STUDIES ON INDIAN HYMENOPHYLLACEAE

PART IV. CONTRIBUTIONS TO OUR KNOWLEDGE OF *MECODIUM BADIUM* COPEL.

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The morphology, anatomy and some stages of sporangial development of a hitherto not worked out Indian Hymenophyllaceous fern, *Mecodium badium* Copel., are described.

INTRODUCTION

The morphology of three species of Hymenophyllaceae, i.e. *Crepidomanes latealatum* (v.d.B) Copeland (Sharma 1960), *Hymenophyllum simonsianum* Hooker (Sharma 1963) and *Meringium edentulum* (v.d.B) Copeland (Rao and Sharma 1963), has already been studied. The present paper, the fourth in the series, deals with the morphology, anatomy and some stages of sporogenesis of a North Indian member of the Hymenophyllaceae, *Mecodium badium* Copel. The cytology and the spore characters of this material, however, could not be satisfactorily studied because the meagre material was lacking in fertile stages and was not suitably fixed.

This species comes under the genus *Hymenophyllum*, according to Hooker and Baker (1868, p. 68), Beddome (1883, p. 34) and Bower (1908, p. 576; 1926, p. 250). In view of the entire nature of the indusial valves it can be placed under the subgenus *Sphaerocionium* Pr. (*Euhymenophyllum* auct.) of *Hymenophyllum* Smith (Christensen 1938, p. 531). According to Holttum (1954, p. 75) it is *Hymenophyllum badium* because of the crisp wings of the stipe, the broad (2 mm) rachis and the indusial lips which are wider than long. This species is also placed under the genus *Mecodium* of Copeland (1938, 1947) which is a synonym of *Hymenophyllum badium* Holttum. In this paper the fern is described under the name *Mecodium badium* Copel. This species is distributed in the Eastern Himalayas, South China, Malaya, Japan, Formosa and the Celebes.

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Material and Methods

The present material was collected from the Khasi and Jaintia Hills of Assam in November 1959 and May 1960 and was preserved in 70% alcohol. A 10% solution of glycerine in water was used for softening the rhizome and petiole. A solution of nitric acid and potassium chlorate was helpful for macerating the tissues. Phloroglucin solution was used for staining the lignified tissues (Foster 1942, p. 141). Microtome sections were cut, 8–15 μ in thickness, and free-hand sections also proved to be useful. Stains used were haematoxylin-orange-G and safranin-fast green.

General Morphology

The plants are epiphytic and measure 9–17 cm in length (Fig. 20). The long, unbranched, creeping rhizome, measuring 0·75 mm in thickness, is dark brown in young plants and black in older ones. The roots are numerous, covered all over by unicellular hairs (Fig. 1) and are opposite in origin, from both the sides of the rhizome.

The fronds measure 8–16 mm in length and 2–6 mm in width and are pinnately lobed (Fig. 20). The stipe is 4–6 cm long, winged, except at the base; wings are slightly crisp, about 2–2·5 mm wide. Pinnae are alternate, close but usually not overlapping and measure 0·5–3·5 cm in length and 0·3–1·5 cm in width. Pinnules are usually 1 mm broad, lobed and are supplied by a free veinlet in each lobe. The venation is free and typically dichotomous (Fig. 2).

The rhizome and petiole appear to be smooth, devoid of dermal appendages, although Nozu (1950, p. 131) has recorded multicellular hairs in the genus *Mecodium*.

The indusium is usually circular, slightly broader than long, measuring 0·5 to 1·5 mm in length, bilipped. The sori occur on the upper half of the leaf and are located in bilipped indusia (Fig. 21).

Anatomy

Root:

Transverse sections of the root (Fig. 22) reveal the epidermis and two to three cells thick cortex of thin-walled cells. Its innermost layer is stratified leaving one to three unthickened cells, probably serving as passage cells (Fig. 22).

The stele is usually diarch (Fig. 22) and the xylem is made up of scalariform, spiral and annular tracheids. The endodermis and pericycle are both single-layered. The narrow cells of the phloem are separated from the xylem by one-layered conjunctive parenchyma.

The root of *Mecodium badium* resembles that of *Hymenophyllum simonsianum* (Sharma 1963) and *Meringium edentulum* (Rao and Sharma 1963) in that the cells of the innermost layers of the cortex have stratified walls and are interrupted by passage cells.

Rhizome:

The rhizome in *Mecodium badium* is slightly thicker than that of *Crepidomanes latealatum* (Sharma 1960), *Hymenophyllum simonsianum* (Sharma 1963) and *Meringium edentulum* (Rao and Sharma 1963) which also shows an entirely different type of anatomy.

Fig. 23 shows a transverse section of an old rhizome. The cortex is differentiated into two zones, an outer thin-walled cortex which is less developed on the lower side and an inner five- to six-layered cortex made up of thick-walled blackish highly stratified cells practically without any lumen inside, as can be clearly made out from Fig. 23.

The stele has mesarch protoxylem and is delimited from the cortex by a single-layered endodermis made up of barrel-shaped cells. The two-layered pericycle is formed of big parenchymatous cells as in *Hymenophyllum simonsianum* (Sharma 1963) and *Hymenophyllum scabrum* (Boodle 1900, p. 457).

The scalariform metaxylem is in two parallel horizontal bands. The upper one is more developed, and is composed of bigger tracheids. The lower one is rather discontinuous and is formed of slightly smaller tracheids. A study of young and old rhizomes showed that the lower xylem is the first to be formed. The two bands are separated by three to four layers of conjunctive parenchyma in which the spirally thickened protoxylem is lodged. The protoxylem is usually free from the metaxylem but may in some cases abut on the lower metaxylem band. This rather peculiar position of the protoxylem is unique in the Hymenophyllaceae as has been noticed by Boodle (1900, p. 458) in *H. scabrum*. The three tracheids (*lt*) attached to the upper xylem band (Fig. 23) are probably the leaf trace tracheids. The phloem surrounds the xylem on both sides, but is separated from it by one to two layers of parenchyma. Macerated and cleared material of the rhizome shows the origin of a common trace from the rhizome protostele. This common trace divides to give rise to the leaf trace and axillary branch trace (Fig. 3).

FIGS. 1–19 (*axbt*—axillary branch trace; *ct*—common trace; *lt*—leaf trace; *mrb*—main rhizome bundle; *r*—receptacle; *rt*—root; *rtt*—root trace; *sp*—sporangium; *uh*—unicellular hairs). 1, part of a root covered all over by unicellular hairs. ×42. 2, a pinna showing dichotomous venation and distribution of sori. ×7. 3, diagram of a partially macerated preparation of a rhizome showing the origin of a common trace and a root trace from the main rhizome bundle. The common trace later divides to give rise to a leaf trace and an axillary branch trace at the petiolar base. ×29. 4–19, different developmental stages in the formation of a sporangium (*see* text for further explanation).

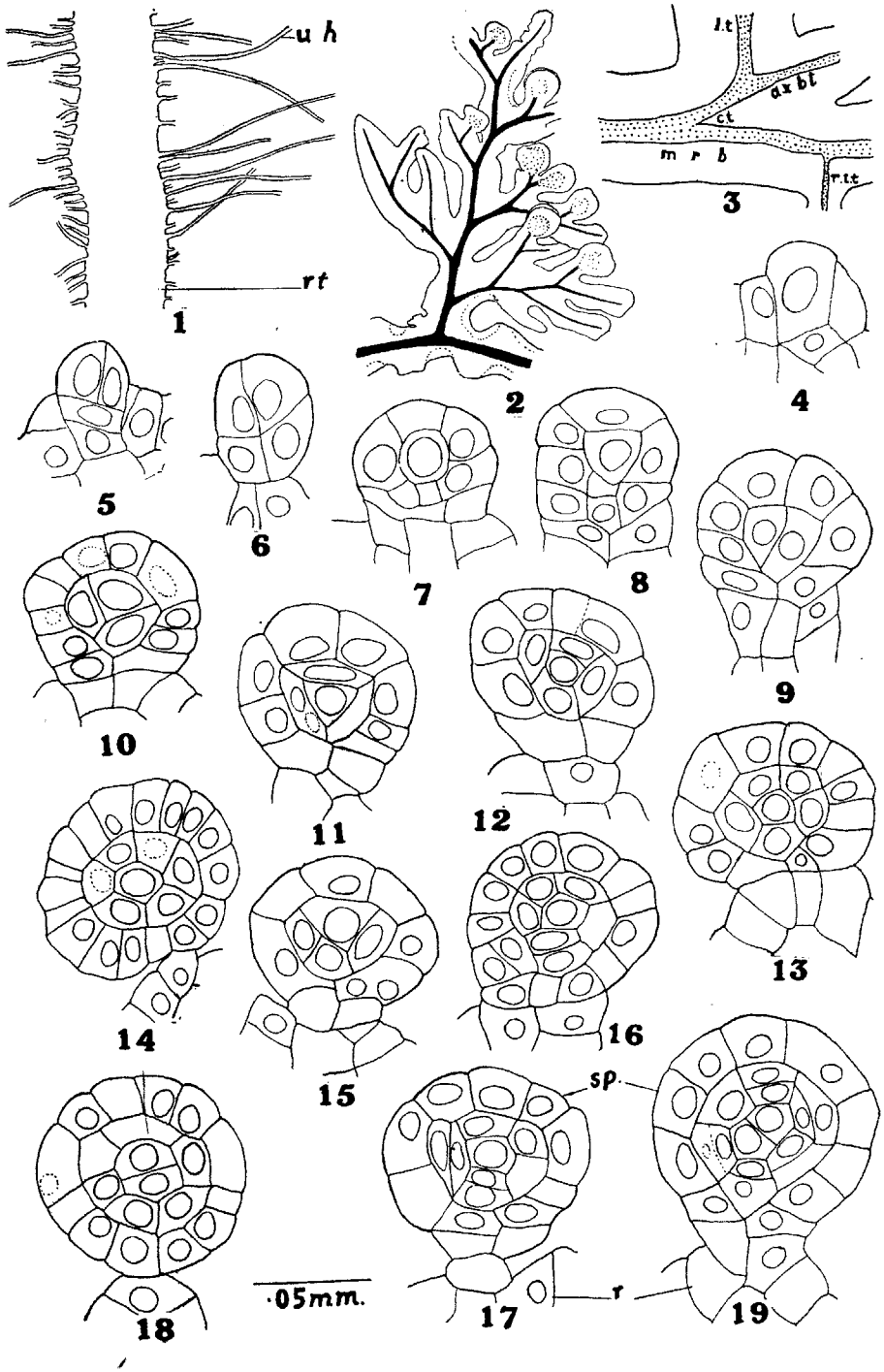
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Fig. 24 shows the stelar part of the transverse section of the basal region of the petiole. The endodermis is torn off and the pericycle is two- to three-layered and made up of big parenchymatous cells. The phloem is not equally developed all round the xylem as in the rhizome, but is more developed on the upper side. The metaxylem is in the form of an inverted V with its two ends curved inwards and attached to two groups of protoxylem, thus differing in form from the two-banded xylem of the rhizome. Parenchyma separates the phloem from the xylem. The cortex at this level of the petiole is just like that of the rhizome and is formed of an outer parenchymatous and an inner sclerenchymatous zone.

The transverse section of the petiole from the middle of the leaf (Fig. 25) shows a part of the one cell thick leaf lamina (*l*) on either side. The epidermis is formed of bigger, rounded and parenchymatous cells. The cortex is made up of only sclerenchymatous cells with slightly stratified walls. The stele itself is exactly similar to that of the basal part and generally resembles that found in *Crepidomanes latealatum*, *Hymenophyllum simonsianum* and *Meringium edentulum* (Sharma 1960, 1962, 1963).

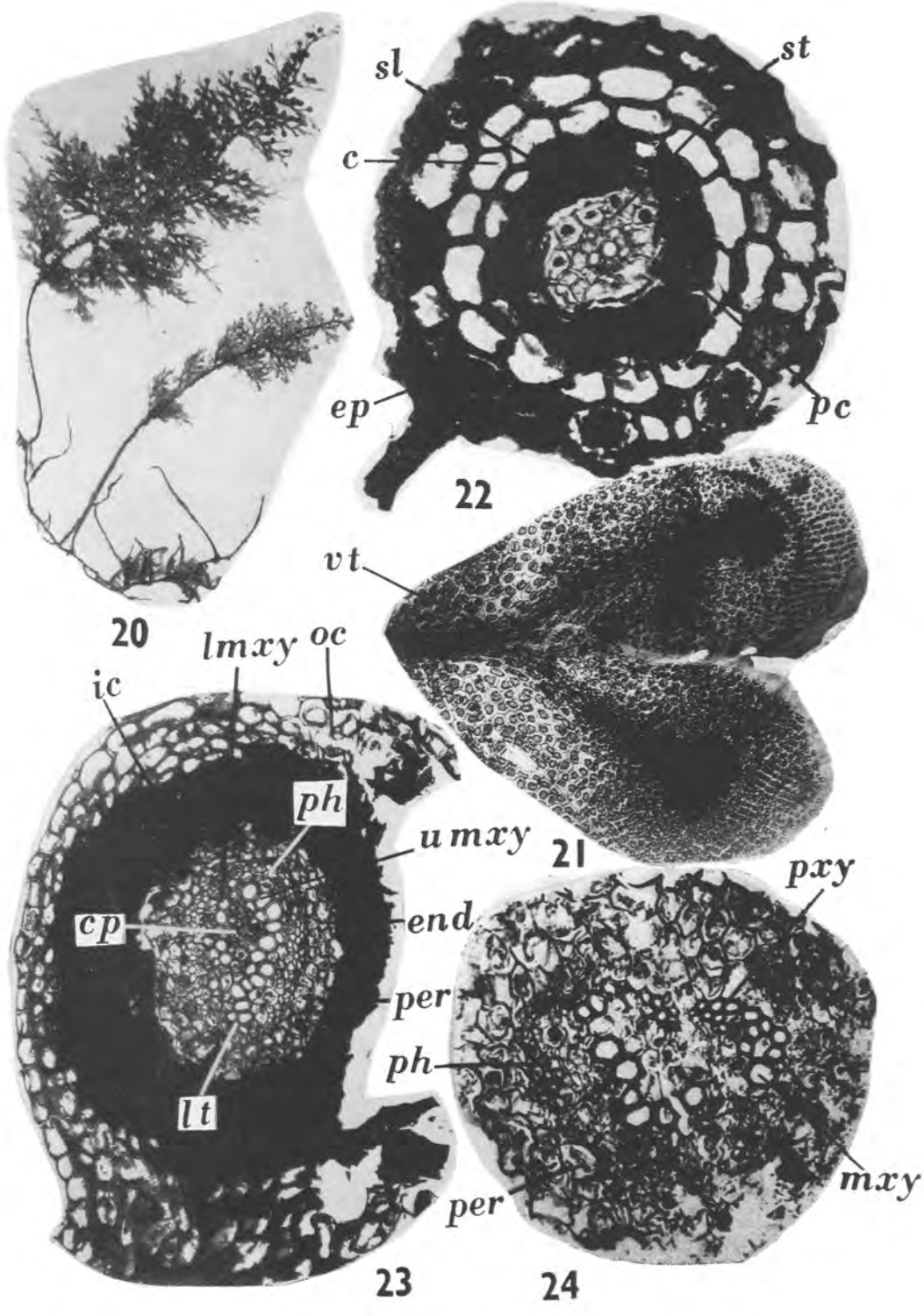
A transverse section of the leaf at its apex shows the epidermis, one- to two-layered cortex, a single-layered endodermis and a pericycle. The xylem is represented merely by four to five tracheids and the phloem is on the lower side. The one cell thick leaf lamina is also seen on both the sides (Fig. 26). Fig. 27 is the surface view of the lamina showing the hexagonal cells with prominent nuclei (*nu*).

Sorus

The sori are terminal, generally two to twelve and confined to the pinnae of the upper half of the leaf (Fig. 20). The indusium is usually circular, slightly broader than long and measures 0·5 to 1·5 mm in length, is bilipped and deeply cleft, till the base (Fig. 21). The short and included receptacle stops growth as soon as the characteristic simultaneous development of the sporangia starts, as in *H. simonsianum*.

Fig. 28 represents the longitudinal section of the young indusium borne terminally on a leaf lamina showing an indusium one cell thick throughout except at the very base where the two flaps join. Here it becomes two to three cells thick. The receptacle is five to six cells thick, globose or slightly elongated and included. It bears four young sporangia showing different

Figs. 20–24 (*c*—cortex; *cp*—conjunctive parenchyma; *end*—endodermis; *ep*—epidermis; *ic*—inner cortex; *lmxy*—lower metaxylem band; *lt*—leaf trace; *oc*—outer cortex; *pc*—passage cell; *per*—pericycle; *ph*—phloem; *pxy*—protoxylem; *sl*—stratified layer; *st*—stele; *umxy*—upper metaxylem band; *vt*—vascular trace). **20**, an entire plant. ×0·6. **21**, portion of a pinna showing two young sori, one cell thick lamina and forked vascular trace supplying the two receptacles, each bearing a few sporangia. ×40. **22**, transverse section of a root. ×228. **23**, transverse section of a rhizome. ×111. **24**, transverse section of a petiole, at its base showing only the stele. ×210.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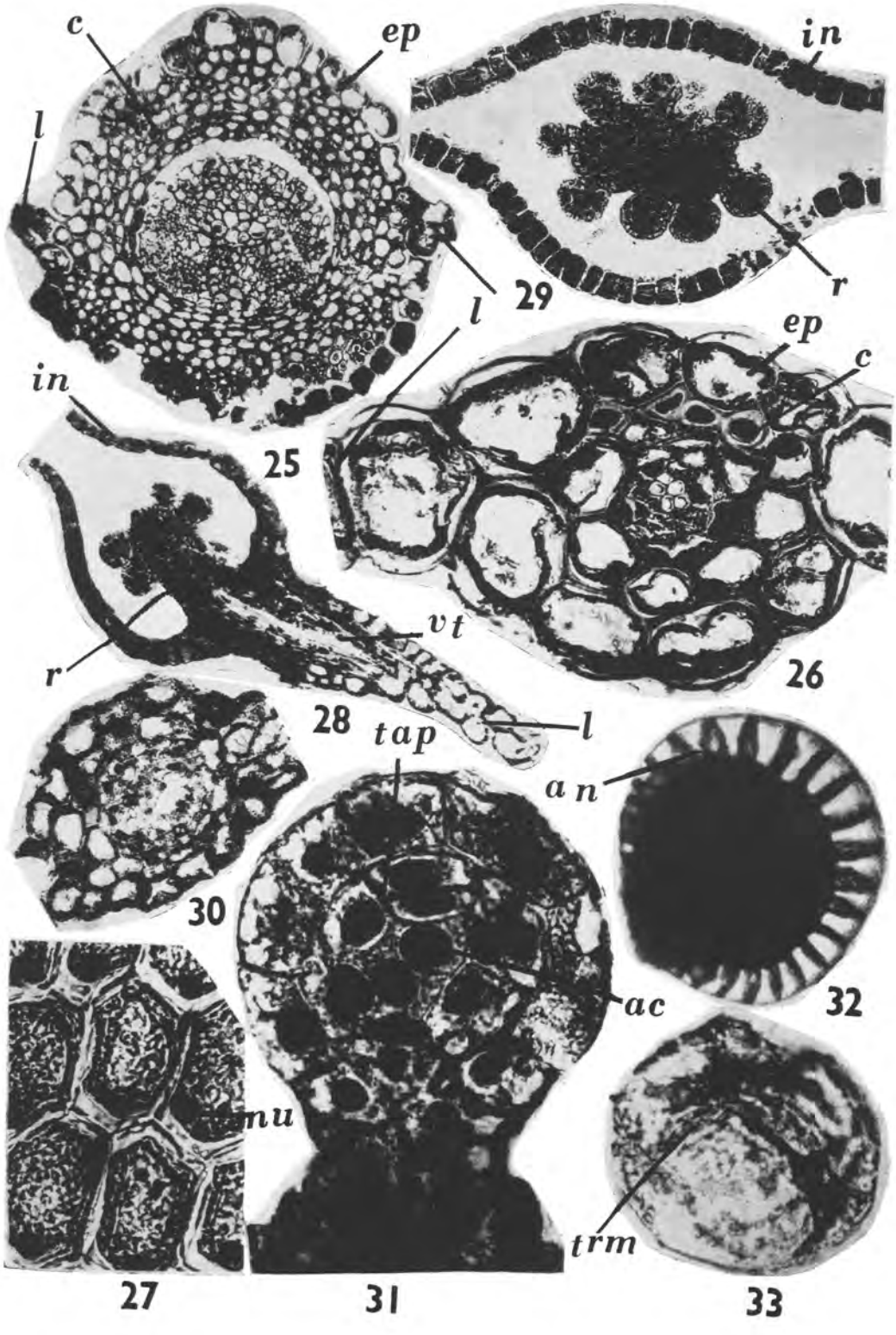
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developmental stages of the sporangium and a single, thick, unbranched, prominent vascular trace entering the receptacle. This is quite unlike that found in *Crepidomanes latealatum* and *Meringium edentulum* (Sharma 1960; Rao and Sharma 1963), where it splits into three before entering into the receptacle. The middle one supplies the receptacle and the other two enter the two flaps along the line of their fusion.

Fig. 29 represents a transverse section of the indusium in its upper portion. Two separate, single-celled flaps of the indusium and a multicelled receptacle bearing eight to nine sporangia can be clearly seen. The receptacle is slightly flattened. Fig. 30 shows a transverse section of the base of the indusium showing the two- to three-celled united portion of the indusium and in the centre the receptacular base.

Sporangial Development

Only some stages in sporangial development could be traced as the material was not enough. The sporangium is initiated from a single superficial big cell having a large nucleus and dense cytoplasm (Fig. 4). The next stage shows the two basal stalk cells and two upper sporangial cells (Fig. 5). The sporangial cells divide and redivide periclinally to give rise to the sporangium proper as in other leptosporangiate ferns. The stalk cell divides once or twice to form the one- to two-celled stalk of the sporangium (Fig. 6). Fig. 7 shows the next advanced stage where a central cell is seen surrounded by one-celled layer which ultimately forms the wall of the sporangium. The central cell is big with a very large nucleus and contains dense cytoplasm. Later on this cell becomes triangular (Fig. 8) and subsequently divides slightly obliquely, forming two unequal cells (Fig. 9), the bigger one dividing again obliquely resulting in the formation of three cells surrounded by a jacket of cells (Fig. 10). By the periclinal division of the upper cell, a central triangular cell is formed and presents in later stages an appearance as in Fig. 11. The cells surrounding this central cell start dividing (Figs. 12–14). Sometimes the central cell may remain undivided while the surrounding peripheral cells may divide on only one side as in Fig. 15. The peripheral layer, surrounding the central cell by periclinal divisions, forms the future tapetum (Figs. 16, 17, 31). Figs. 18, 19 and 31 show the central cell divided into two. This division of

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Figs. 25–33 (*ac*—archesporial cell; *an*—annulus; *c*—cortex; *ep*—epidermis; *in*—indusium; *l*—lamina; *nu*—nucleus; *r*—receptacle; *tap*—tapetum; *trm*—triradiate mark; *vt*—vascular trace). 25, transverse section of a rachis from the middle region. ×132. 26, part of a transverse section of a leaf near its apex. ×419. 27, cells of leaf lamina in surface view. ×419. 28, L.s. of a sorus. ×77. 29, transverse section of the sorus. ×104. 30, transverse section of indusium near its base. ×160. 31, a young sporangium showing the outer jacket of cells, tapetum and two centrally placed archesporial cells. ×635. 32, a mature sporangium showing the annulus in its lateral view. ×183. 33, a spore showing proximal view of surface reticulations and triradiate mark. ×321.

the central cell takes place sometimes before the periclinal divisions of the surrounding layer of cells (Fig. 18). Further stages showing the formation of the spore mother cells and of cytogenesis could not be studied due to lack of older sori.

The mature sporangium measures 108 μ long by 72 μ broad. The annulus is incomplete and is made up of twenty-six to twenty-seven cells whose radial and inner walls are thickened (Fig. 32). A stomium is not well defined and is represented by just a few unthickened cells and resembles that of *Hymenophyllum simonsianum*.

The spores are more or less circular in form, tetrahedral (Fig. 33) and measure on an average 36 μ in polar diameter and 60 μ in equatorial. The range of diameter is 32 μ to 28 μ in polar view and 52 μ to 80 μ in equatorial view. The spore wall is two-layered with an outer ornamented exine and an inner smooth intine. The spore contents are granular and starch grains are also present.

It was found that the germination of spores within the sporangium itself into nine- to ten-celled gametophytes is quite common (Sharma 1962).

Mecodium badium resembles *Hymenophyllum simonsianum* in many respects such as (1) in the simultaneous development of sporangia, (2) in stalks of the sporangia being short, (3) the vascular trace entering up to the receptacle directly without dividing into three at its base, (4) in having an included receptacle and lastly (5) the stomium in both is represented by just a few parenchymatous cells.

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