FURTHER CONTRIBUTION TO OUR KNOWLEDGE OF THE ANATOMY OF *PTILOPHYLLUM*

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ABSTRACT

The epidermal features and the anatomy of the rachis and pinna of a well preserved but fragmentary petrified specimen of *Ptilophyllum* from the Rajmahal hills are described in detail. The rachis contains a double arc of collateral vascular bundles comparable to those found in the Pteridosperms. Sclerenchymatous patches and sclereids are found in the cortex. The epidermal features agree with those already described for this species by Sahni and Rao and others. It is found that a single bundle coming off from the upper corner of the double arc of the vascular bundles of the rachis, divides into 2 at the base of the pinna and repeatedly dichotomises at different levels to form a more or less parallel venation. The bundles of the pinnae are collateral, exarch with a parenchymatous bundle sheath. Isolated and grouped sclereids occur scattered in the palisade and spongy mesophyll.

INTRODUCTION

BANCROFT (1913) gave the outline of the pinnae and rachis of *P. cutchense* from the Rajmahal Hills without mentioning anything further about its anatomy. Rao (1948) in an unpublished paper described the anatomy of the pinnae of *P. cutchense* found in a petrified block from Nipania in the Rajmahal Hills. Examination of a few more blocks (K. 15) from the same locality revealed fully the anatomy of the pinnae and the rachis and also the epidermal features, of some well preserved specimens of *Ptilophyllum* which agree with *P. cutchense* and to some extent with *P. amarjolense* (*see* under Discussion). This forms the subject matter of this paper.

METHOD

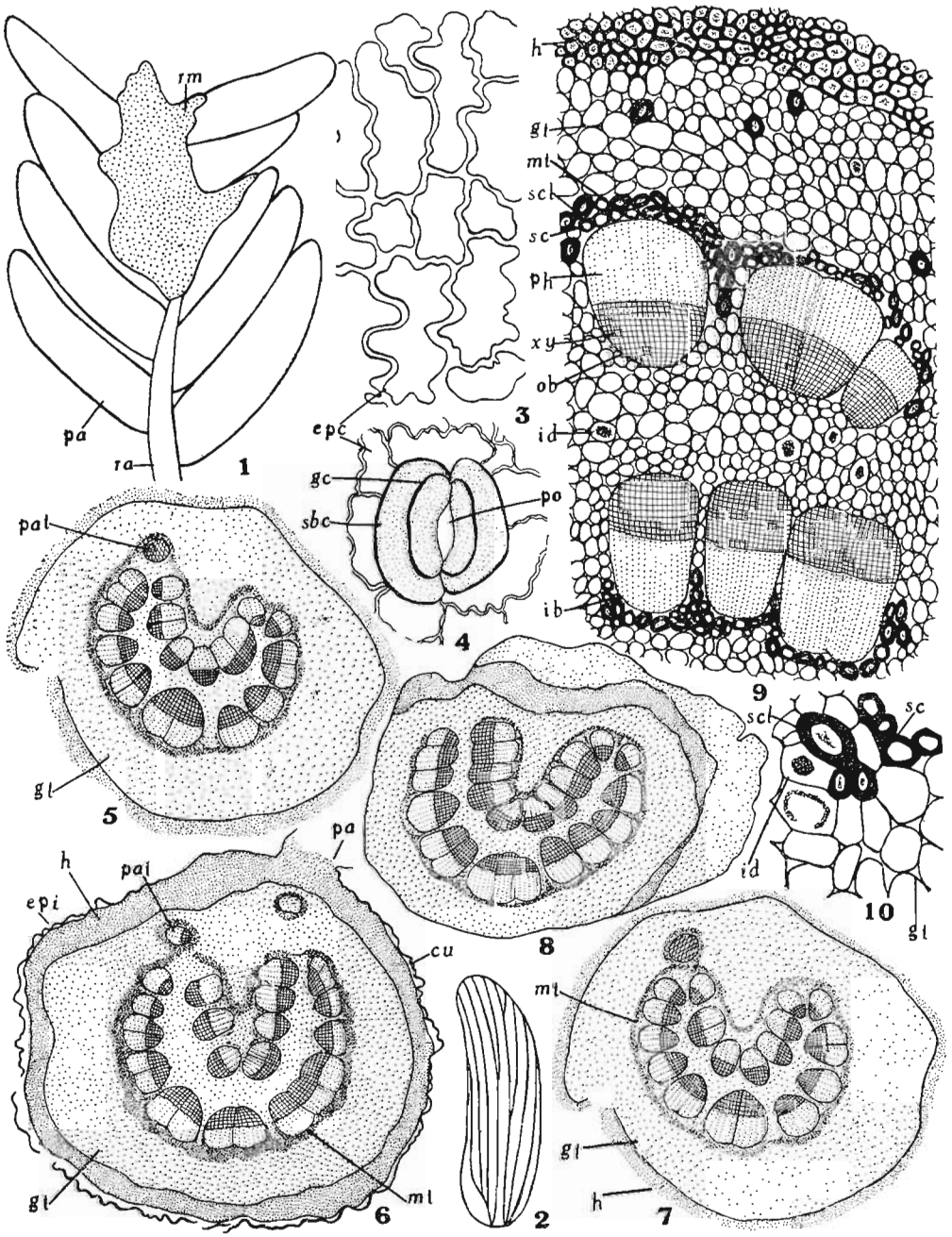
Due to the extreme silicification of the tissues, the details of the anatomy could be studied only after staining the sections with safranin and gentian violet. Both the stains gave good results. Apart from the thin sections, ground by hand the peel method (WALTON, 1928; BARNES & DUERDEN, 1930) was also tried for studying the serial sections. But they were not useful. For the stomatal studies '*Duco prints*' (RAO, 1943) were taken by wetting the surface of the pinnae with absolute alcohol and smearing it with Durofix without any treatment with acid. The peels come off with the impressions of the surface, without any plant bits. This was the only way left, to examine the epidermal features, as no cuticle is preserved and the brittle epidermis does not lend itself for paradermal sectioning. The details of the structure of the stomata were studied from these "Duco prints" and the illustrations also drawn from them. A study of the impressions under strong reflected light was however, helpful in studying the epidermal features. The pinnae and the rachis could however be sectioned satisfactorily.

DESCRIPTION

One fragment of the chert, K. 15, shows 3 pairs of pinnae in the apical part of a leaf (FIG. 1, PHOTO 1). The individual pinna measures 2 mm. broad and 6 to 7 mm. long with obtuse tip. They are short, sub-opposite, slightly overlapping, obliquely placed and attached to the upper side of the rachis. The base of the pinna is rounded (FIG. 2). The upper surface of the pinna is smooth and the lower surface shows veins which are nearly parallel and branch at all levels (FIG. 2). Two veins can actually be seen to enter the very base of the pinna and they branch and form 4-5 parallel veins within the basal part (FIG. 2). Subsequent branching of the veins leads to 7-9 veins in the middle of the pinna, while at the tip only four or five veins are present.

STRUCTURE AND DISTRIBUTION OF THE STOMATA

The upper surface is smooth, devoid of stomata and has, elongated sinuous walled epidermal cells. The lower surface (PHOTO 2) shows the veins, stomata and the epidermal cells with sinuous walls (FIG. 3). Between any two veins occur generally 2-3



All figures are drawn with the help of a camera lucida.

TEXT-FIGS. 1-10.

rows of stomata with a more or less regular orientation (PHOTO 2 & 3). The stomata are roughly oval in outline and measure 43-58 μ long by 36-57 μ broad, slightly sunken, with two subsidiary cells enclosing the entire stoma (FIG. 4). Often a subsidiary cell may be divided into two. The frequency of the stomata is 100-110 per sq. mm. The veins are generally composed of 4 rows (PHOTO 3) of elongated almost straight walled cells which increase to 6 at the forking of the vein. The margin of the pinna is composed of 4 rows of slightly elongated and sinuous walled cells devoid of papillae and stomata.

ANATOMY OF THE RACHIS

The rachis in cross sections (FIGS. 5-8, PHOTO 4 & 5) shows a thick layer of cuticle (FIG. 6) overlying the epidermis which is not well preserved. The hypodermis is made up of small thick walled cells with some contents inside (FIG. 9). The ground tissue consists of thin walled, round or oval to elongated (due to compression) compact cells with small intercellular spaces (FIG. 9). A few thick walled isolated or grouped cells with lamellated walls, are scattered in the ground tissue (FIGS. 9 & 10, PHOTO 6 & 7). They occur in a discontinuous ring outside as well as in between, the fibrovascular bundles (FIGS. 9, 11 & 12, PHOTO 4). They are the sclereids (MENON, MALAVIYA & RAO, 1965) referred to as stone-cells in *Williamsonia sewardiana* flower peduncle by Sahni (1932). The vascular bundles are arranged in a double arc (FIGS. 5-8, PHOTO 4 & 5), the concavity facing upwards and the bundles vary from 25-32 in number. Many of the bundles are in a state of incomplete division (FIGS. 5-8). The bundles of the arc are at places so much united as to suggest a continuous C-shaped strand as in some Pteridosperms. This evidently becomes split up into a number of bundles, which are collateral, endarch with more or less equally well developed phloem, and compact xylem with scalariform thickenings. The xylem in the outer and inner arcs face in opposite directions. The well preserved phloem cells are polyhedral and compact without any intercellular spaces (FIG. 12). Apart from the sclereids, a discontinuous layer of sclerenchyma cells is also present outside, as well as in between, the vascular bundles (FIGS. 9, 11 & 12, PHOTO 6). Both these are joined together and form a more or less continuous ring of mechanical tissue outside the vascular bundles (FIGS. 5-9, 11 & 12, PHOTO 4 & 5).

The sclereids found in the rachis are more or less rounded, oval or slightly elongated (PHOTO 7) often lobed (FIGS. 13-20) and can be referred to the category of *Brachysclereids* or *stone-cells* (TSCHIRCH, 1889 and FOSTER, 1949). The cell contents may partly be the wall substance as they stain with safranin (FIG. 18). The lumen is generally round to oval in shape (FIGS. 13-20). The very thick, finely lamellated secondary walls of the sclereids (FIGS. 13-20) bear round or oval slit-like pits (FIG. 13) and pit-canals (FIGS. 19 & 20) which run through the entire thickness of the wall. The ontogeny of the sclereids could not be studied due to the lack of younger fronds. Apart from the sclereids there are some peculiar type of thin walled cells with dark contents distributed in the ground tissue. They may be referred to as Idioblasts (FIG. 9, PHOTO 4) (ESAU, 1962).

ANATOMY OF THE PINNA

A cross section of the pinna-shows mostly a slightly convex upper and a slightly

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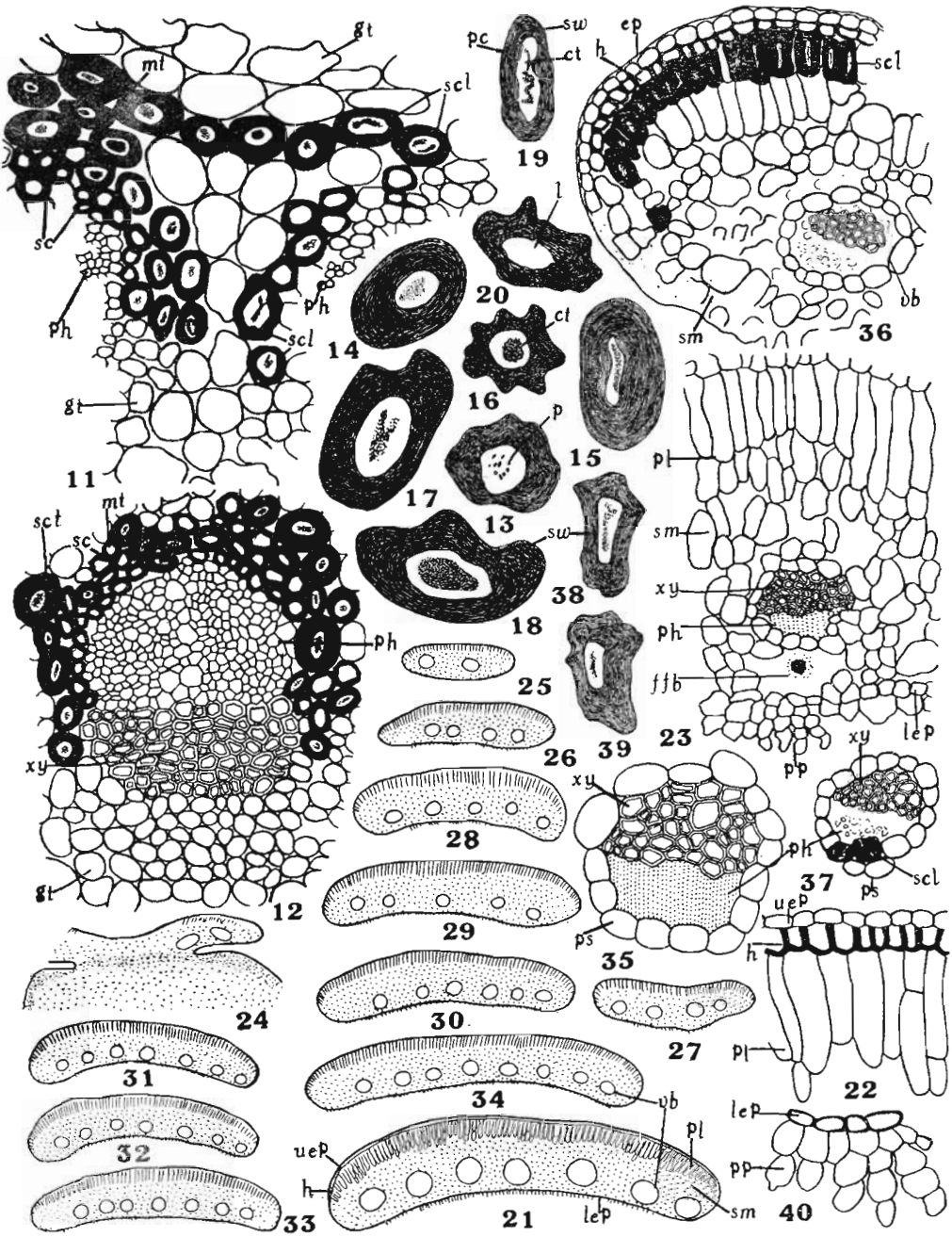
TEXT-FIGS. 1-10 — (*cu*, cuticle; *epi*, epidermis; *epc*, epidermal cell; *gc*, guard cells; *gt*, ground tissue; *h*, hypodermis; *ib*, inner bundle; *id*, idioblast; *mt*, mechanical tissue; *ob*, outer bundles; *pa*, pinna; *pat*, pinna trace; *ph*, phloem; *po*, pore; *ra*, rachis; *rm*, rock material; *sbc*, subsidiary cell; *sc*, sclerenchyma; *scl*, sclereid; *xy*, xylem).

1. An outline sketch of the apical part of the frond with the help of the camera lucida. The venation is not shown. × 12. 2. A single pinna enlarged showing the venation. Only two bundles enter into the very base of the pinna and they divide at various levels. × 12. 3. Epidermal cells as shown by 'Duco print'. × 300. 4. A single stoma from the 'Duco print' enlarged. × 300. 5-8. Transverse sections of the rachis showing the stages of evolution of the pinna trace. Fuller explanation in text. × 20. 9. A sector of the rachis in transverse section showing the various tissues. × 60. 10. A small portion of the outer side of the outer bundles enlarged showing the sclereids. × 140.



All figures are drawn with the help of a camera lucida.

TEXT-FIGS., 11-40.

concave lower surface (FIG. 21, PHOTO 8). Below the upper epidermis of smaller rectangular cells (FIG. 22, PHOTO 9) lies generally a single layered hypodermis, composed of slightly thick walled cells (FIG. 22, PHOTO 9 & 10). The palisade tissue is made up of 1-2 rows of elongated thin walled cells (FIGS. 22 & 23, PHOTO 9 & 10). Towards the margin of the pinnae, the palisade cells are smaller in size and indistinguishable from the spongy mesophyll (PHOTO 9). This extends from the palisade to the lower hypodermis (FIG. 23, PHOTO 9 & 10) and is made up of loosely arranged more or less angular cells (FIG. 23). The vascular bundles passing through the mesophyll number 4-9 and are placed in a single row (FIG. 21, PHOTO 8). Earlier descriptions of the anatomy (BANCROFT, 1913; BOSE, 1953 & VISHNU MITRE, 1956 MS.) have indicated the general disposition of tissues and vascular elements in the pinnae of *Ptilophyllum*. But the origin of the pinna trace and their evolution into the parallel veins of the pinna have not clearly been elucidated. It was found that in the specimen described in this paper, the details could be studied definitely to some extent. Photo 5 and Fig. 5 show that the pinna-trace is single and arises from the corner of the double arc of the vascular bundles. This is gradually pushed out (FIG. 6) and abstricted off (FIG. 7) leaving a gap between the two arcs (FIG. 8, PHOTO 4). Only one such bundle passes into the pinna.

From the upper surface it looks as if the pinna is attached throughout its breadth. The base of the pinna is actually rounded and not auriculate (FIG. 2). The attachment to the rachis is by what appears to be an exceedingly short petiole like structure which cannot be satisfactorily demonstrated. Into this evidently passes the single pinna-trace referred to above and divides into two. Fig. 24 shows these two bundles cut transversely in a rather obliquely sectioned basal part of a pinna. Figs. 25-34 represent transverse sections at different progressive levels in the pinna. It will be seen that the multiple bundles disposed more or less in a parallel manner in the adult pinna are the result of repeated dichotomy of a single trace that passes into the base of the pinna. This is confirmed by Fig. 2, which shows the venation in surface view. Fig. 34 shows the maximum number of veins encountered in the middle of the pinna. The tip of the pinna contains four veins almost the same that is found near the base. The vascular bundles are collateral, exarch with poorly preserved phloem and well preserved xylem elements (FIG. 35, PHOTO 10), which are scalariformly thickened and are quadrangular to hexagonal in section. A parenchymatous sheath (FIG. 35, PHOTO 10) surrounds the vascular bundle. Just as in the rachis here also sclereids or stone-cells are found in a row in the palisade region (FIG. 36) and occur scattered in the spongy mesophyll, where they are confined mostly to the vascular bundles (FIG. 37). They are also slightly elongated with thick, lamellated, pitted, lignified secondary walls (FIGS. 38 & 39). Such stone cells have been described by Sahni in the leaf bases and peduncle of *Williamsonia sewardiana* (1932). The lower epidermis has rectangular cells and bears a number of papillae which are generally 2-3 celled (FIG. 40, PHOTO 10). Sectional

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TEXT-FIGS. 11-40 — (*ct*, cell content; *epi*, epidermis; *ffb*, fungal fruit body; *gt*, ground tissue; *h*, hypodermis; *l*, lumen; *lep*, lower epidermis; *mt*, mechanical tissue; *p*, pits; *pc*, pit canal; *ph*, phloem; *pl*, palisade; *pp*, papilla; *ps*, parenchyma sheath, *sc*, sclerenchyma; *scl*, sclereid; *sm*, spongy mesophyll; *sw*, secondary wall; *upe*, upper epidermis; *vb*, vascular bundle, *xy*, xylem).

11. A portion in between the outer bundles enlarged to show the distribution of sclereids and sclerenchyma. × 140. 12. A vascular bundle shown on an enlarged scale. × 140. 13-20. Different types of sclereids from the rachis. × 300. 21. Transverse section of the pinna. × 32. 22. A portion of the pinna showing the upper epidermis; hypodermis; and palisade cells enlarged. × 140. 23. A sector of the transverse section of the pinna enlarged to show the vascular bundle. × 140. 24-34. Transverse sections of the pinna at the different progressive levels. × 20. 25. Represents the base of the pinna with only two bundles. × 20. 26. Represents a section through the middle part of the pinna showing the maximum number of vascular bundles. × 20. The other figures show varying numbers of vascular bundles due to the dichotomy of the veins. Further explanation is in text. 35. A single vascular bundle of the pinna shown on enlarged scale. × 300. 36. The marginal region of the pinna in transverse section showing a row of sclereids below the hypodermis. × 140. 37. A vascular bundle from the pinna showing the sclereids in the bundle sheath. × 140. 38-39. Sclereids from the pinna. × 300. 40. A portion of the lower epidermis and papillae enlarged. × 300.

views of the stomata could not be clearly made out, but surface "Duco prints" show the stomata and the epidermal cells but not very clearly the papillae. In some of the air spaces, which are obviously caused by decayed cells, as well as in other parts of the pinnae and rachis, there can be recognized a number of fungal fruit bodies (FIG. 23) which measure 10 μ in diameter and contain similar spores measuring 0·3 μ in diameter.

DISCUSSION

The specific name *Cutchense* was first given by Morris (1840) to certain pinnate fronds from Cutch, India. Seward in 1900 recognized for the first time the organic connection of the leaves of *Ptilophyllum cutchense* to a cycadean trunk which was later on named as *Bucklandia indica* (SEWARD, 1917). In 1920 Seward and Sahni instituted a comprehensive species *P. acutifolium* to include almost all the detached leaves of *Ptilophyllum* known from India. Sahni in 1932 reconstructed *Williamsonia sewardiana* and pointed out that the leaves till then known as *P. cutchense* associated with *Williamsonia sewardiana* were similar to those borne on the stem of *Bucklandia indica*. Sahni and Rao in 1933 for the first time separated *P. cutchense* from *P. acutifolium* on some of the morphological and cuticular features of the pinnae as seen in some specimens from the Rajmahal Hills. These features were further confirmed by Ganju (1946) and Jacob and Jacob (1954). A number of new species of *Ptilophyllum* have been described by Ganju (*loc. cit.*), Bose (1953), Jacob and Jacob (*loc. cit.*) and Vishnu Mittre (1956) (*see* TABLE 1). *P. amarjolense* the new species instituted by Bose (1953) includes, according to him, two types of fronds with morphological and cuticular features comparable to those of *P. cutchense* and *P. acutifolium*. *P. amarjolense* is separated from the above two species in the possession of the following features. It differs from *P. cutchense* (1) "in having also pinnae with acute tips like those of *P. acutifolium*"; (2) "in having a very variable width of the lamina and having slightly falcate pinnae at the apical region of the frond and also in the widest fronds"; and (3) its association with a new species of *Bucklandia*, *Bucklandia sahnii*. It differs from *P. acutifolium* in (1) its "pinnae have rounded upper basal corner and they are not decurrent"; (2) in not having the sinuous walls in the upper epidermal cells; and (3) in having only 2-4 stomata in each band.

Ptilophyllum nipanica (VISHNU MITTRE, 1956 MS), based upon just three pinnae, shows a number of morphological and anatomical resemblances with *Ptilophyllum cutchense*, yet it is regarded by Mittre as distinct from *Ptilophyllum cutchense* on the following grounds: (1) falcate with pointed apex of the pinnae; (2) the presence of polar thickenings and papillae on the guard cell and (3) in the absence of nonstomatiferous bands in the stomatiferous region of the pinnae.

It seems to us that the cuticular and morphological variations shown by these two species, *Ptilophyllum amarjolense* and *Ptilophyllum nipanica*, are insufficient to separate them as different species. They may as well be regarded as variants of either *Ptilophyllum cutchense* or *P. acutifolium*. More specimens with a fuller display of morphological and cuticular character are needed before anything definite could be stated about these species.

A very intriguing situation has arisen on account of the discovery of the type specimen of *Ptilophyllum cutchense* Morris. Through the kind courtesy of Dr. Bose we were able to see the photographs of the original specimen of *Ptilophyllum cutchense* Morris as figured in Grant (1840).

The *Ptilophyllum* species represented by this figure looks more like *P. acutifolium* and not at all like the species which have all along been regarded as *P. cutchense* or compared to it. Further, the type specimen does not show cuticular features. In view of this a fundamental doubt is raised whether the specific name *cutchense* has been correctly applied after Morris. We are therefore not referring our specimen definitely to the species *cutchense*. We refrain from any further comments as Dr. Bose is reviewing all the Indian *Ptilophyllum* fronds in an exhaustive monograph.

ACKNOWLEDGEMENTS

We are greatly indebted to Dr. M. N. Bose for showing his slides, photographs and specimens, examining our specimens and discussing certain points. We are

TABLE 1

Characters	*Ptilophyllum cutchense* Morris 1840	*Ptilophyllum cutchense* Feistmental (1876 & 1877)				*Ptilophyllum cutchense* Feist Bancroft 1913	*P. cf. cutchense* McCl. Sp. Sahni & Rao (1933)	*P. cf. cutchense* McCl. Sp. Ganju (1946)	*P. cutchense* Morris, Jacob & Jacob 1954	*P. jamjolaense* Bose (1953)	*P. utpanica* Vishni Mittre (1956)	*Ptilophyllum* sp. (= *P. cutchense*) described in this paper
		P. cutchense	*P.* var. *distans*	*P.* var. *minimum*	*P.* var *curvifolium*							
Form and arrangement of pinnae on the frond	"Fronds pinnate; pinnae closely approximated, linear, lanceolate, more or less elongate, imbricate at the base, attached obliquely; base semicircular or rounded."	"Frond pinnate, long, attenuate towards the apex and base, leaflets short, oblique, subalternating, imbricate or close together, a little curved, obtusely acuminate, on the base scarcely auriculate, obliquely inserted."	"Leaflet shorter, separate."	"Frond very slender and narrow, leaflets short and narrow, whole aspect fern like."	"Leaflets short, incurved throughout their whole length."	"Frond 9 cm. long, pinnae decrease in size towards either end of the fragment, pinnae are entire, subalternate and closely set on the upper side of the terete rachis."	"Pinnae are relatively short and have a rounded apex."	Pinnae short, stout with rounded tip	Agrees with Feistmental's description.	Fragments of the fronds measuring 0·4 to 4·5 cm. in breadth, tapering very gradually below and more suddenly at the apex. The leaves are imparipinnate. Two types of pinnae, one having mostly oblong, short rounded apices resembling *P. cutchense* and the other widest fronds in which pinnae are slightly falcate with more or less acute tips, resembling *P. acutifolium*. Upper basal corners of the pinnae are rounded, while the lower basal angles are not rounded.	"A fragment of a frond 5-6 mm. long and 8-10 mm. broad with the pinna overlapping with each other, disposed in 2 rows, falcate with pointed apex and with upper and lower round corners at the proximal region."	3 pairs of pinnae seen in the fronds, fragments 1·4 cm. long and 1 cm. broad, pinnae short 2 mm. broad and 6-7 mm. long with rounded apex. They are sub-opposite slightly overlapping, obliquely placed. The base of the pinnae is rounded.
Veins	"Equal, slender, parallel"	"Distinct, radiating from the base and forked towards the apex."	—	—	—	Parallel and apparently end blindly. Dichotomies occur even in the upper parts of pinnae.	—	—	Same as Feistmental's description.	"Distinct, nearly parallel and branching at all levels."	"Lateral veins are very few 3-5 in number and occasionally dichotomising."	4-8 nearly parallel veins, dichotomising at all the levels.
No. of cells over the veins	—	—	—	—	—	—	4 rows of elongated epidermal cells.	3 rows of elongated epidermal cells	Cells with slightly sinuous walls.	3-4 rows of much elongated epidermal cells over each vein.	—	Generally 4 rows of elongated epidermal cells
Epidermal cells	—	—	—	—	—	—	—	—	"Squarish or rectangular cells having thin looped walls in both upper and lower epidermis."	The upper epidermal cells are elongated and the lower epidermal cells are irregular in shape with thin sinuous walls having a few folds	Both upper and lower epidermal cells are squarish to rectangular with very much sinuous walls with large loops. Lower epidermis of thick walled cells.	Upper and lower epidermal cells of more or less irregular shape with sinuous walls with loops.
Distribution of stomata	—	—	—	—	—	—	—	Close in distribution.	No uniformity in distribution.	Orientated more or less at right angle to the veins.	"Stomata are evenly placed to contiguous, irregularly arranged, transverse to oblique in orientation."	Orientated more or less at right angles to the veins.
Frequency of the stomata per sq. mm.	—	—	—	—	—	—	—	—	100 sq. mm.	—	—	100-110/sq. mm.
Size and shape of the stomata	—	—	—	—	—	—	—	Round	Sunken, vary much in size, 36 × 66 μ, 50 × 49 μ, 50 × 70 μ, 60 × 66 μ	Dimension of the guard cells 43 × 34 μ.	38-51μ × 35-45 μ (including subsidiary cells).	Sunken, slightly vary in size 43-58 μ × 36-57 μ.
No. of stomata per band	—	—	—	—	—	—	Usually two, sometimes three rows.	Two to three rows.	Two to four rows	Two to four, usually 3, very rarely 5	—	2-3 rows of stomata
Marginal cells	—	—	—	—	—	—	—	Non-stomatal narrow region.	Non-stomatal and non-papillate region with 4-5 rows of cells.	—	Non-stomatal rectangular cells.	Non-stomatal and non-papillate more or less rectangular to elongated cells.
Papillae	—	—	—	—	—	—	—	—	1-3 in the epidermal cells.	—	Seen even in the guard cells.	1-3 in epidermal cells.
Anatomy of Rachis												
Epidermis	—	—	—	—	—	—	—	—	—	Upper layer of rectangular cells	—	Not preserved properly.
Hypodermis	—	—	—	—	—	—	—	—	—	6-7 celled, thick walled cells	—	6-7 celled thick walled cells with contents.
Ground tissue	—	—	—	—	—	—	—	—	—	Isodiametric or oval cells with intercellular spaces between them	Round to oval parenchymatous cells with frequent intercellular spaces.	Isodiametric round to oval cells with sometimes intercellular spaces.
Vascular bundles	—	—	—	—	—	—	—	—	—	Double series in the form of U. Maximum number of bundles 40 or even more. Xylem in all bundles pointing inwards.	Double series in the form of U. Number of bundles 25. Xylem pointing inwards	U-shaped double series bundles number 25-32. Xylem pointing inwards.
Pinna												
Epidermis	—	—	—	—	—	—	—	—	—	Small rectangular cells.	Rectangular cells.	Single layered.
Hypodermis	—	—	—	—	—	—	—	—	—	Single layered slightly thick walled cells which are bluntly tapering inwards.	Single layered more or less isodiametric cells.	Single layered slightly thick walled cells.
Palisade cells	—	—	—	—	—	—	—	—	—	Narrow, elongated, single layered.	Single layered cells.	Narrow, elongated thin walled single layered cells.
Spongy Mesophyll	—	—	—	—	—	—	—	—	—	Loose cells.	Loose and spongy.	Slightly loose cells
Vascular bundles	—	—	—	—	—	—	—	—	—	Situated in between the mesophyll and lower hypodermis. Xylem on the upper side phloem on the lower side.	3-4 in number posses. scalariform tracheids.	4-8 situated between the mesophyll and lower hypodermis. Collateral, endarch bundles with scalariform thickening of the xylem elements.
Papillae	—	—	—	—	—	—	—	—	—	—	—	1-3 celled on the lower side.

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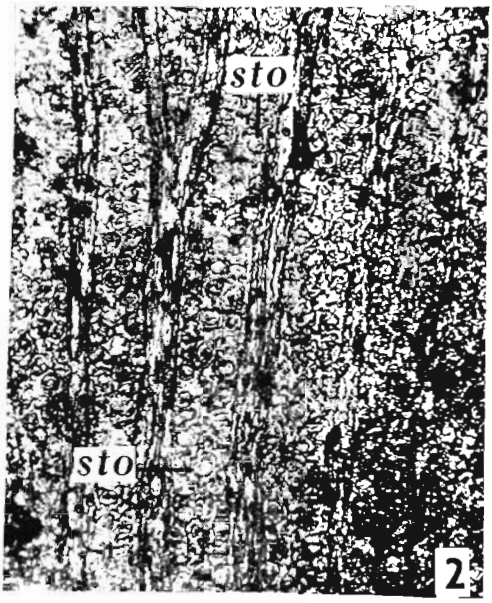

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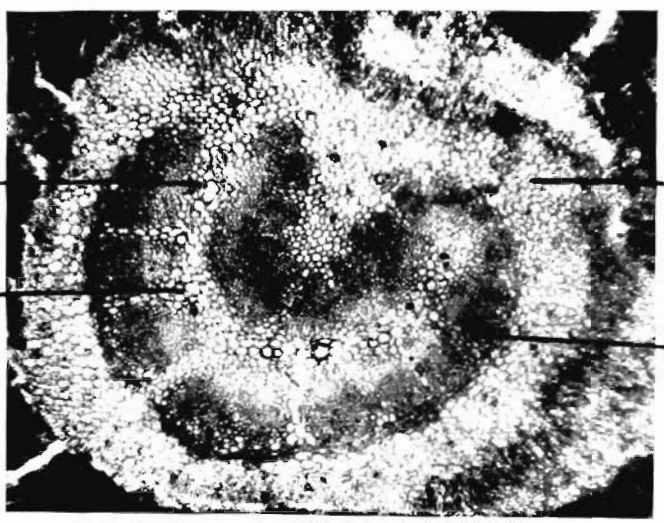

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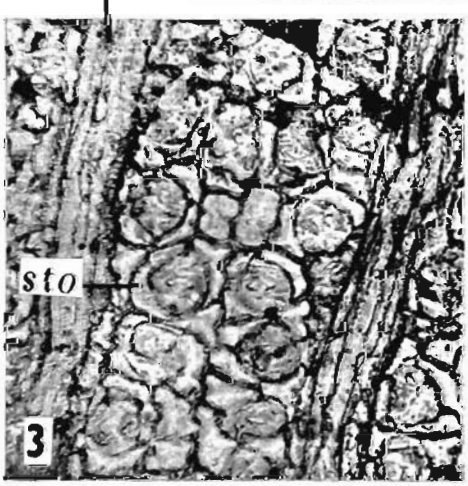

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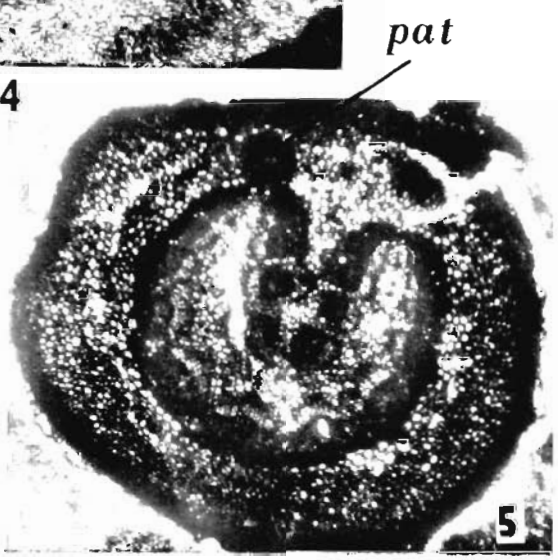

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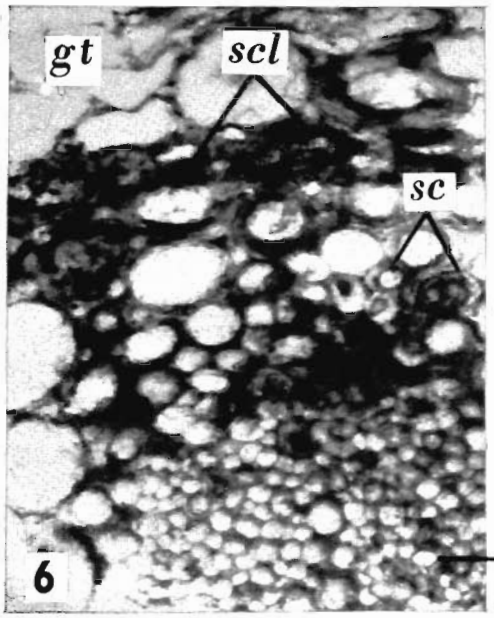
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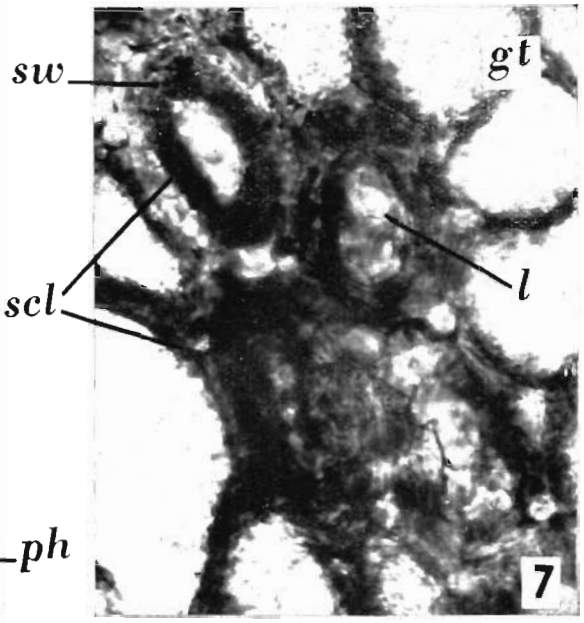
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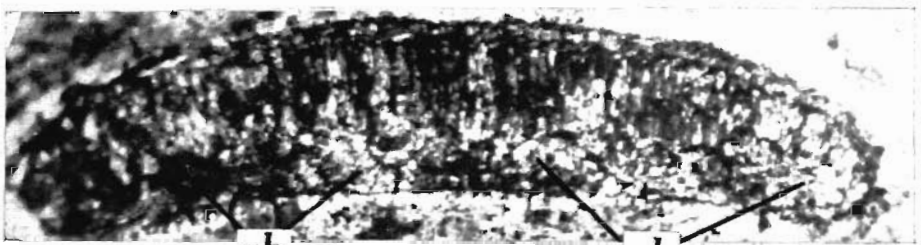
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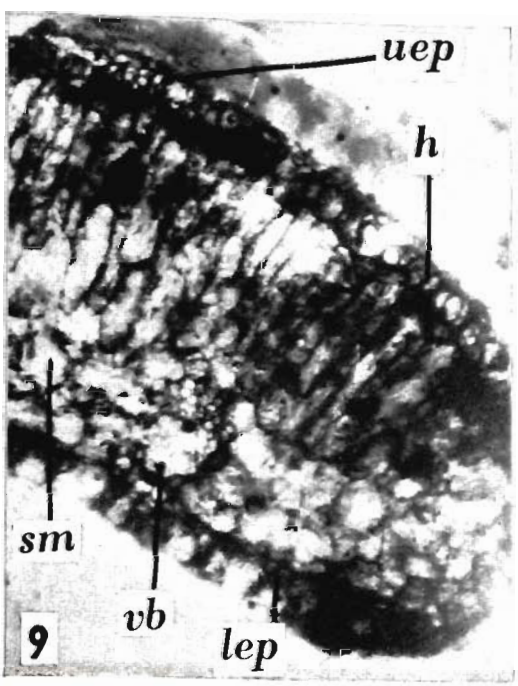
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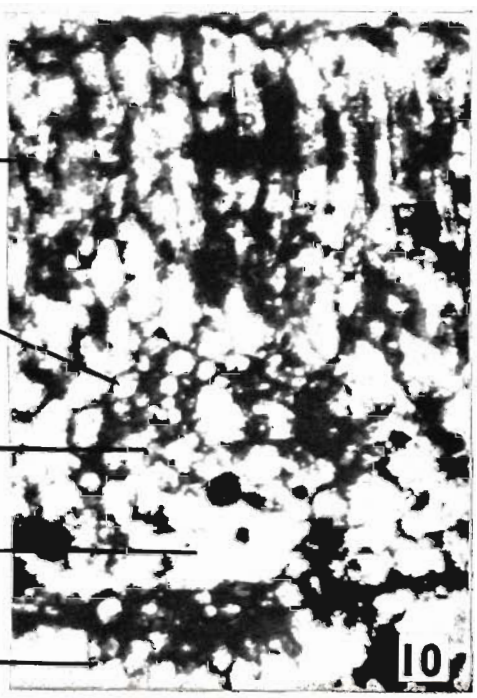
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indebted to Dr. Miss Malaviya for examining our slides and confirming the presence of sclereids. Our grateful thanks are due to the authorities of Birbal Sahni Institute of Palaeobotany, Lucknow, for permission to consult their library. The authors are grateful to the University Grants Commission for their financial aid.

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EXPLANATION OF PLATES

(*All photographs are from untouched negatives*)

PLATE 1

(*fvb*, fibrovascular bundles, *gt*, ground tissue, *id*, idioblast; *pat*, pinna trace; *scl*, sclereid; *sto*, stomata; *v*, vein.

1. The apical portion of the frond enlarged. × 9·9.

2. 'Duco print' of the lower epidermis showing the distribution of the stomata and veins. × 153·6.

3. An enlarged portion of the same showing the arrangement of the stomata. × 173.

4. Transverse section of the rachis showing the bundles arranged in a double c-shape. × 6.

5. Transverse section of the rachis showing the origin of the pinna trace from the corner of the stele. × 4·9.

PLATE 2

(*gt*, ground tissue; *h*, hypodermis; *l*, lumen; *lep*, lower epidermis; *ph*, phloem; *pl*, palisade; *pp*, papilla; *ps*, parenchyma sheath; *sc*, sclerenchyma; *scl*, sclereid; *sm*, spongy mesophyll; *sw*, secondary wall; *uep*, upper epidermis; *vb*, vascular bundle; *xy*, xylem.

6. Magnified portion of a section of the rachis showing sclerenchyma and sclereids. × 286·6.

7. Magnified view of the sclereids showing their lamellated walls. × 580·5.

8. Transverse section of a pinna showing the palisade tissue and a row of vascular bundles. × 28·3.

9. Margin of the pinna enlarged showing the palisade and spongy mesophyll tissues and vascular bundle. × 172·6.

10. Magnified portion of a section of the pinna showing palisade tissue, vascular bundle and papillae. × 191·4.