type species: *S. ischaemodies* Forssk.


Perennial. _Culms_ erect. _Leaf-sheaths_ tight. _Ligules_ membranous with cilia. _Leaf-blades_ linear, scabrous, apex long acuminate. _Inflorescence_ solitary raceme, terminal and axillary. _Spikelet_ in pairs. _Sessile spikelets_ dorsally compressed, fitting between internode and pedicel. _Glumes_; lower glume chartaceous with deeply grooved, particularly below the middle; upper glume boat-shaped, subchartaceous, keeled, ciliate along the upper margins at the apex and passing into a fine bristle. _Lower floret_ neutral, lemma oblong-lanceolate or boat-shaped, awnless; palea linear, awnless. _Upper floret_ perfect; lemma apex bifid with geniculate awn from sinus; palea oblong, awnless. _Pedicelled spikelet_ lanceolate, larger than the sessile spikelet, dorsally compressed. _Pedicels_ same as the rachis. _Glumes_; lower glume lanceolate, distinctly 5-nerved, coriaceous, outer green, inner purple; upper glume boat-shaped or lanceolate, 3-nerved, membranous. _Lodicules_ conical. _Stamens_ brown. _Ovary_ obovate. _Stigmas_ brownish-yellow. _Caryopsis_ dorsally compressed.

A genus of 5 species in the Old World tropics: one species occurs in Thailand.

*S. sulcatum* (Hass.) A.Camus has been reported from Thailand (Nanakorn & Norsaengsri 2001) but no herbarium specimen is available for confirmation.


_Andropogon nervosus_ Rottler in Ges. Naturf. Fr. N.S. 4: 218. 1803.— Type: India, Rottler s.n. (holotype K!).

_Ischaemum laxum_ R. Br.: Prodr. 205. 1810.— Type: Australia, _R. Brown_ 6155 (holotype K!, isotypes BM!, E!).


Perennial. _Culms_ erect, 30–150 cm long, slender, terete, glabrous. _Leaf-sheaths_ tight, 6–15 mm long, terete, glabrous or slightly hirsute. _Ligules_ membranous, ciliate, ca. 1 mm long. _Leaf-blades_ linear, 20–45 cm by 4–6 mm, scabrous, margins
with short rigid hairs, apex long acuminate. *Inflorescence* solitary racemes, long erect or slightly curved, terminal and axillary, 8–12 cm long; joints and pedicels parallel, compressed, 4–5 mm long, densely ciliate with white hairs on both margins and joints. *Sessile spikelets* dorsally compressed, 8–9 mm long, pale green. *Glumes*; lower glume oblong, 8–9 by 1 mm, 4-nerved, chartaceous, deeply grooved, particularly below the middle, distally with transverse veinlets, apex bidentate; upper glume boat-shaped, 6–15 mm long, subchartaceous, keeled, ciliate along the upper margins at the apex and passing into a fine bristle. *Lower floret* neutral, lemma oblong-lanceolate or boat-shaped, 3–6.5 by 0.8 mm, 2-nerved, hyaline, margins entire; palea linear, 6–7 by 0.8 mm, hyaline. *Upper floret* perfect; lemma, 4–7 mm long; bifid, geniculately awned from sinus, awn 2.5–4 cm long, slender, spirally twisted; palea oblong, 6–6.5 by 0.8 mm, hyaline. *Lodicules* conical, 4–5 mm long. *Anthers* brown, ca. 2–3.5 mm long. *Ovary* obovate, 1–2 mm long. *Stigma* brownish-yellow. *Pedicelled spikelet* lanceolate, larger than the sessile spikelet, dorsally compressed; rachis triangular, 4–5 mm long, compressed, white marginal hairs along the angles. *Pedicels* same as the rachis. *Glumes*; lower glume lanceolate, 8–11 mm long, 5-nerved, coriaceous, outer green, inner purple, apex bifid, long-ciliate from the the tightly inflexed margins; upper glume boat-shaped or lanceolate, 5–9 by 1.2–1.5 mm, 3-nerved, membranous, ciliate along the margins. *Lower floret*; lemma lanceolate, 7–7.5 by 1 mm, hyaline, margins folded and ciliate; palea oblong-lanceolate, 6–7 by 0.8 mm, hyaline. *Upper floret*; lemma narrowly lanceolate, 7–8 by 1 mm, hyaline, margins folded and ciliate; upper palea narrowly lanceolate, 6.5–7 by 0.8 mm, hyaline, margins folded. *Caryopsis* dorsally compressed (Figs. 5.6 & 5.33C-E).


**Distribution.**— India to tropical Australia.

**Ecology.**— Open, dry dipterocarp forest, at sea level to 950 m altitude. Flowering between September and April.

**Notes.**— *Sehima nervosum* is distinguished by its pedicelled spikelet, which is larger than the sessile spikelet.
Figure 5.6 *Sehima nervosum*: A. plant; B. spikelet pair; C-D. sessile spikelet: C. lower glume, D. upper glume; E-G pedicelled spikelet: E. pedicelled spikelet with pedicel, F. lower glume, G. upper glume. All line drawings were drawn by P. Traiperm from *P. Traiperm* 300.
5. THELEPOGON

Roem. & Schult., Syst. Veg. 2: 46. 788. 1817.—Type species: *T. elegans* Roem. & Schult.


A genus of 1 species in the tropical Africa, extending eastwards to Asia and occurs in Thailand. The genus is distinguished from *Ischaemum* mainly by the barren pedicel.

1. **Thele pogon elegans** Roem. & Schult., Syst. Veg. 2: 46. 788. 1817.—Type: India, *Heyne* (B), not seen.

Annuals, rhizomatous. *Culms* erect, 80–150 cm tall, somewhat stout, terete, glabrous, rooting at base. *Leaf-sheaths* loose, 3–7 cm long, hirsute with tubercle-based hairs and ciliate along outer margins. *Ligules* membranous with ciliate margins, 1–1.5 mm long. *Leaf-blades* lanceolate to linear-lanceolate, 10–25 by 1.5–2.5 cm, hispid on adaxial surface and glabrous or slightly hispid on abaxial surface, margins undulate and scabrous, base round, apex acute. *Inflorescence* digitate racemes, composed of 2–4 racemes, if many the lowest verticillate, simple or divided, rachis fragile at nodes, nodes with a ring of cilia, rachis internodes cuneate, slightly curved, angular and scabrid along the rib, 7.5–8.5 mm long, rachis internodes tip transverse,
cupuliform; spikelet in pairs, composed of fertile sessile spikelets and sterile pedicelled spikelets. **Sessile spikelet** dorsally compressed, ovate, 6–7 mm long. **Glumes**; lower glume ovate-acute, 5–5.5 mm long, 7-nerved, coriaceous, indurate on margins, rugose on the back; upper glume narrowly ovate, *ca.* 7 mm long, 1-nerved, subcoriaceous, keeled and scabrid, 6–8 transverse ridges on the middle back, ciliate along margins long acuminate at the apex. **Lower floret** sterile; lemma ovate, *ca.* 4.2 mm long, hyaline, enfolded, ciliate along the upper part of both margins; palea narrower than lemma, *ca.* 4.2 mm long, hyaline. **Upper floret** fertile; lemma ovate or boat-shaped, *ca.* 4 mm long, 5-nerved, hyaline, ciliate along the upper part of the margins, bifid in a half length, geniculate awn from a sinus, 20–30 mm long with a twisted column, scabrous on whole length; palea ovate-muticus, *ca.* 3.8 mm long, 3-nerved, hyaline. **Lodicules** cuneate, *ca.* 0.5 mm long. **Anthers** *ca.* 2.5 mm long, yellow. **Stigmas** purple. **Caryopsis** elliptic, *ca.* 3 mm long. **Pedicelled spikelet** absent (Figs. 5.7 & 5.33F-1).


**Distribution.**— Tropical Africa and Asia.

**Ecology.**— Mostly erect grass, growing in a weedy places on roadsides, deciduous forest, or in open area, at 50-300 m altitude. Flowering between October and December.

**Notes.**— *Thelepodon elegans* is easily recognised by a special lower glume of the sessile spikelet, which are strongly rugose. A hispid leaf-blades on adaxial surface and glabrous or slightly hispid on abaxial surface, margins undulate and scabrous.
Figure 5.7 *Thelepodon elegans*: A. plant; B. partial raceme; C. spikelet pair; D. lower glume of sessile spikelet; E. upper glume of sessile spikelet. All line drawings were drawn by P. Traiperm from *P. Traiperm* 276.
B. ROTTBELLIINAE


Inflorescence of single or digitate racemes, terminal, axillary or spathate; racemes fragile, though and rarely tough, the internodes thickened or swollen. Spikelets paired, rarely in three, usually dissimilar. Sessile spikelet bisexual, dorsally compressed; lower glume herbaceous to crustaceous, convex, often sculptured, mostly 2-keeled; lower floret male or barren; upper lemma narrowly ovate, entire, awnless. Pedicelled spikelet variable, the pedicel sometimes fused to the internode.

About 21 genera (Clayton & Renvoize, 1986) distributed in the tropics of both hemispheres, but mainly occur in Asia and Australia, 8 genera (Keng, 1933), 32 species and 1 infraspecific taxa in Thailand.

KEY TO THE GENERA

1. Racemes several
1. Racemes single, paired or digitate
       2. Pedicels partly or wholly fused to the internodes
          3. Sessile spikelet globose
          3. Sessile spikelet columnar
             4. Pedicelled spikelet present
                5. Rachis of raceme tough
                5. Rachis of raceme fragile
                   4. Pedicelled spikelet absent
                      6. Raceme dorsiventral, spikelets all on the same side
                         6. Raceme symmetrical, spikelets arranged in two opposite rows
                            2. Hackelochloa
       2. Hackelochloa
          3. Hemarthria
          7. Rottboellia
       4. Mnesithea
       5. Ophiuros
       6. Phacelurus
       1. Eremochloa
       8. Vossia
       4. Mnesithea
2. Pedicels free to the internodes
    7. Lower glume of sessile spikelet produced into a long flattened tail
       8. Pedicelled spikelet present
          8. Pedicelled spikelet absent
             4. Mnesithea
             1. Eremochloa
1. EREMOCHLOA

Buse in Miq., Pl. Jungh. 1: 357. 1854.— Type species: *E. horneri* Buse [= *E. ciliaris* (L.) Merr.].

Type species: *I. ophiuroides* Munro [= *Eremochloa ophiuroides* (Munro) Hack.].

*Sehima* auct. non Forssk.

Perennial. **Inflorescence** a single terminal, strongly flattened; internodes clavate. **Sessile spikelet**; lower glume chartaceous to coriaceous, the keels pectinately spinose, sometimes winged at tip; lower florets male, with palea. **Pedicelled spikelet** absent or represented by a bristle; **pedicel** free, narrowly foliaceous.

A genus of 11 species from India, Sri Lanka, S China, Indochina, Australia. Distinguished from *Mnesithea* mainly by pectinately spinose at the lower glume of the sessile spikelets.

**KEY TO THE SPECIES**

1. Lower glume apex with apical wings

2. Pedicel less than 1.5 times as long as the sessile spikelet

3. Lower glume setae hook-like, longest ones ca. 0.5 mm long, shorter than the width of the lower glume  
   **9. E. petelotii**

3. Lower glume setae straight, longest ones 1.5–1.6 mm long, as long as the width of the lower glume  
   **11. E. sp.2**

2. Pedicel more than or equal 1.5 times as long as the sessile spikelet

4. Lower glume apex with a small apical wings, 0.1–0.3 length of the lower glume

5. Pedicel subulate or oblique-lanceolate

6. Pedicel subulate, lower glume setae straight, longest ones 1.5–2.0 mm long, equal or shorter than the width of the lower glume  
   **1. E. attenuata**

6. Pedicel oblique-lanceolate, lower glume setae straight, longest ones 2.5–3.0 mm long, much longer than the width of the lower glume  
   **7. E. maxwellii**

5. Pedicel oblique-ovovate or obovate, usually with short or long cordate at apex
7. Pedicel oblique-ovate with short cordate at apex, foliose, 4–4.5 mm long, 0.75–0.85 times as long as the sessile spikelet  
2. E. bimaculata

7. Pedicel obovate with long cordate at apex, 4.5–6 mm long, 0.9–1.2 times as long as the sessile spikelet  
10. E. sp.1

4. Lower glume apex with a large apical wings, more than or equal 0.4 length of the lower glume  
8. E. muricata

1. Lower glume apex without apical wing

8. Pedicel more than 1 times as long as the sessile spikelet

9. Lower glume setae flattened, cataphylls woolly hairy  
5. E. eriopoda

9. Lower glume setae terete, cataphylls glabrous

6. E. lanceolata

8. Pedicel less than 1 times as long as the sessile spikelet

4. E. ciliatifolia

10. Pedicel obovate at apex  

3. E. ciliaris

10. Pedicel subulate without long cordate at apex

1. Eremochloa attenuata Stapf ex Buitenhuiss, Blumea 46 (2): 404. 2001.—Type: Thailand, Phu Kradueng, A.F.G. Kerr 8686 (holotype BM!, isotypes K! & P!).

Perennial grass, tufted, cataphylls slightly appressed hairs. Culms erect, 35–50 cm tall, extravaginal branching at base, internodes with densely pilose hairs, nodes slightly hairs. Leaf-sheaths nearly tight, 4–8 cm long, densely white hairy. Ligules membranous with ciliate margins, 0.3–0.5 mm long. Leaf-blades flat to slightly folded, 8–20 cm by 2–2.5 mm, woolly hairs on both surfaces, acute at apex. Inflorescence racemes, solitary, straight, 4–6 cm long, rachis internodes clavate, 3–3.5 mm long, ca. 0.75–0.9 length of sessile spikelets, sparsely hairy, joints at base with ciliate hairs. Sessile spikelets; lower glume ovate, 4–5 by 1.8–2 mm, distinctly 9–10-nerved, glabrous to sparsely hairy on the back, setae straight, terete, longest ones 1.5–2 mm long, equal or shorter than the width of the lower glume, apex with a small apical wings, 0.2–0.3 length of the lower glume; upper glume oblong, 4–4.5 by ca. 1 mm, 3-nerved, keeled in the middle in the lower half and along the margins, distally with transverse veinlets, sparsely hairy on the lower part of the back, margins folded. Lower floret; lemma oblong, ca. 4 by 1 mm, hyaline, margins folded; palea oblong, ca. 3 by 0.8 mm, hyaline. Upper floret; lemma oblong, ca. 3.2 by 0.8 mm, hyaline, margins folded; palea oblong, ca. 3 by 0.5 mm, hyaline. Lodicules cuneate ca. 0.5 mm long. Anthers brown, ca. 2.5 mm long. Ovary elliptic, ca. 1 mm long. Stigmas
purplish. *Pedicelled spikelet* absent. *Pedicels* subulate, 3–3.5 mm long, 0.6–0.7 times as long as the sessile spikelet (Figs. 5.8A-E & 5.34A-C).


**Distribution.**— Endemic to Thailand.

**Ecology.**— Dry dipterocarp forest, at 450-1800 m altitude. Flowering in November to May.


Perennial grass, tufted, slender rhizomatous, cataphylls glabrous. *Culms* erect, 20–60 cm tall, extravaginal branching at base, internodes glabrous, nodes glabrous. *Leaf-sheaths* loose, 3.5–7 cm long, glabrous. *Ligules* an ecilate membrane, *ca*. 0.5 mm long. *Leaf-blades* flat, 4–12 by 0.2–0.4 mm, glabrous on both surfaces, acute at apex. *Inflorescence* racemes, 1–3 together, straight, 5–8 cm long, rachis internodes clavate, 2–2.5 mm long, 0.45–0.5 length of sessile spikelets, glabrous, joints at base glabrous to slightly with a ring short ciliate hairs. *Sessile spikelets*; lower glume oblong, 4.5–5 by 2 mm, distinctly 5–7-nerved, glabrous on the back, setae straight, terete, longest ones 1.5 mm long, shorter than the width of the lower glume, apex with moderately green apical wings, 0.2–0.3 length of the lower glume; upper glume oblong, *ca*. 4.5 by 1.5 mm, 3-nerved, keeled in the middle in the lower half and along the margins, distally with transverse veinlets, glabrous on the lower part of the back,
margins folded. Lower floret; lemma oblong, ca. 4 by 1 mm long, hyaline, margins folded, ciliate along the upper margins; palea oblong, ca. 2.5 by 1 mm, hyaline. Upper floret; lemma oblong, ca. 3 by 0.8 mm, hyaline; palea oblong, smaller than the lemma, hyaline. Lodicules cuneate ca. 0.5 mm long. Anthers brown, ca. 1.5 mm long. Ovary elliptic, ca. 1.5 mm long. Stigmas purplish. Pedicelled spikelet absent. Pedicels oblique-obovate with short cordate at the apex, foliose, 4–4.5 mm long, 0.75–0.85 times as long as the sessile spikelet (Figs. 5.8F-J & 5.34D-F).


Distribution.— Burma, Thailand, Cambodia, Vietnam, China, Malesia and Australia.

Ecology.— Grass common in dry dipterocarb forest, at altitude 50-650 m. Flowering in May to September.

Vernacular.— Ya hang nok yung (เนียงนกยูง) (Si Sa Ket).

Notes.— Eremochloa bimaculata is usually misidentified as E. mawellii, but it is different from the latter species in having an oblique-obovate pedicels with short cordate at the apex, while oblique-lanceolate pedicels in E. maxwellii.


Nardus ciliaris L., Sp. Pl.: 53. 1753. — Type: Herb. Linn. 73.7 (lectotype LINN!).

E. horneri Buse in Miq., Pl. Jungh. 3: 357. 1854.— Type: Horner 137 (holotype !, phototype BRI, K!).
E. leerssioides (Munro) Hack. in DC., Monogr. Phan. 6: 264. 1889.—Type: C. Wright s.n. (holotype K!, isotype P†).

E. falcata Hack. in DC., Monogr. Phan. 6: 263. 1889.—Type: Meyen s.n. (holotype B†).

E. malayana Ridl., Mat. Fl. Malay Penins. 3: 155. 1907.—Type: Ridley 5154 (holotype SING, isotypes BM!, K†).


Perennial grass, tufted, rhizomatous, cataphylls glabrous to pilose. Culms erect, 25–45 cm tall, extravaginal branching at base, internodes glabrous to pilose, nodes glabrous to slightly pilose. Leaf-sheaths loose, 2–10 cm long, glabrous, margins thin. Ligules membranous, 0.4–1 mm long. Leaf-blades flat to slightly folded, 3–15 cm by 2.5–8 mm, glabrous to sparsely hairy on both surfaces, margins thick and scabrous, acute at apex. Inflorescence racemes, 1–3 together, falcate, 1–5 cm long, rachis internodes clavate, 1.8–2.5 mm long, 0.5–0.6 length of sessile spikelets, pilose, joints at base with short ciliate hairs. Sessile spikelets; lower glume ovate, 4–4.5 by 1.8–2 mm, obscurely 4–7-nerved, glabrous to densely hairy on the back, setae straight, flattened, longest ones 3–3.5 mm long, much longer than of the width of the lower glume, apex wingless; upper glume oblong to elliptic, 3.8–4.2 by ca. 1 mm, 3-nerved, keeled in the middle in the lower half and along the margins, distally with transverse veinlets, slightly appressed hairs on the lower part of the back, margins folded. Lower floret; lemma elliptic, ca. 3 by 0.8 mm, margins folded, hyaline; palea oblong, ca. 2.8 by 0.8 mm, hyaline. Upper floret; lemma oblong, ca. 2.8 by 0.8 mm, hyaline; palea oblong, ca. 2.5 by 0.5 mm, hyaline. Lodicules cuneate ca. 0.5 mm long.
Anthers brown, ca. 2–2.5 mm long. Ovary ovoid, ca. 1.5 mm long. Stigma purplish. Pedicelled spikelet absent. Pedicels subulate, ca. 2-3 mm long, 0.5–0.75 times as long as the sessile spikelet, glabrous to slightly pilose (Figs. 5.8K-N & 5.35A-D).


**Distribution.**— Burma, Laos, Vietnam, China, Taiwan, Singapore, Malesia and Australia.

**Ecology.**— In deciduous, dipterocarp or pine forest, up to 2,200 m altitude. Flowering throughout the year.

**Notes.**— This species has a wide variability in the lower gume of the sessile spikelet.

Annuals grass, tufted, cataphylls with appressed hairs but woolly at base. *Culms* erect, 30–70 cm tall, extravaginal branching at base, internodes pilose, nodes with long ciliate hairs. *Leaf-sheaths* loose, 4–12 cm long, with slightly pilose hairs to densely pilose hairs. *Ligules* membranous with ciliate margins, *ca.* 0.35–0.4 mm long. *Leaf-blades* flat to slightly folded, 5–25 cm by 2–5 mm, obtuse to acute at apex, glabrous to densely hairs on both surfaces, margins pilose. *Inflorescence* racemes, 1–3 together, straight, 3–7 cm long, rachis internodes clavate, *ca.* 2 mm long, 0.4–0.45 length of sessile spikelets, scabrous, joints at base with long ciliate hairs. *Sessile spikelets*; lower glume oblong-ovate, 4–4.7 by *ca.* 2 mm, distinctly 6–9-nerved, with appressed hairs on the back, setae straight, terete, longest ones 3.2–3.5 mm long, much longer than of the width of the lower glume, apex wingless; upper glume elliptic, 4.2–4.5 by 1.2–1.4 mm, 3-nerved, keeled in the middle in the lower half and along the margins, with distally transverse veinlets, appressed hairs on the lower part of the back, margins folded. *Lower floret*; lemma oblong-ovate, *ca.* 4 by 1 mm, hyaline, margins folded; palea elliptic, *ca.* 3.5 by 0.8 mm, hyaline. *Upper floret*; lemma elliptic, *ca.* 3 by 0.8 mm, hyaline; palea oblong, *ca.* 3 by 0.5 mm, hyaline. *Lodicules* cuneate *ca.* 0.6 mm long. *Anthers* brown, *ca.* 3 mm long. *Ovary* elliptic, 1.8–2 mm long. *Stigmas* purplish. *Pedicelled spikelet* reduced to subulate, 0.8–1.3 mm long, pilose. *Pedicels* obovate with long cordate apex, 2.2–2.4 mm long, 0.5 times as long as the sessile spikelet (Figs. 5.9A-C & 5.35E-G).


**Distribution.**—Burma and Vietnam.
Ecology.— Grassland, dipterocarp woodland and pine forests at 250–1,300 m altitude. Flowering between May and November.

Notes.— This species is similar to *E. ciliaris* in having wingless, but differs in the shape of the pedicels.

5. *Eremochloa eriopoda* C.E. Hubbard in Hook., Icon. Pl. 34: t 3376. 1939.— Type: Thailand, Ubon Ratchathani: Muang Samsip, *A.F.G. Kerr* 8354 (holotype K!, isotypes BK!, BM!, TCD!).

Perennial grass, tufted; cataphylls with woolly hairs. *Culms* erect, up to 1 m tall, extraginal branching at base, internodes glabrous to densely hairs, nodes with long ciliate hairs. *Leaf-sheaths* loose, 5–8 cm long, glabrous to slightly pilose, margins with sparse hairs. *Ligules* ciliate, *ca.* 0.35–0.4 mm long. *Leaf-blades* flat to slightly folded, up to 45 cm by 3–4 mm, glabrous to densely hairy on both surfaces, margins glabrous to pilose, usually woolly hairy at base, acute at apex. *Inflorescence* racemes, 1 to several, falcate, 2–4.5 cm long, rachis internodes clavate, 1.5 mm long, *ca.* 0.35 length of sessile spikelets, scabrous, joints at base with long ciliate hairs. *Sessile spikelets*; lower glume oblong-ovate to ovate, 4.5–5 by 1.8–2 mm, obscurely 5–6-nerved, glabrous to densely hairy on the back, setae straight, flattened, longest ones 4–4.5 mm long, much longer than of the width of the lower glume, apex wingless; upper glume elliptic, 4.5–5 by 1.2–1.2 mm, 3-nerved, keeled in the middle in the lower half and along the margins, without distally with transverse veinlet, densely hairy on the lower part of the back, margins folded. *Lower floret*; lemma elliptic, *ca.* 4 by 1 mm long, hyaline, margins folded; palea elliptic, *ca.* 3.5 by 1 mm, hyaline. *Upper floret*; lemma oblong, *ca.* 3.5 by 1 mm, hyaline, margins folded; palea oblong, *ca.* 3.2 by 0.8 mm, hyaline. *Lodicules* cuneate, *ca.* 0.6 mm long. *Anthers* brown, *ca.* 3 mm long. *Ovary* elliptic, *ca.* 2 mm long. *Stigmas* purplish. *Pedicelled spikelet* absent. *Pedicels* subulate, 6–7 mm long, 1.45–1.5 times as long as the sessile spikelet (Figs. 5.9D-G & 5.36A-C).


**Distribution.**—Laos, Vietnam and Malesia.

**Ecology.**—In sandy soil on open rocky area in dry deciduous or dipterocarp forest, at 0-210 m altitude. Flowering in August to January.

**Notes.**—This species very similar to *E. ciliatifolia* in having wingless in the lower glume of sessile spikelet, but differs in the shape of pedicels.


Annuals grass, tufted, cataphylls glabrous. **Culms** erect, 20-40 cm tall, extraginal branching at base, internodes glabrous, nodes glabrous or slightly long pilose. **Leaf-sheaths** loose, 3-6 cm long, glabrous. **Ligules** an eciliate membrane, 0.8-1 mm long. **Leaf-blades** slightly folded, 3-6 cm by 2-3 mm, glabrous or slightly pilose on both surfaces, margins pilose, acute at apex. **Inflorescence** racemes, 1-3, straight to slightly falcate, 2.5-3.5 cm long, rachis internodes clavate, 2-2.3 mm long, 0.4-0.5 length of sessile spikelets, scabrous, jointed at base with long ciliate hairs. **Sessile spikelets**; lower glume ovate, 4-4.5 by 1-1.5 mm, obscurely 5-7-nerved, glabrous to slightly appressed hairy on the back, setae straight, terete, longest ones 2.8-3 mm long, much longer than of the width of the lower glume, apex wingless;
upper glume oblong, 3–4 by 0.8–1 mm, 3-nerved, keeled in the middle in the lower half and along the margins, without distally with transverse veinlet, glabrous on the back, margins folded, scabrous along margins. Lower floret; lemma oblong-ovate, ca. 2.8 mm long, hyaline, margins folded; palea smaller than lemma, ca. 2.8 mm long, hyaline. Upper floret; lemma elliptic, ca. 2 mm long, hyaline, margins folded; palea smaller than lemma, ca. 2 mm long, hyaline. Lodicules cuneate, 0.4 mm long. Anthers brown, 1.8–2 mm long. Ovary elliptic, ca. 1.5 mm long. Stigmas purplish. Pedicelled spikelet absent. Pedicels subulate, 5.5–6.5 mm long, 1.5 times as long as the sessile spikelet (Figs. 5.9H-J & 5.36D-F).


**Distribution.**—Endemic to Thailand

**Ecology.**—Secondary grassland, sandstone forest or edge of dry dipterocarp forest at ca. 125 m altitude. Flowering in October.

**Notes.**—This species has a tiny inflorescence and similar to *E. eriopoda* in having subulate pedicel, but differs in its shape and the length of setae. *Eremochloa lanceolata* having a straight setae, terete, and the longest ones 2.8–3 mm long, whereas setae straight, flattened, and a longest ones 4–4.5 mm long in *E. eriopoda*.


Perennial grass, tufted, slender rhizomatous, cataphylls glabrous. *Culms* erect, up to 80 cm tall, extravaginal branching at base, internodes glabrous, nodes glabrous. *Leaf-sheaths* loose, 3–9 cm long, glabrous. *Ligules* an eciliate membrane, 0.35–0.4 mm long. *Leaf-blades* flat to slightly folded, 5–20 cm long, 2–4 mm, glabrous on both surfaces, acute at the apex. *Inflorescence* racemes, 1–3 together, straight, 5–11 cm long, rachis internodes clavate, 2–2.3 mm long, 0.45–0.65 length of sessile spikelets,
glabrous, jointed at base with short ciliate hairs. *Sessile spikelets*; lower glume oblong-ovate, 3.5–5 by 1.2–1.5 mm, obscurely 6–8-nerved, glabrous on the back, setae straight, terete, longest ones 2.5–3 mm long, much longer than the width of the lower glume, apex with a moderately green apical wings, 0.2–0.3 length of the lower glume; upper glume oblong, ca. 3.5 by 1.5 mm, 3-nerved, keeled in the middle in the lower half and along the margins, distally with transverse veinlets, glabrous on the lower part of the back, margins folded. *Lower floret* lemma elliptic, ca. 3 by 1 mm, hyaline, margins folded; palea elliptic, ca. 3 by 0.8 mm, hyaline. *Upper floret*; lemma elliptic, ca. 3 by 1 mm, hyaline; palea elliptic, ca. 2.8 by 0.8 mm, hyaline. *Lodicules* cuneate, ca. 0.5 mm long. *Anthers* brown, ca. 1.6 mm long. *Ovary* elliptic, ca. 1.5 mm long. *Stigmas* purplish. *Pedicelled spikelet* absent. *Pedicels* oblique-lanceolate, foliose, 3.5–5.5 mm long, 0.7–1 times as long as the sessile spikelet (Figs. 5.10A-C & 5.37A-C).


**Distribution.**— Endemic to Thailand.

**Ecology.**— Secondary grassland in deciduous forest, at altitude ca. 125 m. Flowering in October.

**Notes.**— This species is very similar to *E. bimaculata* in having 2 apical wings, but differs in its shape of pedicels. Pecicels oblique-lanceolate, foliose, 3.5–5.5 mm long in *E. mawellii*, while oblique-ovovate with short cordate at apex, foliase, 4–4.5 mm long in *E. bimaculata*.

8. *Eremochloa muricata* (Retz.) Hack. in DC., Monogr. Phan. 6: 262. 1889.


*Aegilops ciliaris* Koen. ex Roem. & Schult., Syst. 2: 772.— Type: India (isotype K!).
Perennial grass, tufted, slender rhizomatous, cataphylls woolly. *Culms* erect, 30–45 cm tall, extraginal branching at base, internodes glabrous, nodes slightly pilose. *Leaf-sheaths* loose, 5–8 cm long, glabrous to pilose. *Ligules* membranous with ciliate margins, *ca.* 1–1.5 mm long. *Leaf-blades* flat to slightly folded, 6–15 cm long, 4–5 mm wide, glabrous on both surfaces, margins entire or pilose, acute at the apex. *Inflorescence* racemes, 1–2, straight, 4–6 cm long, rachis internodes clavate, 3–3.2 mm long, about 0.5 length of sessile spikelets, glabrous, jointed at base glabrous *Sessile spikelets*; lower glume elliptic, *ca.* 6 by 2 mm, distinctly 4–7-nerved, glabrous on the back, setae straight, terete, longest ones *ca.* 2 mm long, as long as the width of the lower glume, apex with large apical wings, 0.4 length of the lower glume; upper glume elliptic, 5–5.5 by *ca.* 1.2 mm, 3-nerved, keeled in the middle in the lower half and along the margins, without distally with transverse veinlet, with sparse short hairs on the lower part of the back, margins folded. *Lower floret*; lemma elliptic, *ca.* 4.5 by 1 mm, hyaline, margins folded; palea elliptic, *ca.* 5 by 0.8 mm, hyaline, slightly folded. *Upper floret*; lemma elliptic, *ca.* 3.5 by 0.8 mm, hyaline, folded; palea oblong, *ca.* 4 by 0.5 mm, hyaline, margins folded. *Lodicules* cuneate, *ca.* 0.5 mm long. *Anthers* brown, *ca.* 2–2.5 mm long. *Ovary* ovoid, *ca.* 1 mm long. *Stigmas* purplish. *Pedicelled spikelet* absent. *Pedicels* obliquely obovoid, 5–5.5 mm long, 0.9–0.95 times as long as the sessile spikelet (Figs. 5.10D-F & 5.37D. & E).


**Distribution.**— India, Indo-China, Australia.

**Ecology.**— Growing on an open sandy soil in deciduous forest, at 0-50 m altitude. Flowering in July to November.

**Notes.**— *Eremochloa muricata* differs from other *Eremochloa* in having a large apical wings on lower glume of sessile spikelet.

Perennial grass, tufted, cataphylls glabrous. *Culms* erect, up to 1 m tall, extravaginal branching at base, internodes glabrous, nodes glabrous. *Leaf-sheaths* loose, 3–8 cm long, glabrous. *Ligule* ciliate, 0.35–0.40 mm long. *Leaf-blades* flat, up to 45 cm, 0.7–1 cm, glabrous on both surfaces, margins scabrous, acute at the apex. *Inflorescence* racemes, solitary, straight, 3–10 cm long, rachis internodes clavate, 2.5–3 mm long, ca. 0.4 length of sessile spikelets, glabrous, jointed at base glabrous or glabrescent. *Sessile spikelets*; lower glume ovate, 5–5.5 by ca. 1.5 mm, distinctly 3–6-nerved, glabrous on the back, setae hook-like, terete, longest ones ca. 0.5 mm long, shorter than the width of the lower glume, apex with a large apical wings, 0.4–0.5 length of the lower glume; upper glume lanceolate, 4.5–5 by ca. 0.8 mm, 3-nerved, keeled in the middle in the lower half and along the margins, keeled scabrous, obscurely distally with transverse veinlets, glabrous on the lower part of the back, margins folded. *Lower floret*; lemma elliptic, ca. 3.5 by 1 mm, hyaline, margins folded; palea lanceolate, ca. 3.5 by 0.5 mm, hyaline. *Upper floret*; lemma oblong, ca. 2.8 by 0.5 mm, hyaline; upper palea oblong, ca. 2.5 by 0.5 mm, hyaline. *Lodicules* cuneate, ca. 0.5 mm long. *Anthers* brown, ca. 1.5 mm long. *Ovary* elliptic, ca. 2 mm long. *Stigmas* purplish. *Pedicelled spikelet* absent. *Pedicels* narrowly lanceolate, ca. 8–8.5 mm long, ca. 1.6 times as long as the sessile spikelet (Figs. 5.10G-I & 5.37F. & G).


**Distribution.**—Cambodia, Vietnam.

**Ecology.**—Tufted grass common in paddy field, at ca. 250 m altitude. Flowering in September to December.

**Notes.**—Only known from three collections from two different localities. As the previous data said to be very common in paddy field, however I have not seen in their localities.

10. *Eremochloa* sp.1

Perennial grass, tufted, slender rhizomatous, cataphylls glabrous. *Culms* erect, 40–100 cm tall, extravaginal branching at base, internodes glabrous, nodes ciliate.
Leaf-sheaths loose, 8–12 cm long, glabrous to hirsute. Ligules membranous, ciliate, 1.5–2 mm long. Leaf-blades flat, 12–47 cm by 3–5 mm, glabrous on both surfaces, margins scabrous and pilose, 1–2 mm long acute at apex. Inflorescence racemes, solitary, straight, 6–8 cm long, rachis internodes clavate, 2–2.3 mm long, 0.45–0.65 length of sessile spikelets, sparsely hairy, jointed at base, glabrous or sparsely hairy. Sessile spikelets; lower glume oblong-ovate to ovate, 4.5–5 by 1.5–2 mm, distinctly 7–9-nerved, glabrous on the back, setae straight, terete, longest ones 2–2.5 mm long, as long as the width of the lower glume or sometimes slightly longer than apex with a moderately green apical wings, 0.1–0.3 length of the lower glume; upper glume oblong, ca. 3.5 by 1.5 mm, 3-nerved, keeled in the middle in the lower half and along the margins, distally with transverse veinlets, with sparse hairs on the lower part of the back, margins folded. Lower floret; lemma oblong, ca. 3 by 1 mm long, hyaline, margins folded, ciliate along the upper margins; palea oblong, ca. 3 by 0.7 mm, hyaline. Upper floret; lemma oblong, ca. 2.5–3 by 1 mm, hyaline; palea lanceolate, ca. 2.8 by 0.5 mm, hyaline, margins folded. Lodicules cuneate, ca. 0.5 mm long. Anthers brown, ca. 0.8–1 mm long. Ovary ovoid, ca. 1 mm long. Stigmas purplish. Pedicelled spikelet absent. Pedicels obovate with a long cordate apex, 4.5–6 mm long, 0.9–1.2 times as long as the sessile spikelet (Figs. 5.11 & 5.38A-C).


Distribution.—Endemic to Thailand.

Ecology.—Growing on sandy soil in dipterocarp forest, at ca. 300 m altitude. Flowering between August and September.

Notes.—Eremochloa sp.1 is similar to E. maxwellii but differs considerably in having obovate with a long cordate pedicel, while oblique-lanceolate pedicel in E. maxwellii.

11. Eremochloa sp.2

Perennial grass, tufted, slender rhizomatous, cataphylls glabrous. Culms erect, 20–30 cm tall, extravaginal branching at base, internodes glabrous, nodes glabrous.
Leaf-sheaths loose, 3.5–7 cm long, glabrous to hirsute. Ligules ciliolate, ca. 1.5–2 mm long. Leaf-blades flat to slightly folded, 3–15 cm by 4–5 mm, glabrous on both surfaces, margins entire, acute at apex. Inflorescence racemes, solitary, straight, 3.5–6 cm long, rachis internodes clavate, 3–3.5 mm long, 0.65–0.7 length of sessile spikelets, sparsely hairy, jointed at base glabrous or sparse with a ring of short cilia. Sessile spikelets; lower glume oblong, 4–4.5 by ca. 1.5 mm, distinctly 4–6-nerved, glabrous on the back, setae straight, terete, longest ones 1.5–1.6 mm long, as long as the width of the lower glume apex with a large apical wings, 0.5–0.6 length of the lower glume; upper glume oblong, 4–4.2 by ca. 1 mm, 3-nerved, keeled in the middle in the lower half and along the margins, distally with transverse veinlets, glabrous on the lower part of the back, margins folded. Lower floret; lemma oblong, ca. 3.8 by 0.8 mm, hyaline, margins folded; palea oblong, ca. 3 by 0.5 mm, hyaline. Upper floret; lemma oblong, ca. 3 by 0.8 mm, hyaline; palea oblong, ca. 3.2 by 0.6 mm, hyaline, margins folded. Lodicules cuneate, ca. 0.5 mm long. Anthers brown, ca. 1 mm long. Ovary ovoid, ca. 1 mm long. Stigmas purplish. Pedicelled spikelet absent. Pedicels subulate, slightly expanded and foliöse on the lower part, 7–7.5 mm long, 1.7–1.8 times as long as the sessile spikelet (Figs. 5.12A-C & 5.38D-F).


**Distribution.**—Endemic to Thailand.

**Ecology.**—Growing on the rock near stream, at ca. 1,300 m altitude. Flowering in October.

**Notes.**—Eremochloa sp.2 resembles *E. muricata*, but can be distinguished from the latter in having a subulate pedicel, while an obliquely ovoid pedicel in *E. muricata*.
Figure 5.8 A-E. *Eremochloa attenuata*: A-C. lower glume of the sessile spikelet; D. upper glume of the sessile spikelet; E. pedicelled spikelet with rachis joint. F-J. *E. bimaculata*: F. lower glume of the sessile spikelet; G. upper glume of the sessile spikelet; H. pedicelled spikelet with rachis joint; I. & J. two views of partial raceme. K-N. *E. ciliaris*: K. & L. lower glume of the sessile spikelet; M. upper glume of the sessile spikelet; N. pedicelled spikelet with rachis joint.
Figure 5.9 A-C. *Eremochloa ciliatifolia*: A. lower glume of the sessile spikelet; B. upper glume of the sessile spikelet; C. pedicelled spikelet with rachis joint. D-G. *E. eriopoda*: D. lower glume of the sessile spikelet; E. upper glume of the sessile spikelet; F. pedicelled spikelet with rachis joint; G. spikelet pair. H-J. *E. lanceolata*: H. lower glume of the sessile spikelet; I. upper glume of the sessile spikelet; J. pedicelled spikelet with rachis joint.
Figure 5.10 A-C. Eremochloa maxwellii: A. lower glume of the sessile spikelet; B. upper glume of the sessile spikelet; C. pedicelled spikelet with rachis joint. D-F. E. muricata: D. lower glume of the sessile spikelet; E. upper glume of the sessile spikelet; F. pedicelled spikelet with rachis joint. G-I. E. petelotii: G. lower glume of the sessile spikelet; H. upper glume of the sessile spikelet; I. pedicelled spikelet with rachis joint.
Figure 5.11 *Eremochloa* sp.1: A. plant; B. lower glume of the sessile spikelet; C. upper glume of the sessile spikelet; D. pedicelled spikelet with rachis joint.

All line drawings were drawn by P. Traiperm from *P. Traiperm* 125.
Figure 5.12 *Eremochloa* sp.2: A. lower glume of the sessile spikelet; B. upper glume of the sessile spikelet; C. pedicelled spikelet with rachis joint.
2. HACKELOCHLOA


A genus of 2 species throughout the tropics. Distributed in weedy places; both species occur in Thailand.

**KEY TO THE SPECIES**

1. Sessile spikelets subglobose, *ca.* 1.5 mm long. Lower glume of the sessile spikelets pitted and tubercle on the back1.  
   \[**H. granularis**\]

   1. Sessile spikelets broadly oblong, *ca.* 2.5 mm long. Lower glume of the sessile spikelets ridged and reticulate on the back  
   \[2. **H. porifera**\]


   *Cenchrus granularis* L., Mant. 2, App. 575. 1771.—Type: India orientalis, *Herb. Linn.* 1217-12 (LINN!).

Annuals grass, tufted or solitary. *Culms* erect, 15–80 cm tall, subterete on the lower part, grooved on the upper part, glabrous. *Leaf-sheath* loose, flat, pilose with tubercle-based hairs, 1–4 cm long. *Ligules* *ca.* 1 mm long, membranous with cilia. *Leaf-blade* linear, 2–13 by 1–1.5 cm, pilose with tubercle-based hairs on both surfaces especially on the margins, base round or subcordate, apex acute. *Inflorescence* composed of several racemes on terminal and axillary, with 1–5 racemes, each raceme subtended by spatheole, raceme 5–15 mm long; peduncle 10–30 mm long; rachis
oblong, flattened, 12–15 mm long, fragile at the nodes; adherent to upper glume of sessile spikelets, rachis internode tip transverse, cup-shaped; spikelets dorsally compressed, in pairs, sessile and the other one pedicelled. Sessile spikelets subglobose, united with rachis. Glumes; lower glume turgidly swollen and hemispherical, coriaceous, ca. 1.5 mm diam., pitted and tubercled on the back; upper glume broadly ovate-obtuse, ca. 1 mm long, hyaline, enfolded, adhering to the cavity. Lower floret; lemma ovate, ca. 0.8 mm long, hyaline; palea absent. Upper floret; lemma ovate-obtuse, ca. 0.8 mm long, hyaline; palea ovate, ca. 0.6 mm long, hyaline. Anthers 3, ca. 0.2 mm. Pedicelled spikelet neuter. Pedicels completely fused with rachis; united whoolly; oblong. Glumes; lower glume elliptic, ca. 10 mm long, 4–5-nerved, keeled, scabrous on keel; upper glume elliptic, 6–8 mm long, 5–6-nerved, enfolded, keeled and scabrous on back. Caryopsis orbicular, dorsally compressed (Figs. 5.13 & 5.39A. & B).


**Distribution.**— Worldwide.

**Ecology.**— In dry dipterocarp forests, scattered on grassy slope in forest, up to 1,450 m altitude. Flowering in July to March.

**Vernacular.**— Ya kha naeng (*ŋwɛn*me) (Chiang Rai).

**Notes.**— This species resembles *Hackelochloa porifera* in having lower glume turgidly swollen and hemispherical. It differs from the latter in having a small lower glume, 1.5 mm diam., pitted and tubercled on the back, raceme 5–15 mm long.
while lower glume ca. 2.5 mm long, ridged and reticulate on the back and raceme 2.5–4.5 cm long in *H. porifera*.

**Used.**—*H. granularis* is prescribed internally with a little sweet oil, in cases of enlarged spleen and liver (Bor, 1960).

2. **Hackelochloa porifera** (Hack.) D. Rhind, Grasses of Burma: 77. 1945.


Annuals grass, tufted or solitary. **Culms** erect, 50–200 cm tall, suberete, glabrous. **Leaf-sheath** loose, flat, hirsute with tubercle-based hairs, 2–6 cm long. **Ligules** membranous, 2.5–3.5 mm long, ciliate. **Leaf-blade** broadly linear, 5–30 by 1–2.5 cm, hirsute with tubercle- based hairs on both surfaces, margins scabrous, base round, apex acute. **Inflorescence** composed of several raceme on terminal and axillary, with 2–4 racemes, each raceme subtended by spatheole, raceme 2.5–4.5 cm long; peduncle 3–8 cm long; rachis oblong, flattened, 20–22 mm long, fragile at the nodes; adherent to upper glume of sessile spikelets, rachis internode tip transverse, cup-shaped; spikelets dorsally compressed, in pairs, sessile and the other one pedicelled. **Sessile spikelets** broadly oblong, united with rachis. **Glumes**; lower glume turgidly swollen, hemispherical, ca. 2.5 mm long, coriaceous and robust, ridged and reticulate on the back; upper glume broadly ovate, boat-shaped, 1.5–1.8 mm long, membranous, adhering to the cavity. **Lower floret** barren; lemma broadly ovate-obtuse, ca. 1 mm long, hyaline; palea absent. **Upper florets** fertile; lemma broadly ovate-obtuse, ca. 1 mm long, hyaline; palea ovate, ca. 0.8 mm long, hyaline. **Pedicelled spikelet** neuter. **Pedicels** completely fused with rachis; united wholly; oblong, 18–20 mm long. **Glumes**; lower glume narrowly ovate, 3–3.5 mm long, 5–6-nerved, enfolded, scabrous on the margins; upper glume elliptic, 2.8–3 mm long, 5-nerved enfolded, keeled and scabrous on back. **Caryopsis** orbicular, dorsally compressed, 1–1.2 mm in diam. (Figs. 5.14 & 5.39C-E).

2005, *P. Traiperm* 311 (BCU, BKF, KKU)].

**Distribution.**—India, Indo-China.

**Ecology.**—In bamboo forest or weedy in open ground, at sea level to 1,500 m altitude. Flowering in September to November.

**Notes.**—*Hackelochloa porifera* has been treated as a synonym of *H. granularis* by Veldkamp *et al.* in 1986, but I still to retain *H. porifera* as a species because of the difference of the lower glume of the sessile spikelet of the two species.
Figure 5.13 *Hackelochloa granularis*: A. plant; B. raceme; C. & D. two views of the lower glume of the sessile spikelet; E. rachis joint; F. pedicelled spikelet.

All line drawings were drawn by P. Traiperm from *P. Traiperm 299.*
Figure 5.14 *Hackelochola porifera*: A. plant; B. partial raceme; C. rachis joint with sessile and pedicelled spikelet; D. pedicelled spikelet; E. lower glume of the sessile spikelet. All line drawings were drawn by P. Traiperm from *P. Traiperm* 311.
3. HEMARTHRIA


*Perennial*, mostly rambling. *Inflorescence* axillary, a single flattened dorsiventral raceme with tough rachis; internodes clavate, usually obliquely articulated. *Sessile spikelet*; lower glume rigidly herbaceous, smooth, indistinctly winged above, obtuse to caudate; upper glume sometimes awned; lower florets barren, without palea. *Pedicelled spikelet* resembling sessile, but base truncate, lacking callus; *pedicel* fused to internode.

A genus of 14 taxa in the Old World tropics and subtropics, especially in SE Asia, 1 introduced in the New World. Typically found in wet places habitats; 6 species occur in Thailand.

### KEY TO THE SPECIES

1. Sessile spikelets about twice as long as the joints
   4. *H. longiflora*

1. Sessile spikelets less than twice as long as the joints

2. Culms erect to decumbent
   3. Lower glume caudate
      5. Margins of the lower glume scabrous
         4. Culms rooting at the lower nodes
      5. Margins of the lower glume smooth
         4. Culms tufted, not rooting at the lower nodes
   3. *H. debilis*

2. Culms creeping

4. *H. altissima*

5. *H. compressa*

6. *H. pratensis*

5. *H. stolonifera*


Perennial grass, rhizomatous. **Culms** erect to decumbent up to 80 cm tall, rooting at lower nodes, compressed, nodes and internodes glabrous. **Leaf-sheaths** loose, glabrous except upper margins pilose. **Ligules** ciliolate, 0.5–1 mm long. **Leaf-blade** linear-acuminate, 5–20 by 0.2–0.7 mm, folded, scabrous along the margins towards the tips and mid-nerved, glabrous, base round, pilose near mouth, slightly folded. **Inflorescence** racemes, compressed, 4–10 cm long, one to several per node on terminal and axillary, rachis internodes and nodes glabrous, callus triangular, ca. 1 mm long, glabrous. Spikelets oblong; pedicel of the pedicelled spikelet and the internode the rachis fused and together hollowed to accommodate the sessile spikelet. **Sessile spikelet** flat. **Glumes**: lower glume oblong, 4.5–6 by ca. 1 mm, 4-5 scarcely nervled, coriaceous, pale green or dark purple, scabrous along margins and on the lower nerve, glabrous on the back, bifid, with 2 apical wings; upper glume boat-shaped, 4.5–5 mm long, membranous, adhering to the hollow of the rachis, acute. **Lower floret** barren; lemma oblong-obtuse ca. 4 mm long, hyaline, slightly folded; palea absent. **Upper floret** fertile; lemma lanceolate-acute, 3.5–4 mm long, hyaline, folded; palea oblong-obtuse, ca. 1.5 mm long, hyaline, slightly folded. **Anthers** 3, ca. 2 mm long. **Pedicelled spikelet**; pedicels oblong, compressed, 4.5–5 mm long, slender, scabrous along keeled. **Glumes**: lower glume oblong-obtuse, 5–5.5 by ca. 0.1 mm, coriaceous, folded, scabrous along margins, apex slightly winged; upper glume boat-shaped, acuminate, 5–5.5 by ca. 0.8 mm, coriaceous, keeled and scaberulous on the back. **Lower floret**; lemma oblong-muticous, ca. 4 mm long, hyaline, slightly
folded; palea absent. *Upper floret*; lemma lanceolate-acute or boat-shaped, ca. 3.5 mm long, hyaline; palea oblong, ca. 2 mm long, hyaline (Figs. 5.15A-D & 5.40A-D).


**Distribution.**— Worldwide.

**Ecology.**— Common among the other grasses in open pine forest at 1,300 m altitude. Flowering in March.

**Notes.**— *Hemarthria altissima* is easily confused with *H. compressa* by shape and size of the lower glume, but it differs from the latter in having margins of the lower glume scabrous while margins smooth in *H. compressa*.

2. *Hemarthria compressa* (L. f.) R. Br., Prodr. 207. 1810.


Perennial grass, rhizomatous. **Culms** erect to decumbent up to 1 m tall, rooting at the lower nodes, compressed, nodes and internodes glabrous. **Leaf-sheaths** loose, 2–4.5 cm long compressed and keeled, glabrous except the upper margins pilose, 2–4.5 cm long. **Ligules** a ciliolate, 0.3–1 mm long. **Leaf-blades** linear-acuminate, up to 10 by ca. 0.2 cm folded, scaberulous along the margins towards the tips and midnerve, glabrous, base round, slightly enfolded. **Inflorescence** racemes, compressed, 7–12 cm long, rachis internodes and nodes glabrous, callus triangular. Spikelets oblong; pedicel of the pedicelless spikelet and the internode of the rachis fused and together hollowed to accommodate the sessile spikelet. **Sessile spikelet** flat. **Glumes**; lower glume oblong, 4.5–6 by ca 1.5 mm, 6–7 scarcely nervsed, coriaceous, pale green or dark purple, margins smooth and folded, glabrous on the back, bifid, with 2 apical wings; upper glume boat-shaped, 4.5–6 mm long, membranous, adhering to the hollow of the rachis, apex acute. **Lower floret** barren; lemma enfolded, 3–4 mm long, hyaline, muticous. **Upper floret** fertile; lemma oblong, 3.5–4 by 1 mm, hyaline, slightly enfolded, acute sometime muticous; palea oblong, ca. 1.5 mm long, hyaline, muticous. **Anthers** 3, ca. 2 mm long. **Lodicules** cuneate, ca. 0.5 mm long.
Ovary cylindrical, ca. 0.8 mm long. Pedicelled spikelet; pedicels compressed, 4.5-7 mm long, glabrous, slender. Glumes; lower glume oblong, 5-6 mm long, 7-8 scarcely nerves, coriaceous, pale green or dark purple, slightly enfolded, margins scabrous, glabrous on the back, tapering to the apex; upper glume boat-shaped, acuminate, 6-7 mm long, coriaceous, keeled and scaberulous on the back. Lower floret; lemma oblong-muticous, ca. 3.2 mm long, hyaline, enfolded, palea absent. Lodicules cuneate, ca. 0.5 mm long. Anthers ca. 2 mm long. Ovary cylindrical, ca. 0.5 mm long (Figs. 5.15-E-H & 5.40-E-J).


Distribution.— India, China, Indo-China, Malesia.

Ecology.— Growing in paddy field near swampy place, moist places along roads, water courses, at sea level to 1,300 m altitude. Flowering in March to November.

Annuals grass, caespitose, slender. *Culms* erect, 20–60 cm tall, terete, internodes glabrous, nodes pubescent. *Leaf-sheaths* loose. *Ligules* membranous with ciliate hairs, *ca*. 1 mm long. *Leaf-blades* linear, enfolded, 1–3.5 by 0.1–0.4 cm, glabrous, apex acuminate. *Inflorescence* composed of several racemes, compressed on terminal or axillary, 10–15 cm long, rachis internodes oblong, flat, 7–10 mm long, glabrous, nodes glabrous. Spikelets dorsally compressed. *Sessile spikelet* shorter than the rachis internodes, 9–10 mm long. *Glumes*; lower glume oblong to elliptic, 8.5–10 mm long, 5–7-nerved, coriaceous, flattened, caudate, bifid, scabrous along tail; upper glume lanceolate or boat-shaped, 7.8–8.5 mm long, 3-nerved, thinner than lower glume, glabrous on the back, apex with long caudate, scabrous along tail. *Lower floret* sterile; lemma oblong-obtuse, 3–5 by *ca*. 0.5 mm, hyaline, slightly folded; palea absent. *Upper floret* fertile; lemma oblong-obtuse, 2.5–4.5 by *ca*. 0.5 mm, hyaline; palea absent. *Lodicules* cuneate, 0.5 mm long. *Pedicelled spikelet* 8–8.5 mm long. *Pedicels* oblong, slender, 5–6 mm long, glabrous, the pedicel and the internode of the rachis fused and together hollowed to accommodate the sessile spikelet but sometimes separated from the hollow internodes. *Glumes*; lower glume oblong-elliptic, 8–8.5 mm long, 7-nerved, flattened, caudate, bifid, scabrous along tail; upper glume boat-shaped, 8–8.5 mm long, 3–5-nerved, caudate, scabrous. *Upper floret*; lemma *ca*. 2.5 by 0.4 mm, hyaline. *Lodicules* cuneate, *ca*. 0.5 mm long. *Anthers* *ca*. 1 mm long. *Ovary* cylindrical. *Caryopsis* ellipsoid, *ca*. 1.5 mm long (Figs. 5.16A-E & 5.41A-E).


**Distribution.**— Endemic to Thailand.

**Ecology.**— Growing in swampy area, at 50 m altitude. Flowering in July.

**Notes.**— Known only from the type specimen.


*Rottboellia longiflora* Hook.f., Fl. Brit. India. 7: 154. 1896.— Type: Griffith *KD* 1009 (holotype K!).
Type: Vietnam, Tonkin, Balansa 1783 (holotype P!, isotypes K!, L!).

H. longiflora (Hook.f.) A. Camus var. tonkinensis A. Camus in Fl. Gén. Indochine 7: 379. 1922.

Perennial grass, tufted. Culms erect, 0.7–1 m tall, compressed, internodes glabrous, nodes grayish ciliate, 1–1.5 mm long. Leaf-sheaths loose, folded, 5–6.5 cm long, glabrous but pilose and scabrous along the margins. Ligules densely whitish-grey ciliate, 1–1.2 mm long. Leaf-blades linear, 13–20 by 5–6 mm, margins scabrous, apex acute. Inflorescence racemes, one to several per node, dorsally compressed on axillary or terminal. Spikelets dorsoventrally compressed. Sessile spikelet about twice as long as the rachis internodes. Glumes; lower glume lanceolate, 15–17 by 1.5–1.8 mm, 6–8-nerved, coriaceous, strigillose on the back, scabrous along the margins towards the tips, acuminate and caudate, bifid; upper glume boat-shaped, 10–12 by 1.5–1.8 mm, 1-nerved, coriaceous, thinner than the lower glume adhering to the hollow of the rachis but sometimes separated from the hollow, acuminate and caudate. Lower floret barren; lemma oblong-obtuse, ca. 5 mm long, hyaline, slightly folded; upper floret fertile; lemma oblong-ovate, 4–4.5 by ca. 1 mm, hyaline, enfolded, apex acute; palea ovate, 3.8–4 by ca. 1 mm, hyaline, enfolded, apex acute. Anthers 3, 0.5–1 mm long. Ovary elliptic, ca. 1.5 by 0.5 mm. Pedicelled spikelet; pedicels flattened, 5–8 mm. Glumes; lower glume linear to lanceolate, 11–13 by ca. 1 mm, 5–7-nerved, subcoriaceous, scabrous along the margins towards the tips, apex acuminate and caudate; upper glume boat-shaped, 13–18 by ca. 1 mm, subcoriaceous, apex acuminate and caudate, scabrous keeled on the back. Lower florets barren; lemma oblong-obtuse, 1–1.5 mm long. Upper floret fertile; lemma ca. 3.2 mm long, hyaline, enfolded; palea ca. 2.8 mm long, hyaline, enfolded (Figs. 5.16F-M & 5.41F-J).

[Paknam Songkram, 7 May 1932, A.F.G. Kerr 21357 (BKF, BM, K)]; Khon Kaen
[Khon Kaen on the way to Chumphae, 6 Jul. 1959, T. Smitinand 5839 (BKF, K)];
EASTERN: Nakhon Ratchasima [N of Korat, 5 Jul. 1959, F.Floto 7313 (BKF, C, K);
Chakkarat, M. Norsaengsri 2403 (KKU)]; SOUTH-WESTERN: Kanchanaburi [Si
Sawat, 27 May 1962, Kasem 186 (BK)]; CENTRAL: Chai Nat [Chao Phya Dam, 3
(BM, TCD)]; SOUTH-EASTERN: Chanthaburi [Plain of Makham, 14 Jun. 1963,
Thai-Danish 10092 (BKF, C)].

Distribution.— China, Indo-China, Malesia.

Ecology.— Erect grass, common by path in wet place, at 5-2,350 m altitude. Flowering
in April to October.

Notes.— Extremely variable in size of the lower glume of sessile spikelet. In the
present species the two glumes of both spikelets are long awned, and the sessile
spikelets are twice as long as the joint.


Rottboellia pratensis Balansa, J. Bot. (Morot) 4: 110. 1890.— Type: Vietnam,
Couaïnak, Balansa 1786 (holotype L!, isotype K!).

1921.

H. subulata Reeder in J. Arnold. Arbor. 29: 350. 1948.— Type: New Guinea,
Middle Fly River, Brass 7552 (holotype US, isotypes A, L!).

Perennial grass, tufted, caespitose, not rooting from the lower nodes. Culms
erect, 50-100 cm tall, terete, nodes and internodes glabrous. Leaf-sheaths loose, 6-15
cm long, glabrous, pilose at the margins. Ligules ciliate, 5-10 mm long. Leaf-blades
narrowly linear, enfolded, up to 50 by 2-3 mm, pilose on adaxial surface, abaxial
surface glabrous, margins scabrous, apex acute, sometime muticous. Inflorescence
racemes, compressed on terminal or axillary up to 20 cm long, rachis internodes
oblong, 11-12 mm long, glabrous, nodes glabrous, callus ca. 3 mm long, glabrous.
Spikelets oblong; the pedicel of the pedicelled spikelet and the internode of the rachis
fused and together hollowed to accommodate the sessile spikelet. Sessile spikelet
compressed. Glumes; lower glume linear-oblong, 7.5-8 by 1.2-1.5 mm, 6-7-nerve,
coriaceous, pale green, scaberulous along the margins towards the end, apex bifid with 2-apical wings; upper glume boat-shaped, 6.5–8 mm long, membranous, adhering to the hollow of the rachis, acute to acuminate. Lower floret barren; lemma oblong, 5–5.5 by ca. 1 mm, hyaline, slightly folded, muticous. Upper floret fertile; lemma oblong-muticous, ca. 5.5 by 1 mm, hyline; palea oblong, 2–2.5 by ca. 0.5 mm, hyaline, muticous. Lodicules 2, cuneate, ca. 0.8 mm long. Ovary cylindrical, ca. 1 mm long. Anthers ca. 4.5 mm long. Pedicelled spikelet; pedicels terete, slender, glabrous up to 20 mm long. Glumes; lower glume long triangular, 9–9.5 by 1 mm, 5-nerved, coriaceous, pale green, slightly enfolded, margins scabrous, acute or muticous, tapering to the apex; upper glume boat-shaped, 9–10 mm long, coriaceous, pale green, keeled and scabrous on the back, folded, tapering to the end. Lower floret barren; lemma oblong, 5–5.5 by ca. 1 mm, hyaline, acute or muticous at the apex. Upper floret fertile; lemma oblong-acute, 4.5–5 by ca. 1 mm, hyaline, enfolded, palea linear, ca. 2 by 0.3 mm, hyaline, muticous. Lodicules 2, cuneate, ca. 0.8 mm long. Anthers 4–4.5 mm long. Ovary cylindrical (Figs. 5.17 & 5.42A-F).


Distribution.—Indo-China, Malesia.

Ecology.—Caespitose grass on open area in pine forest, altitude 1300 m. Flowering in October to March.

Notes.—At the base of the erect culm a tuft of leafless sheaths is found, the apices of which are sometimes blackened from burning. The species grows in savannas, and is apparently fire-resistant, developing new shoots after the fire.

Perennial grass, stoloniferous. *Culms* creeping, slender 25–30 cm tall, prostrate, terete, internodes glabrous, nodes glabrous. *Leaf-sheaths* loose, pubescent, margins ciliate. *Ligules* membranous with ciliate hairs, *ca.* 0.8 mm long. *Leaf-blades* linear, 3–20 cm by 1.5–3 mm, glabrous on both surface sometimes with bulbous-based bristles near mouth, margins scabrous, apex retuse. *Inflorescence* racemes, solitary, straight, terminal, 10–13 cm long, rachis internodes columnar, flattened, *ca.* 3 mm long, adherent to upper glume of sessile spikelet, glabrous, nodes glabrous. *Spikelets* oblong; the pedicel of the pedicelled spikelet and the internode of the rachis fused and together hollowed to accommodate the sessile spikelet. *Sessile spikelet* dorsally compressed. *Glumes*; lower glume elliptic-oblong, 5.5–6 mm long, 11-nerved, flattened, glabrous, apex obtuse; upper glume boat-shaped, *ca.* 6 mm long, 3-nerved, glabrous, apex acute. *Lower floret* barren; lemma oblong, *ca.* 4.5 mm long. Upper floret; lemma oblong *ca.* 3.9 mm long, hyaline. *Anthers* 2.5–3.5 mm long. *Pedicelled spikelet* *ca.* 7 mm long, callus glabrous. *Pedicels* flattened, slender, glabrous up to 20 mm long. *Glumes*; lower glume linear to lanceolate-acuminate, 6.5–7 mm long, 11–13-nerved, flattened, glabrous; upper glume boat-shaped, 7–7.5 mm long, 9-nerved, keeled scabrous, apex acuminate. *Lower floret*; lemma oblong, *ca.* 4.5 mm long. *Upper floret*; lemma *ca.* 4 mm long. *Anthers* *ca.* 3 mm long (Figs. 5.18 & 5.42G-I).


**Distribution.**— Endemic to Thailand.

**Ecology.**— Creeping on wet place, at sea level. Flowering in June.

**Notes.**— Known only from the type specimens and also reported that this species seems unique for its stoloniferous habit.
Figure 5.15 A-D. *Hemarthria altissima*: A. partial raceme; B. lower glume of the sessile spikelet; C. lower glume of the pedicelled spikelet; D. upper glume of the pedicelled spikelet. E-H. *H. compressa*: E. partial raceme; F. & G. lower glume of the sessile spikelet (two views); H. lower glume of the pedicelled spikelet; I. upper glume of the pedicelled spikelet.
Figure 5.16 A-E. Hemarthria debilis: A. partial raceme; B. lower glume of the sessile spikelet; C. upper glume of the sessile spikelet; D. lower glume of the pedicelled spikelet; E. upper glume of the pedicelled spikelet. F-M. H. longiflora: F. partial raceme; G. & H. lower glume of the sessile spikelet (two views); I. upper glume of the sessile spikelet; J. & K. lower glume of the pedicelled spikelet; L. & M. upper glume of the pedicelled spikelet.
Figure 5.17 *Hemarthria pratensis*: A. plant; B. partial raceme; C. & D. sessile spikelet: C. lower glume, D. upper glume; E. lower glume of the pedicelled spikelet. All line drawings were drawn by P. Traiperm from *P. Traiperm* 158.
Figure 5.18 *Hemarthria stolonifera*: A. lower glume of the sessile spikelet; B. lower glume of the pedicelled spikelet; C. upper glume of the pedicelled spikelet.
4. MNESITHEA

Kunth, Rév. Gram. 1: 153. 1829.— Type species: M. laevis (Retz.) Kunth.


Diperium Desv., Opusc.: 76. 1831.— Type species: D. cylindrical Desv. (= M. laevis).


Cyclotera Stapf in Ind. Lond. 5: 459. 1931. nom nud.— Type species: C. selloana.

Perennial, often robust with broad leaf-blades. Leaf-sheath tight. Inflorescence racemes, terminal or axillary and often spathate, a single cylindrical or flattened dorsiventral raceme, spikelets paired or occasionally in triplets of 2 sessile and 1 pedicelled, usually in three on below. Sessile spikelet paired or solitary, callus truncate with central peg. Glumes; lower glume oblong, coriaceous, winged or wingless, chartaceous to crustaceous, smooth, areolate or cancellate, 2-keeled, keels winged towards tip; upper glume awnless. Lower floret barren, with or without a small palea or absent. Pedicelled spikelet well developed or vestigial; pedicel free, clavate or foliaceous, sometimes auriculate at tip or rarely absent. Pedicels free from the internode, rarely fused to internode.

A genus of 8 species occurs in Thailand.

KEY TO THE SPECIES

1. Pedicelled spikelet absent
   4. M. laevis

1. Pedicelled spikelet present

2. Lower glume of the sessile spikelet with 4–7 upwardly directed hooks on each lateral keel
   2. M. glandulosa
2. Lower glume of the sessile spikelet entirely devoid of hooks
3. Back of the lower glume of the sessile spikelet glabrous, smooth or continuous slits
4. Joint at base with a ring of cilia

3. M. helferi

4. Joint at base glabrous

5. Lower glume of the sessile spikelet ovate, indurate, 4.5–5 by ca. 1.5 mm, apex with 2 apical wings, continuous ridge along the length and interrupted by tubercles or tubercle-based hairs on the back or glabrous

6. M. striata

5. Lower glume of the sessile spikelet oblong, indurate, 5–5.5 by 1.2–1.5 mm, apex with unequal wings, 7–8 longitudinal rows of small pits between the nerves on the back, margins at base puberulous

8. M. sp.1

3. Back of the lower glume of the sessile spikelet scaberulous or hairy

6. Lower glume of the sessile spikelet without apical or lateral wing

1. M. cancellata

6. Lower glume of the sessile spikelet with apical wings or wings along margins

7. Back of the lower glume of the sessile spikelet with continuous ridge along the length and interrupted by hairs or tubercle-based hairs

5. M. mollicoma

7. Back of the lower glume of the sessile spikelet smooth and densely appressed hairs

7. M. thailandica


Rottboellia cancellata Ridl., J. As. Soc. Straits 59: 228. 1911.— Type: Malay Peninsula, H.N. Ridley 15231 (holotype K!).

C. clathrata Henrard, Blumea 4: 519. 1941.— Type: Vietnam, Annam: Quinhon, Balansa s.n. (isotype L!).


Coelorachis foveolata (Holtt.) Jansen, Reinwardtia 2: 256. 1953.


Perennial grass, caespitose. Culms erect, slender, up to 1 m tall, internodes terete, glabrous, nodes with a ring of short ciliate hairs. Leaf-sheaths loose, 5–10 cm long, glabrous except for the margins and nodes densely hairy. Ligules short membranous with long ciliate margins. Leaf-blades 10–40 by 0.5–0.8 mm, adaxial
surface slightly hairy, abaxial surface glabrous, margins scabrous, apex acute. Inflorescence racemes, 5–7 cm long, terminal and axillary, subtended by a spatheole, exserted, terete, rachis internodes oblong with cup-shaped transverse tip, 3–4 mm long, distinctly 6–7-nerved, glabrous, joint at base glabrous, spikelets oblong, dorsally compressed, 4–6 mm long, callus glabrous, base oblique with central peg. Sessile spikelets 3–4 mm long. Glumes; lower glume oblong-ovate, indurate, 3–3.5 by ca. 1.5 mm, cancellate on the back, apex wingless; upper glume boat-shaped, 2.5–3.5 by ca. 1 mm, 3-nerved, glabrous, keeled along the midnerved from base to apex on the back, keeled scabrous, apex acute. Lower floret; lemma oblong, 2–2.5 mm long, hyaline, folded; palea absent. Upper floret; lemma oblong, ca. 2 mm long, hyaline, folded. Lodicules cuneate, 0.7 mm long. Ovary elliptic, ca. 0.7 mm long. Anthers 1.2–1.5 mm long. Pedicelled spikelet reduced into 2 asymmetrical glumes, ca. 1.5–2.5 mm long. Pedicels ribbon-like 2.5–3 mm long, distinctly 2 green lines, glabrous (Figs. 5.19A-D & 5.43A. & B).


**Distribution.**— Indo-China, Malesia.

**Ecology.**— Grass in rather dense tussock, in open dry deciduous forest, wet and sandy soil, at 50–1,300 m altitude. Flowering in July to April.
Notes.— *Mnesithea cancellata* is very close to *M. mollicoma*, but differing in the cancellate and wingless at the lower glume of the sessile spikelet, whereas the lower glume of *M. mollicoma* is continuous ridge along the length and interrupted by hairs or tubercle-based hairs and having unequal narrow wings along margins.


Type: Java, *Hb. Trinius* s.n. (holotype LE).


*R. muricata* var. *javanica* Retz.— Type: Indonesia: Java, *Junghuhn, F.W.* s.n. (lectotype K!).

Perennial grass. *Culms* erect, a large stout tufted with prop roots below, up to 1–2 m tall, internodes glabrous or glabrescent, nodes with a ring of short ciliate hairs. *Leaf-sheaths* tight, glabrous, 8–20 cm long. *Ligules* a membranous with ciliate hairs, 1–1.5 mm long. *Leaf-blades* lanceolate, ca. 100 by 1.5–3.5 cm, slightly appressed hairs on both surfaces, margins scabrous, round to a subcordate base, acuminate at the apex. *Inflorescence* racemes, 7–10 cm long, terminal and axillary, subtended by a spatheole, exserted, terete, rachis internodes cupuliform, 3–4 mm long, scabrous, joint at base scabrous, spikelets oblong, dorsally compressed, 5–6 mm long, callus scabrous, base truncate with central peg. *Sessile spikelets* 5–5.5 mm long. *Glumes*; lower glume oblong-ovate to ovate, 4–5.5 mm long, obscurely 6–7-nerved, glabrous on the back and with hooks on each lateral side in the basal part, margins enfold apex acute with 2-apical wings; upper glume boat-shaped, 4–4.5 mm long, chartaceous, glabrous, keeled along the midnerve from base to apex on the back, keeled scabrous, apex acute. *Lower floret* barren; lemma ovate-acute, 3–3.5 mm long, 3-nerved, hyaline, ciliolate on margins, enfolded; palea ca. 0.6 mm long. *Upper florets* fertile; lemma elliptic, 2–2.5 mm long, 3-nerved, hyaline; palea ca. 0.7 mm long. *Anthers* 3, ca. 2.5 mm long, purple. *Lodicules* cuneate, ca. 0.5 mm long. *Stigmas* 2. *Pedicelled spikelet* reduced to 2 glumes. *Pedicels* ribbon-shaped, 6–6.5 by ca. 1.5 mm, 7-nerved, comprising 2 subequal glumes. *Glumes*; lower glume ovate, ca. 1.5 mm long, winged along one side; upper glume more reduce (Figs. 5.19E-G & 5.43C-E).
Suteesorn 1820 (BK)], Narathiwat [Bacho, 10 Jan. 1969, P. Sankhachand 1677 (BK)].

**Distribution.**—Indo-China, Malesia.

**Ecology.**—Grass common by on sandy bank by stream or edge of deciduous forest, up to 1,100 m altitude. Flowering in May to January.

**Vernacular.**—Ya khao pa (น้ําหมัก) (Kanchanaburi).

**Notes.**—This species is easily recognised by hooks on each lateral side in the basal part of the lower glume of the sessile spikelet.


*Rottboellia helferi* Hook.f., Fl. Brit. Ind. 7: 158. 1896.—Type: India, *Helfer* 913 (holotype K!).


*Coelorachis helferi* (Hook.f.) Henr., Blumea 4: 518. 1941.

Perennial grass, caespitose, with a young propagule below. **Culms** erect, 50–100 cm tall, internodes glabrous to pilose, nodes pubescent. **Leaf-sheaths** tight, 6–10 cm long, glabrous to pilose. **Ligules** membranous, 0.5–0.8 mm long. **Leaf-blades** 15–50 by 0.8–1.5 cm, glabrous to pubescent on both surfaces, margins scabrous and pilose, acuminate at apex. **Inflorescence** composed of racemes, 9–12 cm long, terminal and axillary, subtended by a spatheole, rachis internodes cupuliform on upper part, basal part cuneate, glabrous, nodes with a ring of long cilia; spikelets in pairs or tripets, 1–2 sessile spikelets and 1 pedicelled spikelet, callus long pilose, base truncate with central peg. **Sessile spikelets** dorsally compressed. **Glumes**; lower glume ovate, indurate, 3–3.5 by 1–1.2 mm, glabrous on the back, margins entire, sometimes pilose on the lower part, apex bident with oblique, 2 apical wings, wing unequal, the biggest wing usually along the apex to the base; upper glume ovate, 2.5–3 by ca. 1 mm, 3-nerved, keeled along the midnerves from base to the apex, glabrous on the back, apex acute. **Lower floret**; lemma ovate, ca. 2 by 0.8 mm, hyaline, folded; palea absent. **Upper floret**; lemma ovate, ca. 2.5 by 1.5 mm, hyaline. **Lodicules** cuneate, 0.5 mm long. **Anthers** ca. 2 mm long. **Pedicelled spikelet** oblong, 0.5–0.8 mm long,
reduced into 2 asymmetrical glumes. *Pedicels* ribbon-like, ca. 3 by 0.5 mm, distinctly 2 green lines, glabrous, apex truncate and curved (Figs. 5.19H-K and 5.44A. & B).


**Distribution.**— Indo-China, Malesia.

**Ecology.**— Tufted grass in evergreen, deciduous forest or swampy area at 25-200 m altitude. Flowering in April to December.

**Notes.**— The collections of *A.F.G. Kerr* 10745 having a glabrous rachis nodes.


*Ophiuros undatus* Nees, Hook. Kew Journ. 2. 1850.— Type: Philippines, Luzon, *Cumming, H.* 1339 (holotype K!, isotypes L!, P!).

*Mnesithea laevis* var. *hirta* (Retz.) Kunth in Révis. Gramin. 1: 154.— Type: Indonesia, Sulawesi, Saloe Karadjoie, *P.J. Eyma* 361 (isotype L!).
Perennial grass, tufted. **Culms** slender, erect, 30–100 cm long, terete, glabrous. **Leaf-sheath** tight, 4–7 cm long, glabrous, upper part with long ciliate hairs at margins. **Ligules** an eciliate membrane, ca. 0.5 mm long. **Leaf-blade** linear, incurved, 15–70 by 0.2–0.5 cm, glabrous on both sides, abruptly acute. **Inflorescence** racemes, terminal or axillary, 7–21 cm long, rachis internodes cuneate, 3.5–4 mm long, apex crateriform; spikelets sunken, arranged in two or three, usually in three on below. **Sessile spikelets** paired or solitary, oblong; dorsally compressed. **Glumes**; lower glume oblong, 3–3.5 by ca. 1 mm, coriaceous, glabrous, apex obtuse, wingless; upper glume oblong, ca. 3 by 1 mm, membranous, slightly enfolded, obtuse at apex. **Lower floret**; lemma lanceolate, 2.5–2.8 mm long, hyaline; palea absent. **Upper floret**; lemma lanceolate, ca. 2.8 mm long, hyaline; palea absent. **Pedicelled spikelet** absent. **Pedicels** fused to internode, united wholly (Figs. 5.20 & 5.44C-E).


**Distribution.**— India, China, Indo-China.

**Ecology.**— Dry deciduous, dipterocarp, bamboo or pine forest, up to 400 m altitude. Flowering in July to May.

**Notes.**—A.F.G. Kerr 13508 has a longitudinal slit on the back of the lower glume of the sessile spikelet.


**Rottboellia mollicoma** Hance, J. Bot. 9: 134. 1871.— Type: China, Hance 7558 (holotype, isotype and syntype K!, isotype BM!).

**Mnesithea pubescens** Ridl., Journ. As. Soc. Straits, xliiv. 44: 207. 1905.— Type: Malay Peninsula, H.N. Ridley 11017 (holotype K!).


Perennial grass, caespitose, with a young propagule. **Culms** erect, 30–100 cm tall, internodes pilose with appressed hairs, nodes pubescent. **Leaf-sheaths** loose, 6–10 cm long, pubescent. **Ligules** membranous with long ciliate margins, ca. 1–1.5 mm long. **Leaf-blades** 20–60 by 0.8–1.8 cm, pubescent on both surfaces, apex acute. **Inflorescence** composed of racemes, 8–14 cm long, terminal and axillary, subtended by a spatheole, rachis internodes cupuliform on upper part, basal part cuneate, glabrous, nodes with a ring of ciliate hairs; spikelets in pairs or triquets, callus pubescent. **Sessile spikelets;** lower glume oblong-ovate, indurate, 3.5–4.5 by 1.8–2 mm, subequal narrow winged along margins, continuous ridge along the length and interrupted by hairs or tubercle-based hairs; upper glume ovate or boat-shaped, ca. 3.5 by 1 mm, 3-nerved, keeled along the upper back, glabrous, apex acute. **Lower floret;**
lemma ovate, ca. 2.5 by 1 mm, hyaline, folded; palea absent. *Upper floret*; lemma ovate, ca. 3 by 2 mm, 3-nerved, hyaline; palea ovate, ca. 2.8 by 1 mm, hyaline. *Lodicules* cuneate, 0.5 mm long. *Anthers* ca. 2 mm long. *Pedicelled spikelet* ovate, 0.5–1.5 mm long, reduced into 2 asymmetrical glumes. *Pedicels* oblong or ribbon-like, 3–4.5 by 0.5–0.8 mm with distinctly 2 green lines, glabrous, apex truncate, curved (Figs. 5.21A-D & 5.45A-C).


**Distribution.**— China, Indo-China, Malesia.

**Ecology.**— Tufted grass common in mixed deciduous forest, at sea level to 1,200 m altitude. Flowering throughout the year.


*Rottboellia striata* Nees ex Steud., Syn. Pl. Glum. 1: 361. 1855.— Type: Wall. Cat. no. 8877 C (lectotype K!).


**KEY TO THE VARIETIES**

1. Leaf-blades glabrous on both surfaces; lower glume of the sessile spikelet glabrous or nearly smooth on the back
   - a. var. striata

1. Leaf-blades pubescent on both surfaces; lower glume of the sessile spikelet with continuous ridges along the length and interrupted by tubercles or tubercle-based hairs, margins glabrous
   - b. var. pubescens

a. var. striata

Perennial grass, caespitose, large stout tufted with propagules below. **Culms** erect, up to 2 m tall, terete, internodes glabrous, nodes slightly hairy or glabrescent. **Leaf-sheaths** nearly tight, 5–12 cm long, glabrous, margins pilose. **Ligules** membranous with ciliate margins, 1.5–2 mm long. **Leaf-blades** 30–60 by 1–2 cm, glabrous on both surfaces, margins scabrous and pilose, apex acute. **Inflorescence** composed of many racemes, 8–12 cm long, terminal and axillary, subtended by a spatheole, rachis internodes oblong, flattened at base swollen at the upper part, 4–6.5 by ca. 1 mm, glabrous, nodes glabrous; spikelets in pairs or tripets, callus glabrous. **Sessile spikelets** dorsally compressed. **Glumes**; lower glume oblong, indurate, 3.5–5
by 1–1.5 mm, glabrous or nearly smooth on the back, apex with 2 small apical wings; upper glume boat-shaped, acute, 3–4 by 1–1.5 mm, keeled on the back, on the upper part, glabrous. Lower floret; lemma ovate-acute, ca. 2.8 by 0.8 mm, 3-nerved, hyaline, glabrous; palea lanceolate, ca. 2 by 0.5 mm, hyaline, glabrous. Upper floret; lemma ovate-acute, ca. 2.8 by 0.8 mm, hyaline, glabrous; palea boat-shaped, ca. 2.5 by 0.5 mm, hyaline, glabrous, apex acute. Lodicules cuneate, 0.5 mm long. Anthers 1.8–2 mm long. Pedicelled spikelet oblong or ovate, 1–2.5 mm long, reduced into 2 asymmetrical glumes, glumes dissimilar, winged at the apex, slightly folded, glabrous. Pedicels oblong or ribbon-like 3.5–4.5 by ca. 1 mm, with distinct 2 green lines, glabrous, apex concave (Figs. 5.21E-J & 5.45D-F).


Distribution.— China, India, Indo-China.

Ecology.— On sunny slope, edge of dipterocarp forest or in evergreen forest, up to 1,225 m altitude. Flowering in June to February.

Vernacular.— Ya khon (นิ้วใหญ่) (Nakhon Ratchasima).


Rottboellia striata Nees ex Steud. var. pubescent Hack. in DC., Monogr. Phan. 6: 302. 1889.— Type: India, Khasia, Meghalaya, J.D. Hooker & T. Thomson s.n. (holotype K!, isotype L!).

Coelorachis striata var. pubescens (Hack.) Bor, Grasses Burma, Ceyl., India Pak.: 121. 1960.

Perennial grass, caespitose, large stout tufted with propagules below. Culms erect, up to 1.5 m tall, terete, internodes glabrous, nodes slightly hairy to pubescent. Leaf-sheaths tight, 6.5–15 cm long, glabrous to pilose, if glabrous usually pilose at margins. Ligules membranous with ciliate margins. Leaf-blades up to 70 by 1–2.5 cm, pilose or pubescent on both surfaces, margins scabrous and pilose, apex acute. Inflorescence composed of many racemes, 7–11 cm long, terminal and axillary, subtended by a spatheole, rachis internodes clavate, swollen at the upper part, 3.5–4.5 by 1–1.5 mm, glabrous, nodes glabrous; spikelets in pairs or tripets, callus glabrous. Sessile spikelets dorsally compressed. Glumes; lower glume ovate, indurate, 4.5–5 ca. 1.5 mm, continuous ridge along the length and interrupted by tubercles, or tubercle-based hairs, margins glabrous, apex with 2 apical wings; upper glume boat-shaped, ca. 3.5 by 1 mm, keeled on the back, on the upper part, glabrous, apex acute. Lower floret; lemma ovate-acuminate, ca. 2.8 by 0.8 mm, hyaline, glabrous, slightly folded; palea lanceolate, ca. 2 by 0.3 mm, hyaline, muticous. Upper floret; lemma lanceolate, ca. 2 by 0.3 mm, hyaline, glabrous; palea boat-shaped, ca. 2.5 by 0.8 mm, hyaline,
glabrous, apex acute. *Lodicules* cuneate, ca. 0.5 mm long. *Anthers* 2–2.5 mm long. *Pedicelled spikelet* oblong, 0.5–2 mm long, reduced into 2 asymmetrical glumes, glumes dissimilar, winged at apex, slightly folded, glabrous. *Pedicels* oblong or ribbon-like, 3.5–4.5 by 0.8–1 mm, with distinct 2 green lines, glabrous, apex concave (Fig. 5.21K-N).


**Distribution.**—China, India and Indo-China.
Ecology.— Grass common in moist localities in mixed deciduous forest, at 100-2,200 m altitude. Flowering in September to April.

Notes.— Newly recorded for the country.

7. Mnesithea thailandica P. Traiperm & T. Boonkerd sp. nov. (ined.)

Perennial with caespitose. Culms erect, slender, 26 cm tall, internodes pilose to pubescent, nodes dense ciliate hairs. Leaf-sheaths loose, 2.5–6 cm long, pilose. Ligules membranous with ciliate margins, ca. 0.5 mm long. Leaf-blades 5–20 by 0.4–0.8 mm, pilose on both surfaces, apex acute. Inflorescence racemes, ca. 6 cm long, terminal, subtended by a spatheole, rachis internodes cupuliform, 2–2.5 mm long, with densely appressed hairs, nodes pubescent; spikelets in pairs, callus pubescent. Sessile spikelets dorsally compressed. Glumes; lower glume triangular, ca. 4 by 2 mm, indurate, margins folded, smooth and densely appressed hairs on the back, apex with 2 narrow wings; upper glume ovate or boat-shaped, ca. 3 by 1.3 mm, keeled on the upper and pilose along keel. Pedicelled spikelet oblong, ca. 1 mm long, reduced into 2 asymmetrical glumes, keeled along the margins, with densely appressed hairs on surface. Pedicels oblong or ribbon-like ca. 3 by 0.6 mm, with densely appressed hairs (Figs. 5.22 & 5.46A-D).

Thailand.— EASTERN: Roi Et [Suwannaphum, Nayai, Ban Hang Hoei, 10 June 1982, Y. Paisooksantivathana & S. Sutheesorn y 1048-82 (BK)].

Distribution.— Endemic to Thailand.

Ecology.— Common in paddy field, at 100 m altitude. Flowering in June.

Note.— Mnesithea thailandica is distinguished by the appressed hairs on the inflorescence. It is similar to Malaysian species, M. geminata but differs in having a small erect and slender culm, ca. 26 cm tall. The species has pubescent hairs on the back of the triangular lower glume, rachis nodes, pedicels and rachis internode, while lanceolate and hirsute below and glabrous on rachis nodes, pedicels and rachis internode in M. geminata.

8. Mnesithea sp.1

Perennial grass, caespitose, large stout tufted with propagules below. Culms erect, up to 2 m tall, terete, internodes glabrous, nodes glabrous to pubescent. Leaf-
sheaths tight, 5–10 cm long, slightly pilose on margins. Ligules membranous, ca. 2 mm long. Leaf-blades 20–80 by 1.5–2.5 cm, glabrous to pilose on both surfaces, margins scabrous and pilose, apex acuminate. Inflorescence composed of several racemes, slightly flattened, 6–8 cm long, terminal and axillary, subtended by a spatheole, rachis internodes oblong, flattened but swollen at the tip or the upper part, 5–6.5 by 1.2–1.5 mm, 7–10-nerved, glabrous, nodes glabrous; spikelets in pairs alternating rows, callus glabrous. Sessile spikelets dorsally compressed. Glumes; lower glume oblong, indurate, 5–5.5 by 1.2–1.5 mm, 7–8-nerved, 7–8 longitudinal rows of small pits between the nerves, glabrous on the back, margins at base puberulous, folded, unequal winged at apex; upper glume boat-shaped, ca. 5 by 1 mm, keeled on the back, along the midnerve, margins slightly folded, glabrous, apex acute. Lower floret; lemma ovate-acute, ca. 4.8 by 1.5 mm, hyaline, glabrous, slightly folded; palea ovate-acute, ca. 2 by 0.8 mm, hyaline. Upper floret; lemma ovate, ca. 3.5 by 0.8 mm, hyaline; palea boat-shaped, ca. 4.5 by 1 mm, hyaline. Lodicules cuneate, 0.5 mm long. Anthers 2–2.5 mm long. Pedicelled spikelet oblong-ovate, 1.8–2.5 mm long, reduced into 2 asymmetrical glumes, glumes dissimilar, narrowly winged along margins, folded, glabrous. Pedicels oblong or ribbon-like, 4.5–5 by 0.8–1.2 mm, with distinct 2–6 green lines, glabrous, apex truncate, pedicels fused to the internodes at the lower part (Figs. 5.23 & 5.46E-G).


Distribution.—Endemic to Thailand.
Ecology.— Common in Oak pine forest, roadsides, small ravine extending out from hillside. Grass 1-2 m. tall, along edge of small dried-up stream, at altitude 600-1,800 m altitude. Flowering between June and March.

Note.— Most materials of M. sp.1 in Thailand were identified as M. striata. This species is different from M. striata by having oblong lower glume of the sessile spikelet, indurate, 5-5.5 by 1.2-1.5 mm, apex with unequal wings, 7-8 longitudinal rows of small pits between the nerves of the back, margins at base puberulous, while ovate lower glume of the sessile spikelet, indurate, 4.5-5 by ca. 1.5 mm, apex with 2 apical wings, continuous ridge along the length and interrupted by tubercles or tubercle-based hairs on the back or glabrous in M. striata. It is very clear that I found the two taxa in their same locality.
Figure 5.19 A-D. Mnesithea cancellata: A. partial raceme; B. lower glume of the sessile spikelet; C. pedicelled spikelet; D. rachis joint. E-G. M. glandulosa: E. partial raceme; F. lower glume of the sessile spikelet; G. rachis joint with pedicelled spikelet. H-K. M. helferi: H. partial raceme; I. lower glume of the sessile spikelet; J. pedicelled spikelet; K. rachis joint.
Figure 5.20 *Mnesithea laevis*: A. plant; B. partial raceme; C. spikelet pair; D. lower glume of the sessile spikelet. All line drawings were drawn by P. Traiperm from *P. Traiperm* 307.
Figure 5.21 A-D. *Mnesithea mollicoma*: A. two views of rachis joint with sessile and pedicelled spikelet; B. three of spikelets; C. lower glume of the sessile spikelet; D. pedicelled spikelet. E-J. *M. striata*: E. partial raceme; F. rachis joint with sessile and pedicelled spikelet; G. & H. lower glume of the sessile spikelet; I. & J. pedicelled spikelet with rachis joint. K-N. *M. striata* var. *pubescens*: K. partial raceme; L. & M. lower glume of the sessile spikelet; N. pedicelled spikelet.
Figure 5.22 *Mnesithea thailandica*: A. plant; B. partial raceme; C. rachis joint with sessile and pedicelled spikelet; D. lower glume of the sessile spikelet; E. pedicelled spikelet with pedicel. All line drawings were drawn by P. Traiperm from the type specimen.
Figure 5.23 *Mnesithea* sp.1: A. plant; B. partial raceme; C-E. lower glume of the sessile spikelet; F. pedicelled spikelet. All line drawings were drawn by P. Traiperm from *P. Traiperm* 347.
5. OPHIUROS

Gaertn., Fruct. 3: 3. 1805.—Type species: *O. corymbosa* (L. f.) Gaertn. (= *O. exaltatus*).


A genus of 4 species in the tropical Africa to southern China and Australia; only 1 species occurs in Thailand.


   *Aegilops exaltata* L., Mant. 2. App.: 575. 1771.—Type: India, Malabar, *Koenig* s.n. (not seen).

Perennial grass, caespitose. *Culms* erect, robust, 100–200 cm long, terete, glabrous. *Leaf-sheath* tight, 4–10 cm long, glabrescent, margins pilose. *Ligules* membranous, *ca.* 1 mm long. *Leaf-blade* lanceolate, 15–40 by 1–1.5 cm, chartaceous, glabrous or glabrescent on both surfaces, margins pilose with tubercle-based hairs, base round, apex acute. *Inflorescence* composed of 1 to several racemes, rachis internode oblong, 3–4 mm long, excavated. *Sessile spikelets* dorsally compressed, 3.5–4 mm long, sunken in the hollow of rachis internode. *Glumes*; lower glume oblong, 3.5–4 by *ca.* 1 mm, 4–6-nerved, coriaceous, slightly pitted or distinct on the back along the length of nervé, apex acute; upper glume elliptic, boat-shaped, *ca.* 3 by 1 mm, 3–nerved, hyaline. *Upper florets* fertile; lemma elliptic, *ca.* 2.8 by 1 mm, hyaline, enfolded, apex acute; palea lanceolate, *ca.* 2.5 by 0.7 mm, hyaline. *Lodicules* cuneate, *ca.* 0.5 mm long. *Ovary* elliptic, *ca.* 0.4 mm long. *Lower floret* sterile; lemma ovate, *ca.* 2.8 by 1 mm long, hyaline, margins slightly enfolded; palea lanceolate, *ca.*
2.8 by 0.7 mm long, hyaline, enfolded. Pedicelled spikelet absent. Pedicels fused to internode, united wholly (Figs. 5.24 & 5.47A-C).


**Distribution.**— China, India, Indo-China, Malesia, Australia.

**Ecology.**— Growing in moist savannah on clayey soil, at 800-2,200 m altitude. Flowering between October and December.

**Vernacular.**— Ya khao phot phi (เขาโพธิ์พิภ) (Saraburi).

**Notes.**— *Put* 1150 and *C.F. van Beusekom et al.* 4290 with a deeply pitted or distinct on the back along the length of nerves in lower glume of sessile spikelet.
Figure 5.24 *Ophiuros exaltatus*: A. plant; B. partial raceme; C. spikelet pairs; D. lower glume of the sessile spikelet; E. joint. All line drawings were drawn by P. Traiperm from *P. Traiperm* 176.
6. PHACELURUS


*Thysia* Stapf in Fl. Trop. Afr. 9: 48. 1917.— Type species: *T. inflate* Stapf


A genus of 8 species in the tropics and subtropics of the Old World; 2 species occur in Thailand.

**KEY TO THE SPECIES**

1. Raceme solitary, the spikelets spreading, lower glume of the sessile spikelets lanceolate, 16–17 by ca. 1.5 mm

1. Raceme borne on along central axis, lower glume of the sessile spikelets oblong or narrowly ovate, 3–3.5 by 1–1.2 mm


Perennial, tufted. *Culms* erect, *ca*. 45 cm tall, slender, terete, internodes glabrous, nodes glabrous or slightly hairy. *Leaf-sheaths* loose, glabrous. *Ligules* ciliate. *Leaf-blades* 30–50 by 0.5–0.7 cm, chartaceous, glabrous or glabrescent on both surfaces, margins scabrous, midnerve distinct. *Inflorescence* composed of racemes, raceme solitary, the spikelets spreading, up to 20 cm long, rachis internodes and nodes glabrous. *Sessile spikelets*. *Glumes*; lower glume lanceolate, 16–17 by *ca*. 1.5 mm, coriaceous, glabrous on the back, scabrous wing on keel, tapering to apex, caudate; upper glume lanceolate-acuminate, 11–12 by *ca*. 1 mm, coriaceous, glabrous on the back, scabrous wing on keel. *Lower floret* male, lemma linear, 9–10 by *ca*. 1 mm, hyaline, folded upper margins scabrous; palea lanceolate-acute, 7–7.5 by *ca*. 0.8 mm, hyaline, slightly folded. *Lodicules ca.* 1.5 mm long. *Anthers ca.* 2 mm long. *Upper floret*; lemma linear, *ca*. 8 by 0.8 mm, hyaline, folded; palea linear, *ca*. 7 by 0.8 mm, hyaline, folded. *Ovary ca.* 1.5 mm long. *Pedicelled spikelet* usually resembling the sessile spikelet. *Pedicels* oblong, flattened. *Glumes*; lower glume linear-obtuse, 22–23 by *ca*. 1.5 mm, obliquely plicate, coriaceous, scabrous wing on keel, glabrous on the back, apex caudate; upper glume lanceolate, 10–11 by *ca*. 1.3 mm, coriaceous, plicate, scabrous wing on keel on the back. *Lower floret*; lemma lanceolate, plicate, 8–9 by *ca*. 1 mm, hyaline, folded, upper margins ciliate; palea linear-obtuse, 7–8 by *ca*. 0.8 mm, hyaline, folded. *Anthers ca.* 2 mm long. *Upper floret*; lemma lanceolate-acuminate, 7–7.5 by *ca.* 1 mm, hyaline, folded upper margins scabrous; palea linear, 6.5–7 mm long, hyaline, folded (Fig. 5.47D–F).


**Distribution.**—Cambodia.

**Ecology.**—Tufted grass, common along edge of swampy, at 200-250 m altitude. Flowering between August and December.

**Notes.**—*P. cambogiensis* was recorded only two times from Thailand. I can not be collected even their original localities.

*Rotthoellia zea* C.B. Clarke, J. Linn. Soc., Bot. 25: 86, t. 35. 1889.— Type: India, Munypore, *C.B. Clarke* 41980 (holotype K!).

*R. thyrsoida* Hack. in DC., Monogr. Phan. 6: 283. 1889.— Type: India, Khasia, *J.D. Hooker & T. Thomson* s.n. (isotypes K!, L!).


Perennial grass, tufted, large stout plant. *Culms* erect, up to 2.5 m tall, terete, internodes glabrous, nodes ciliate. *Leaf-sheaths* loose, 15–30 cm long, glabrous, margins with white pilose hairs. *Ligules* ciliolate. *Leaf-blades* oblong-lanceolate, 30–150 by 1–1.5 cm, chartaceous, adaxial surface scabrous and slightly long hairy sometimes short hairs, abaxial surface glabrous, midnerve distinct, margins scabrous and slightly pilose, apex acuminate. *Inflorescence* compound racemose, terminal, composed of numerous racemes (25–45), borne along a central axis, central inflorescent axis up to 50 cm long, rachis semi-terete, glabrous, rachis internodes cuneate, 3–8 mm long, glabrous. *Sessile spikelets* ovate, dorsally compressed, 3–4 mm long, callus truncate. *Glumes*; lower glume oblong or narrowly ovate, 3–3.5 by 1–1.2 mm, coriaceous, muticous keeled and narrowly winged all along the margins, scabrous; upper glume ovate, boat-shaped, 3–3.5 by *ca.* 1 mm, 3-nerved, chartaceous, keeled along the back and scabrous, apex acute. *Lower floret* male or barren; lemma narrowly ovate, 3–3.2 by *ca.* 1 mm, 3-nerved, hyaline, margins enfolded; palea absent. *Upper floret* perfect; lemma ovate, boat-shaped, *ca.* 3 by 1 mm, hyaline, keeled along the back; palea lanceolate, *ca.* 2 by 0.5 mm, hyaline, margins enfolded. *Pedicelled spikelet* usually resembling but smaller than the sessile spikelet. *Pedicels* linear, flattened, 1–2 mm long. *Glumes*; lower glume oblong-ovate, 3–3.5 by *ca.* 0.1 mm, coriaceous, with scabrous wing along the margins, apex acute; upper glume boat-shaped, *ca.* 3 by 1 mm, subcoriaceous, with scabrous wing on keeled on the back, apex acute. *Lower floret*; lemma oblong-ovate, *ca.* 3 by 0.8 mm, 3-nerved, hyaline, apex acute, folded; palea absent. *Upper floret*; lemma oblong-ovate, 2.5–3 by *ca.* 0.8 mm, hyaline, folded; palea ovate, 2–2.5 by *ca.* 0.8 mm, hyaline, folded, apex acute. *Caryopsis* ellipsoid, *ca.* 1.5 mm long (Fig. 5.48A-D).

**Distribution.**—India, Indo-China.

**Ecology.**—Tufted grass, common in oak and pine forest on clayey soil, at altitude 800-900 m. Flowering between June and December.

**Notes.**—*Phacelurus zea* is easily recognised from *P. cambogiensis* by a robust plant with a compound racemes inflorescence on terminal, which composed of numerous racemes (25-45) borne along a central axis.

7. **ROTTBOELLIA**


  **Stegosia** Lour., Fl. Cochín.: 51. 1790.—Type species: *S. cochinchinensis* Lour.


Annual tufted. **Culms** erect. **Leaf-sheaths** tight, hirsute. **Ligules** membranous with ciliolate margins. **Leaf-blades** linear-lanceolate or broadly linear. **Inflorescence** racemes, terminal and axillary. **Sessile spikelets** fertile and sunk in concavities on lateral internodes of rachis. **Glumes**; lower glume ovate, coriaceous, smooth, 2-toothed; upper glume boat-shaped, subcoriaceous. **Lower floret** staminate. **Upper floret** perfect. **Pedicelled spikelet** staminate or neutral, reduced and compressed. **Pedicel** wholly fuse to the internodes.

A genus of 4 species in the Old World tropics and introduced to the Caribbean; 1 species occurs in Thailand.


  **Stegosia cochinchinensis** Lour., Fl. Cochín. 1: 51. 1790.—Type: Cochinchina, (holotype BM!, isotypes K!, L!).

Ophiuros appendiculatus Steud.—Type: Javanica, Zollinger 7257 (holotype P!, isotype L!).

Annual grass. Culms erect, 0.7–2 m tall, terete, internodes solid, supported below by stilt roots, hirsute. Leaf-sheaths tight, terete, usually more hirsute, margins open. Ligules membranous with ciliolate hairs, brown. Leaf-blades linear-lanceolate or broadly linear, up to 45 by 1–2 cm, scabrous with minute stiff hairs above, very rough along margins, apex tapering to a long fine point. Inflorescence racemes, terminal and axillary, 1–4 racemes together, several inflorescences per culm, 8–15 by 0.2–0.3 cm. Sessile spikelets fertile and sunk in concavities on lateral internodes of rachis. Glumes; lower glume ovate, 4.5–5 by ca. 2 mm, 9–11-nerved, coriaceous, smooth or very slightly rough on the back, subacute at apex, entire or very minutely 2-toothed; upper glume boat-shaped, 9–12-nerved, subcoriaceous, apex acute. Lower floret staminate; lemma boat-shaped, 3–4 by 1.4–1.5 mm, 3-nerved, membranous, apex acute; palea ovate, 4–4.5 by 1.6–1.7 mm, 2-nerved, membranous acute. Lodicules conical, 4–5 mm long, entire marginal. Anthers ca. 2 mm long, brown. Upper floret perfect; lemma boat-shaped, obliquely ovate, 3–3.5 by 3.5–4 mm, 3-nerved, chartaceous; palea hastate, 2.5–3 mm long, 2-nerved, membranous. Anthers 2.3–3 mm long, purple or brown. Ovary elliptic, 1–1.5 mm long. Stigmas purple. Pedicelled spikelet staminate or neutral, reduced and compressed, 3.5–4 mm long. Pedicels wholly fused to the internodes, flattened (Figs. 5.25 & 5.48E-G).

Distribution.—Worldwide.

Ecology.—Weed on roadsides in open area, at sea level up to 1,300 m altitude. Flowering throughout the year.

Vernacular.—Ya ko (นโยบาย) (Trat); Ya khayong (yna) (Krung Thep Maha Nakhon); Ya prong khai (yna) (Lampang); Itchgrass, Corngrass.

Notes.—*Rottboellia cochinchinensis* is readily distinguished from others genus in subtribe Rottboelliinae by the internodes of the inflorescence are cory. This species is variable in size and likely to spread further as it is one of the world’s worst weed.
Figure 5.25 *Rottboellia cochinchinensis*: A. plant; B. & C. spikelet pairs (two views); D. & E. lower glume of the sessile spikelet; F. lower glume of the pedicelled spikelet; G. upper glume of the pedicelled spikelet. All line drawings were drawn by P. Traiperm from P. Traiperm 133.
8. VOSSIA

Wall. & Griff., J. As. Soc. Bengal. Nat. Hist. 5: 572. 1836. nom. cons. non Adanson 1763.—Type species: *V. procera* Wall. & Griff. (*V. cuspidata*).


A genus of only 1 species in Tropical Africa and India and also occurs in Thailand. Typically found in semi-aquatic habitats.


*Ischaenum cuspidatum* Roxb., Fl. Brit. Ind. 1: 325. 1820.—Type: Bengal (not seen).

*V. procera* Wall. & Griff., J. As. Soc. Beng. 5: 573. 1836.—Type: India Bengalae orientalis, Barak (not seen).

Perennial grass, caespitose. *Culms* erect, up to 2 m tall, internodes terete, glabrous, nodes glabrous. *Leaf-sheaths* tight, glabrous. *Ligules* membranous with ciliate margins. *Leaf-blades*; adaxial surface pilose, abaxial surface glabrous, midnerve distinct and hooked along midnerve or sometimes without, scabrous along margins. *Inflorescence* composed of racemes, racemes 1–3: single, or paired, or digitate, *ca.* 15 cm long, terminal, rachis internodes clavate, flattened, *ca.* 1 cm long, scabrous along keel, nodes glabrous or slightly scabrous. *Sessile spikelets* dorsally compressed. *Glumes*; lower glume oblong-ovate, indurate, 2.3–2.5 cm by *ca.* 3.5 mm, coriaceous, glabrous on the back but scabrous along margins, with long caudate apex; upper glume oblong or boat-shaped, 10.5–11 by *ca.* 3.0 mm, 3-nerved, keeled along the upper part on the back and scabrous along keel, apex acute. *Lower floret*; lemma
oblong-acute, 9–9.5 by 1.8–2 mm, hyaline, glabrous but hairy along margins, folded; palea oblong-acute, ca. 7.5 by 1.2 mm, hyaline, glabrous, folded. Upper floret; lemma oblong-acute, ca. 7.5 by 1.5 mm, hyaline, hairy along margins, folded; palea oblong-acute, ca. 8 by 1 mm, hyaline, slightly hairs along the upper margins, folded. Lodicule cuneate, ca. 0.8 mm long. Ovary ellipsoid, ca. 1 mm long. Pedicelled spikelet very similar to but smaller than the sessile spikelets. Pedicels cuneate, flattened, 7–8 mm long, scabrous along margins. Glumes; lower glume oblong-ovate, 2.3–2.4 by 2.5–2.8 mm, glabrous on the back, with scabrous margins, with long caudate apex; upper glume oblong-ovate or boat-shaped, ca. 8.5 by 2 mm, keeled on the upper back, scabrous along keeled, upper margins hairy, apex acute. Lower floret; lemma oblong-acute, ca. 7 by 1.5 mm, hyaline, glabrous, folded; paleas oblong-ovate, ca. 6.5 by 1 mm, hyaline, folded, apex acute, glabrous. Upper floret; lemma oblong-ovate, ca. 6.5 by 1 mm, hyaline, glabrous slightly folded; palea ovate, ca. 6.5 by 1.5 mm, hyaline, hairy along the upper margins, folded (Figs. 5.26 & 5.49).


Distribution.— Throughout tropical Africa and Southeast Asia.

Ecology.— Growing on the canal banks, at sea level. Flowering in October.

Notes.— Only one collection of V. cuspidata in BK herbarium has been recorded.
Figure 5.26 *Vossia cuspidata*: A. plant; B. & C. spikelet pairs; D. upper glume of the sessile spikelet with joint. All line drawings were drawn by P. Traiperm from *C. Chermsirivathana* s.n. (BK).
5.3 Discussion and Conclusion

5.3.1 Ecology

Ecological data of the subtribes Ischaeminae and Rottboelliinae in Thailand are summarized in Table 5.1.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Habit</th>
<th>Habitat</th>
<th>Altitude (m)</th>
<th>Flowering periods</th>
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<tr>
<td>1. <em>Apluda mutica</em></td>
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<td>df</td>
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<td>pdf, swp</td>
<td>0-1,300</td>
<td>All year round</td>
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<td>bf</td>
<td>0</td>
<td>Nov.</td>
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<td>5. <em>I. hirtum</em></td>
<td>annual</td>
<td>ns, rs</td>
<td>50-1,300</td>
<td>Nov.-Dec.</td>
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<td>8. <em>I. lacei</em></td>
<td>perennial</td>
<td></td>
<td></td>
<td>Nov.</td>
</tr>
<tr>
<td>10. <em>I. muticum</em></td>
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<td>bf</td>
<td>0</td>
<td></td>
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<tr>
<td>11. <em>I. rugosum</em></td>
<td>annual</td>
<td>pdf, rs</td>
<td>0-800</td>
<td>All year round</td>
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<tr>
<td><strong>Subtribe Rottboelliinae</strong></td>
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<td>19. <em>Eremochloa attenuata</em></td>
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<td>dtf</td>
<td>450-1,800</td>
<td>Nov.-May</td>
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<td>All year round</td>
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<td>dtf, pf</td>
<td>250-1,300</td>
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Table 5.1 Ecological data of the subtribes Ischaeminae and Rottboelliinae in Thailand (Cont.).

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Habit</th>
<th>Habitat</th>
<th>Altitude (m)</th>
<th>Flowering periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>29. <em>E. sp.2</em></td>
<td>annual</td>
<td>ns</td>
<td>1,300</td>
<td>Oct.</td>
</tr>
<tr>
<td>30. <em>Hackelochloa granularis</em></td>
<td>annual</td>
<td>dtf</td>
<td>1,450</td>
<td>Jul.-Mar.</td>
</tr>
<tr>
<td>31. <em>H. porifera</em></td>
<td>annual</td>
<td>bb, wd</td>
<td>1,500</td>
<td>Sept.-Nov.</td>
</tr>
<tr>
<td>32. <em>Hemarthria altissima</em></td>
<td>perennial</td>
<td>pf</td>
<td>1,300</td>
<td>Mar.</td>
</tr>
<tr>
<td>33. <em>H. compressa</em></td>
<td>perennial</td>
<td>swp, rs</td>
<td>1,300</td>
<td>Mar.-Nov.</td>
</tr>
<tr>
<td>34. <em>H. debilis</em></td>
<td>annual</td>
<td>swp</td>
<td>50</td>
<td>Jul.</td>
</tr>
<tr>
<td>39. <em>M. glandulosa</em></td>
<td>perennial</td>
<td>ns, df</td>
<td>0-1,100</td>
<td>May-Jan.</td>
</tr>
<tr>
<td>41. <em>M. laevis</em></td>
<td>perennial</td>
<td>df, dtf, pf</td>
<td>400</td>
<td>Jul.-May</td>
</tr>
<tr>
<td>42. <em>M. mollicoma</em></td>
<td>perennial</td>
<td>df</td>
<td>1,200</td>
<td>All year round</td>
</tr>
<tr>
<td>43. <em>M. striata</em></td>
<td>perennial</td>
<td>dtf, ef</td>
<td>1,225</td>
<td>Jun.-Feb.</td>
</tr>
<tr>
<td>44. <em>M. striata var. pubescens</em></td>
<td>perennial</td>
<td>df</td>
<td>100-2,200</td>
<td>Sept.-Apr.</td>
</tr>
<tr>
<td>45. <em>M. thailandica</em></td>
<td>perennial</td>
<td>pdf</td>
<td>100</td>
<td>Jun.</td>
</tr>
<tr>
<td>46. <em>M. sp.1</em></td>
<td>perennial</td>
<td>pf</td>
<td>60-1,800</td>
<td>Jun.-Mar.</td>
</tr>
<tr>
<td>50. <em>Rottboellia cochinchinensis</em></td>
<td>annual</td>
<td>wd</td>
<td>0-1,300</td>
<td>All year round</td>
</tr>
<tr>
<td>51. <em>Vossia cuspidata</em></td>
<td>perennial</td>
<td>rs</td>
<td>0</td>
<td>Oct.</td>
</tr>
</tbody>
</table>

Total number of taxa: 51

habitats: bb = bamboo forest, bf = beach forest, dtf = dipterocarp forest, ef = evergreen forest, sf = sandstone forest, ns = near stream, rv = rivers sides, df =
deciduous forest, pf = pine forest, sf = secondary forest; rs = roadsides, svn = savannah, swp = swampy area, pdf = paddy field, weedy area = wd; − = no data.

It can be seen that grass members of the subtribe Ischaeminae can grow in many types of habitat from sea level up to high altitude (2,350 m). They can be found along roadside (5 taxa), paddy field (3 taxa), swampy area (3 taxa) and savannah (3 taxa). Some species occur in deciduous forest (2 taxa), beach forest (2 taxa), near stream (2 taxa), dipterocarp forest (2 taxa), secondary forest (2 taxa) and evergreen forests (2 taxa). Two species is restricted to rivers sides (Ischaemum magnum) and pine forest (I. barbatum var. lodiculare). The Ischaeminae plants in commonly produce flowers in November to December but only two species, I. barbatum and I. muticum produce a flower all year round.

In the subtribe Rottboelliaeae, the grass can be found from sea level up to high elevation (2,350 m). Most species are often found in dry dipterocarp forest or dry deciduous forest, each comprising of 10 taxa. However, nine and seven taxa are also observed in pine forest and swampy area, respectively. There are few taxa occasionally found near stream (2 taxa), weedy area (2 taxa), along roadsides (2 taxa) and in evergreen forest (2 taxa). Three species were reported in different habitat such as in bamboo forest (Hackelochloa porifera), sandstone forest (Eremochloa lanceolata) and savannah (Ophiuros exaltatus). The flowering period is between August and November. E. ciliaris, Mnesithea mollicoma and Rottboellia cochinchinensis produce flowers throughout the year.

5.3.2 Distribution

Most species of Ischaeminae are recorded in the penninsula (12 taxa), south-eastern (10 taxa), eastern (10 taxa) and northern (9 taxa) Thailand, while Rottboelliaeae are mostly distributed in the north-eastern (22), eastern regions (21 taxa) and northern regions (14 taxa) (Table 5.2). Some taxa in both subtribes can be found throughout the country, especially Apluda mutica, Ischaemum indicum, I. rugosum, Mnesithea glandulosa and Rottboellia cochinchinensis which are distributed in all floristic regions (Table 5.2).
Table 5.2 The distributions of the Ischaeminae and Rottboellinae in Thailand.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Floristic Regions of Thailand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td><strong>Subtribe Ischaeminae</strong></td>
<td></td>
</tr>
<tr>
<td>1. <em>Apluda mutica</em> (C)</td>
<td>/</td>
</tr>
<tr>
<td>2. <em>Ischaemum barbatum</em> (C)</td>
<td>/</td>
</tr>
<tr>
<td>3. <em>I. barbatum var. lodiculare</em></td>
<td>-</td>
</tr>
<tr>
<td>4. <em>I. hansenii</em> (R)</td>
<td>-</td>
</tr>
<tr>
<td>5. <em>I. hirtum</em></td>
<td>-</td>
</tr>
<tr>
<td>6. <em>I. hubbardii</em> (R)</td>
<td>/</td>
</tr>
<tr>
<td>7. <em>I. indicum</em> (C)</td>
<td>/</td>
</tr>
<tr>
<td>8. <em>I. lacei</em> (R)</td>
<td>/</td>
</tr>
<tr>
<td>9. <em>I. magnum</em></td>
<td>-</td>
</tr>
<tr>
<td>10. <em>I. muticum</em></td>
<td>-</td>
</tr>
<tr>
<td>11. <em>I. rugosum</em> (C)</td>
<td>/</td>
</tr>
<tr>
<td>12. <em>I. tenuifolium</em></td>
<td>-</td>
</tr>
<tr>
<td>13. <em>I. timorense</em></td>
<td>/</td>
</tr>
<tr>
<td>14. <em>I. sp.1</em>, ***</td>
<td>-</td>
</tr>
<tr>
<td>15. <em>I. sp.2</em>, ***</td>
<td>-</td>
</tr>
<tr>
<td>16. <em>Kerriochloa siamensis</em></td>
<td>-</td>
</tr>
<tr>
<td>17. <em>Sehima nervosum</em></td>
<td>/</td>
</tr>
<tr>
<td>18. <em>Thelepogon elegans</em></td>
<td>/</td>
</tr>
<tr>
<td><strong>Subtribe Rottboellinae</strong></td>
<td></td>
</tr>
<tr>
<td>19. <em>Eremochloa attenuata</em></td>
<td>/</td>
</tr>
<tr>
<td>20. <em>E. bimaculata</em></td>
<td>-</td>
</tr>
<tr>
<td>21. <em>E. ciliaris</em> (C)</td>
<td>/</td>
</tr>
<tr>
<td>22. <em>E. ciliatifolia</em></td>
<td>-</td>
</tr>
<tr>
<td>23. <em>E. eriopoda</em></td>
<td>-</td>
</tr>
<tr>
<td>24. <em>E. lanceolata</em> *</td>
<td>-</td>
</tr>
<tr>
<td>25. <em>E. maxwellii</em> *</td>
<td>-</td>
</tr>
<tr>
<td>26. <em>E. muricata</em> (R)</td>
<td>-</td>
</tr>
<tr>
<td>27. <em>E. pel telotti</em> (R)</td>
<td>-</td>
</tr>
<tr>
<td>28. <em>E. sp.1</em>, ***</td>
<td>-</td>
</tr>
<tr>
<td>29. <em>E. sp.2</em>, ***</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 5.2 The distributions of the Ischaeminae and Rottboelliiinae in Thailand (Cont.).

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Floristic Regions of Thailand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>30. Hackelochoa granularis</td>
<td>/</td>
</tr>
<tr>
<td>31. H. porifera</td>
<td>/</td>
</tr>
<tr>
<td>32. Hemarthria altissima</td>
<td>-</td>
</tr>
<tr>
<td>33. H. compressa</td>
<td>/</td>
</tr>
<tr>
<td>34. H. debilis * (R)</td>
<td>-</td>
</tr>
<tr>
<td>35. H. longiflora</td>
<td>/</td>
</tr>
<tr>
<td>36. H. pratensis</td>
<td>-</td>
</tr>
<tr>
<td>37. H. stolonifera * (R)</td>
<td>-</td>
</tr>
<tr>
<td>38. Mnesithea cancellata</td>
<td>/</td>
</tr>
<tr>
<td>39. M. glandulosa (C)</td>
<td>/</td>
</tr>
<tr>
<td>40. M. helferi</td>
<td>-</td>
</tr>
<tr>
<td>41. M. laevis</td>
<td>/</td>
</tr>
<tr>
<td>42. M. mollicoma</td>
<td>/</td>
</tr>
<tr>
<td>43. M. striata</td>
<td>/</td>
</tr>
<tr>
<td>44. M. striata var. pubescence **</td>
<td>/</td>
</tr>
<tr>
<td>45. M. thailandica *, *** (R)</td>
<td>-</td>
</tr>
<tr>
<td>46. M. sp.1*, ***</td>
<td>/</td>
</tr>
<tr>
<td>47. Ophiuros exaltatus</td>
<td>-</td>
</tr>
<tr>
<td>48. Phaelurus cambogiensis (R)</td>
<td>-</td>
</tr>
<tr>
<td>49. P. zea</td>
<td>-</td>
</tr>
<tr>
<td>50. Rottboellia cochinchinensis (C)</td>
<td>/</td>
</tr>
<tr>
<td>51. Vossia cuspidata (R)</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total number of taxa</strong></td>
<td>24</td>
</tr>
</tbody>
</table>

* indicate endemic to Thailand, ** = new record for Thailand, and *** = probably new to science, C = common species, R = rare species, N = Northern, NE = North-Eastern, E = Eastern, SW = South-Western, C = Central, SE = South-Eastern, PEN = Peninsular, / = present, - = absent.

According to the study, twelve endemic taxa are endemic species to Thailand. Three taxa of Ischaeminae and nine taxa of Rottboelliiinae are presently known from
one or two floristic regions, one or several localities in each region. Those taxa are listed as follow:

1. *Ischaemum hansenii* is restricted to Trang (Ko Talibong).

2. *I.* sp. 1 is found in Chanthaburi (Khao Soi Dao) and Krabi (Phanom Bencha).

3. *I.* sp. 2. This species is only found in Ranong (Phu Khao Yai).

4. *Eremochloa attenuata* is recorded in Chiang Mai [Doi Inthanon, Doi Suthep, near Fang, Wang Bua Ban], Lamphun (between Tak & Lamphun, Khun Tan National Park), Lampang (Ngao Mae Huad), Loei (Phu Kradueng).

5. *E. lanceolata* is presented in Nakhon Ratchasima (Khao Kuap), Ubon Ratchathani (Pha Taem National Park, Warin Chamrap).

6. *E. mawellii* is found in Si Sa Ket (Dongrak, Kantharalak), Ubon Ratchathani (Warin Chamrap).

7. *E.* sp. 1 only occurs in Khon Kaen (Khok Phu Taka), Chaiyaphum (Nong Bua Daeng), Nakhon Ratchasima (Huai Thalaeng).

8. *E.* sp. 2 is confined to Loei (Phu Kradueng).

9. *Hemarthria debilis* is limited to Chanthaburi (Makham).

10. *H. stolonifera* is restricted to Chanthaburi (Makham).

11. *Mnesithea thailandica* is confined to Roi Et (Suwanaphoom).

12. *M.* sp. 1 is only recorded in Mae Hong Son (Pai), Chiang Mai (Doi Suthep, Doi Inthanon, Chiang Doi Hills, Doi Chiang Dao, Pha Hom Pok, Wang Tao, Khun wang highland, Mae John Luang), Kanchanaburi (Huai Bankau).

Moreover, there are 12 taxa are not endemic to Thailand, but rather have a restricted distribution, either confined to one or two floristic regions or found in a single locality. Further works are needed to determine the population size and their distribution. Those taxa are listed as follow:

1. *Ischaemum hirtum* is recorded in Phetchabun (Nam Nao National Park) and Chaiyaphum (Nam Phrom).

2. *I. hubbardii* is limited to Chiang Mai (Doi Inthanon).

3. *I.lacei* is restricted to Chiang Mai (Doi Nang Ka).

4. *I. magnum* is confined to Krung Thep Maha Nakhon.

5. *Kerriochloa siamensis* occurred in Ubon Ratchathani (Warin Chamrap, Pha Taem Nat. Park) and Chanthaburi (Kao Knap).
6. *Eremochloa petelotii* is presented in Nakhon Ratchasima (Phimai) and Surin (Thung Kula Rong Hai)

7. *Hackelochoa porifera* is limited to Chiang Mai (nursery of Queen Sirikit Botanical Garden).

8. *Hemarthria altissima* is restricted to Loei (Phu Kradueng).

9. *H. pratensis* is limited to Loei (Phu Kradueung).

10. *Phacelurus cambogiensis* is confined to Nakhon Ratchasima (Phimai: Sai Ngam).

11. *P. zeae* is found in Phetchabun (Tung SaLaeng Luang Nat. Park) and Chaiyaphum (Tungkamang).

12. *Vossia cuspidata* is limited to Krung Thep Maha Nakhon (Bang Khen).

Nine taxa have been recorded only once or twice in Thailand from the last two decades and no new or recent collection has been made, *e.g.* *E. petelotii, H. altissima, H. debilis, H. stolonifera, I. hansenii, I. lacei, M. thailandica, P. cambogiensis* and *V. cuspidata*. Those taxa are listed as follow:

1. *Eremochloa petelotii* is found only in two collections which collected in Nakhon Ratchasima (Phimai) in December 27th, 1958 by *T. Smitinand* and in Surin (Thung Kula Rong Hai, Chumphon Buri) by *S. Sutheesorn* in September 17th, 1972. This species is said to be common in paddy fields, however it could not be found from this study.

2. *Hemarthria altissima* was collected by *T. Smitinand* in Loei (Phu Kradueng, near camp) in March 11th, 1952. It is said to be common among the other grasses in open pine forest at 1,300 m altitude.

3. *H. debilis* is growing on swampy area, at 50 m altitude in Chanthaburi (5 km N of Makham). It is only known from the type specimen that collected by *K. Larsen* in June 15th, 1963.

4. *H. stolonifera* is only known from the type specimen collected by *K. Larsen* in Chanthaburi (Makham) in June 13th, 1963. This species is found creeping on wet place, at sea level.

5. *Ischaemum hansenii* is only known from the type specimen, *B. Hansen & T. Smitinand* that collected in Trang (Ko Talibong) in November 10th, 1966. The plants were creeping on rocks, at sea level.
6. *Ischaemum lacei* has been recorded only once in Thailand in Chiang Mai (Doi Nang Ka) in November 4th, 1930 by Put.

7. *Mnesithea thailandica* was collected in Roi Et (Suwanaphoom, Nayai, Ban Hang Hoey) in June 10th, 1982 by Y. Paisooksantivathana & S. Sutheesorn. This plant is common in paddy field, at 100 m altitude.

8. *Phacelurus cambogiensis* has been recorded only twice in Thailand. Both collections were collected by T. Smitinand from Nakhon Ratchasima (Phimai: Sai Ngam) in August 26th and December 27th, 1958. They are common along edge of swampy area, at 200-250 m altitude.

9. *Vossia cuspidata* has been recorded only once in Krung Thep Maha Nakhon (Bang Khen) in 1960 by C. Chermsirivathana. The plant was found growing on the canal bank.

The above mentioned species could not be found from their previously described habitats. Though, they were common in their localities in the past. There are several potential answers for their missing from my surveys such as the possibility of domination by a new weed species which preventing the growth of the other plant species. Another answer is that the environment in which those species were found have changed, either naturally or unnaturally, probably due to human disturbance. Change in species flowering periods may also be another reason why the above species could not be found, this also includes the fact that when I went to collect the specimens it was too early or too late for the species to produce flowers, therefore the grass plant was not easily notice and could not be collected.

Three taxa in Ischaeminae and 7 taxa in Rottboelliinae are rare species, while 4 and 3 common taxa have been noted in Ischaeminae and Rottboelliinae, respectively.

**5.3.3 New records and new species**

Nanakorn & Norsaengsri (2001) have reported a total of 21 and 31 taxa of the subtribes Ischaeminae and Rottboelliinae in Thailand, respectively (Table 5.3). One species of Ischaeminae and one variety of Rottboelliinae are newly recorded for Thailand from this research.
I. hubbardii is found along Kio Mae Pan nature trail, Doi Inthanon National Park, Chiang Mai, characterized by its tuberculate-pilose leaves with a lower glume that has 10–14 distinct nerves and transverse hump on the lower 1/3 of the glume. It is similar to I. indicum (Houtt.) Merr. in having glabrous surface on the back of the lower glume of sessile spikelets but differing in the unequal narrow lateral wings above and hairs on both leaf surfaces. The lower glume of the sessile spikelet in the Thai specimens has a transverse, nearly flat hump on the lower 1/3 of the glume although the hump is slightly convex on the back in the type specimen from India. So far, this species has been found at high altitude in India and Thailand and seems to be a member of the Indo-Burmese elements, but no Burmese collection yet. Further work in this area is needed.

M. striata var. pubescens is found in north, north-eastern, eastern, south-western and peninsular Thailand. Hairy forms of M. striata are segregated at the varietal level in the treatment of the subtribe Rottboelliinae in this study, however this variety is a first record for the country.

There are two species in Ischaeminae and four species in Rottboelliinae which are expected to be new species.

1. Ischaemum sp.1 resembles I. barbatum in lower glume of the sessile spikelet. However, the latter is easily distinguished by the presence of coarsely ridge more than one across the back or with 2 or more nodules along the margins. I. sp. 1 has pubescent leaf-blade on both surface, margins recurved or folded while I. barbatum has flattened leaf-blade, both surface glabrous to pilose.

2. I. sp.2 is similar to I. lacei, but can be distinguished by its glabrous of leaf blade, while the leaf-blade of I. lacei is pilose with tubercle-based hairs on both surfaces.

3. Eremochloa sp.1 is very closely related to E. maxwellii but differs considerably in having obovate with a long cordate pedicel, while obliquely-lanceolate pedicel in E. maxwellii. This species is collected from the north-eastern Thailand.

4. Eremochloa sp.2 resembles E. muricata, but can be distinguished from the latter in having a subulate pedicel, while an obliquely obovoid pedicel in E. muricata. This species is only found in Phu Kradueng, Loei.
5. *M. thailandica* P. Traiperm & T. Boonkerd (ined.) is distinguished by the appressed hairs on the inflorescence. It is similar to *M. geminata* in Malaysian species, but differs in having a small erect and slender culm, ca. 26 cm tall. The species has pubescent hairs on the back of the triangular lower glume, rachis nodes, pedicels and rachis internode, while *M. geminata* has lower glume lanceolate, covered with hairs below and glabrous on rachis nodes, pedicels and rachis internode.

6. *M. sp.1* is closely related to *M. striata* in having the lower glume of the sessile spikelet oblong, indurate, 5–5.5 by 1.2–1.5 mm; apex with unequal winged, 7–8 longitudinal rows of small pits between the nerves of the back, margins at base puberulous, while the lower glume of the sessile spikelet ovate, indurate, 4.5–5 by ca. 1.5 mm, apex with 2 apical wings, continuously ridged along the length and interrupted by tubercles or tubercle-based hairs on the back or glabrous in *M. striata*.

### 5.3.4 Comparison with other works

Comparison of the previous studies (Table 5.3), there are eight taxa which are additionally reported from this study, namely *Ischaemum hubbardi, I. sp.1, I. sp.2, Eremochloa sp.1, E. sp.2, Mnesithea striata var. pubescens, M. thailandica* and *M. sp.1*. Seven misidentified taxa are found in this study, e.g., *I. mangaluricum* (*I. babartum*), *Sehima sulcatum* (*Andropogon sp.*), *E. zeylanica* (*E. bimaculata*), *M. geminata* (*M. mollicoma*), *Ophiuros bombaiensis* (*M. laevis*), *O. megaphyllus* (*O. exaltatus*) and *Thaumastochloa cochinchinensis* (*M. laevis*).

Nanakorn & Norsaengsri (2001) reported the occurrence of 52 species of the two subtribes in Thailand. However, two species which they previously mentioned, *Ischaemum angustifolium* (Hack.) and *I. fieldingianum* Rendle, can not collect even from their original localities. Furthermore there is no specimen under these names, deposited in any herbaria in Thailand or overseas. It is probably due to missed identified.
Table 5.3 Comparative treatment of Ischaeminae and Rottboelliiinae by some authors.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Nanakorn &amp; Norsaengsri 2001</th>
<th>Buitenbui &amp; Veldkamp 2001</th>
<th>Present study</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Apluda mutica</td>
<td>/</td>
<td></td>
<td>/</td>
</tr>
<tr>
<td>2. Ischaemum angustifolium ***</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>3. I. aristatum</td>
<td>/</td>
<td>/</td>
<td>=I. barbatum Retz.</td>
</tr>
<tr>
<td>4. I. barbatum</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>5. I. barbatum var. glaberrimum</td>
<td>/</td>
<td>/</td>
<td>=I. barbatum Retz.</td>
</tr>
<tr>
<td>6. I. barbatum var. lodiculare</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>7. I. fieldingianum ***</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>8. I. hansenii</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>9. I. hirtum</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>10. I. hubbardii</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>11. I. indicum</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>12. I. lacei</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>13. I. magnum</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>14. I. mangaluricum **</td>
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<td>16. I. rugosum</td>
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<tr>
<td>17. I. tenuifolium</td>
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<td>/</td>
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<tr>
<td>31. E. bimaculata</td>
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<td>32. E. ciliaris</td>
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Table 5.3 Comparative treatment of Ischaeminae and Rottboelliinae by selected authors (Cont.).

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<tr>
<th>Taxa</th>
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<th>Buitenhu &amp; Veldkamp 2001</th>
<th>Present study</th>
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<td>34. <em>E. eriopoda</em></td>
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<td>35. <em>E. lanceolata</em></td>
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<tr>
<td>36. <em>E. maxwellii</em></td>
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<td>37. <em>E. muricata</em></td>
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<td>38. <em>E. pelletotti</em> Merr.</td>
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<td>41. <em>E. sp.2</em></td>
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<td>42. <em>H. granularis</em></td>
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<td>44. <em>Hemarthria altissima</em></td>
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<td>46. <em>H. debilis</em> Bor</td>
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<td>47. <em>H. longiflora</em></td>
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<td>= <em>H. pratensis</em></td>
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<tr>
<td>51. <em>Mnesithea cancellata</em></td>
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<td>52. <em>M. geminata</em> **</td>
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<td>53. <em>M. glandulosa</em></td>
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<td>55. <em>M. laevis</em></td>
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<td>56. <em>M. merquensis</em></td>
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<td>57. <em>M. mollicoma</em></td>
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<td>58. <em>M. striata</em></td>
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<td>59. <em>M. striata var. pubescence</em></td>
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<td>60. <em>M. thailandica</em></td>
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<td>61. <em>M. sp.1</em></td>
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<td>62. <em>Opisthura bombaiensis</em> **</td>
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<td>63. <em>O. exalatus</em></td>
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Table 5.3 Comparative treatment of Ischaeminae and Rottboellini inae by some authors (Cont.).

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Nanakorn &amp; Norsaengsri 2001</th>
<th>Buitenhui &amp; Veldkamp 2001</th>
<th>Present study</th>
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<tr>
<td>64. <em>O. megaphyllus</em></td>
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<td>--</td>
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<tr>
<td>65. <em>Phaceurus cambogiensis</em></td>
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<td>/</td>
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<tr>
<td>66. <em>P. zea</em></td>
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</tr>
<tr>
<td>67. <em>Rottboellia cochinchinensis</em></td>
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<td>/</td>
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<tr>
<td>68. <em>Thaumastochloa cochinchinensis</em></td>
<td>/</td>
<td>--</td>
<td>misidentified</td>
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<tr>
<td>69. <em>Vossia cuspidata</em></td>
<td>/</td>
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<td>/</td>
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<tr>
<td><strong>Total taxa</strong></td>
<td><strong>52</strong></td>
<td><strong>51</strong></td>
<td></td>
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</table>

* indicate newly repoted taxa, ** = misidentifed taxa, *** = taxa which can not be found the specimen cited to its scientific name, / = present and – = absent.

5.3.5 A taxonomic problems in some genera and species

**Coelorachis Brongn. & Mnesithea Kunth**

*Mnesithea* has been described previously by the presence of 2 sessile spikelets separated by a pedicel at each rachis node, but this character is now known to be variable. Furthermore, in the present study a pair of sessile spikelets also occur sporadically in the racemes of species that normally have single sessile spikelets.

The genus *Coelorachis* Brongn. differs from the other genera by a free of pedicel and a presence of the pedicelled spikelet, but these characters are unstable. It was found that the lower part are partially or completely fused to the rachis node in several species of *Coelorachis*. The pedicelled spikelet varies from well developed to minute vestige, and its absence in traditional *Mnesithea* is just the final step. Hence, Veldkamp et al. (1986) has treated the genus *Coelorachis* as a synonym of *Mnesithea* Kunth. The result from this present study also support their treatment.

**Hackelochoa Kuntze & Mnesithea Kunth**

*Hackelochoa* Kuntze, a genus of the Old World tropics. There are two species: *H. granularis* (L.) O. Kuntze and *H. porifera* (Hack.) Rhind. Veldkamp et al. (1986) combined *Hackelochoa* with *Mnesithea* despite their morphological
differences and the aberrant basic number of the chromosome count from *Mnesithea* (Pohl & Davidse, 1971). In this study I treated *Hackelochloa* as distinct genus based on its globose sessile spikelets with wingless lower glumes.

**H. granularis** (L.) O. Kuntze. & *H. porifera* (Hack.) D. Rhind

According to Veldkamp et al. (1986) the species *H. porifera* has been treated as a synonym of *H. granularis* because they failed to find any representative specimen in the Rijsherbarium and they did not except the different characters of *H. porifera* from *H. granularis* such as robust plant, large-spikelet. After collecting two living specimens and compared with the type specimens of the two species. The type material of *H. porifera* at K, collected from India by C.B. Clarke 9752-A (Sikkim, Darjeeling, isotype), showed apparently fairly robust plant with indeed large sessile spikelets with prominent sculpture on lower glumes (Table 5.4). Therefore, I retain *H. porifera* and *H. granularis* as distinct species as was noted by Bor (1960).

Table 5.4 Comparison of some morphological characters of *H. granularis* and *H. porifera*.

<table>
<thead>
<tr>
<th>Characters</th>
<th><em>H. granularis</em></th>
<th><em>H. porifera</em></th>
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</thead>
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<tr>
<td>Habit</td>
<td>culms erect, 15–80 cm tall</td>
<td>culms erect, 50–200 cm tall</td>
</tr>
<tr>
<td>Leaf-blade</td>
<td>linear, 2–13 by 1–1.5 cm</td>
<td>broadly linear, 5–30 by 1–2.5 cm</td>
</tr>
<tr>
<td>Inflorescence</td>
<td>1–5 racemes, each raceme 5–15 mm long, peduncle 10–30 mm long</td>
<td>2–4 racemes, each raceme 2.5–4.5 cm long, peduncle 3–8 cm long</td>
</tr>
<tr>
<td>Size of the lower glume of the sessile spikelet</td>
<td><em>ca.</em> 1.5 mm diam.</td>
<td><em>ca.</em> 2.5 mm long</td>
</tr>
<tr>
<td>Sculpture on the lower glume of the sessile spikelet</td>
<td>pitted and tubercled on the back</td>
<td>ridged and reticulate on the back</td>
</tr>
</tbody>
</table>

*Ischaemum indicum* (Houtt.) Merr.

The extreme variations of hairiness and size and form of an apical wings in lower glume of the sessile spikelet are certainly distinct (Bor, 1960). However, they are connected by a complete series of intermediates. So it seems better not to divide
this species into a number of infraspecific species at present, but a monographic study is needed to clear the taxonomic status of this species.

5.3.6 Lectotypification

The Lectotypification of five taxa in the subtribe Ischaeminae are made. They are *Ischaemum aristatum* subsp. *imberbe* var. *imbricatum* (synonym of *I. barbatum*), *I. aristatus* var. *arfakense* (synonym of *I. barbatum*), *I. lacei*, *I. magnum* and *I. macrurum* (synonym of *I. timorense*).

5.3.7 New combination

Careful examination of recent collections of *I. tenuifolium* proved that this species does indeed belong to the genus *Andropogon*. The plants have digitate racemes, 3–7 racemes, 6–12 cm long, borne upon subequal flattened raceme-bases and the lower glume of sessile spikelet concave. These are all diagnostic features of *Andropogon* (Clayton & Renvoize, 1986). This study also presented a detailed anatomical description of the genus but these species fail to conform completely to the general pattern in the genus *Ischaemum*. So, *I. tenuifolium* is transferred to be a member of the genus *Andropogon*.

5.3.8 New Synonymy

Bor (1962a) described a new variety of *I. barbatum* from Chiang Mai: Doi Suthep, northern Thailand as *I. barbatum* var. *glaberrimum*. After carefully studied the types of the species and variety I found that they are conspecific. Therefore, the latter variety is reduced to a synonym of the former.
Figure 5.27  *Apluda mutica*: A. habit. *Ischaemum barbatum* var. *barbatum*: B. & C. inflorescence. *I. barbatum* var. *lodiculare*: D. inflorescence.
Figure 5.28 A-C. *Ischaemum hansenii*: A. plant; B. inflorescence; C. spikelet in pairs.

D-F. *I. hirtum*: D. plant; E. partial inflorescence; F. spikelet in pairs.
Figure 5.29 A. & B. *Ischaemum hubbardii*: A. habit; B. inflorescence. C-E. *I. indicum*: C. habit; D. inflorescence; E. partial inflorescence.
Figure 5.30  A. & B. *Ischaemum lancei*: A. plant; B. inflorescence. C-E. *I. magnum*: C. plant; D. inflorescence; E. spikelet in pairs.
Figure 5.31  A. & B. *Ischaemum muticum*: A. habit; B. inflorescence. C-E. *I. rugosum*: C. habit; D. inflorescence; E. partial inflorescence.
Figure 5.32 A-C. *Ischaemum timorense*: A. plant; B. inflorescence; C. partial inflorescence. D. & E. *I.* sp.1: D. habit; E. inflorescence.
Figure 5.33 A-B. Kerriochloa siamensis: A. habit; B. partial inflorescence. C-E. Sehima nervosum: C. habit; D. & E. partial inflorescence. F-I. Thelepegon elegans: F. habit; G. leaf-sheath and leaf blade; H. partial inflorescence; I. inflorescences.
Figure 5.34 A-C. *Eremochloa attenuata*: A. plant; B. partial inflorescence; C. lower glume, upper glume and joint with pedicelled spikelet. D-F. *E. bimaculata*: D. habit; E. partial inflorescence; F. reversed of partial inflorescence.
Figure 5.35 A-D. *Eremochloa ciliaris*: A. habit; B-D. inflorescence. E-G. *E. ciliatifolia*: E. habit; F. partial inflorescence; G. lower glume, upper glume and joint with pedicelled spikelet.
Figure 5.36 A-C. *Eremochloa eriopoda*: A. habit; B. inflorescence; C. lower glume, upper glume and joint with pedicelled spikelet. D-F. *E. lanceolata*: D. habit; E. inflorescence; F. lower glume, upper glume and joint with pedicelled spikelet.
Figure 5.37 A-C. *Eremochloa maxwellii*: A. habit; B. partial inflorescence; C. lower glume, upper glume and joint with pedicelled spikelet. D. & E. *E. muricata*: D. plant; E. lower glume, upper glume and joint with pedicelled spikelet. F. & G. *E. peltelotii* F. partial inflorescence; G. lower glume, upper glume and joint with pedicelled spikelet.
Figure 5.38 A-C. *Eremochloa* sp.1: A. habit; B. partial inflorescence; C. lower glume, upper glume and joint with pedicelled spikelet. D-F. *Eremochloa* sp.2: D. habit; E. inflorescence; F. lower glume, upper glume and joint with pedicelled spikelet.
Figure 5.39  A. & B. Hackelochloa granularis: A. habit; B. inflorescence. C-E. H. porifera: C. habit; D. & E. inflorescence.
Figure 5.40 A-D. *Hemarthria altissima*: A. plant; B. partial inflorescence; C. lower glume of sessile spikelet; D. lower glume and upper glume of pedicelled spikelet. E-J. *H. compressa*: E. habit; F. inflorescence; G. & H. partial inflorescence; I. lower glume of sessile spikelet; J. lower glume and upper glume of pedicelled spikelet.
Figure 5.41  A-E. *Hemarthria debilis*: A. plant; B. partial inflorescence; C. lower glume and upper glume of sessile spikelet; D. reverse of lower glume and upper glume of sessile spikelet; E. lower glume and upper glume of pedicelled spikelet. F-J. *H. longiflora*: F. plant; G. partial inflorescence; H. varies of lower glume of sessile spikelet; I. variations of lower glume of pedicelled spikelet; J. reversed of lower glume of pedicelled spikelet.
Figure 5.42 A-F. *Hemarthria pratensis*: A. habit; B. partial inflorescence; C. & D. partial inflorescence; E. lower glume of sessile spikelet; F. lower glume and upper glume of pedicelled spikelet. G-I. *H. stolonifera*: G. plant; H. lower glume of sessile spikelet; I. lower glume and upper glume of pedicelled spikelet.
Figure 5.43 A. & B. *Mnesithea cancellata*: A. habit; B. partial inflorescence. C-E. *M. glandulosa*: C. habit; D. inflorescence; E. partial inflorescence.
Figure 5.44 A. & B. *Mnesithea helferi*: A. habit; B. partial inflorescence. C-E. *M. laevis*: C. habit; D. & E. partial inflorescence.
Figure 5.45 A-C. *Mnesithesa mollicoma*: A. plant; B. young inflorescence; C. partial inflorescence. D-F. *M. striata*: D. habit; E & F. partial inflorescence.
Figure 5.46 A-D. *Mnesithea thailandica*: A. plant; B. inflorescence; C. spikelets with a joint; D. pedicel with pedicelled spikelet and lower glume of the sessile spikelet. E-G. *M*. sp.1: E. habit; F. inflorescence; G. partial inflorescence.
**Figure 5.47** A-C. *Ophiuros exaltatus*: A. plant; B. partial raceme; C. lower glume of sessile spikelet and joint. D-F. *Phacelurus cambogiensis*: D. plant; F. partial inflorescence; G. spikelet in pairs.
Figure 5.48 A-D. *Phacelurus zea*: A. habit; B. partial raceme; C. panicle inflorescence; D. partial raceme. E-G. *Rottboellia cochinchinensis*: E. habit; F. inflorescence; G. partial inflorescence.
Figure 5.49 *Vossia cuspidata*: A. whole plant; B. partial inflorescence.
Figure 5.50 Distribution of *Apluda mutica* (A), *Ischaemum barbatum* (B), *I. barbatum* var. *lodiculare* (C) and *I. hansenii* (D).
Figure 5.51 Distribution of *Ischaemum hirtum* (A), *I. hubbardii* (B), *I. indicum* (C) and *I. lacei* (D).
Figure 5.52 Distribution of *Ischaemum magnum* (A), *I. muticum* (B), *I. rugosum* (C) and *I. tenuifolium* (D).
Figure 5.53 Distribution of *Ischaemum timorense* (A), *I*. sp. 1 (B), *I*. sp. 2 (C) and *Kerriochloa siamensis* (D).
Figure 5.54 Distribution of *Sehima nervosum* (A), *Thelepogon elegans* (B), *Eremochloa attenuata* (C) and *E. bimaculata* (D).
Figure 5.55 Distribution of *Eremochloa ciliaris* (A), *E. ciliatifolia* (B), *E. eriopoda* (C) and *E. lanceolata* (D).
Figure 5.56 Distribution of *Eremochloa maxwellii* (A), *E. muricata* (B), *E. peltelotii* (C) and *E. sp.1* (D).
Figure 5.57 Distribution of *Eremochloa* sp. 2 (A), *Hackelochloa granularis* (B), *H. porifera* (C) and *Hemarthria altissima* (D).
Figure 5.58 Distribution of *Hemarthria compressa* (A), *H. debilis* (B), *H. longiflora* (C) and *H. pratensis* (D).
Figure 5.59 Distribution of *Hemarthria stolonifera* (A), *Mnesithea cancellata* (B), *M. glandulosa* (C) and *M. helferi* (D).
Figure 5.60 Distribution of *Mnesithea laevis* (A), *M. mollicoma* (B), *M. striata* (C) and *M. striata* var. *pubescens* (D).
Figure 5.61 Distribution of Mnesithea thailandica (A), M. sp. 1 (B), Ophiuros exaltatus (C) and Phacelurus cambogiensis (D).
Figure 5.62 Distribution of *Phacelurus zea* (A), *Rotboellia cochinchinensis* (B) and *Vossia cuspidata* (C).
CHAPTER VI

GENERAL CONCLUSION

A preliminary taxonomic account of both subtribes is presented. Thirteen genera, 49 species and 2 infraspecific taxa are enumerated and described. Among these, *Ischaemum* (13 species and 1 infraspecific taxa) and *Eremochloa* (11 species) are the two largest genera. The members of both subtribes generally are found along roadsides, in paddy fields, swampy areas, near streams, savannas, deciduous forest, beach forest, dipterocarp forest, secondary forest, evergreen forest and pine forest from sea level to 2,350 m. Of these, *Apluda mutica, Ischaemum indicum, I. rugosum, Mnesithea glandulosa* and *Rottboellia cochinchinensis* are common as they are found in all floristic regions in Thailand. However, 12 species are endemic and rather have a restricted distribution.

One new combination of the genus *Andropogon* L.: *I. tenuifolium* (A. Camus) P. Traiperm & T. Boonkerd (ined.) is made. Two taxa, *Ischaemum hubbardi* and *Mnesithea striata* var. *pubescens* are newly recorded for the country. A variety i.e. *Ischaemum barbatum* var. *glaberrimum* was treated as synonym of *I. barbatum*. Five taxa of *Ischaemum*, i.e. *I. aristatum* subsp. *imberbe* var. *imbricatum*, *I. aristatus* var. *arfakense*, *I. lacei*, *I. magnum* and *I. macrurum* are lectotypified.

It is expected that six species in the genera *Ischaemum*, *Eremochloa* and *Mnesithea* are new species. (1) *Ischaemum* sp.1 resembles *I. barbatum* in the lower glume of the sessile spikelet. However, the latter is easily distinguished by having more than one coarse-ridge across the back of the lower glume of the sessile spikelet and by the two or more nodules along the margins. *Ischaemum* sp. 1 has a leaf-blade pubescent on both surfaces, and margin recurved or folded; while *I. barbatum* has a flat leaf-blade, which is glabrous to pilose on both surfaces. It was found at Khao Soi Dao, Chanthaburi and Khao Panom Bencha, Krabi. The molecular study showed that these two species are in the same clade with a moderate bootstrap support of 78%, therefore *Ischaemum* sp.1 can be proposed as a new species or a new variety of *I. barbatum*. (2) *Ischaemum* sp.2 is similar to *I. lacei*, but can be distinguished by its glabrous leaf blade, whereas the leaf-blade of *I. lacei* is pilose with tubercle-based hairs on both surfaces. It was only found at Phu Khao Yah National Park, Ranong.
the molecular results, \( I. \) sp.2 is also in the same clade with \( I. \) indicum with weakly bootstrap support of 74%. Hence, \( Ischaemum \) sp.2 can be proposed as a new species or a new variety of \( I. \) indicum. (3) \( Eremochloa \) sp.1 is very closely related to \( E. \) maxwellii but differs considerably in having an obovate and long cordate pedicel as compare with the obliquely-lanceolate pedicel in \( E. \) maxwellii. This species is found in north-eastern Thailand. The results of the molecular study confirmed that \( Eremochloa \) sp.1 can be proposed as a new species, not a variety of \( E. \) maxwellii. (4) \( Eremochloa \) sp.2 resembles \( E. \) muricata, but can be distinguished from the latter by its subulate pedicel, in contrast to the obliquely obovoid pedicel in \( E. \) muricata. This species is only found at Phu Kradueng, Loei. (5) \( Mnesithea \) thailandica is distinguished by having appressed hairs on the inflorescence. It is similar to \( M. \) geminata, but differs in having a small, erect and slender culm, ca. 26 cm tall. The species has pubescent hairs on the back of the triangular lower glume, rachis nodes, pedicels and rachis internode, while \( M. \) geminata is lanceolate and hirsute on the lower glume below and glabrous on rachis nodes, pedicels and rachis internode. (6) \( Mnesithea \) sp.1 is closely related to \( M. \) striata. \( Mnesithea \) sp.1 is characterized by the lower glume of the sessile spikelet oblong, indurate, 5–5.5 by 1.2–1.5 mm, an apex with unequal wings, 7–8 longitudinal rows of small pits between the nerves of the back of the leaf blade, and margins at base puberulous. In contrast, \( M. \) striata has indurate ovate lower glume at the sessile spikelet, 4.5–5 by ca. 1.5 mm, the apex has 2 apical wings, and having continuous ridge along the length and interrupted by tubercles or tubercle-based hairs on the back or glabrous. The molecular analysis supported that \( Mnesithea \) sp.1 should be proposed as a new species in the genus \( Mnesithea \).

In comparison with a previous study of grass group in Thailand (Nanakorn & Norsaengsri, 2001), there are eight additional taxa reported from this study, namely \( Ischaemum \) hubbardii, \( I. \) sp.1, \( I. \) sp.2, \( E. \) sp.1, \( E. \) sp.2, \( M. \) striata var. pubescens, \( M. \) thailandica and \( M. \) sp.1. Seven misidentified taxa are re-determined and listed in this study, viz. \( Ischaemum \) mangaluricum (\( I. \) barbatum), \( Sehima \) sulcatum (\( Andropogon \) sp.), \( Eremochloa \) zeylanica (\( E. \) bimaculata), \( Mnesithea \) geminata (\( M. \) mollicoma), \( Ophiuros \) bombaiensis (\( M. \) laevis), \( O. \) megaphyllum (\( O. \) exaltatus) and \( Thaumastochloa \) cochinchinensis (\( M. \) laevis).

The epidermal peels and transverse sections of leaf-blades and culms have also been investigated in 25 species of the 12 genera from the two subtribes. It was
shown that a number of anatomical characters are taxonomically useful for separating the related genera in the subtribes Ischaeminae and Rottboelliinae of Thai grass: leaf blade outline, ribs and furrows on both surfaces, bulliform cells, midrib and keel, number of vascular bundles in the keel, shape of sclerenchyma at margins, intercostal long cells, papillae, prickles, macro-hairs, silica bodies, culm outline and central cavity in ground tissue of culm. However, this anatomical study does not support the previous segregation of the two subtribes Ischaeminae and Rottboelliinae. It also does not support the morphological classification system proposed by Clayton & Renvoize (1986).

The phylogenetic analysis of 44 samples from 38 taxa was conducted on non-coding chloroplast DNA trnL intron and trnL-F spacer and nuclear ribosomal internal transcribed spacer (ITS) sequence data. The Maximum Parsimony analysis was conducted using PAUP* 4.0b10. Both data sets were analyzed separately before being combined into a single data set. The analysis indicated that a combined ITS and trnL-F analysis strengthens the signal and also points to a non-monophyletic origin of both subtribes which correspond with previous studies (Kellogg & Watson, 1993). However, these two groups of subtribes do not support the subtribal designations by Clayton & Renvoize (1986). Two main lineages can be identified as identical to the analysis of trnL-F data, while the analysis of ITS provides evidence for phylogenetic examination of closely related taxa or among the species. The trnL-F and combined analyses suggest that Hemarthria, Hackelochloa and Eremochloa are monophyletic. Resolution within the Ischaemum and Mnesithea clades is rather weak to high bootstrap support showing that both genera are not monophyletic.

The taxonomic study suggested that *I. tenuifolium* belongs to the genus *Andropogon* instead of *Ischaemum*. The species has 3–7 digitate racemes, 6–12 cm long, borne upon sub-equal flattened raceme-bases, and the lower glume of sessile spikelet is concave, which are all diagnostic features of *Andropogon* (Clayton & Renvoize, 1986). This new combination is in agreement with the anatomical description of the genus, while the species fails to conform completely to the general pattern in the genus *Ischaemum*. In addition to this, the molecular analysis exhibits a poor bootstrap supported (<50%) topology of *I. tenuifolium* excluded from the genus *Ischaemum*.

The genus *Coelorachis* has been reduced as a synonym of *Mnesithea* by Veldkamp et al., (1986); this was confirmed by the present taxonomic study. In
several species of *Coelorachis* the lower part of pedicel is completely fused to the rachis node. The pedicelled spikelet varies from well developed to minute vestige, and its absence in traditional *Mnesithea* is just the final step. On the other hand, the analysis of the combined molecular data set demonstrates a weakly bootstrap supported clade to separate *M. laevis* from other *Mnesithea* species, and also the anatomical study emphasizes that there are some heterogeneity of these species within the genus. The analysis of the combined data set suggests the segregation of the genus *Mnesithea*, which corresponds to the classification system proposed by Clayton & Renvoize (1986).
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fluorescent in situ hybridization to study allopolyploid *Miscanthus* (Poaceae).


Goffinet, V. Hollowell & R. Magill (eds.), Molecular systematics of Bryophytes.


Triniuse, C.B. 1820. *Fundermenta Agrostographiae*. Sive theoria
Constructionisfloris graminei; adjecta synopsi generum graminum hucusque connitorum. 18, Vienmae.


APPENDICES
APPENDIX A

The floristic regions and provincial map of Thailand
The floristic regions and provincial map of Thailand

FLORISTIC REGIONS AND PROVINCES OF THAILAND

I. N (NORTHERN)
1. Mae Hong Son
2. Chiang Mai
3. Chiang Rai
4. Phayao
5. Nan
6. Lamphun
7. Lampang
8. Phrae
9. Uttaradit
10. Tak
11. Sukhothai
12. Phitsanulok
13. Kamphaeng Phet
14. Phichit
15. Nakhon Sawan

II. NE (NORTH-EASTERN)
16. Phetchabun
17. Loei
18. Nong Bua Lam Phu
19. Udorn Thani
20. Nong Khai
21. Sakon Nakhon
22. Nakhon Phanom
23. Mukdahan
24. Kalasin
25. Maha Sarakham
26. Khon Kaen

III. E (EASTERN)
27. Chaiyaphum
28. Nakhon Ratchasima
29. Buri Ram
30. Surin
31. Roi Et
32. Yasothon
33. Amnat Charoen
34. Sisaket
35. Ubon Ratchathani

IV. SW (SOUTH-WESTERN)
36. Uthai Thani
37. Kanchanaburi
38. Ratchaburi
39. Phetchaburi
40. Prachuap Khiri Khan

V. C (CENTRAL)
41. Chai Nat
42. Sing Buri
43. Lop Buri
44. Suphan Buri
45. Ang Thong
46. Phra Nakhon Si Ayutthaya
47. Saraburi
48. Nakhon Pathom
49. Pathum Thani
50. Nakhon Nayok
51. Nonthaburi
52. Krong Thep Maha Nakhon (Bangkok)
53. Samut Prakan
54. Samut Songkhram
55. Samut Sakhon

VI. SE (SOUTH-EASTERN)
56. Sa Kaeo
57. Prachuap Buri
58. Chachoengsao
59. Chon Buri
60. Rayong
61. Chanthaburi
62. Trat

VII. PEN (PENINSULAR)
63. Chumphon
64. Ranong
65. Surat Thani
66. Phangnga
67. Phuket
68. Krabi
69. Nakhon Si Thammarat
70. Phatthalung
71. Trang
72. Satun
73. Songkhla
74. Pattani
75. Yala
76. Narathiwat
APPENDIX B

Specimens examined in anatomical study
### Specimens examined in anatomical study

<table>
<thead>
<tr>
<th>Species</th>
<th>Localities</th>
<th>Voucher</th>
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</tr>
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<td></td>
<td>Khun Tan, Lampang</td>
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<td>Tarutao, Satun</td>
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<td>5. <em>I. rugosum</em></td>
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<td>Klang, Rayong</td>
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<td><strong>Subtribe Rottboellinae</strong></td>
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<tr>
<td>13. <em>E. lanceolata</em></td>
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<td>14. <em>Hackelochloa granularis</em></td>
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APPENDIX C

Specimens examined in molecular study
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APPENDIX D

Paraffin Method adapted from Thammathaworn (1995)
PARAFFIN METHOD ADAPTED FROM THAMMATHAWORN (1995)

Outline Paraffin Method

1. Fixation (FAA 70%) and Cutting specimens
2. Suctioning (24 hours)
3. Washing (alcohol 50% 3 times)
4. Dehydration (TBA series)
5. Infiltration
6. Embedding
7. Microtoming
8. Affixing section to slide
9. Prestaining and Staining
10. Mounting and Label

1. Fixation (FAA70%) and Cutting specimens
   Prepare FAA70% using formalin 5% v/v, glacial acetic acid 5% v/v and 70%ethyl alcohol 90% v/v, mix well. Pour FAA 70% in up to the ¾ make in a vial (small glass bottle) with a secure lid (called fixative vial). Then wash fresh specimens with tap water and then cut them into pieces, 1 cm. high, with a razor blade then immediately put the specimens into a fixative vial (now called specimen vial).

2. Suctioning
   This step ensures that the fixative and chemical substances in the next steps get into every cell of the specimen (especially a problem for plant cells which have a lot of air space and a lumen, e.g. aquatic plants). Place the specimen vial into the dessicator, which is connected to a vacuum pump. Suction at 25 in Hg Vac for about 30-60 minutes, until there are no more the air bubbles moving from the specimens, then keep the specimen vial at room temperature for at least 24 hours before moving to the next step.

3. Washing
   Rinse the specimens down with ethyl alcohol 50% for 3 times. Pouring fixative out into the “Used FAA” container then fill the vial with 50% alcohol, close the lid and gently move the vial around and pour the alcohol out, then fill the vial with 50% alcohol and leave the specimens in the alcohol for about 10 minutes. Repeat the washing 3 times.
4. Dehydration (Tertiary Butyl Alcohol (TBA) series)

2.1 Prepare the TBA grade I, II, III, IV and V as follows:

<table>
<thead>
<tr>
<th></th>
<th>TBA Grade (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Distilled water</td>
<td>50</td>
</tr>
<tr>
<td>Ethyl alcohol 95%</td>
<td>40</td>
</tr>
<tr>
<td>Tertiary Butyl Alcohol</td>
<td>10</td>
</tr>
<tr>
<td>Ethyl alcohol 100%</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total percentage of alcohol</strong></td>
<td><strong>50</strong></td>
</tr>
</tbody>
</table>

2.2 Rinse the specimens with the TBA series using the same method as used for washing. Leave the specimens in each TBA grade for 24 hours. Then rinse the specimens with absolute TBA and leave in absolute TBA for 24 hours then repeat the rinse with absolute TBA 3 times to ensure all water is removed and that the wax will be able to infiltrate the specimens.

5. Infiltration

5.1 Prepare the hot air oven at 56°C then leave the paraffin wax (Paramat, pastillated, melting point 56°C) in a beaker in the hot air oven to melt the wax.

5.2 Prepare a mixture of absolute TBA: paraffin oil (TBA: Oil) = 1:1 v/v.

5.3 Rinse the specimens with the TBA: Oil mixture and then leave the specimens in the mixture for about 1 hour at room temperature.

5.4 Pour the melted wax (from the hot air oven) into a cleaned vial (wax vial) and fill to about ¼ make in a vial and leave the wax to set at room temperature.

5.5 Take the specimens from the TBA: Oil mixture and place on top of the wax vial and cover it with some the same mixture then leave the wax vial in the hot air oven for 24 hours.

5.6 Repeat this step for each vial each time, pour the melted wax and mixture off into the “Used paraffin” paper container then quickly replace with pure fresh melted wax and then leave the vial in the oven for 24 hours.

5.7 Repeat step 6, 2 times.
6. Embedding

6.1 Prepare embedding paper base moulds (for specimens whose depth is more than 5 mm) or stainless steel base molds (for specimens whose depth is less than or equal to 5 mm). Place these and the plastic holder molds into the hot air oven.

6.2 Pour the melted wax into the base mould which is kept warm on the hotplate then take a specimen from the vial and put into the base mold containing melted wax.

6.3 Move the base mould from the hotplate to the table and then set the specimens upright (for transverse section cutting) using warm needles to manipulate them then put the plastic warm holder mould on top of the base mould to form a set and pour the melted wax on top until the set is full then leave at room temperature without moving the mold to let the wax set. After the wax in the paper base mold is set, take the paper off and trim the wax into a “cubic block”, which the specimens are in the center. For specimen whose depth is more than 5 mm, as unable to put the holder mold on top of the paper base mold, prepare the “block without specimens” (make the block using the set of stainless steel base mold and plastic holder without specimen in the wax) then stick the “block without specimen” together with the “cubic block” using a hot spatula touching each surface of the blocks to melt the wax and then press them to form one piece.

6.4 Trim the blocks into a trapezium shape.

6.5 Keep the blocks in refrigerator at least 15 minutes.

7. Microtoming

Cut the blocks on a sliding microtome with disposable blades, 10-15 μm thickness, set the clearance angle to 5°-10°. The thin pieces with specimens produced by cutting the block are called “sections or ribbons”.

8. Affixing section to slide

8.1 Melt 0.25 g of gelatin powder with 200 ml hot water in a beaker, then add 300 ml tap water and then put the beaker on the drying plate (50°C).

8.2 Put the section in the warm gelatin solution, keep the shiny surface up and then leave for a minute to extend the section.

8.3 Lift the section using a cleaned, twin frosted microscope slide and using needles arrange the position of the section on the slide as desired. Then leave the slide to stand beside the drying plate, to drain the solution, for a few minutes.
8.4 Keep the dry slides into the microscope slide case for 20 days (up to 5 months).

9. **Prestaining and Staining**

   As the stain (toluidine blue) is water based, it is necessary to remove the embedding wax from the sections before staining.

   9.1 Prepare toluidine blue stain using toluidine blue 0.5 g in tap water 100 ml, stir well, filter, paper then keep in bottle.

   9.2 Prepare a Coplin’s staining jar with solution of each step as follows: (Transferring the slides to other solutions in each step in the fume hood)

<table>
<thead>
<tr>
<th>Step</th>
<th>Solutions</th>
<th>Time in solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Absolute Xylene</td>
<td>10 mins</td>
</tr>
<tr>
<td>2</td>
<td>Absolute Xylene:Absolute alcohol = 1:1</td>
<td>3-5 mins</td>
</tr>
<tr>
<td>3</td>
<td>Absolute ether:Absolute alcohol = 1:1</td>
<td>3-5 mins</td>
</tr>
<tr>
<td>4</td>
<td>Absolute alcohol</td>
<td>3-5 mins</td>
</tr>
<tr>
<td>5</td>
<td>Alcohol 95%</td>
<td>3 mins-4 hrs</td>
</tr>
<tr>
<td>6</td>
<td>Alcohol 70%</td>
<td>up-down 3 times</td>
</tr>
<tr>
<td>7</td>
<td>Alcohol 50%</td>
<td>up-down 3 times</td>
</tr>
<tr>
<td>8</td>
<td>Alcohol 30%</td>
<td>up-down 3 times</td>
</tr>
<tr>
<td>9</td>
<td>Toluidine blue</td>
<td>2 hours</td>
</tr>
<tr>
<td>10</td>
<td>Wash with tap water in beaker</td>
<td>up-down 3 times</td>
</tr>
<tr>
<td>11</td>
<td>Alcohol 30%</td>
<td>up-down 3 times</td>
</tr>
<tr>
<td>12</td>
<td>Alcohol 50%</td>
<td>up-down 3 times</td>
</tr>
<tr>
<td>13</td>
<td>Alcohol 70%</td>
<td>up-down 3 times</td>
</tr>
<tr>
<td>14</td>
<td>Alcohol 95%</td>
<td>up-down 3 times</td>
</tr>
<tr>
<td>15</td>
<td>Absolute alcohol</td>
<td>up-down 3 times</td>
</tr>
<tr>
<td>16</td>
<td>Absolute Xylene:Absolute alcohol = 1:1</td>
<td>3-5 mins</td>
</tr>
<tr>
<td>17</td>
<td>Absolute Xylene</td>
<td>3-15 mins</td>
</tr>
</tbody>
</table>

10. **Mounting and Label**

   The slides can then be mounted permanently in DPX mountant for microscopy. Label slides with plant name, plant organ (leaf, scape), collector and collector number, transverse section, toluidine blue.
APPENDIX E

Molecular protocols and data matrix
MOLECULAR PROTOCOLS

Nina Rønsted 29.4.03

Isolation of total cellular DNA for long term storage


1. Preheat 10 ml of isolation buffer containing 40 µl of beta-mercaptoethanol in a 50 ml plastic centrifuge tube in a 65 °C water bath. Preheat mortar and pestle as well.

2. Grind 0.3 g of silica or freeze dried or 0.2 g of herbarium leaf material in a mortar. Add the buffer and grind until a uniform slurry is obtained. Return the slurry to the centrifuge tube and leave at 65 °C for 10 minutes as above.

3. Add 10 ml SEVAG to each tube. Mix gently and open cap slightly to release gas. Leave the tubes on their side on a shaker for 1 hour (½-1½).

4. Spin at 8000 rpm at 25°C for 10 minute (Beckman J2-MC centrifuge). Ideally the aqueous (top) phase will be clear and colourless.

5. Transfer aqueous phase containing DNA with a pipette to a 50 ml centrifuge tube. An aliquot of 300 µl can be taken off for QIA quick column cleaning at this stage. Dispose SEVAG and plant debris in waist container.

If long term storage is not needed. Amounts may be reduced or the centrifuge tube with DNA may be stored in a freeze for an unknown time.

Further cleaning for inclusion in the Kew DNA bank:

6. Add 2/3 volume of -20 °C isopropanol (herbarium sample) or 2 volume of -20 °C EtOH (Fresh, freeze, silica dried sample). Put in -20 °C freeze, for at least 24 hours to precipitate DNA.

7. Spin at 3000 rpm for 5 minutes, pour off liquid and add 3 ml of 70% ethanol, dislodge pellet to facilitate washing (Harrier 15/80 MSE centrifuge, Sanyo).

8. Spin down DNA at 3000 rpm for 3 minutes, pour off liquid and leave tube on its side overnight to allow alcohol to evaporate.
9. Resuspend DNA in 3 ml 1.5 mg/ml CsCl – EtBr solution. Cover samples in foil to keep dark (EtBr degrades in sunlight). Shake until pellet dissolves (min 24 hours).

10. Pour DNA into ultra centrifuge rotor tube. Add CsCl – EtBr until total weight is 8.04-8.06 g (this weight ensures a minimum of air between sample and lids in the ultra centrifuge used at Jodrell, Which is important to avoid damage to tubes and rotor at the high speed used).

11. Spin at 45000 rpm (at least 14 hours) or 58000 for 5 hours (Beckman Ultracentrifuge XL-80).

12. Please tubes with sample on ultra violet light box. Remove 600 μl of solution above band. Take of 1200 μl of the band and transfer to transparent tubes. (If it is not possible to see the band, the 1200 μl is taken off at the same level as the band in the other sample. The rest of the sample is saved until the final gel check of DNA has shown that the level taken off did contain the DNA). At this stage sample can be left in a dark place until further clean up.

13. Add an equal volume of CsCl satisfied butanol, shake and leave tubes on the side for 15 minutes to remove EtBr. Shake tubes gently occasionally.

14. Rinse a 5 litre beaker and fill to 2 litres with milli-Q water (4 litre for 20 or more sample s). Rinse 800 ml beaker and fill to 200 ml with milli-Q water.

15. Cut dialysis tubing into 10 cm strips and rinse in 800 ml beaker.

16. Clamp lower end of each piece of tubing and pipette samples (lower layer) into tubings. Clamp top end of tubings, avoiding air bubbles in the sample.

17. Place samples in the 5 ml beaker making sure the samples are kept under stirred water. The samples are left 2-4 hours.

18. The samples are then concentrated by transferring to a tray and adding sugar (purity unimportant). Leave samples for 20-40 min depending on how much samples need to be concentrated (to obtain about 1 ml).

19. Rinse out 5 litre breaker and add 25 ml dialysis buffer and 2 litre milli-Q water (or 50 ml and 4 litre water for 20 samples or more). Put samples into water and leave for 4 hours to overnight ensuring that they are kept under stirred water.

20. Repeat step 19 again.

21. Transfer samples into 1.5 ml eppendorf tubes. Check DNA levels on gel and store at -20 °C or 80 °C for long term storage (at least up to 10 year).
Isolation buffer: (2 x CTAB): 100 mM Tris-HCl, pH 8, 1.4 M NaCl, 20 mM EDTA, 2% CTAB (hexadecyltrimethylammonium bromide), 2% PVP.

Silica: Sigma S4883, 28-200 M

SEVAG: 24:1 chloroform:isoamylic alcohol

SSC satisfied BuOH: 1:1. BuOH:sodium citrate (0.15 molar NaCl & 0.015 molar sodium citrate)

Dialysis buffer 80X: 10mM Trizma® base, 1mM EDTA, pH adjusted to 8 by HCl.

Dialysis tuning: Cellulose membrane. Sigma cat.no. D-9277

CsCl (cesium chloride) and EtBr (ethidium bromide) are considered possible carcinogens and should be handled with gloves, disposable pipettes and tubes.

**QIAquick purification of total DNA**

Reference: QIAGEN QIAquick Spin Handbook 01/99 page 20-21. QIAquick PCR purification kit (250) QIAGEN Cat. No. 28106

1. Insert QIAquick columns into a vacuum manifold.
2. Add 750 µl Buffer PB and 150 µl of the total DNA and apply vacuum.
3. Repeat loading until all of the total DNA is passed through the column, always making sure to use
4. 5:1 volumes of Buffer PB to DNA extract.
5. Wash with 750 µl Buffer PE.
6. Switch vacuum off and transfer columns to the provided 2 ml collection tubes. Spin at 13,000 rpm for about 1 min to remove residual EtOH (PE Buffer).
7. Cut lids of sterilized 1.5 ml eppendorf tubes and place the QIAquick column into the tubes. Add 50 µl (or less depending on concentration of DNA) Buffer NE directly on the membrane of the columns and leave for 30 min to dissolve DNA in the elution buffer.
8. Spin 1 min at 13,000 rpm, cap tubes and store at -20 °C after checking DNA levels on gel.
Making an agarose gel

1. Tape sides of gel tray to hold the gel while setting, and place well forming combs.
2. Dissolve 1 g agarose in 100 ml TBE buffer in microwave for 1.5 min with loose lid. Shake gently after one min.
3. Let cool until not smoking. Add 4 µl EtBr and shake gently.
4. Pour into gel tray and leave for 20 min to set.
5. Place gel in eletrophoresis tray and cover with TBE buffer.

TBE buffer: 216 g Trizma® base, 110 g Boric acid, 16.6 g EDTA in 2 L Milli-Q water.
EtBr solution: 1 g EtBr in 100 ml water. Wrap in foil and stir for hours. Carcinogenic!

Gel check of DNA levels

1. Spot 5 µl of blue loading dye for each DNA sample on s strip of parafilm.
2. Mix 5 µl of DNA with the spot of dye and load the mix into a well on the gel.
   A standard can be loaded for reference.
3. Run for 10-20 min at 80 A.
4. View gel under UV light and photograph for later reference.

Loading dye: 40 g sucrose in 100 ml Milli-Q water, add 0.025 g bromophenol blue and stir to obtain a deep dark blue colour.

**QUICK COLUMN CLEAN PROTOCOL**

**Materials needed:**

3 Types of Buffer:
1. PB Buffer (alters pH)
2. PE Buffer (washing buffer) (NT3)
3. EB Buffer (elutes DNA through filter) (NE)
   - 300 µl of extracted sample in Eppendorf tubes
   - column tubes: pink in white(by blue “pig”)

1. **PB Buffer:** For this buffer there has to be a ratio 5 : 1 (5 parts of PB buffer to 1 part of DNA) = 750 µl PB : 150 µl DNA sample)
Number pink and white column tubes (each separately) with the sample numbers (1 to …)

Line up pink tubes onto pig; open levers underneath them (from horizontal to vertical position);

**Transfer 750 µl PB buffer and 150 µl** (using P1000 and P200 pipette accordingly) **of the sample** into pink column tube (=total of 900 µl). Mix well (by absorbing and releasing solution in tube with pipette).

(For transfer of buffer into all tubes, the same pipette tip can be used, but for transfer of sample a new pipette tip has to be used for each sample).

Turn on switch on wall and let solution run through column (approx. 1-2 min.).

**Repeat above** with second lot of sample (another 150 µl). Keep Eppendorf tubes, as they are needed again later.

2. PE Buffer

After second lot of sample with PB buffer has run through column. **Add 750 µl of PE buffer** to column (again, one pipette tip to used for all samples) and let run through column.

Then remove pink tubes from pig, close them and attach white lower tube part to it and put into small centrifuge (balancing sample equally in centrifuge). Let it spin approx. 1 min. (looking at your watch, as time switch on centrifuge has to be switch on to run, but does not stop at appropriate time; after a minute, press stop bottom and wait until green light comes on before opening centrifuge.)

Take out tubes from centrifuge and discard white lower tube with percipient into waste glass on desk.

3. EB Buffer

Put pink, column tubes into respective Eppendorf tubes. Cut off lid of Eppendorf tubes, but keep! Add **50 µl of EB buffer right into centre of white filter** at bottom of each pink column tube.

**Change pipette tip after each sample.**

Then close lids and let it sit for 1 minute for buffer to elude through filter. Then out both, pink column tubes inside Eppendorfs, into small centrifuge and spin for 1 min.
Stop centrifuge, and now you should have sample (approx. 48 µl) in Eppendorf tubes.

Discard of pink column tubes into waste glass, or waste bin. Finished!

4. **Run gel** to check DNA content of samples.
BIOGRAPHY

Miss Paweena Traiperm was born on November 24\textsuperscript{th}, 1978 in Ayutthaya Province. She earned her Bachelor Degree in Science in Biology from the Department of Biology, Faculty of Science, Khon Kaen University, Khon Kaen, in 2000. In 2003, she received her Master of Science in Botany from the Department of Botany, Faculty of Science, Chulalongkorn University, then continued her study in Biological Science Ph.D. Program, Faculty of Science, Chulalongkorn University from 2004-2007.