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, Mnesithea, 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 3.1 Anatomical characteristic of the subfamilies of the Poaceae (Ellis, 1986).

Subfamilies / Characters	POOIDEAE	BAMBUSOIDEAE	ARUNDINOIDEAE	CHLORIDOIDEAE	PANICOIDEAE
MIDRIB	median bundle only simple vasculature no adaxial parenchyma	keeled complex vasculature adaxial parenchyma rare	keeled or not simple vasculature no adaxial parenchyma	keeled or not simple vasculature adaxial parenchyma rare	keeled simple vasculature adaxial parenchyma common
CHLORENCHYMA	non-radiate diffuse (or compact) parenchyma cells	non-radiate compact(or diffuse) arm and fusoid cells	non-radiate compact (or diffuse) rachymorphous cells	strongly radiate uniform tabular cells rachymorphous cells	strongly or weakly radiate variable cells rachymorphous cells
INTERCOSTAL LONG CELLS	fusiform or rectangular straight walled or sinuous	rectangular sinuous walled	rectangular sinuous walled	rectangular sinuous walled	rectangular sinuous walled (rarely straight walled)
STOMATA	parallel sided guard cells sunken	triangular or domed guard cells flush	domed or triangular guard cells flush	triangular (rarely domed) guard cells flush	domed or triangular guard cells flush
PAPILLAE	absent	common cuticular many/cell	absent (rarely present)	common cuticular one/cell	common or absent inflated or cuticular one or many/cell
MICROHAIRS	absent	elongated, finger-like	elongated, finger-like	inflated, spherical	elongated, finger-like
SILICA BODIES	horizontally elongated oblong nodular	vertically elongated dumbbell, saddle, cross, olyroid	horizontally elongated square, oblong, cross, saddle, dumbbell	equidimensional saddle, square, angular, round,dumbbell	horizontally elongated dumbbell, cross, nodular

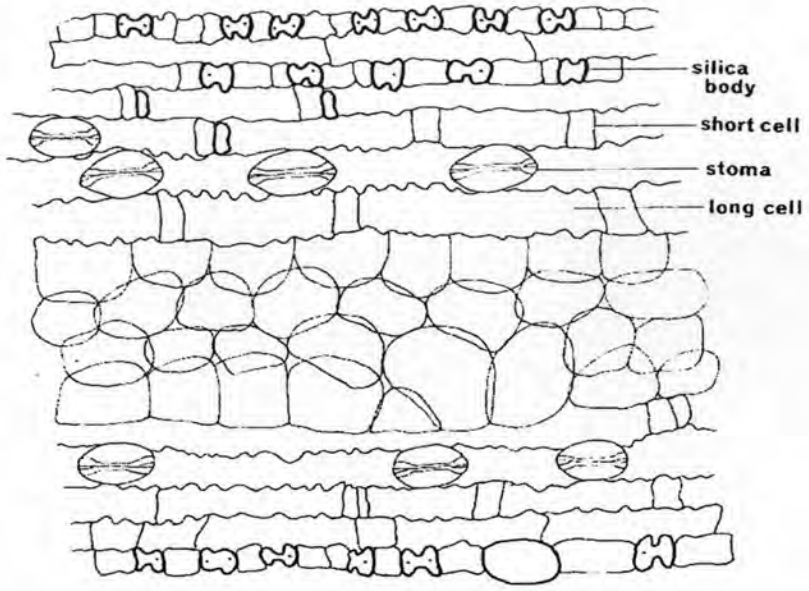

Figure 3.1 Upper epidermis of *Lasiurus scindicus* x 340 (after Renvoize, 1982).

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).

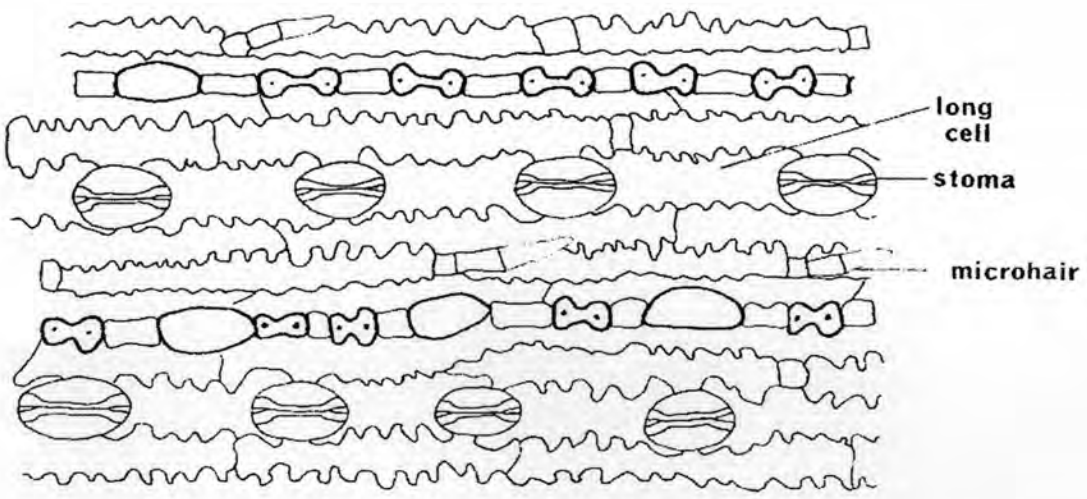

Figure 3.2 Lower epidermis of *Ischaemum afrum* x 340 (after Renvoize, 1982).

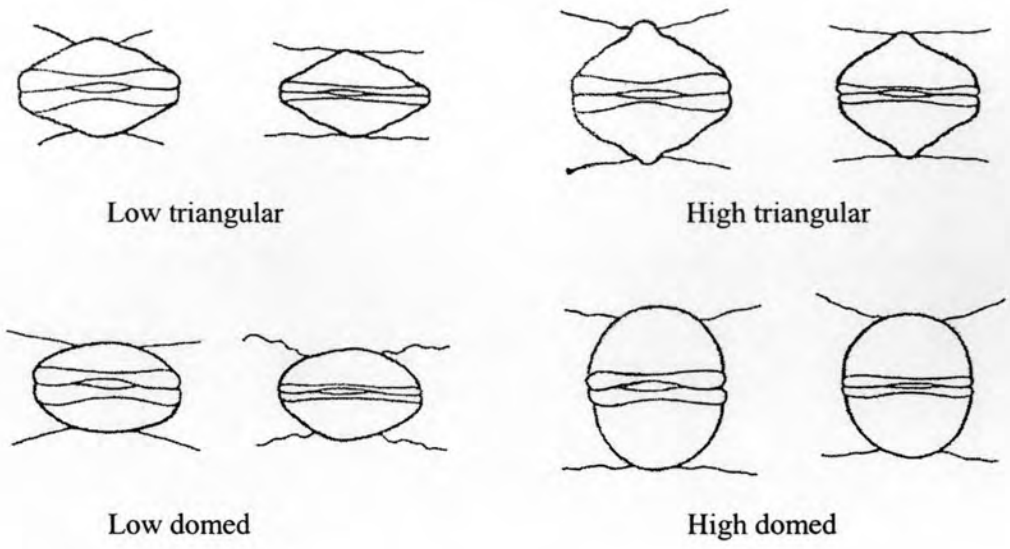

Figure 3.3 Shape of subsidiary cells in grass leaves (after Ellis, 1979).

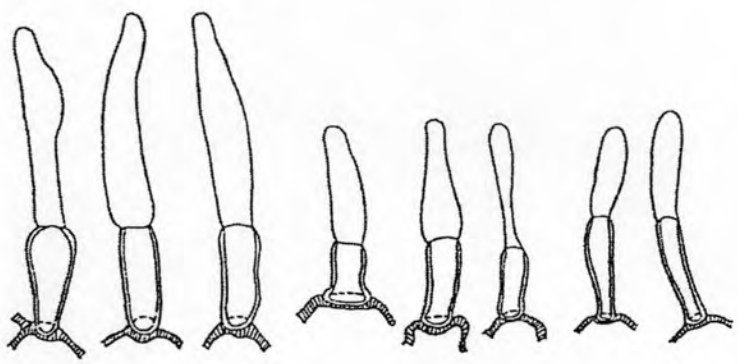

Figure 3.4 Shape of micro-hairs in grass leaves (after Metcalfe, 1960).

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).

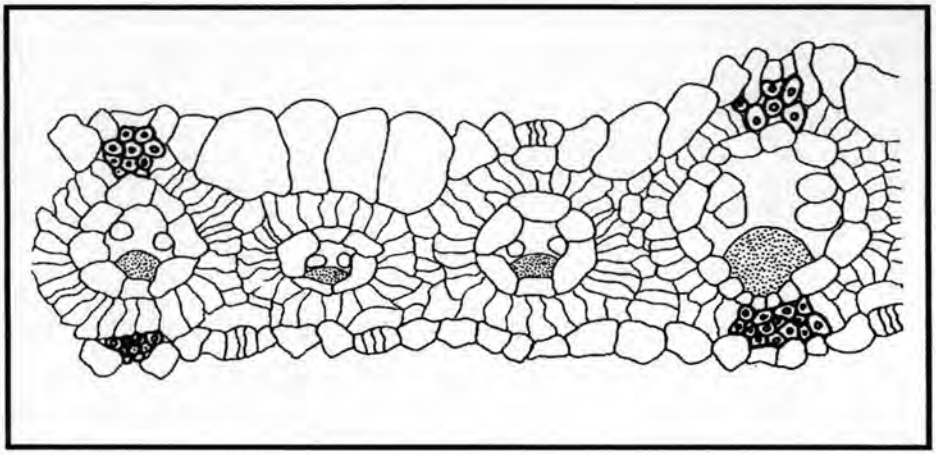

Figure 3.5 Transverse section of *Themeda triandra* x 340 (after Renvoize, 1982).

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, Eriochrysis, Eulalia, Eulaliopsis, Glyphochloa, Hemarthria, Heteropogon, Imperata, Miscanthus, Mnesithea, Ophiuros, Oxyrachis, Rhytachne, Saccharum, Spodiopogon, Thelepogon, Tripsacum* and *Zea* (Renvoize, 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.

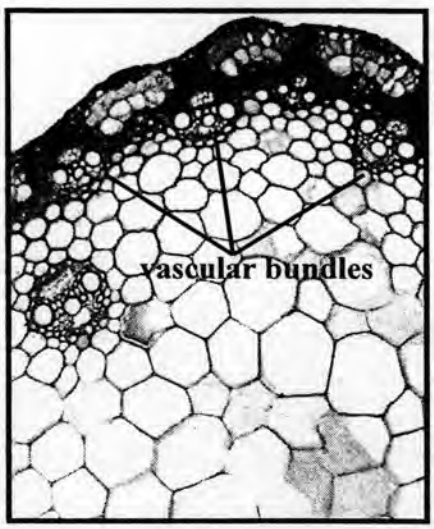

Figure 3.6 Transverse section of *Bouteloua hirsuta* culm internode showing vascular bundles arranged around the margin of a persistent central ground tissue (after Gould & Shaw, 1983).

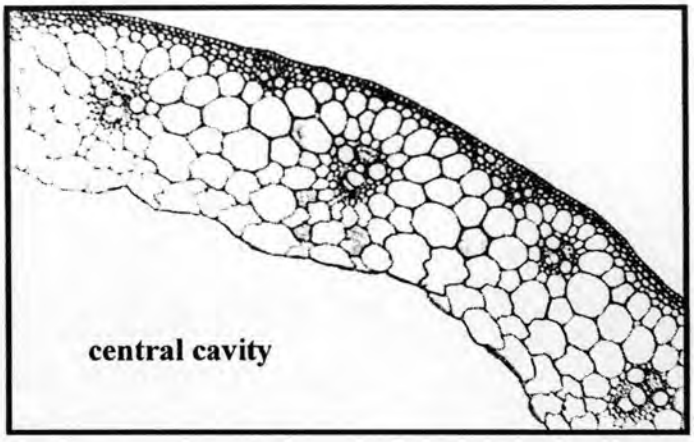

Figure 3.7 Transverse section of *Triticum aestivum* culm internode showing large central cavity (after Gould & Shaw, 1983).

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).

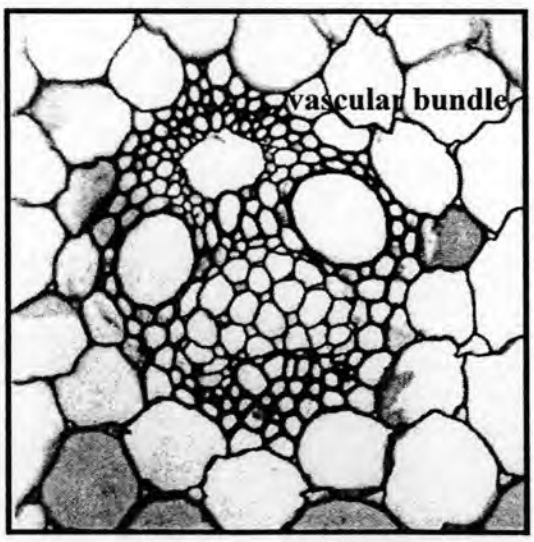

Figure 3.8 Transverse section of vascular bundle from culm of *Zea mays* (after Gould & Shaw, 1983).

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 μm 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 Rottboelliinae 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*: elonged 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 girder 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 girder 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 girder 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. *Prickle 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. *Prickle 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 ½ the vertical width of the long cells, more than one papillus per cell, same size and shape on individual cells but diferrence 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*: dumb-bell 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. *Prickle 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*: equidimentional, 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 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, 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 isodiametric.

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, 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 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 muticous 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 Rottboelliinae

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 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*: 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; 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. *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 isodiametric.

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; macro-hairs 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 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*: 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 girder 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. *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 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 isodiametric.

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 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; 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 isodiametric.

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 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*: 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 bulliform 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. *Costal short cells*: tall and narrow in shaped, smooth in outline.

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.

Leaf in transverse section (Fig. 3.29D-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; 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. *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, 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 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*: 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. 3.29G).

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 *Rottboellia*: 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 dumb-bell shaped silica bodies. *Papillae*: absent. *Prickle hairs*: present at the margins, 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 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 *Mnesithea laevis* having a shortened cell with deeply sinuous walls. Renvoize (1982) noted that the genus *Mnesithea* 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 *Mnesithea* 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 (Metcalfe, 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 *Thelepogon*, while this study found one to seven rows in *Hemarthria*, more than 10 rows in *Ophiuros* and up to 18 rows in *Thelepogon*. 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 *Ischaemum* but they are absent in *Apluda*, *Sehima* and *Thelepogon*. However, some species in the genus *Ischaemum*

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 Rottboelliinae.

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 Rottboelliinae 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 Rottboelliinae, 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 occured in all genera in subtribe Ischaeminae, except in genus *Thelepogon* 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*, *Ophiuros*, *Phacelurus* and *Rottboellia*. However, the degree of infolding or inrolling varies with the environment conditions and thus is not of much value diagnostically (Metcalfe, 1960).

The arrangement of the bulliform cells can be recognized in the subtribes Ischaeminae and Rottboelliinae 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 *Thelepogon* in Ischaeminae and *Eremochloa*, *Hackelochloa*, *Ophiuros* and *Phacelurus* in Rottboelliinae, while the second group comprised of *Apluda*, *Ischaemum* and *Sehima* in subtribe Ischaeminae and *Hemarthria*, *Mnesithea* and *Rottboellia* in subtribe Rottboelliinae.

The midrib of *Thelepogon* 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 Rottboelliinae, 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 hubbardii*, *Eremochloa bimaculata* and *Phacelurus zea*.

The genus *Ischaemum* from the subtribe Ischaeminae and genus *Eremochloa* and *Hemarthria* form the subtribe Rottboelliinae 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 Rottboelliinae 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 Rottboelliinae 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.

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

Table 3.3 The main anatomical differences separating the species in the genus *Ischaemum*.

Genus / Characters	*I. hirtum*	*I. hubbardii*	*I. muticum*	*I. rugosum*	*I. tenuifolium*	*I.* sp.1
Leaf anatomy						
Midrib	conspicuous, triangular-shaped	conspicuous, triangular-shaped to slightly round	conspicuous, triangular-shaped	inconspicuous	conspicuous triangular to round-shaped	conspicuous or inconspicuous, triangular-shaped
Ribs and furrows	absent	absent	absent	present on both surfaces	present on adaxial surface	absent
Number of vascular bundles in the keel	> 6	> 6	> 6	1	3-6	5
Papillae	present on abaxial surface	present on abaxial surface	present on abaxial surface	present on adaxial surface	absent	present on abaxial surface
Macro-hairs	present	present	absent	present	absent	present
Culm anatomy						
Pith cavity	present, somewhat irregular-shaped	present, somewhat circular-shaped	present, somewhat irregular-shaped	present, somewhat circular-shaped	absent	not seen

Table 3.4 Comparative anatomical features of genera in subtribe Rottboelliinae.

Genus / Characters	*Eremochloa*	*Hackelochloa*	*Hemarthria*	*Mnesithea*	*Ophiuros*	*Phacelurus*	*Rottboellia*
Leaf anatomy							
Leaf blade outline	standard V-shaped, 45-90°	two halves of lamina curved upwards on either side of the midrib	infolded, two halves of lamina curved upwards on either side of median bundle, two arms forming an incomplete narrow ellipse	two halves of lamina curved upwards on either side of the midrib or open V-shaped	two halves of lamina curved upwards on either side of the midrib formed U-shaped, tall and narrow	two halves of lamina wided very open V-shaped, more than 90° to each other	two halves of lamina folded toward each other on either side of the midrib formed standard V-shaped, 90° to each other
Ribs and furrows	absent, except *E. attenuata*, present on both surface, a quarter to one half of the leaf thickness	absent	absent or present on adaxial surface with no regular pattern in *He. compressa*.	absent	absent	absent	nodular on adaxial surface
Bulliform cells	arranged in irregular groups	arranged in irregular groups	simple fans or arranged in irregular groups	simple fans or arranged in irregular groups	arranged in irregular groups	arranged in irregular groups	simple fans
Midrib	conspicuous, rounded, triangular or v-shaped	conspicuous, triangular-shaped	conspicuous, rounded or U-shaped or inconspicuous	conspicuous, V-shaped, triangular, rounded or semicircular-shaped	conspicuous, rounded or semicircular-shaped	very conspicuous, elongated U-shaped	conspicuous, rounded or semicircular-shaped
Number of vascular bundles in keel	1	5	1 to > 6	1 to > 6	> 6	> 6	> 5
Sclerenchyma at margins	curved or crescent-shaped	point-cap shaped	point-cap shaped	point-cap shaped except, crescent-shaped in *M. laevis*	point-cap shaped	point-cap shaped	point-cap shaped
Abaxial intercostal long cells	elongated cells, moderately to deeply undulating	elongated cells, deeply undulating	elongated cells, moderately to deeply undulating	shortened to elongated cells, slightly to deeply undulating	elongated cells, moderately undulating	elongated cells, deeply undulating	elongated cells, deeply undulating
Abaxial intercostal short cells	paired	paired	paired	solitary or paired	paired	paired	solitary, rarely paired
Papillae	absent	absent	absent	absent	absent	absent	absent
Prickles	absent	absent	absent	absent	absent	absent	present on both surfaces, common on adaxial suface
Macro-hairs	present or absent	Present	absent	present or absent	absent	absent	Absent
Abaxial silica bodies	dumb-bell or intermediate between cross and dumb-bell shaped, relatively short, not elongate	dumb-bell shaped, relatively short, not elongate	intermediate between cross and dumb-bell shaped, relatively short, not elongate	dumb-bell or transverse dumb-bell shaped, relatively short, not elongate	intermediate between cross and dumb-bell or transverse dumb-bell shaped, constricted narrow central	dumb-bell or intermediate between cross and dumb-bell shaped, relatively short, not elongate	dumb-bell shaped, relatively short, not elongate
Culm anatomy							
Culm outline, diameter (mm)	oval or circular, 0.5-2	slightly oval, 1-5	oval, 1.5-3	circular to oval, 1.5-7	somewhat circular, 2-2.5	oval, *ca.* 10	circular, 3-7
Pith cavity	present, oval or irregular-shaped	absent	present, oval or rectangular-shaped	absent	absent	absent	absent

Table 3.5 The main anatomical differences separating the species in the genus *Mnesithea*.

Genus / Characters	*M. cancellata*	*M. glandulosa*	*M. laevis*	*M. mollicoma*	*M.* sp.1
Leaf anatomy					
Leaf blade outline	two halves of lamina curved upwards on either side of the midrib	two halves of lamina curved upwards on either side of the midrib	two halves of lamina wide very open V-shaped, more than 90°	two halves of lamina curved upwards on either side of the midrib	two halves of lamina curved upwards on either side of the midrib
Midrib	conspicuous, rounded or semicircular-shaped	conspicuous, rounded or semicircular-shaped	conspicuous, V-shaped - shaped	conspicuous, rounded or semicircular-shaped	conspicuous, rounded or triangular-shaped
Number of vascular bundles in keel	> 6	> 6	1	> 6	> 6
Sclerenchyma at margins	point-cap shaped	point-cap shaped	crescent-shaped	point-cap shaped	point-cap shaped
Abaxial intercostal long cells	elongated cells, slightly undulating	elongated cells, moderately undulating	shortened cells, deeply undulating	elongated cells, moderately undulating	elongated cells, slightly undulating
Abaxial intercostal short cells	solitary or paired	Solitary or paired	paired	solitary or paired	paired
Stomata	triangular-shaped, subsidiary cells	triangular-shaped, subsidiary cells	almost parallel-sided or intermediate between parallel-sided and low dome-shaped subsidiary cells	triangular-shaped, subsidiary cells	triangular-shaped, subsidiary cells
Abaxial silica bodies	dumb-bell shaped, relatively short, not elongate	dumb-bell shaped, relatively short, not elongate	transverse dumb-bell, relatively short, not elongate	dumb-bell shaped, relatively short, not elongate	dumb-bell shaped, relatively short, not elongate
Culm anatomy					
Culm outline and width	circular or slightly oval, 1.5-2.5	oval, 2.5-3.5	oval, 1.5-2.5	oval, 2-2.5	oval, 3.5-7

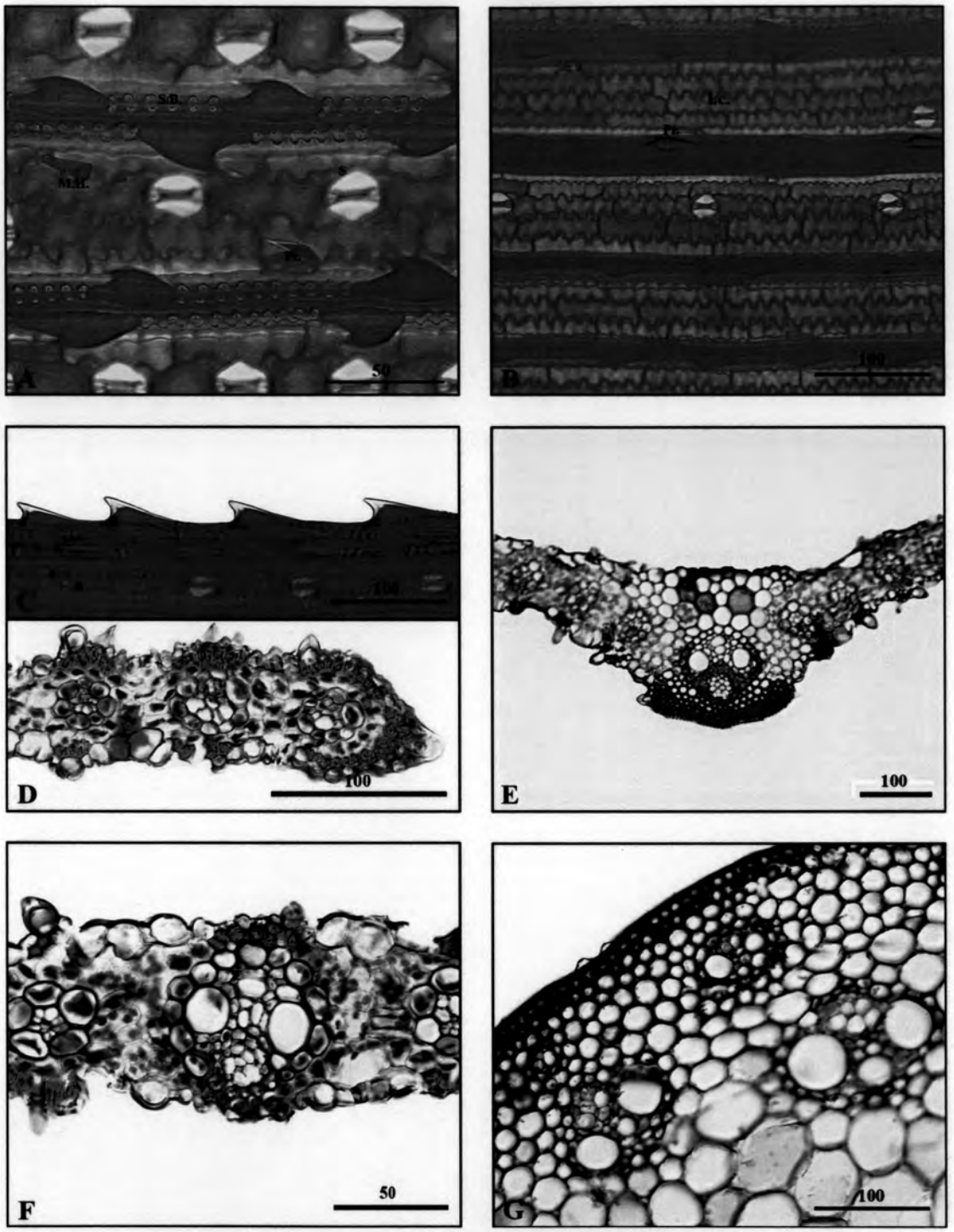

Figure 3.9 Leaf and culm anatomy of *Apluda mutica* (*P. Traiperm* 152 and 321): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. (SB= silica bodies; MH= micro-hairs; S=stomata; Pr=prickles; lc=long cells) Scale bar in μm.

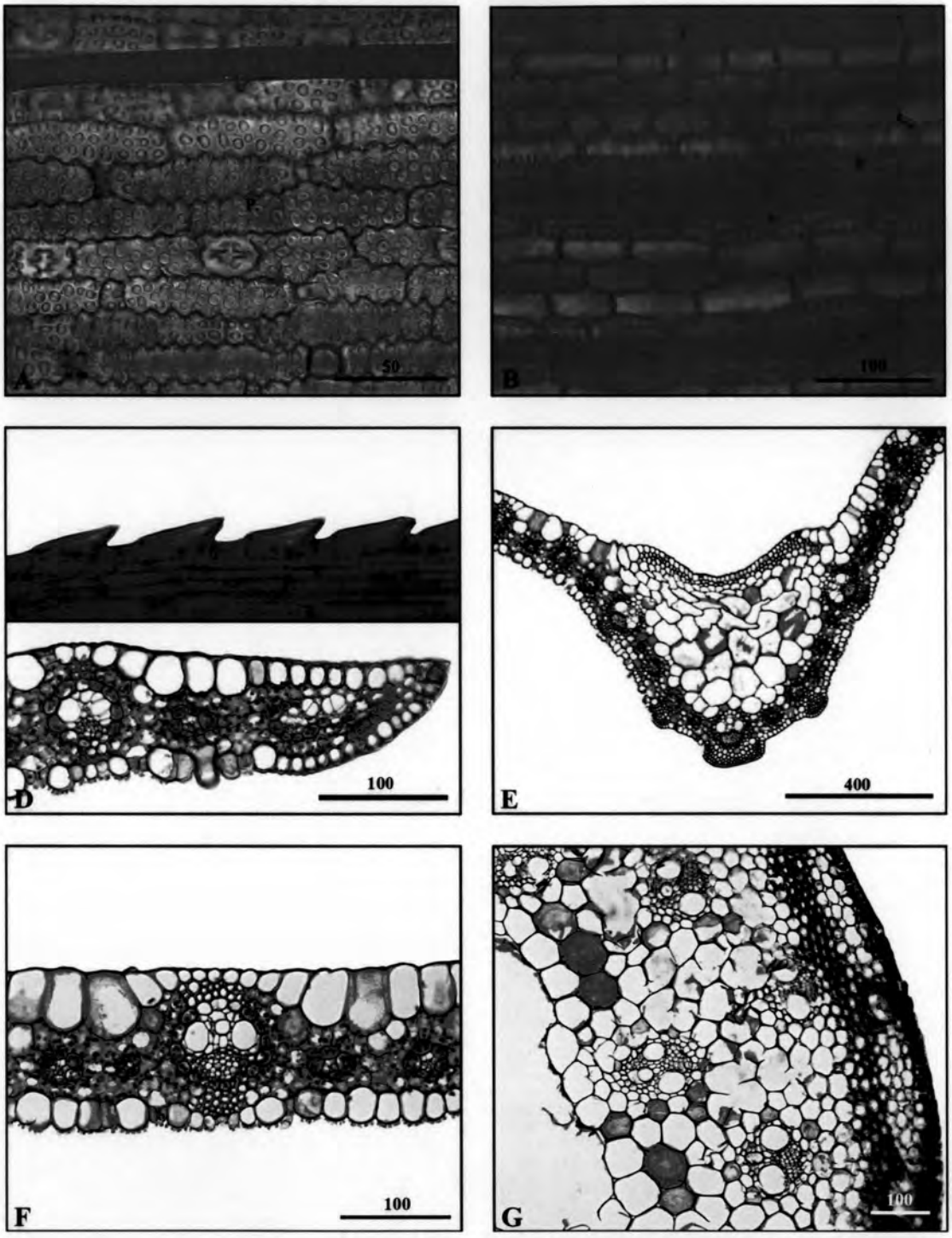

Figure 3.10 Leaf and culm anatomy of *Ischaemum hirtum* (*P. Traiperm* 171): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. (P=papillae) Scale bar in μm.

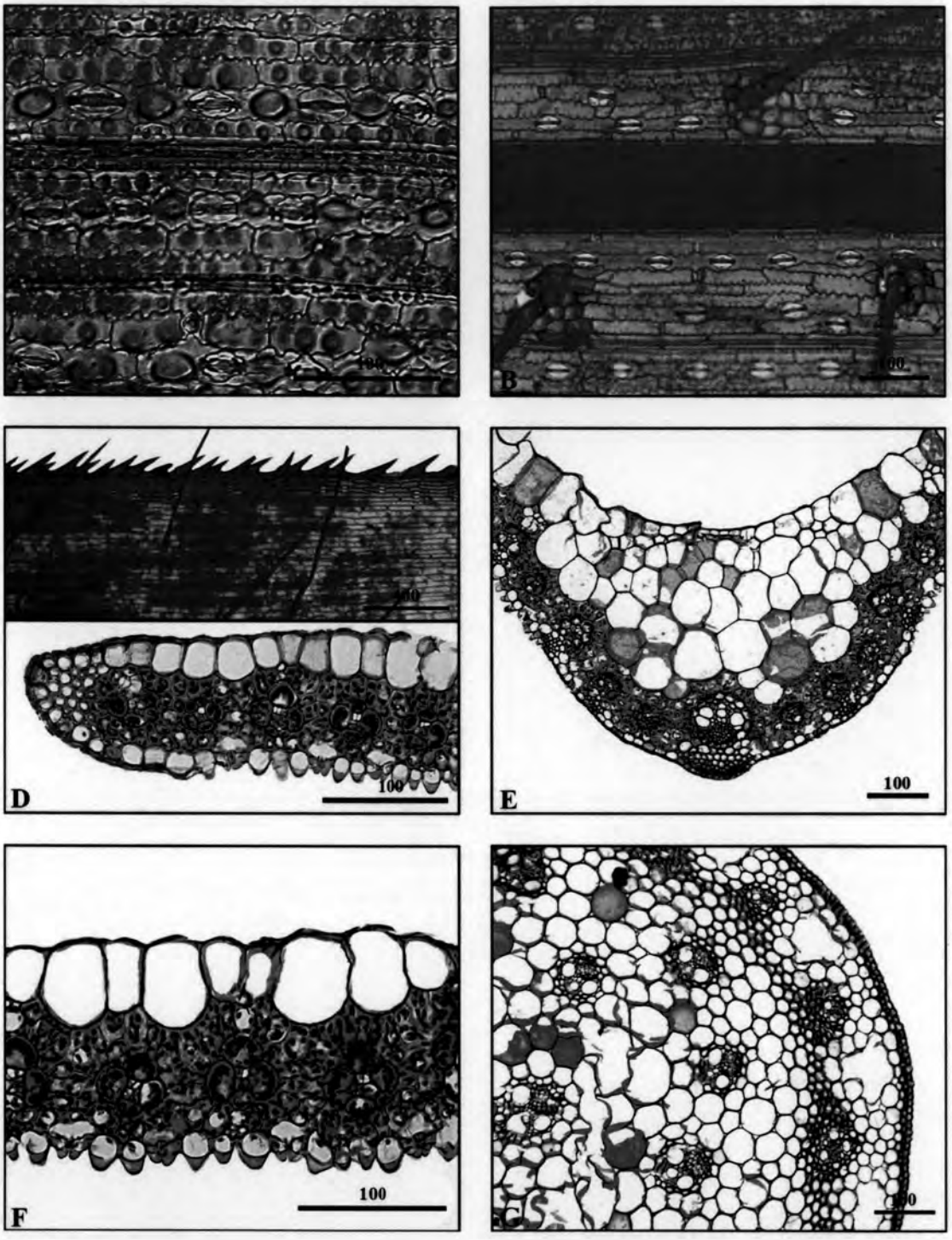

Figure 3.11 Leaf and culm anatomy of *Ischaemum hubbardii* (*P. Traiperm* 308): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.

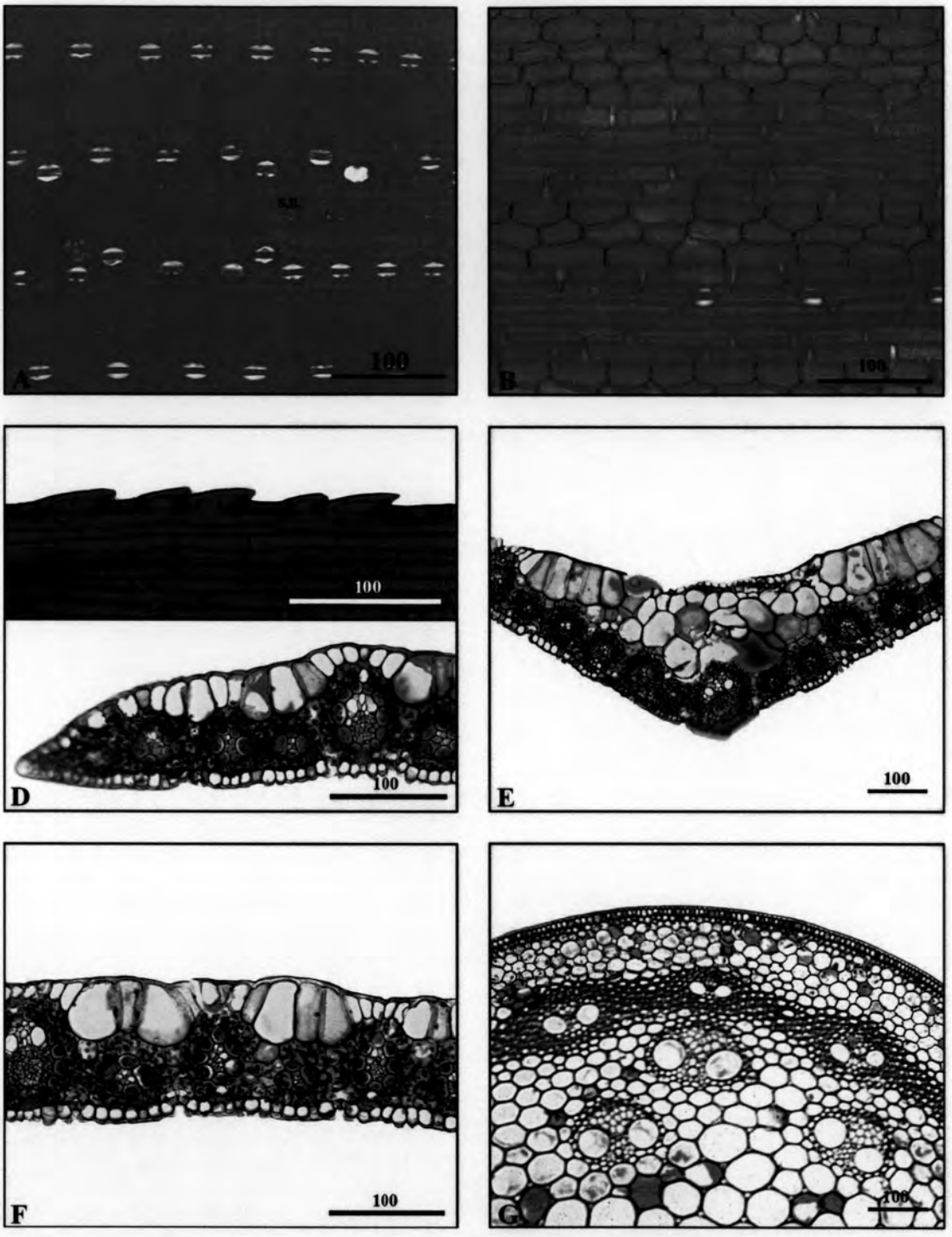

Figure 3.12 Leaf and culm anatomy of *Ischaemum muticum* (*P. Traiperm* 138 and 199): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. (SB=silica bodies) Scale bar in μm.

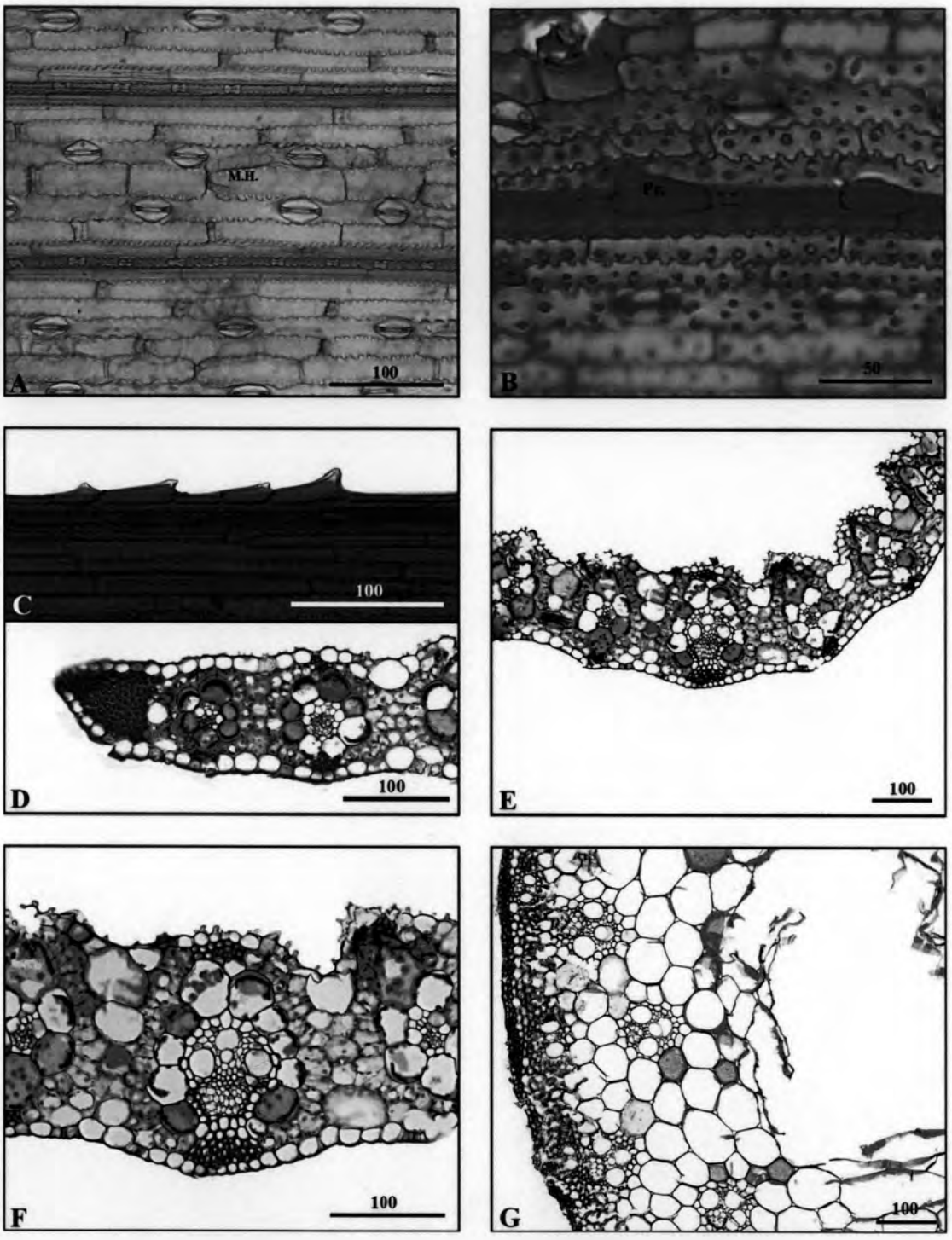

Figure 3.13 Leaf and culm anatomy of *Ischaemum rugosum* (*P. Traiperm* 127 and 293): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. (MH=micro-hairs; Pr=prickles) Scale bar in μm.

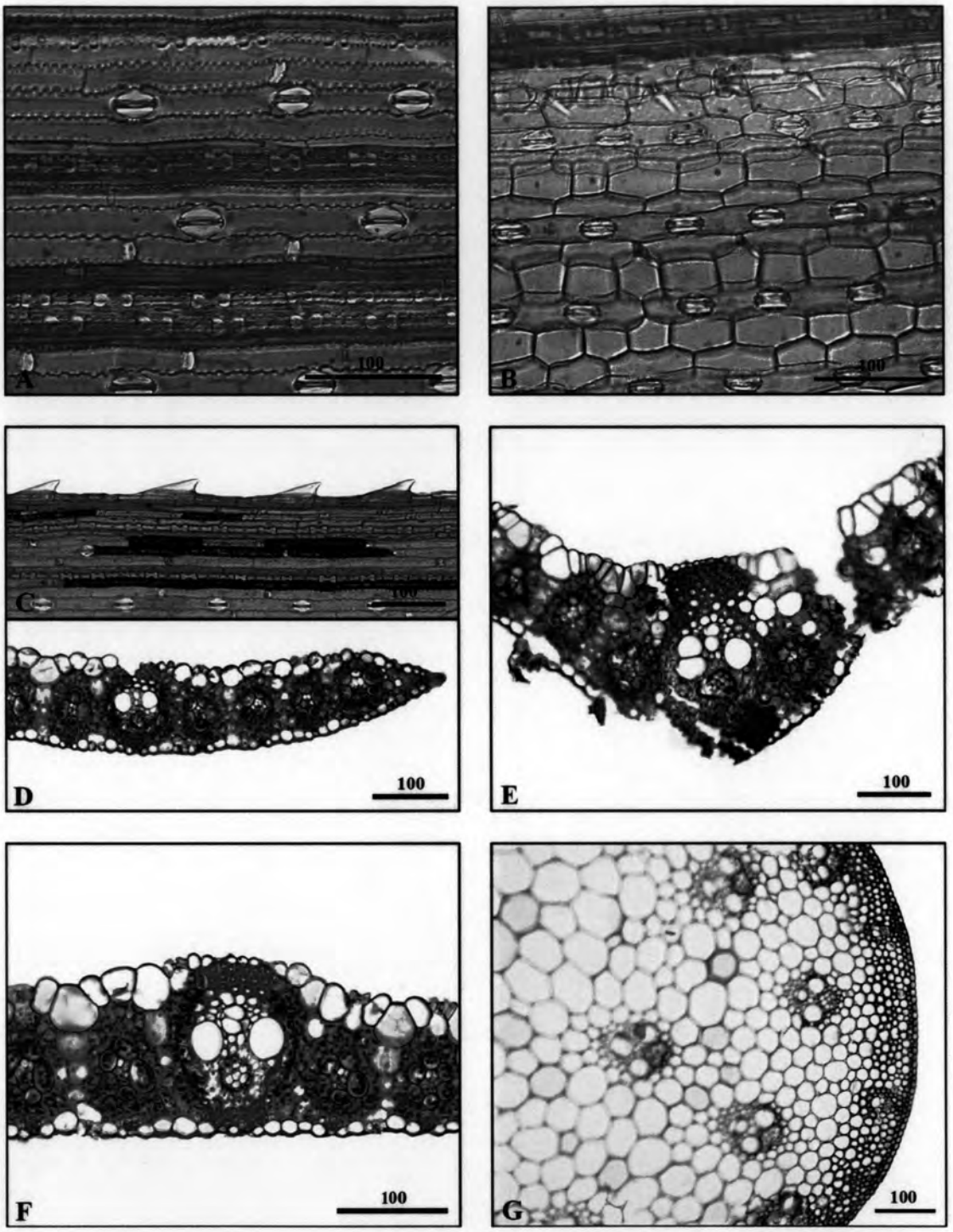

Figure 3.14 Leaf and culm anatomy of *Ischaemum tenuifolium* (*P. Traiperm* 233 and 287): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.

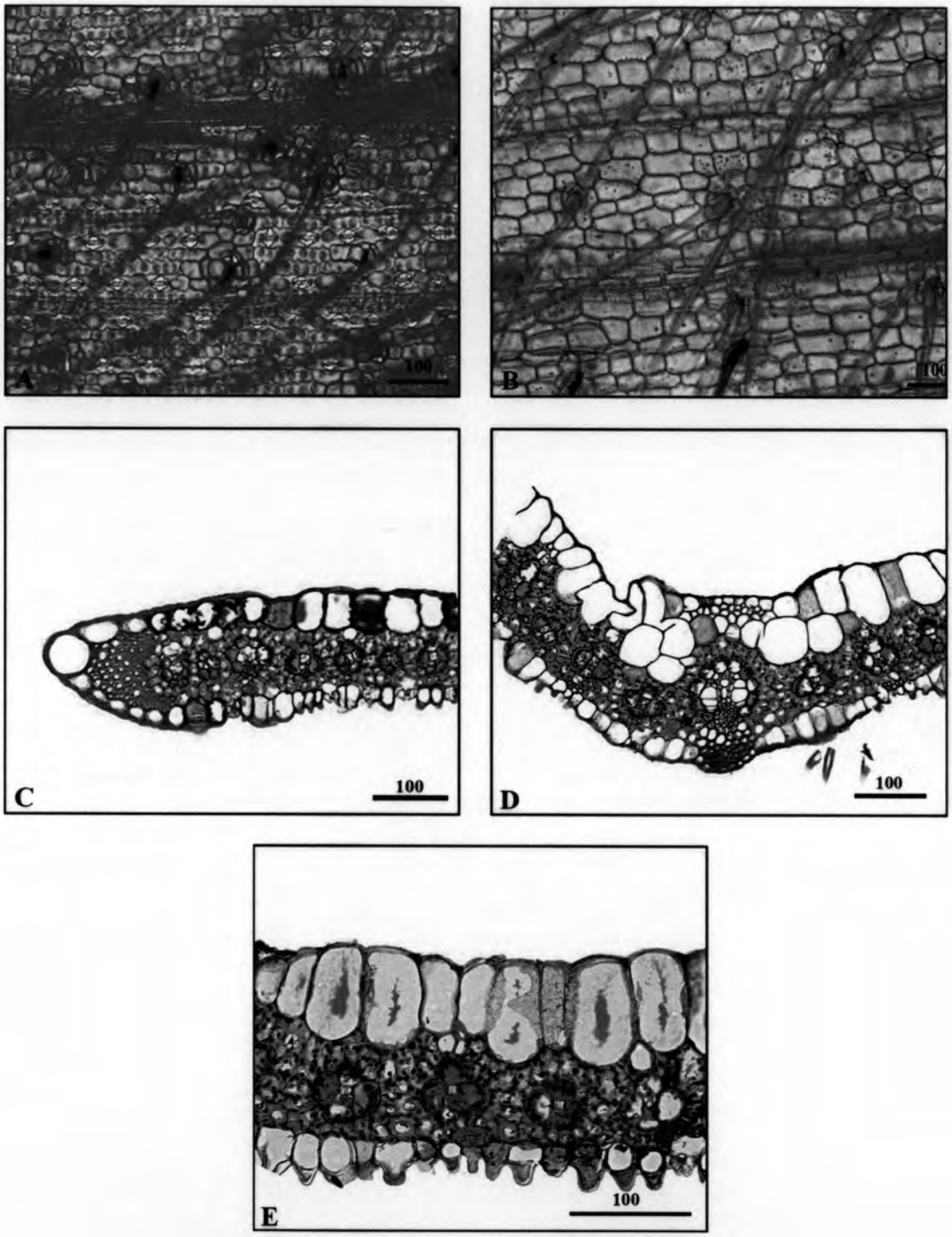

Figure 3.15 Leaf anatomy of *Ischaemum* sp.1 (*P. Traiperm* 327): A. abaxial epidermis, B. adaxial epidermis, C-E. x.s. leaf. Scale bar in μm.

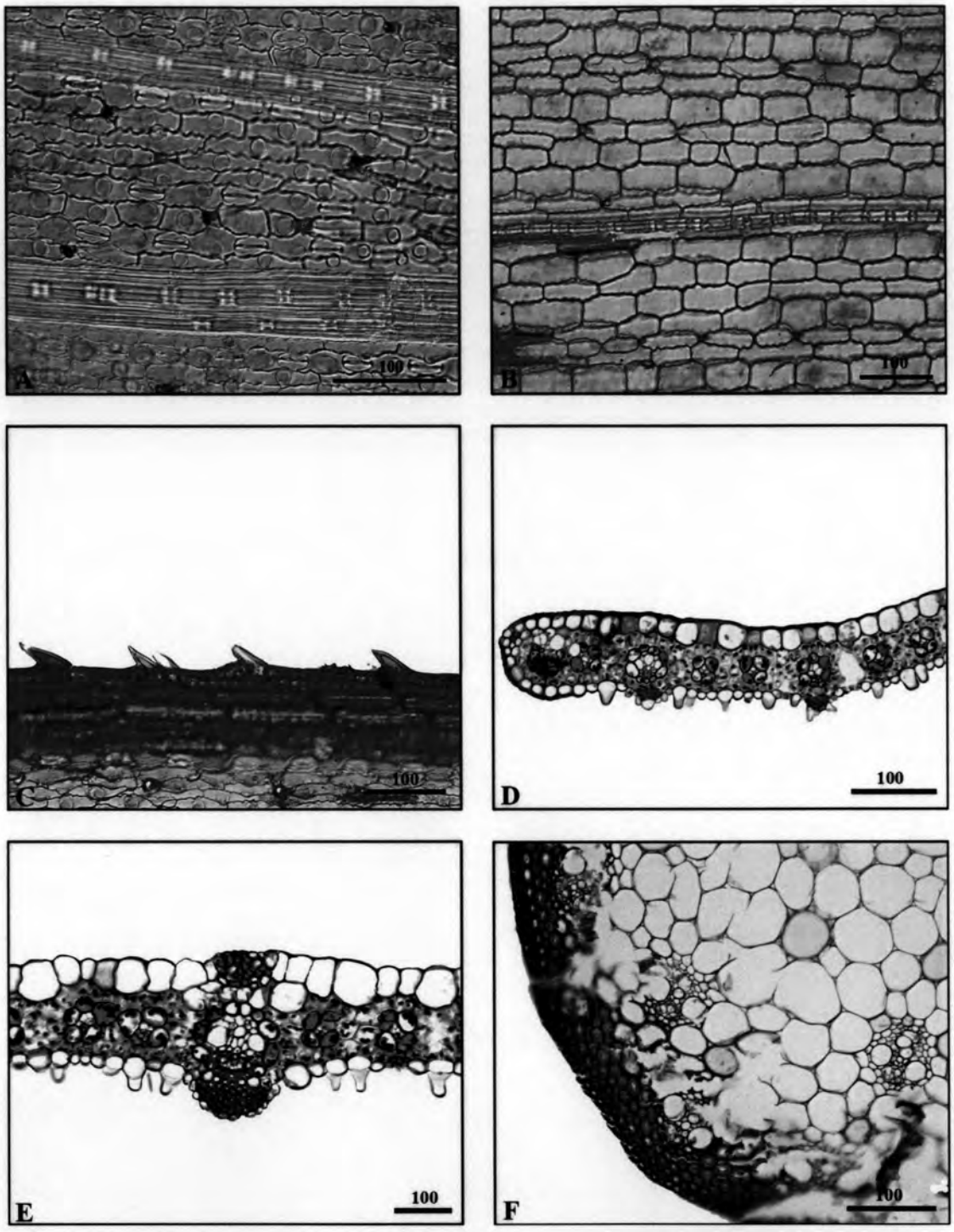

Figure 3.16 Leaf and culm anatomy of *Kerriochloa siamensis* (*P. Traiperm* 235): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-E. x.s. leaf, F. x.s. culm. Scale bar in μm.

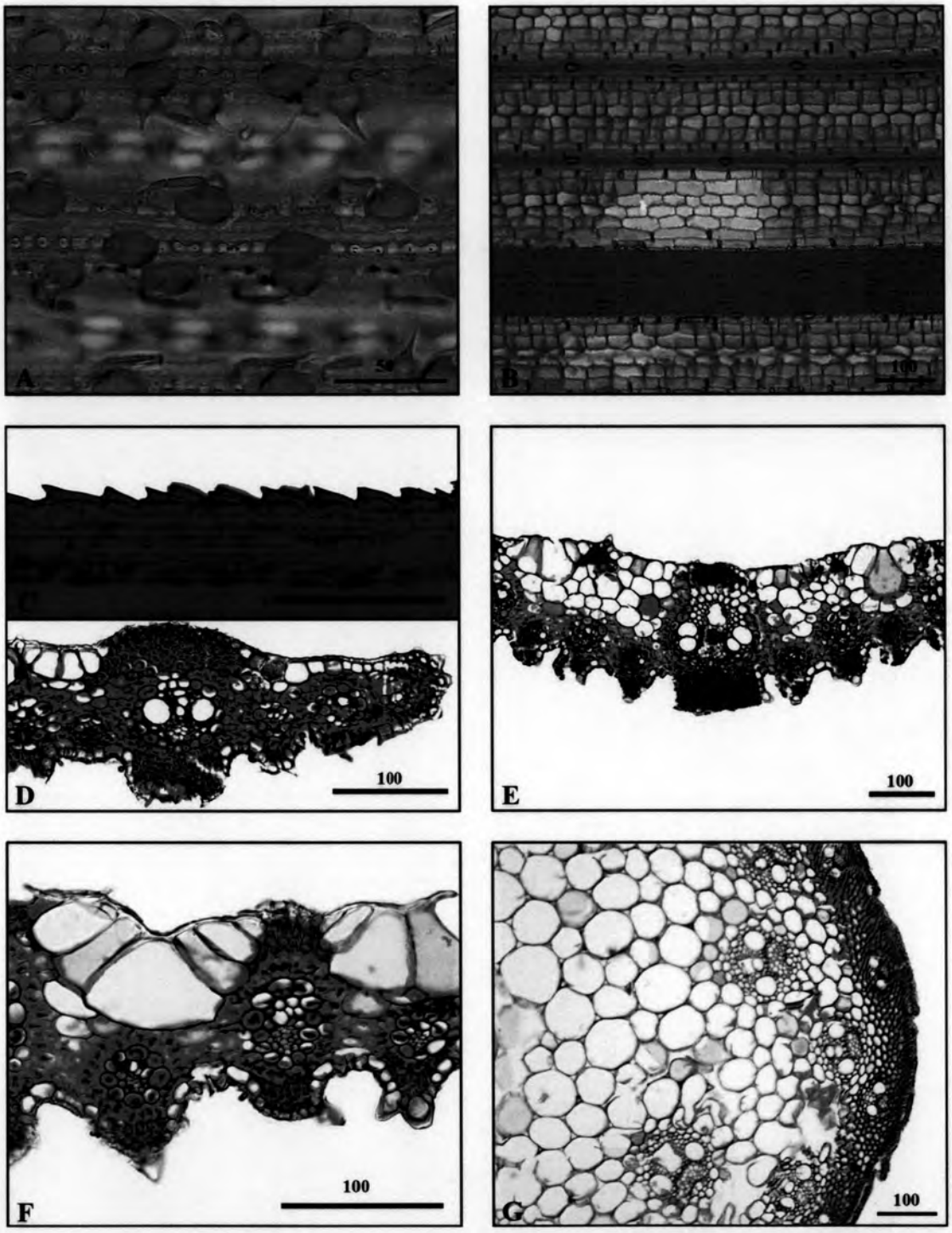

Figure 3.17 Leaf and culm anatomy of *Sehima nervosum* (*P. Traiperm* 170 and 323): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.

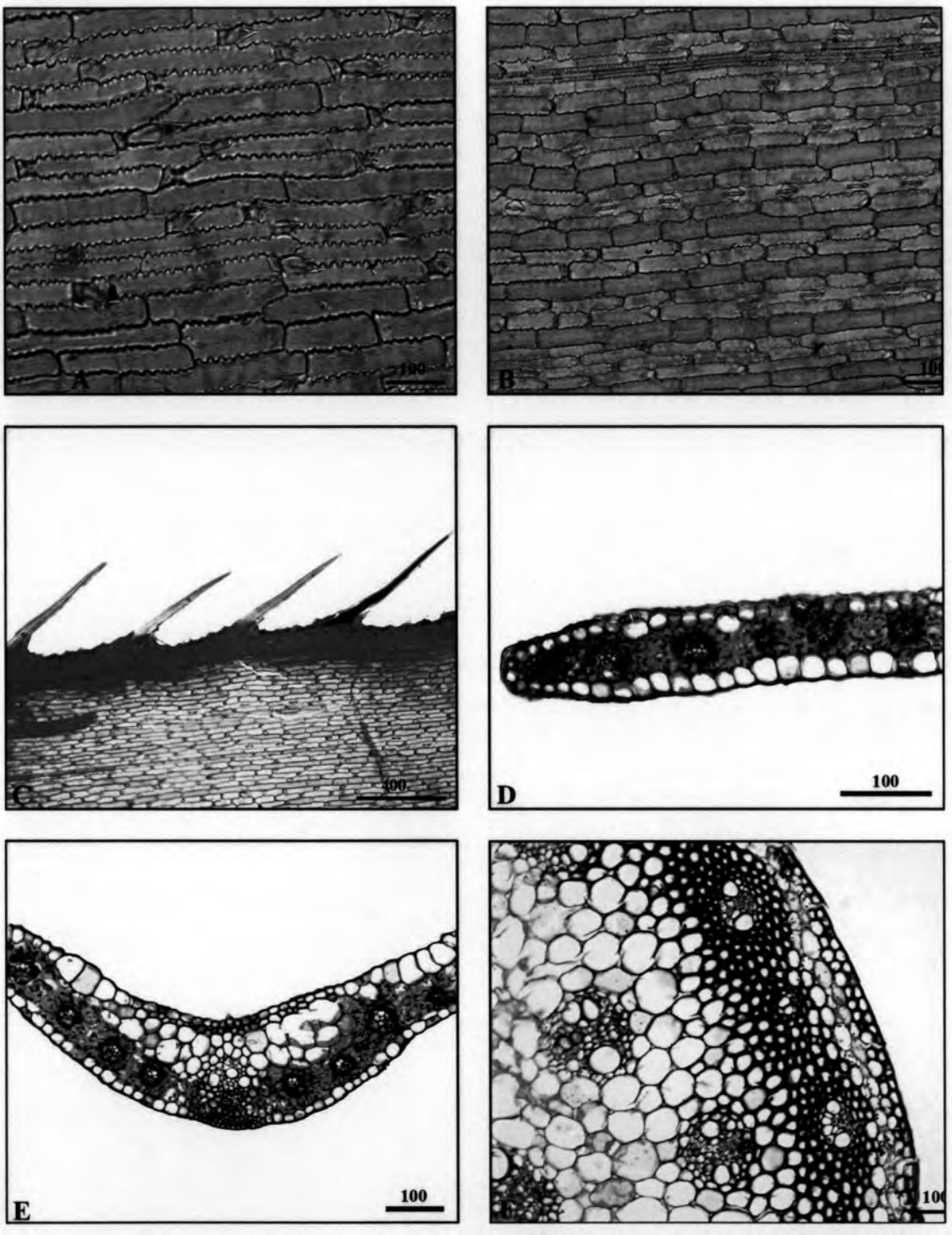

Figure 3.18 Leaf and culm anatomy of *Thelepogon elegans* (*P. Traiperm* 276): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-E. x.s. leaf, F. x.s. culm. Scale bar in μm.

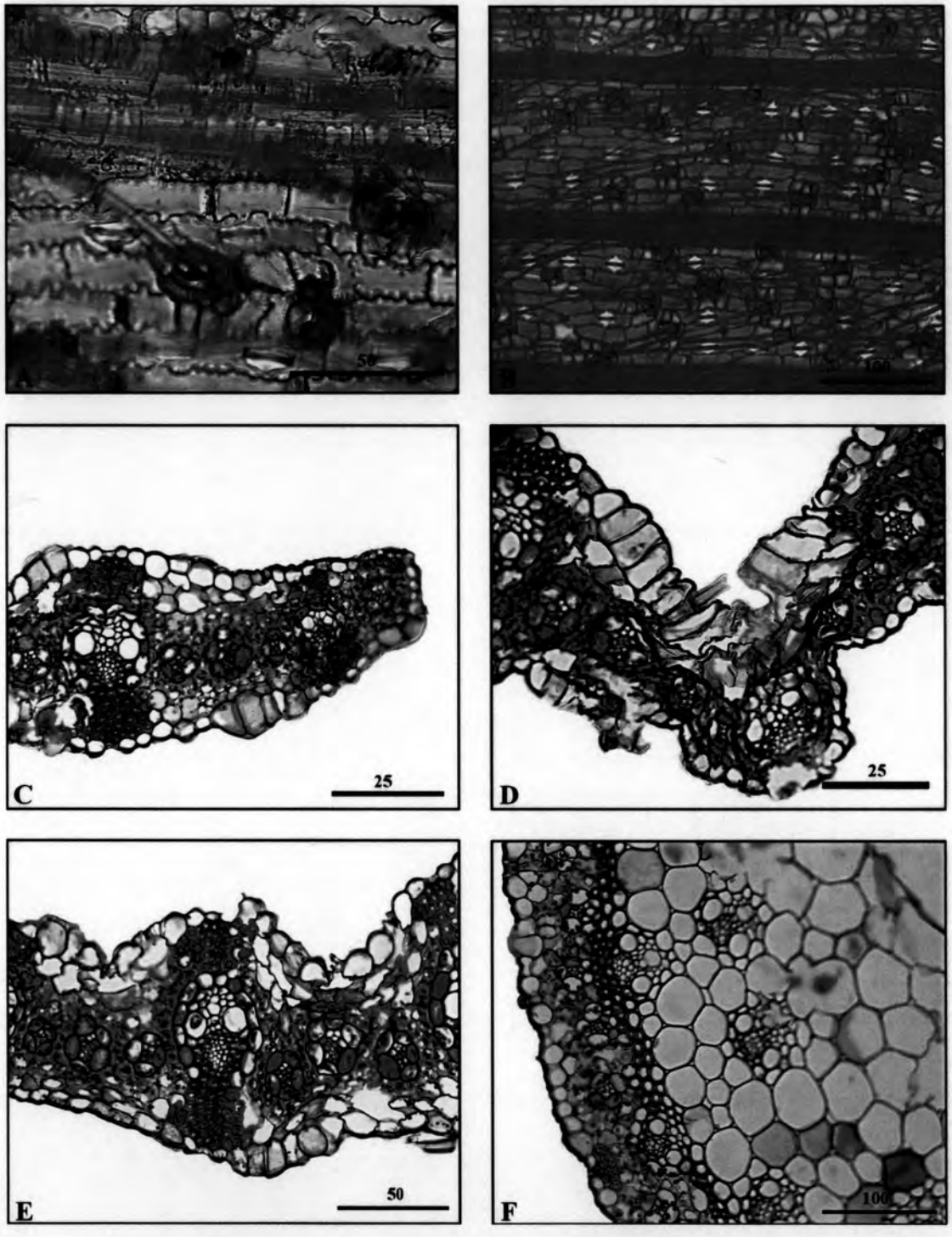

Figure 3.19 Leaf and culm anatomy of *Eremochloa attenuata* (*P. Traiperm* 162): A. abaxial epidermis, B. adaxial epidermis, C-E. x.s. leaf, F. x.s. culm. Scale bar in μm.

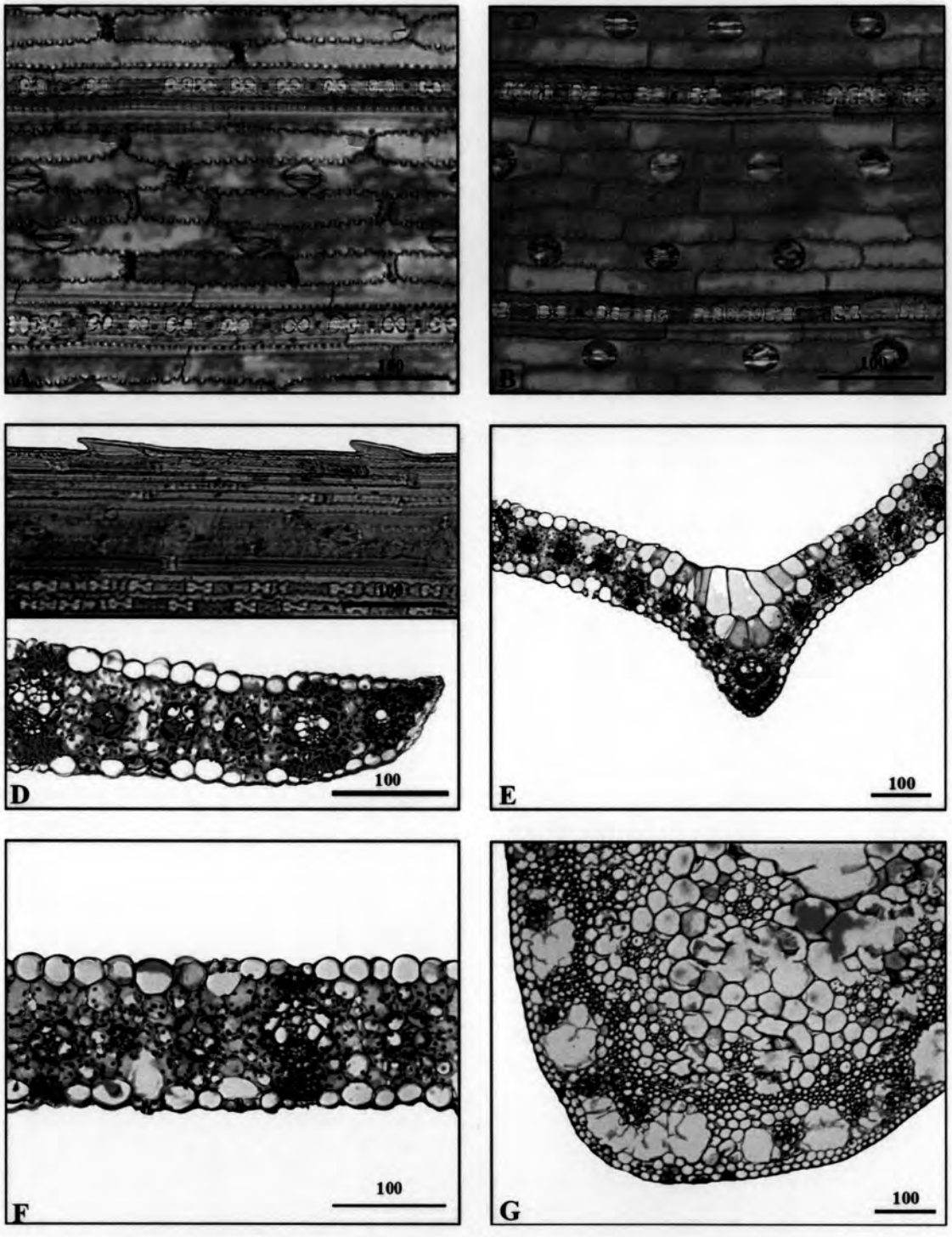

Figure 3.20 Leaf and culm anatomy of *Eremochloa bimaculata* (*P. Traiperm* 116): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.

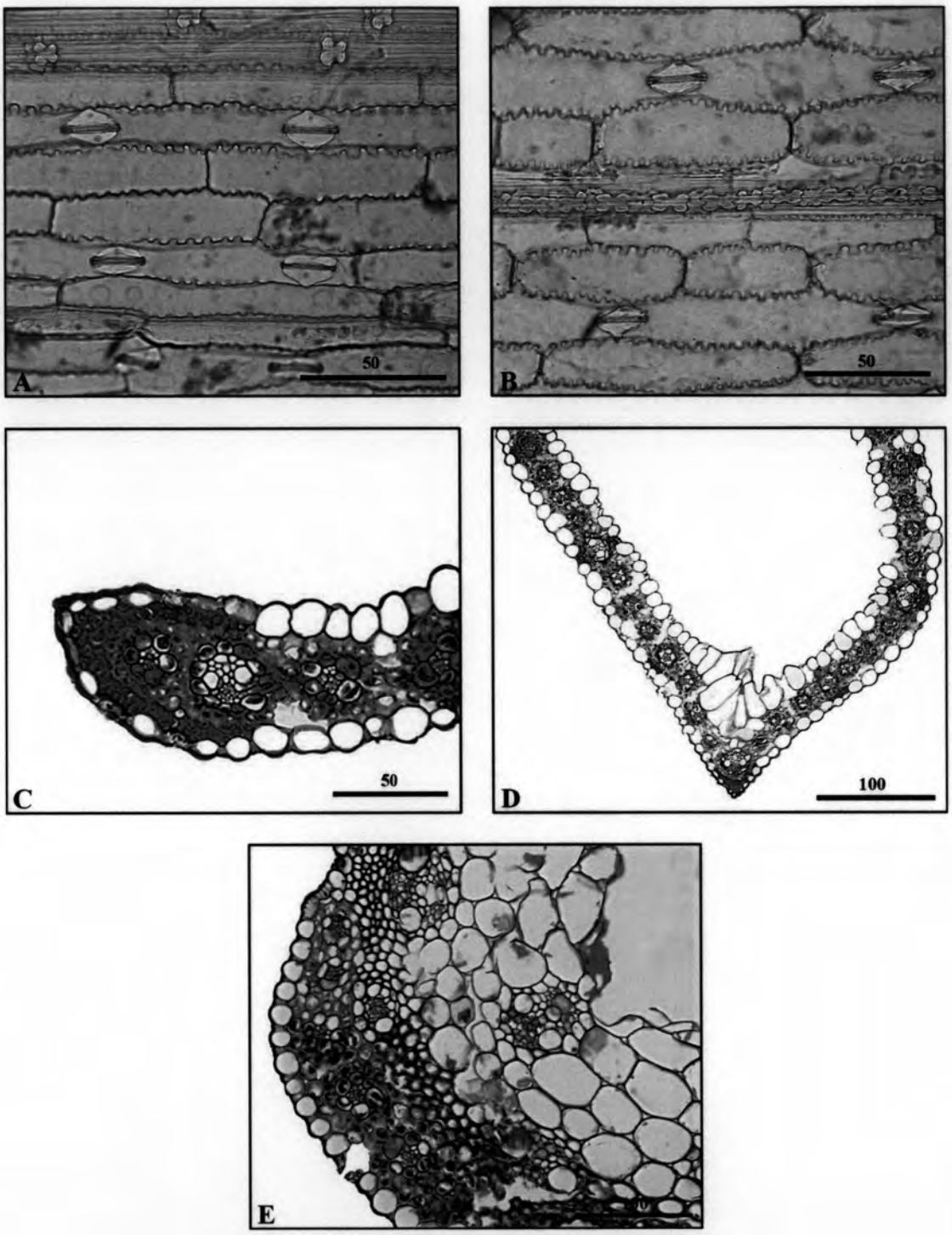

Figure 3.21 Leaf and culm anatomy of *Eremochloa lanceolata* (*P. Traiperm* 242): A. abaxial epidermis, B. adaxial epidermis, C-D. x.s. leaf, E. x.s. culm. Scale bar in μm.

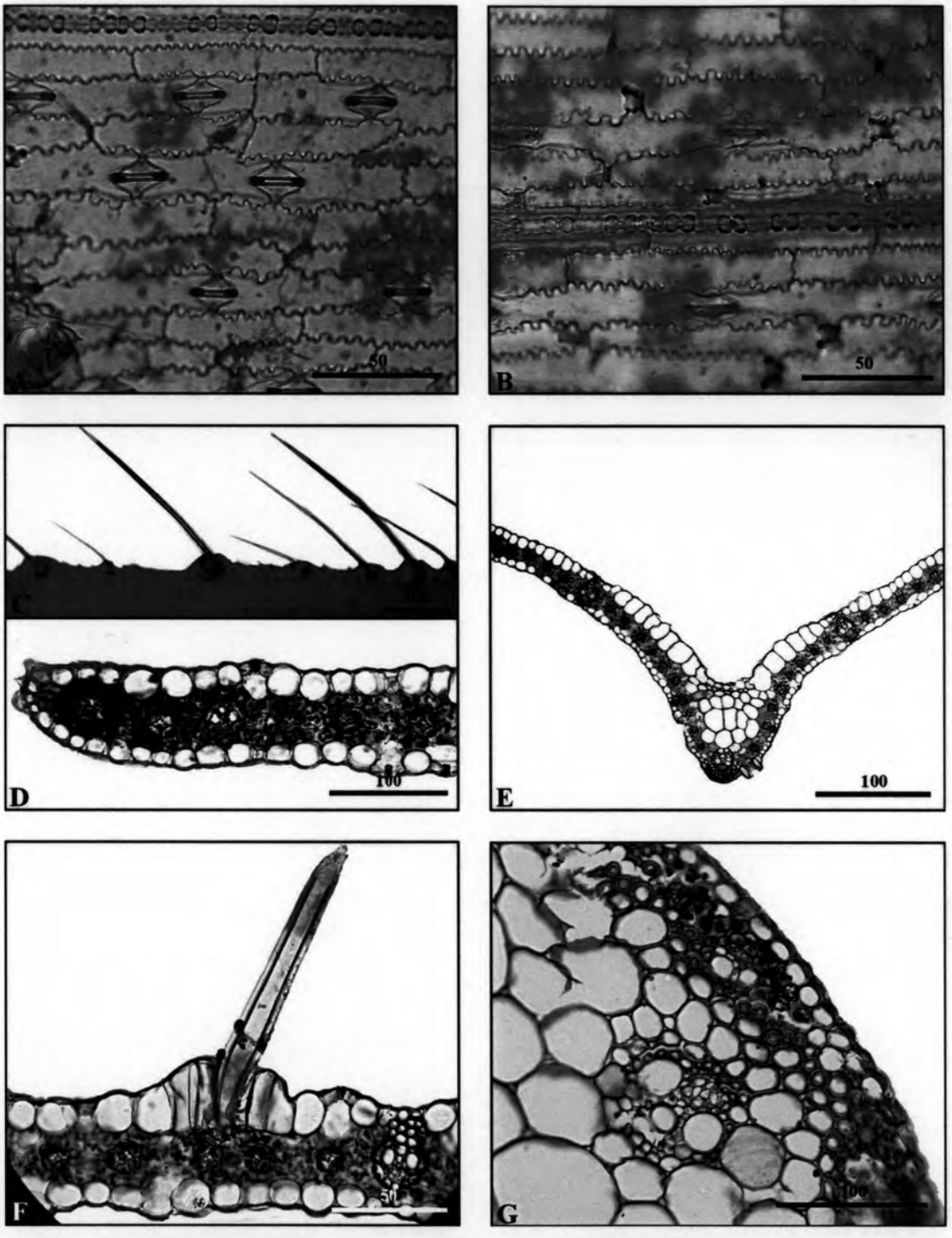

Figure 3.22 Leaf and culm anatomy of *Hackelochloa granularis* (*P. Traiperm* 303): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.

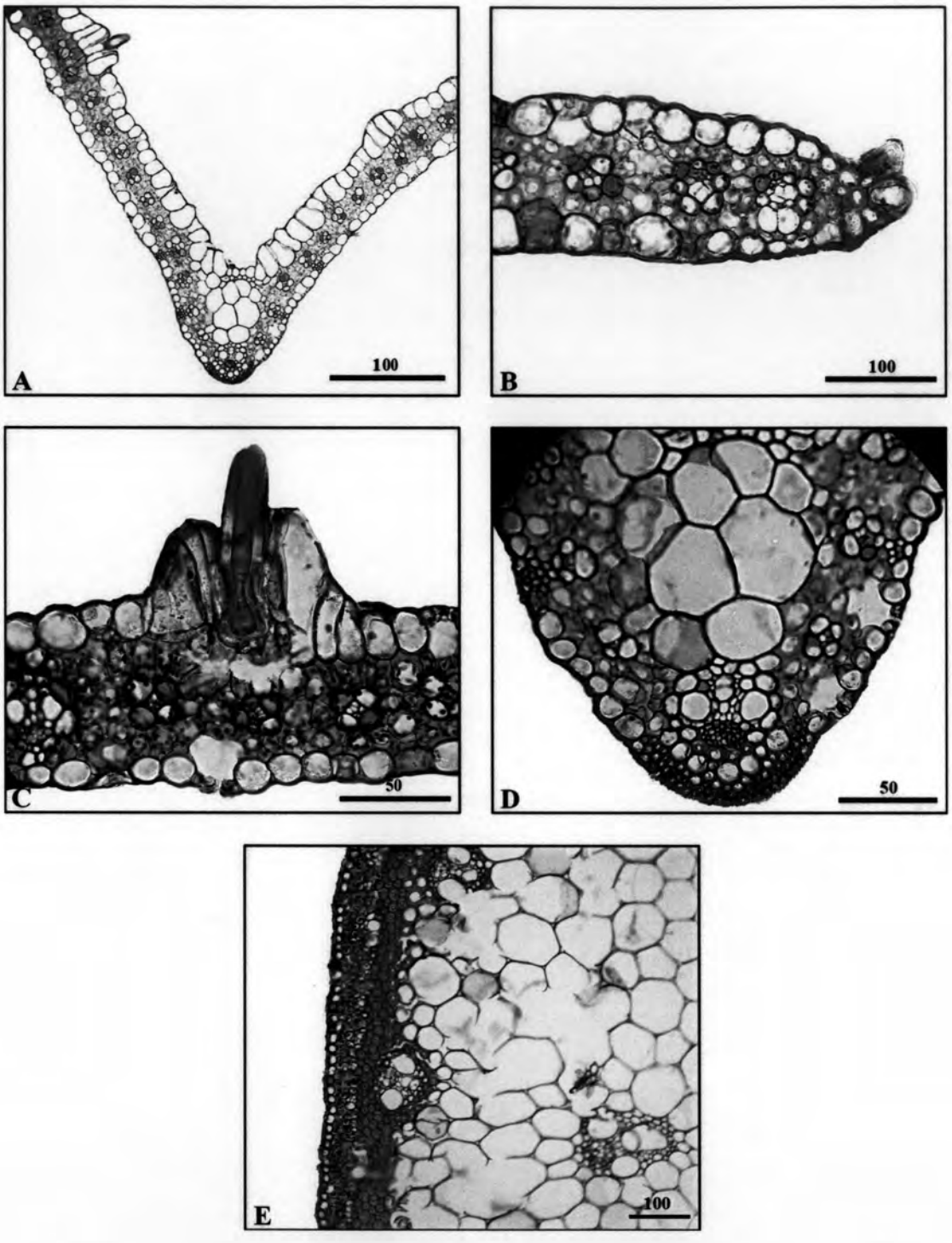

Figure 3.23 Leaf and culm anatomy of *Hackelochloa porifera* (*P. Traiperm* 311): A-D. x.s. leaf, E. x.s. culm. Scale bar in μm.

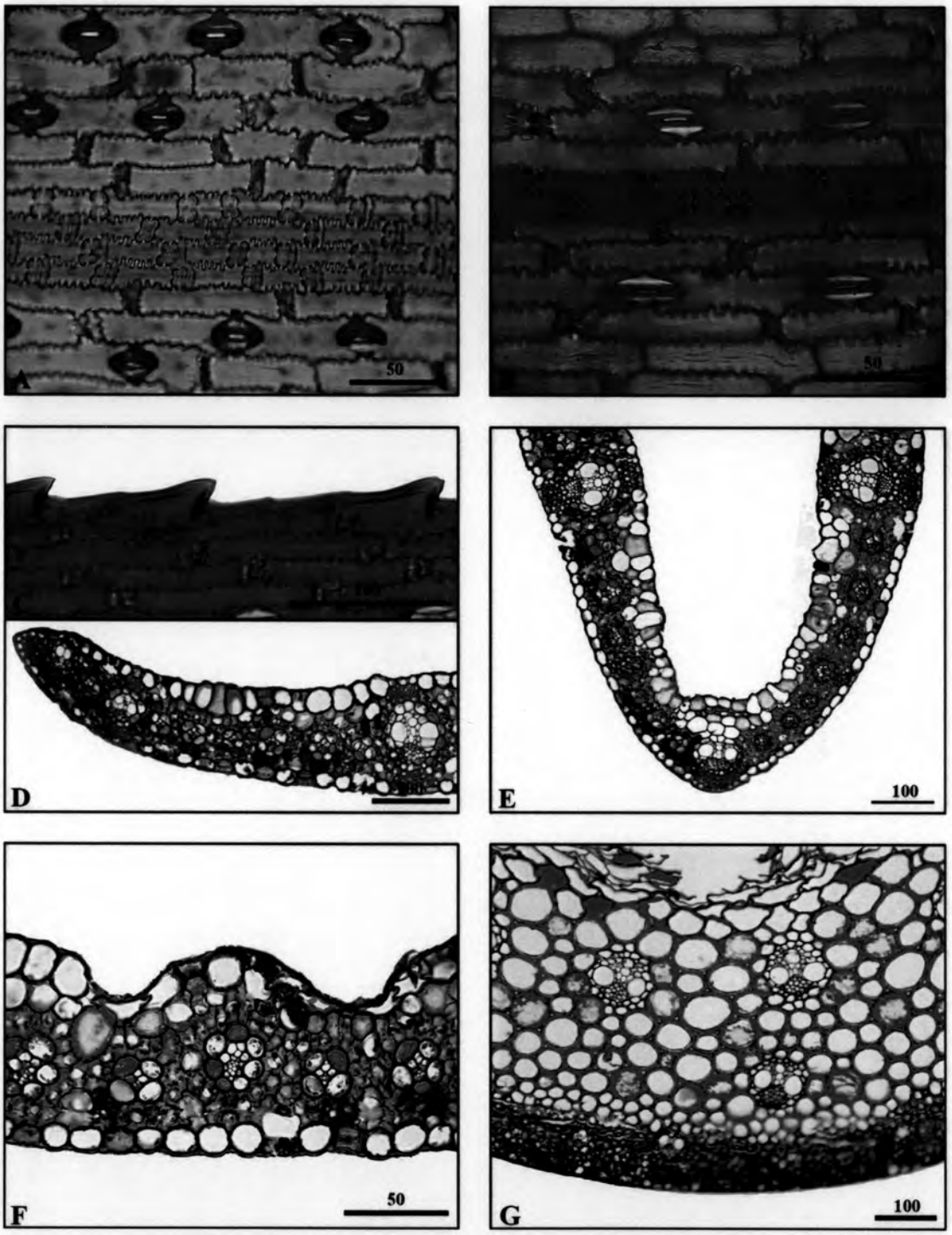

Figure 3.24 Leaf and culm anatomy of *Hemarthria compressa* (*P. Traiperm* 187): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.

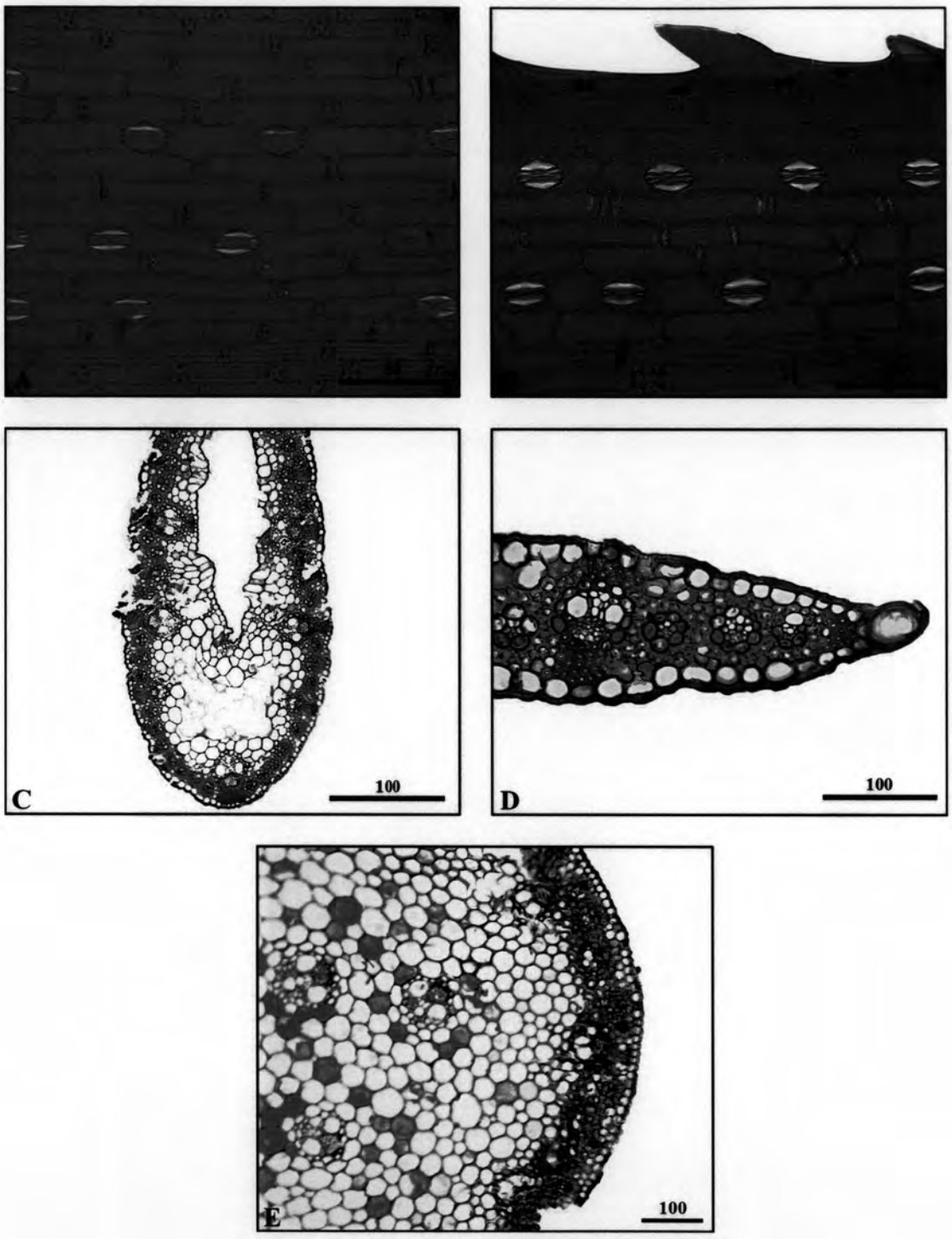

Figure 3.25 Leaf and culm anatomy of *Hemarthria pratensis* (*P. Traiperm* 158): A. abaxial epidermis, B. adaxial epidermis, C-D. x.s. leaf, E. x.s. culm. Scale bar in μm.

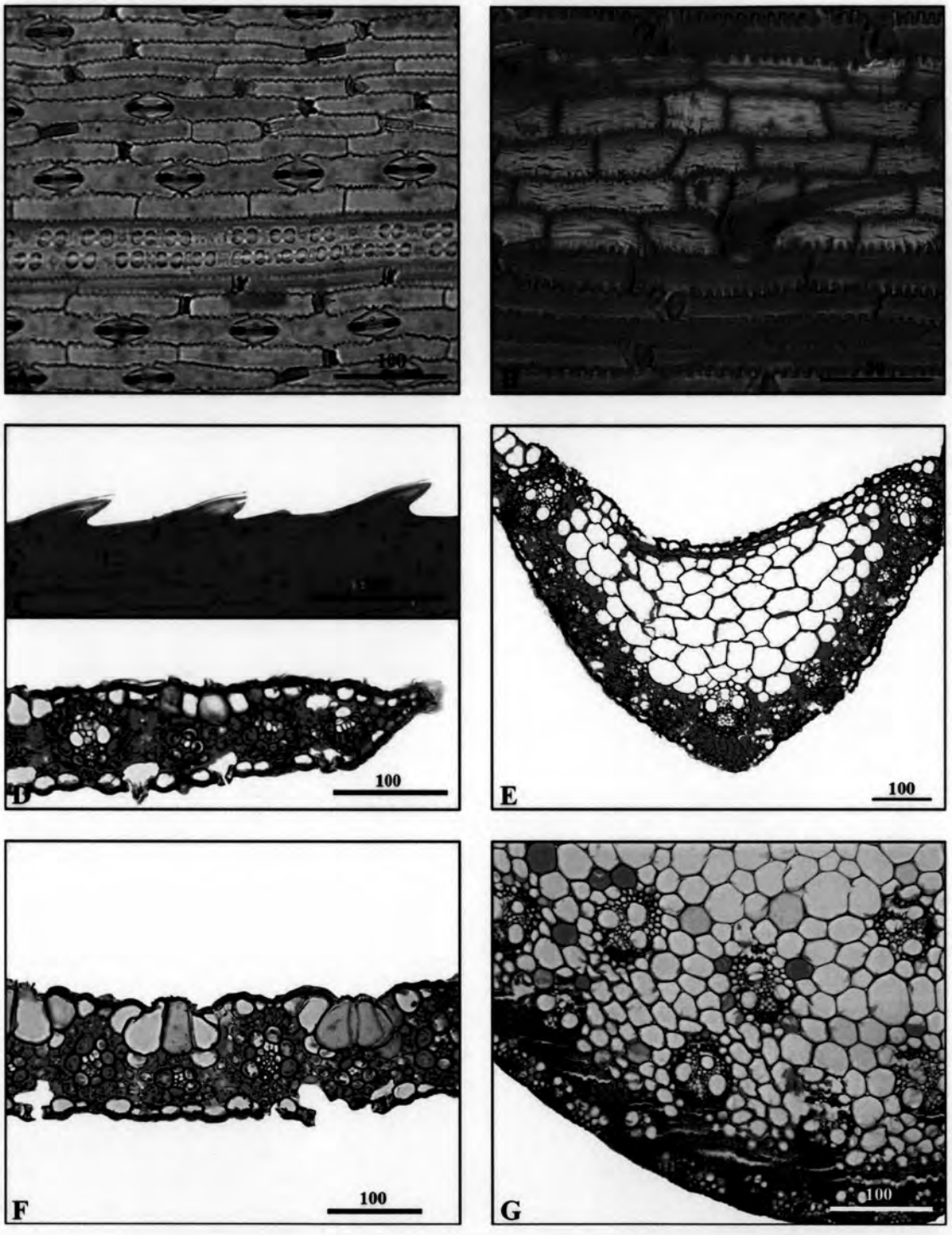

Figure 3.26 Leaf and culm anatomy of *Mnesithea cancellata* (*P. Traiperm* 161 and 183): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.

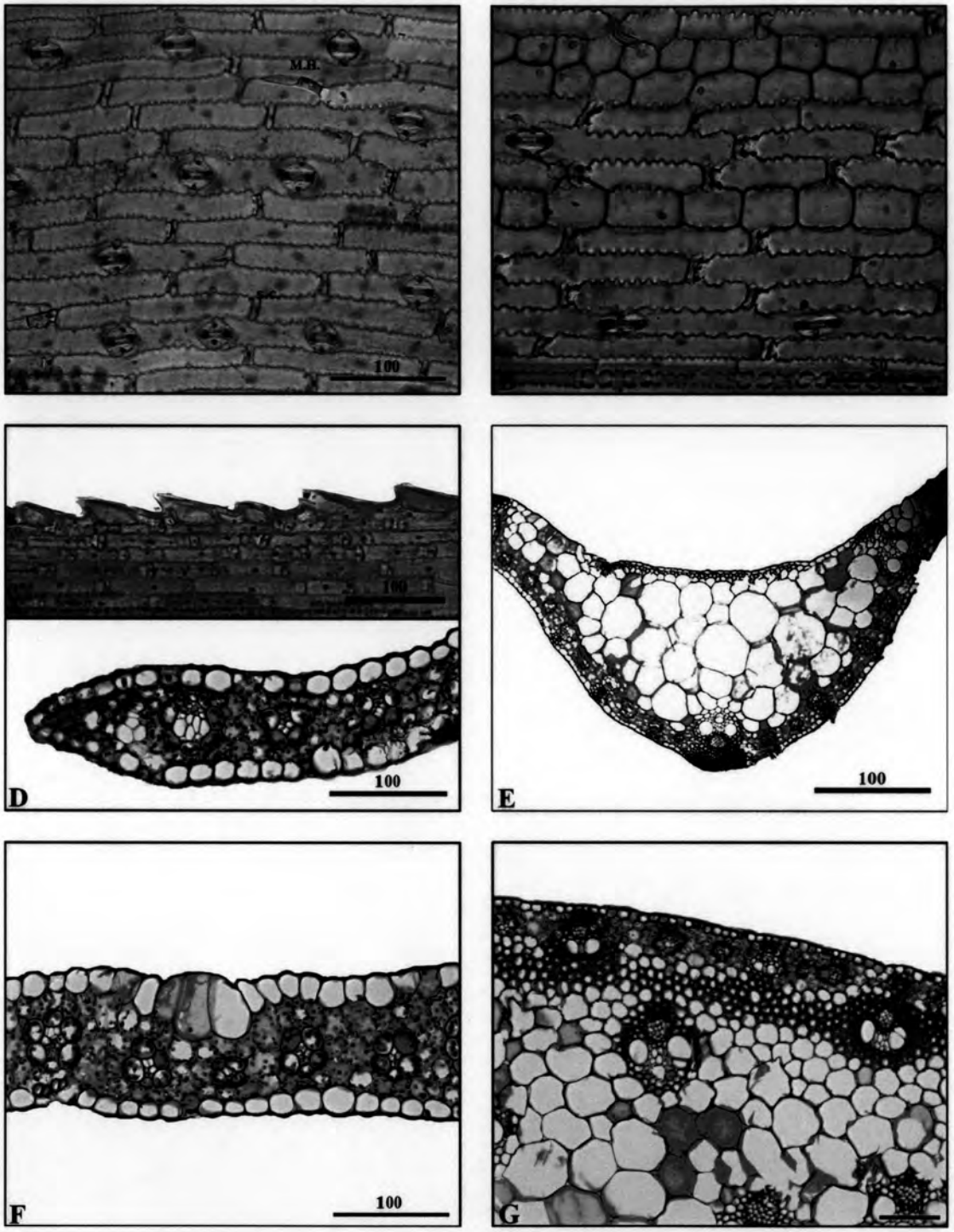

Figure 3.27 Leaf and culm anatomy of *Mnesithea glandulosa* (*P. Traiperm* 139): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. (MH=micro-hairs; sc=short cells) Scale bar in µm.

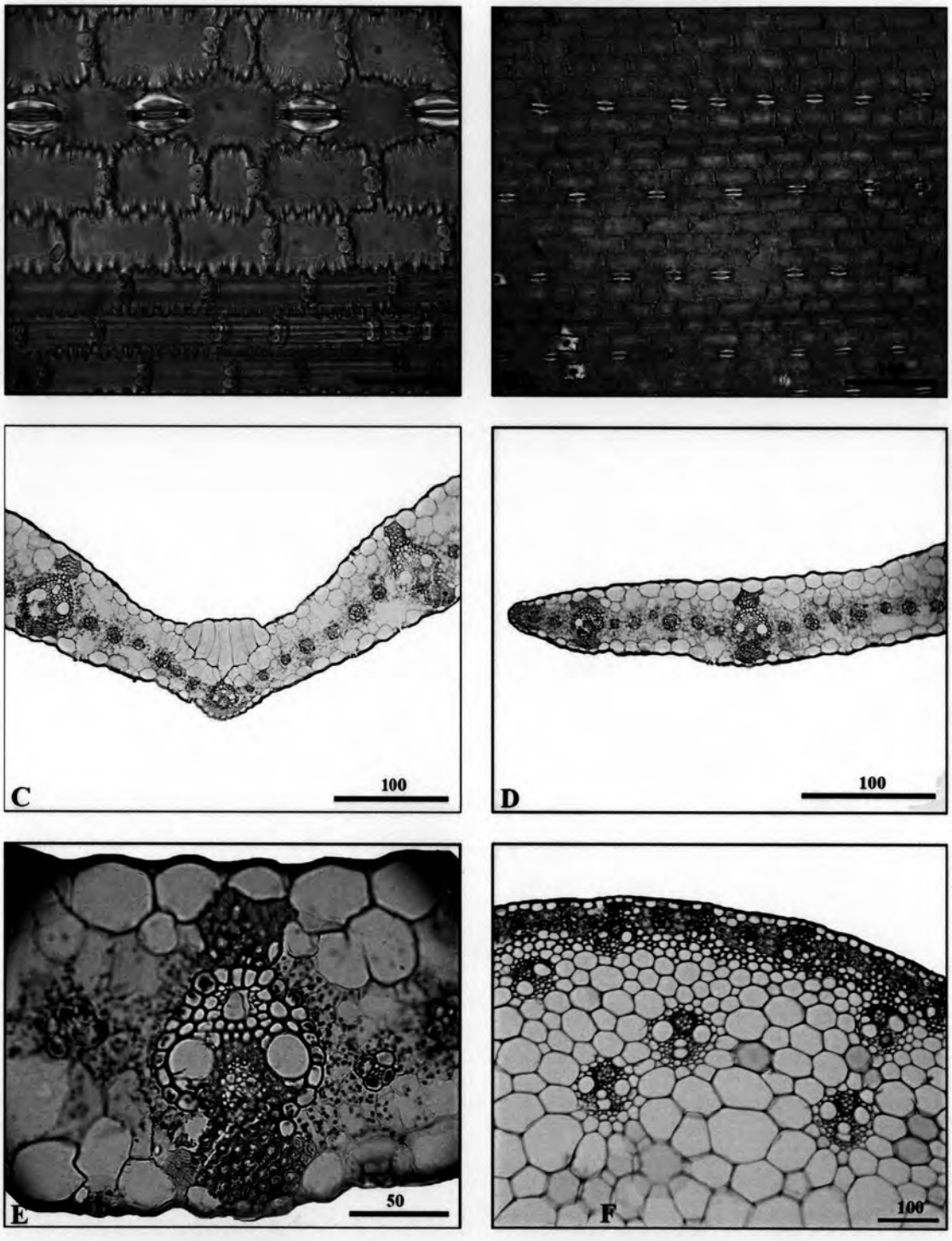

Figure 3.28 Leaf and culm anatomy of *Mnesithea laevis* (*P. Traiperm* 307): A. abaxial epidermis, B. adaxial epidermis, C-D. x.s. leaf, E. x.s. culm. Scale bar in μm.

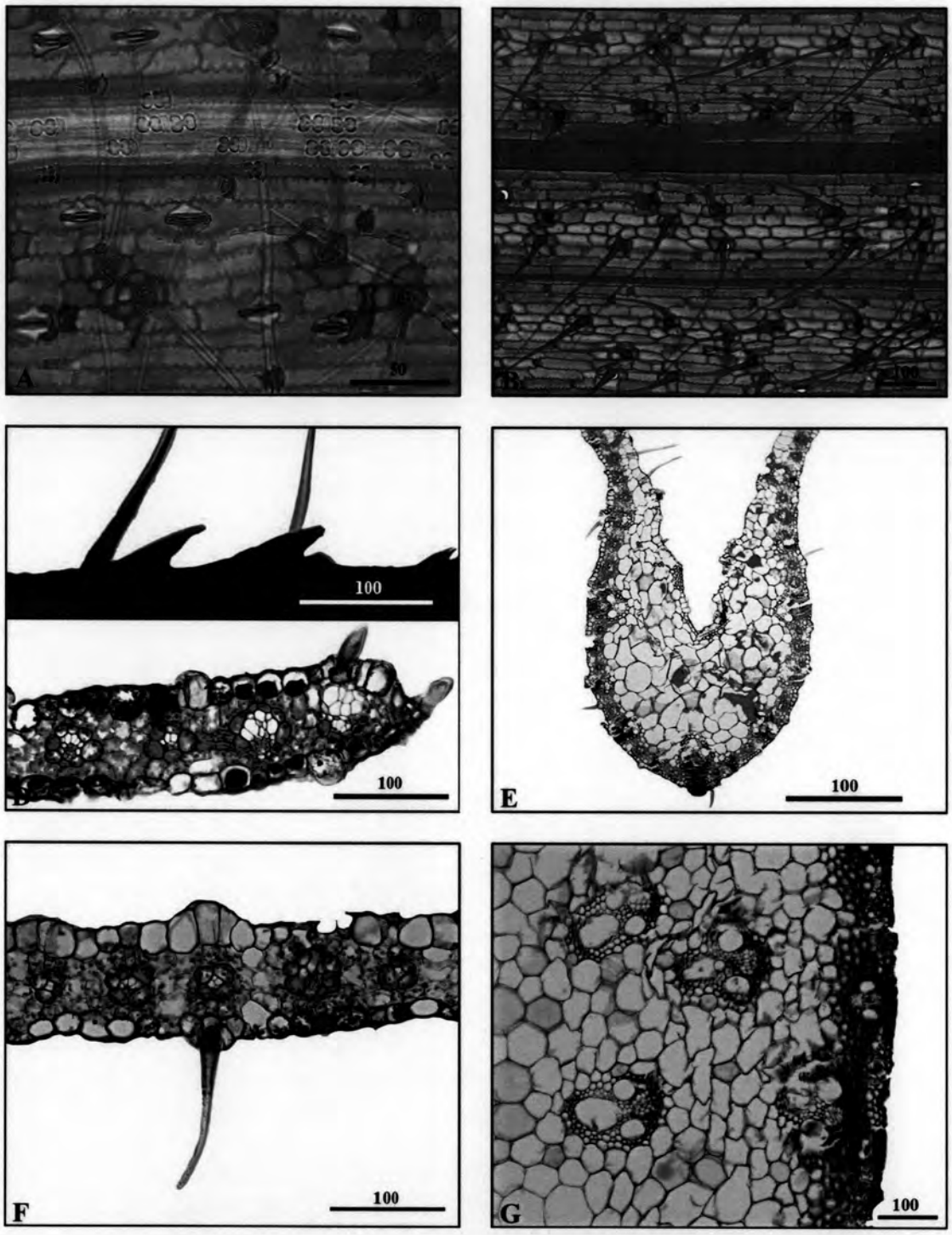

Figure 3.29 Leaf and culm anatomy of *Mnesithea mollicoma* (*P. Traiperm* 131): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf, G. x.s. culm. Scale bar in μm.

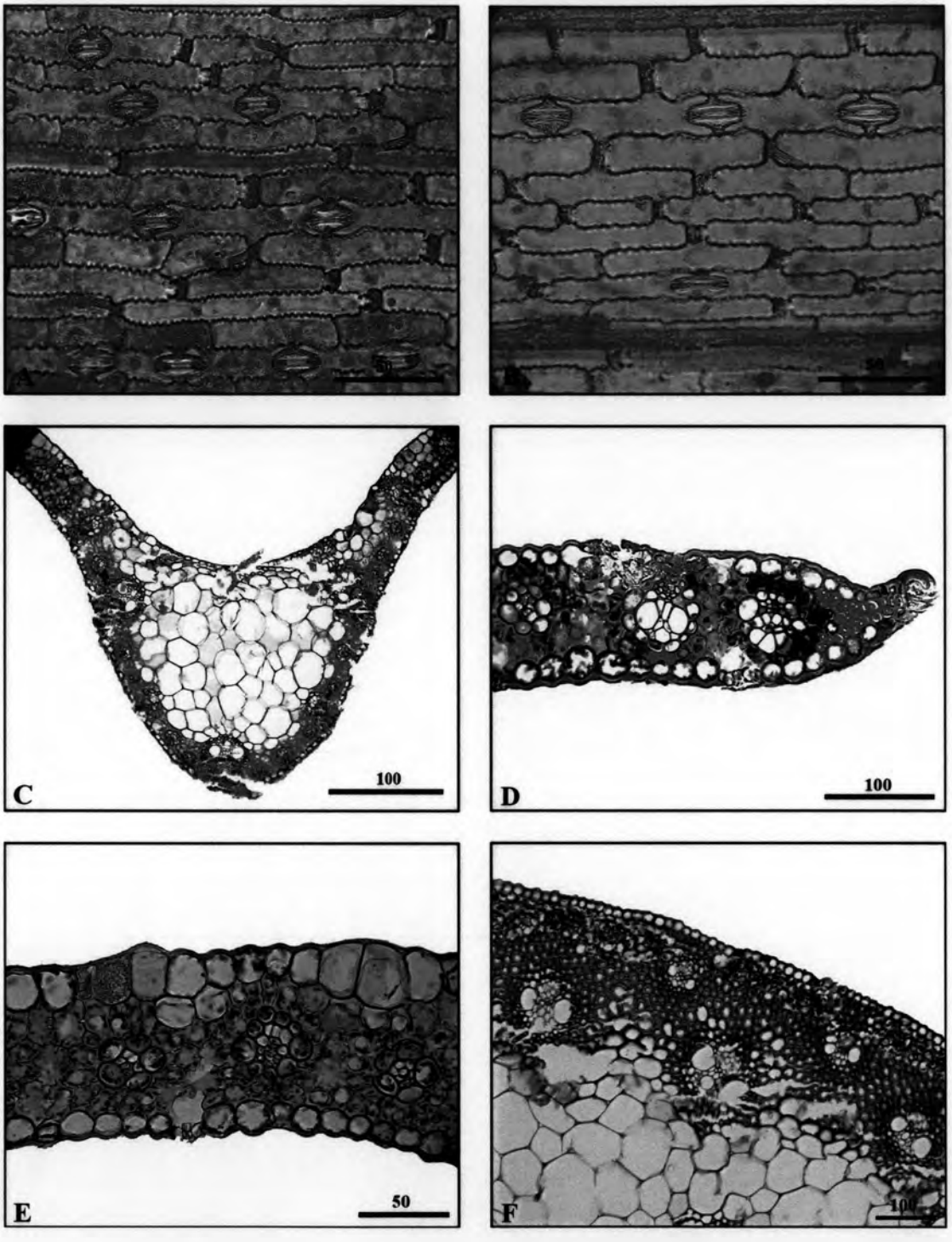

Figure 3.30 Leaf and culm anatomy of *Mnesithea* sp.1 (*P. Traiperm* 347): A. abaxial epidermis, B. adaxial epidermis, C-E. x.s. leaf, F. x.s. culm. Scale bar in μm.

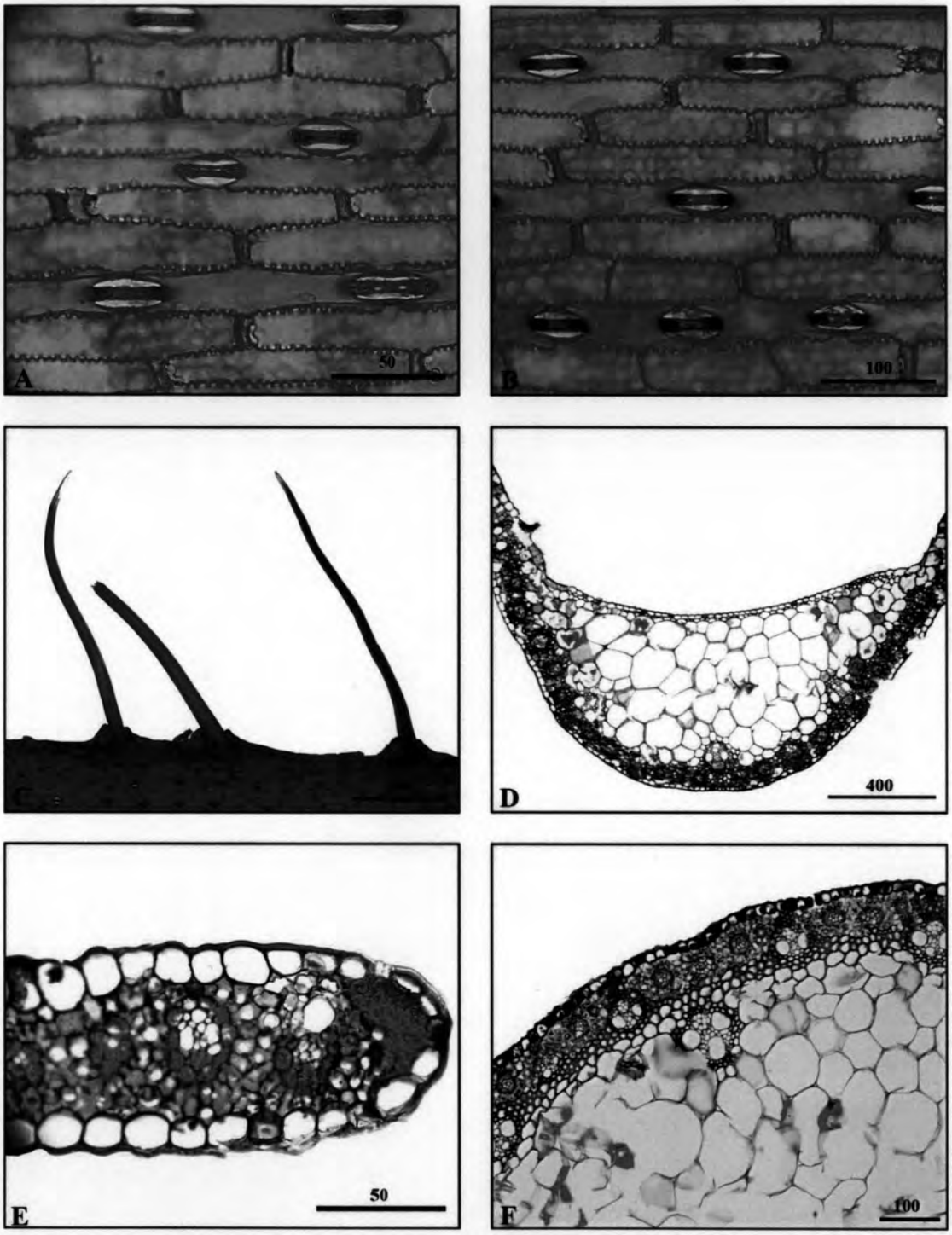

Figure 3.31 Leaf and culm anatomy of *Ophiuros exaltatus* (*P. Traiperm* 186): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-E. x.s. leaf, F. x.s. culm. Scale bar in μm.

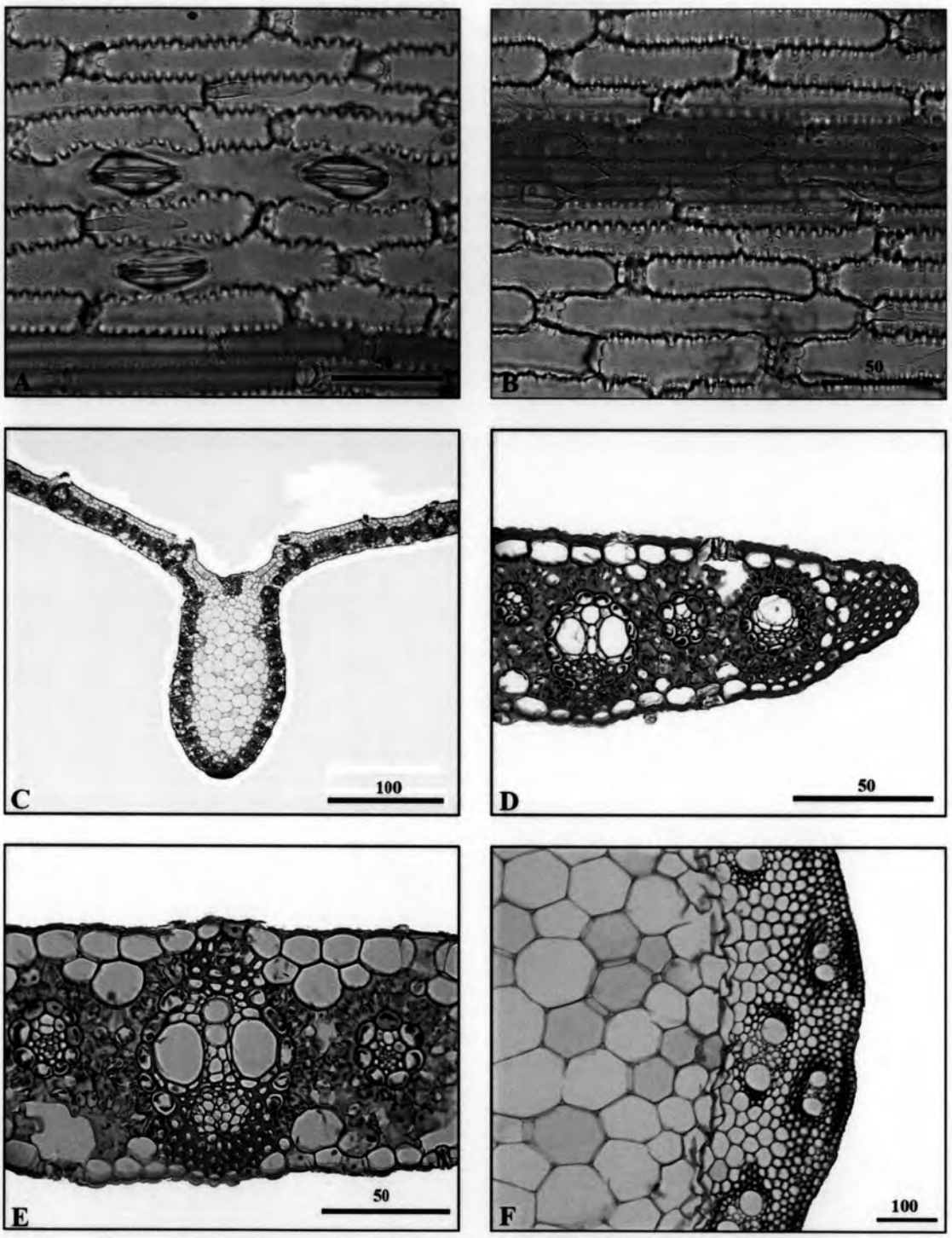

Figure 3.32 Leaf and culm anatomy of *Phacelurus zea* (*P. Traiperm* 222): A. abaxial epidermis, B. adaxial epidermis, C-E. x.s. leaf, F. x.s. culm. Scale bar in μm.

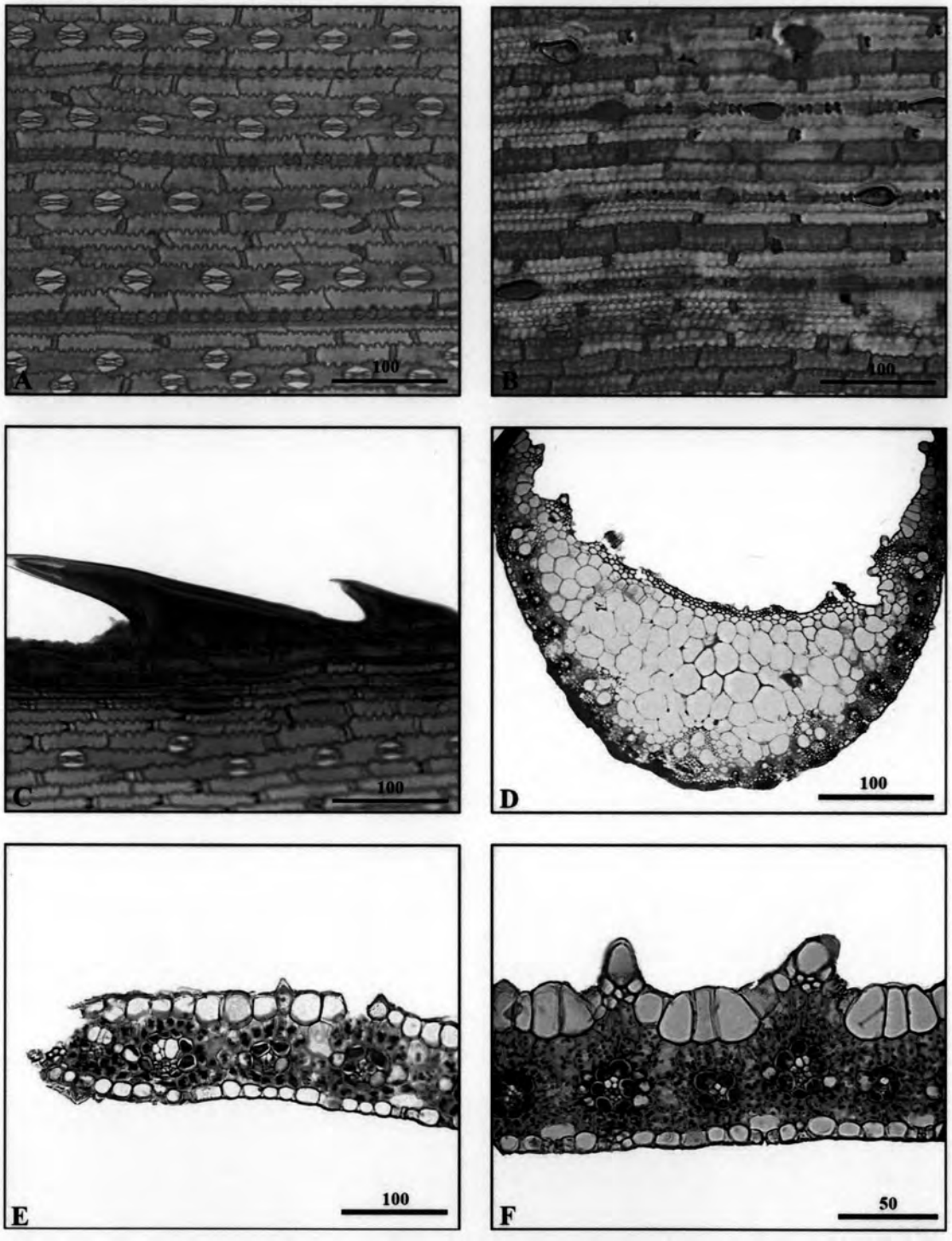

Figure 3.33 Leaf anatomy of *Rottboellia cochinchinensis* (*P. Traiperm* 133): A. abaxial epidermis, B. adaxial epidermis, C. leaf margin, D-F. x.s. leaf. Scale bar in μm.