

Micromorphology and vegetative anatomy of Taxodiaceae L.

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Micromorphology and anatomy of leaves of ten genera of Taxodiaceae viz. *Arthrotaxis laxifolia* R. Br., *Cryptomeria japonica* D. Don, *Cunninghamia lanceolata* Don., *Glyptostrobus linneaus* Linn, *Metasequoia glyptostroboides* Miki, *Sequoiadendron giganteum* Buch. *Sequoia sempervirens* Endl., *Sciadopitys verticillata* Sieb & Zucc., *Taiwania cryptomerioides* R. Br. and *Taxodium distichum* L. Rich, were studied and compared using light (LM) and scanning electron microscope (SEM) in order to evaluate their taxonomic significance. The leaves of these taxa show wide morphological and anatomical variations with respect to their form size, mode of attachment, as well as their epidermal features. The cellular structure as observed under (SEM) are discussed in detail and the diagnostic features suggested which would be useful in intergeneric and interspecific identification of the taxa under present investigation.

Key-words - Micromorphology, anatomy, Taxodiaceae.

INTRODUCTION

THE family Taxodiaceae (Coniferales) is well known for having some of the world's most curious trees and include 10 genera of which 7 are monotypic, viz. *Arthrotaxis laxifolia* R. Br., *Cryptomeria japonica* D. Don, *Cunninghamia lanceolata* Don., *Glyptostrobus linneaus* Linn, *Metasequoia glyptostroboides* Miki, *Sciadopitys verticillata* Sieb & Zucc., *Sequoia sempervirens* Endl., *Sequoiadendron giganteum* Buch., *Taiwania cryptomerioides* R. Br., and *Taxodium distichum* L. Rich.

The foliage leaves in gymnosperms vary widely in their form and structure and these differences have been found helpful in taxonomic studies. In their studies on the external morphology of conifer leaves Florin (1931), Laubenfels (1953) Koehne (1893), Shaw (1914), Mirov (1967), Chaturvedi (1993 a, 1993 b, 1994 & 1995) have used a wide range of morphological features. Emphasizing the importance of the leaf structure in the taxonomic studies Carlquist (1961) points out that no generic monograph can be complete without the study of leaf anatomy. Vasil and Sahni (1994) have worked on the morphology and embryology of *Taxodium mucronatum*. Takaso and Tomlinson (1989) have worked on the cone and ovule ontogeny in *Taxodium*, *Glyptostrobus*, *Cryptomeria*, *Callitris*, *Sequoia*, *Sequoiadendron* and *Sciadopitys*. It was, there-

fore, felt necessary to undertake the present study to determine the significance of morphological (LM & SEM) and anatomical features of members of Taxodiaceae and the extent of application in the taxonomic identification and at the same time illustrate the significant features to facilitate their comparison with fossil counterpart.

MATERIAL AND METHODS

Material for the present investigation was obtained from Royal Botanical Garden, Edinburgh and Arnold Arboretum, Massachusetts, U.S.A.

Light microscopy: Cuticles were isolated in Schulzes fluid (conc HNO₃ + KCLO₃) and subjected to alkali treatment (10% ammonium hydroxide). Cuticles were separated with the help of needles and mounted in glycerine jelly after staining in safranin and washing in water. Slides were made permanent and sealed with colourless Kopal varnish. Measurements were based on 25 readings in each case. For anatomical studies microtome and hand sections of the leaves were cut serially from apex to base. Light microscopic photomicrographs were taken under Leitz Biomed microscope.

Scanning Electron Microscopy: It was done at National Botanical Research Institute, Lucknow. Fragments of suitable size of the mature leaf samples were dehydrated serially in 50-100% al-

cohol, dried and then coated with gold and examined with the JSM 35 C JEOL, Japan Scanning Electron Microscope. All electron micrographs were made at the Electron Microscope Unit, National Botanical Research Institute, Lucknow, India.

OBSERVATION

The general external morphology, LM, SEM and anatomical features of the taxa studied are described in chronological order:

1. *Athrotaxis laxifolia* R. Br. Leaves ovate, lanceolate, margin entire, base appressed, arrangement alternate or distinctly decussate, $1\frac{1}{2}$ " long \times $\frac{1}{4}$ " wide, homomorphic and amphistomatic. Cuticle thin, stomata on both the surfaces, but more on lower side. Stomata present in 2 broad zones alternating with non-stomatiferous zones. Epidermal cells over the non-stomatiferous region thin walled 18 (24) 36 μm long \times 24 (32) 40 μm wide, arranged in longitudinal rows. In the stomatiferous region the epidermal cells measure 20 (60) 80 μm long \times 17 (20) 22 μm wide rest as in the non-stomatiferous region. Stomata haplocheilic, surrounded by 4-6 subsidiary cells which measure 18(24) 30 μm long \times (08) 10 μm wide, guard cells 20(32)38 μm long \times 07(08)10 μm wide. Stomatal pore 14(16)24 μm long \times 00(0.5)1 μm wide. Orientation of stomata is almost horizontal but at places oblique. Stomatal frequency is 23.25 st/mm^2 and stomatal index 25.32. Distinct polar and lateral lamellae present.

Abaxial anticlinal walls are marked by ridges of varying height and thickness. Stomata numerous, deeply sunken, small wax flakes are scattered at places (Pl. 3, fig 3).

Anatomy of leaves shows single layered thin walled, rectangular epidermal cells, stomata at places. Hypodermis sclerenchymatous double layered at places, mesophyll multilayered with

rounded cells. Resin canals 3, vascular bundle single, conjoint. On the lateral sides of the vascular bundle transfusion tissue is present showing bordered pits here and there (Pl. 4, fig. 5).

2. *Cryptomeria japonica* D. Don. Leaves linear, subulate, bluntly keeled on dorsal side and sharply keeled on ventral side, margin entire, base thick and decurrent, spirally arranged $1\frac{1}{2}$ " long \times $\frac{1}{2}$ " wide, homomorphic and amphistomatic.

Cuticle thin, stomata on both the surfaces, stomata present in 2 broad zones alternating with non-stomatiferous zones. Epidermal cells over the non-stomatiferous region thin walled 18(22)32 μm long \times 24(32)40 μm wide, arranged in longitudinal rows. In the stomatiferous region epidermal cells measure 20(62)80 μm long \times 17(20)22 μm wide. Other details similar to the cells of the non-stomatiferous region. Stomata haplocheilic surrounded by 4-6 subsidiary cells which measure 16(22)30 μm long \times 06(07) 10 μm wide, guard cells 20(32)38 μm long \times 07(08)12 μm wide, stomatal pore 14(18)22 μm long \times 00(0.5)1 μm wide. Orientation of stomata is almost horizontal but at places oblique. Stomatal frequency is 24.20 st/mm^2 and stomatal index 26.12. Polar and lateral lamellae present.

The leaf shows bands of stomatiferous and non-stomatiferous region, stomata numerous with thick raised ridges, small wax flakes are present at places (Pl. 2, figs. 1 & 5; Pl. 3, fig. 2).

Epidermis consists of thin walled rectangular cells. Stomata present here and there, hypodermis sclerenchymatous, single layered. Mesophyll multilayered, thin walled cells, resin canal, vascular bundle single conjoint. Transfusion tissue consists of bordered pits and parenchyma cells (Pl. 4, fig. 10).

3. *Cunninghamia lanceolata* Don. Leaves linear, lanceolate, margin serrate, base broad decurrent, spirally arranged, $1\frac{1}{2}$ " - $2\frac{1}{2}$ " long

Plate 1

Fig. 1 *Taxodium distichum* leaf cuticle showing haplocheilic stomata surrounded by six subsidiary cells, polar and lateral lamellae distinct \times 320.

Fig. 2 *Taiwania cryptomerioides* leaf cuticle showing stomata as in fig. 1 \times 320.

Fig. 3 *Metasequoia glyptostroboides* leaf cuticle showing distribution of stomata \times 120.

Fig. 4 *Sequoiadendron giganteum* leaf cuticle showing stomata as in fig. 1 \times 320.

Fig. 5 *Sequoia sempervirens* leaf cuticle showing stomatiferous and

nonstomatiferous region \times 120.

Fig. 6 Epidermal cells in the stomatiferous and non-stomatiferous region short and broad in *T. distichum*, *T. cryptomerioides*, *Sequoia sempervirens* \times 320.

Fig. 7 Epidermal cells of the non-stomatiferous region showing oil bodies and sinuous walled cells \times 320.

Fig. 9 T.S. Leaf of *Metasequoia* showing stomata \times 320.

Fig. 10 Epidermal cells in non-stomatiferous region of *Cunninghamia lanceolata* \times 320.

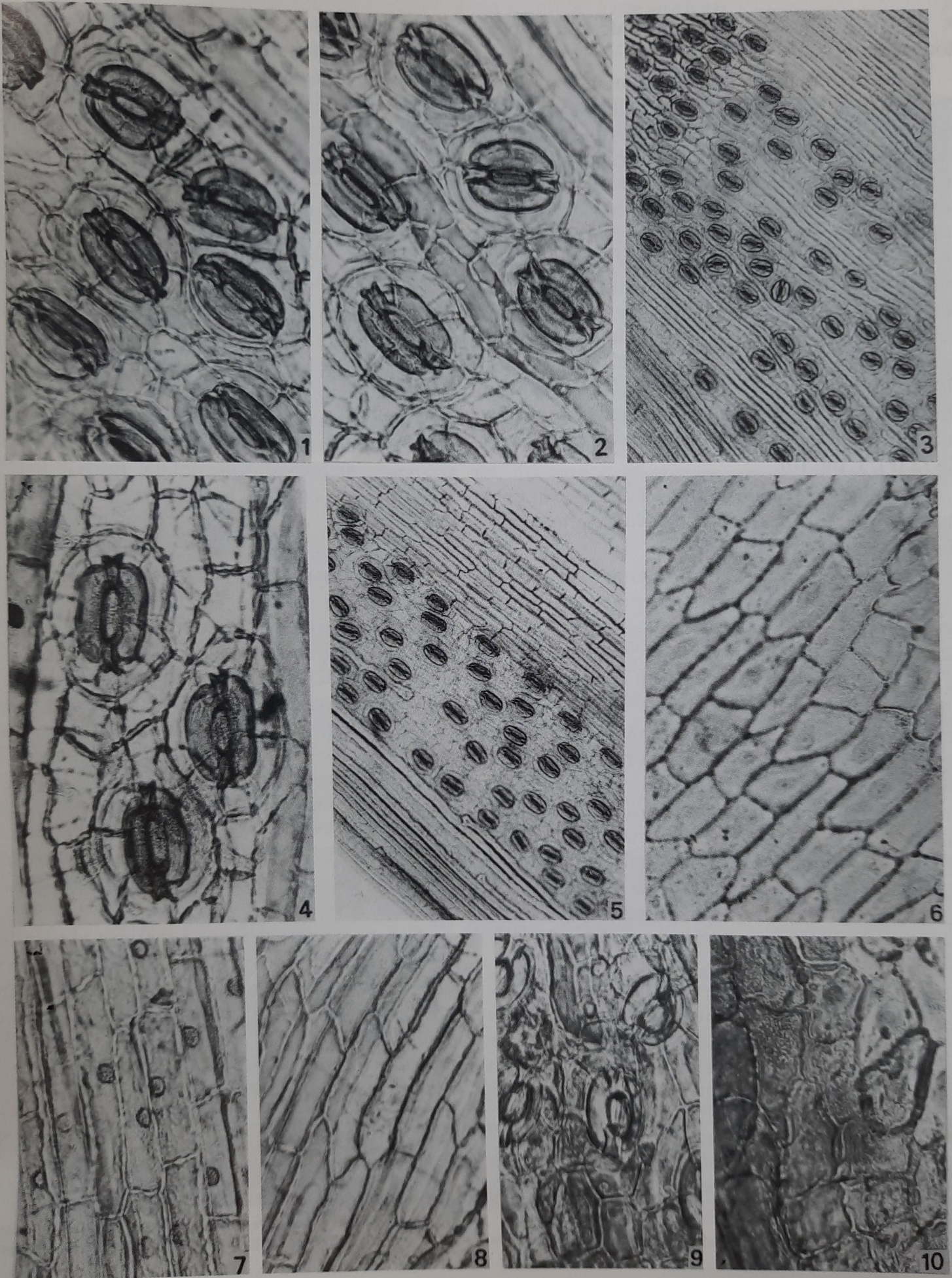


Plate 1

x 1/6'' - 1/8'' wide, homomorphic and hypostomatic.

Cuticle thin, hypostomatic, stomata present in two broad zones on either side of vein alternating with non-stomatiferous zone. Epidermal cells over the non-stomatiferous region are thin walled and arranged in longitudinal rows, cells broader than long, 20(32)36 μm long x 20(32) 38 μm wide. Epidermal cells over the stomatiferous region are similar to the cells of non-stomatiferous region. Cells measuring 20(40)54 μm long x 12(18)22 μm wide. Stomata haplocheilic surrounded by 4-6 subsidiary cells. Cells measuring 14(22)36 μm long x 06(06)08 μm wide guard cells measuring 20(32)38 μm long x 07(8)09 μm wide, stomatal pore 14(20)24 μm long x 00(.05)1 μm wide. Orientation of stomata is usually horizontal but at places oblique. Stomatal index is 26.12 (Pl. 1, fig. 10).

Anticlinal walls show ridges, stomata numerous, sunken, small wax flakes scattered (Pl. 3, fig. 5).

Leaf anatomy shows single layered thin walled rectangular epidermal cells, hypodermis single layered sclerenchymatous. Mesophyll multilayered, consisting of thin walled cells, resin canals 3, vascular bundle single, conjoint. Transfusion tissue showing border pits (Pl. 4, fig. 9).

4. *Glyptostrobus linneaus* Linn. Leaves linear, scale like, margin serrate, base appressed, arrangement alternate, 1/2'' long x 1/8'' wide, dimorphic and amphistomatic. Cuticle thin amphistomatic, stomata in two broad zones alternating with non-stomatiferous zones. Epidermal cells over the non-stomatiferous region thin walled 20(26)36 μm long x 38(34)92 μm wide arranged in longitudinal rows. In the stomatiferous region epidermal cells measure 30(80)92 μm long x 20(31)35 μm wide. Stomata haplocheilic, surrounded by 4-6 subsidiary cells which measure 18(22)32 μm long x 06(07)09 μm wide, guard cells 22(32)40 μm long x 07(08)10 μm wide. Stomatal pore 14(15)22 μm long x 00(0.5)1 μm wide. Orientation of stomata is al-

most horizontal. Stomatal frequency is 22.12 st/mm² and stomatal index 25.20. Distinct polar and lateral lamellae present.

Ventral surface shows numerous stomata, deeply sunken with raised ridges, wax flakes present at places on the surface (Pl. 2, fig. 3).

Leaf anatomy shows thin-walled almost rectangular epidermal cells, sunken stomata present at places. Hypodermis single layered, sclerechymatous, cells longer than broad. Mesophyll multilayered, consisting of thin walled irregular cells, resin canals 3. Vascular bundle single, conjoint, transfusion tissue is present consisting of parenchyma cells and bordered pits (Pl. 4, fig. 11).

5. *Metasequoia glyptostroboides* Miki. Leaves twisted petiolate, margin entire, base spreading, arrangement opposite decussate, tip-pointed, 1-1¹/₂'' long x 1/6'' wide, homomorphic and hypostomatic.

Cuticle thin, hypostomatic, stomata present in zones one either side of the vein alternating with non-stomatiferous zone. Epidermal cells over the non-stomatiferous region are thin walled and arranged in longitudinal rows, measuring 20(36) 38 μm long x 26(32)40 μm wide. Epidermal cells over the stomatiferous zone measure 20(48) 56 μm long x 12 (18)24 μm wide. Stomata haplocheilic, surrounded by 4-6 subsidiary cells, size of guard cells 20(32) 38 μm long, x 7(8)9 μm wide, subsidiary cells 15(24) 30 μm long x 5(6)8 μm wide, stomatal pore 14(20)24 μm long x 0(0.5) 1 μm wide. Stomatal frequency 24.52 st/mm² and stomatal index 27. Distinct polar and lateral lamellae present (Pl. 1, fig. 9).

Anticlinal walls showing pronounced papillae in the stomatiferous region are usually absent over the non-stomatiferous region. Stomata in longitudinal rows, subsidiary cells papillate over-arching the guard cells. Cells in the non-stomatiferous region arranged in longitudinal rows, anticlinal walls ridged (Pl. 3, fig. 1).

Plate 2

Fig. 1 *Cryptomeria japonica* leaf showing contiguous stomata with raised ridges x 1000.

Fig. 2 *Sciadopitys verticillata* leaf shows sunken stomata with pronounced cuticular rim x 3000.

Fig. 3 *Glyptostrobus linneaus* leaf showing many sunken stomata with raised ridges x 1000.

Fig. 4 *Sequoia sempervirens* leaf showing sunken stomata with pronounced rim, small wax flakes x 1000.

Fig. 5 *Sciadopitys verticillata* leaf shows numerous papillae x 200.

Fig. 6 *Sequoiadendron giganteum* leaf showing sunken stomata, micropapillae on the periclinal wall and small wax flakes x 1000.

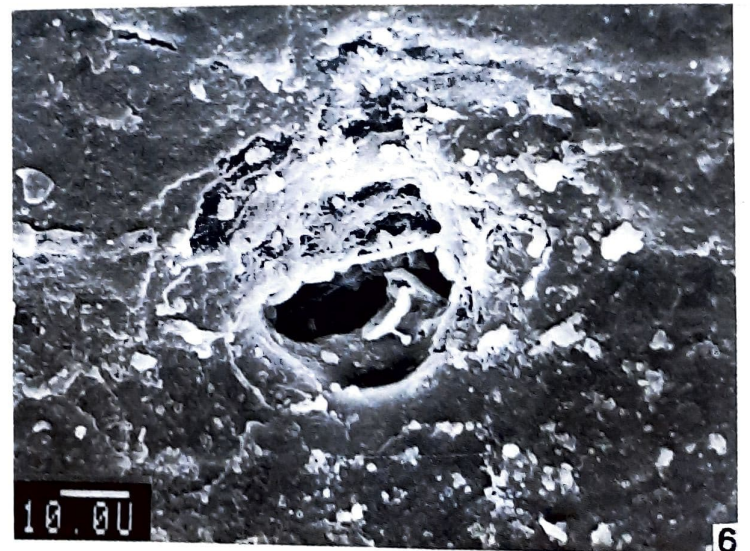
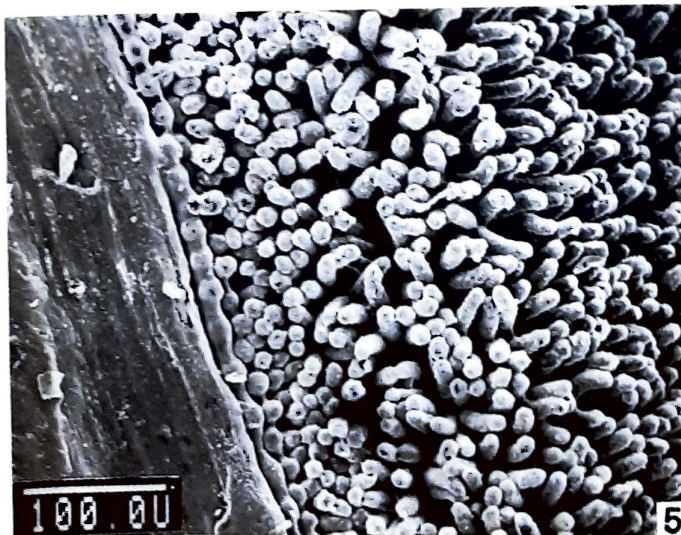
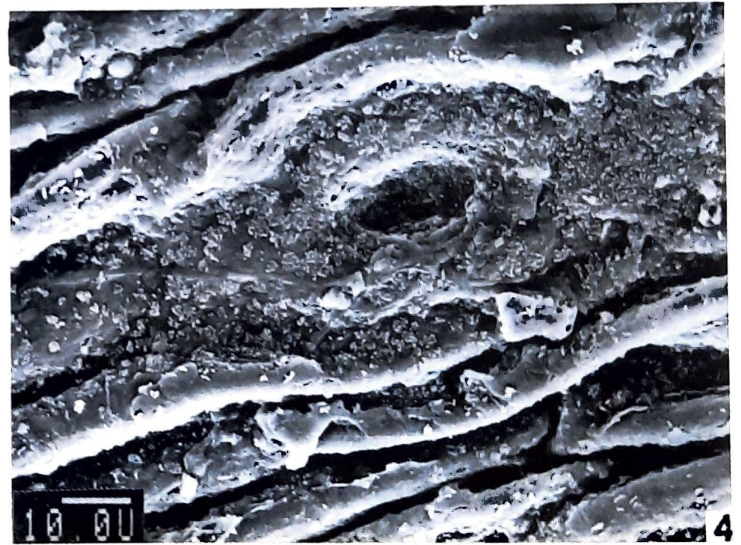
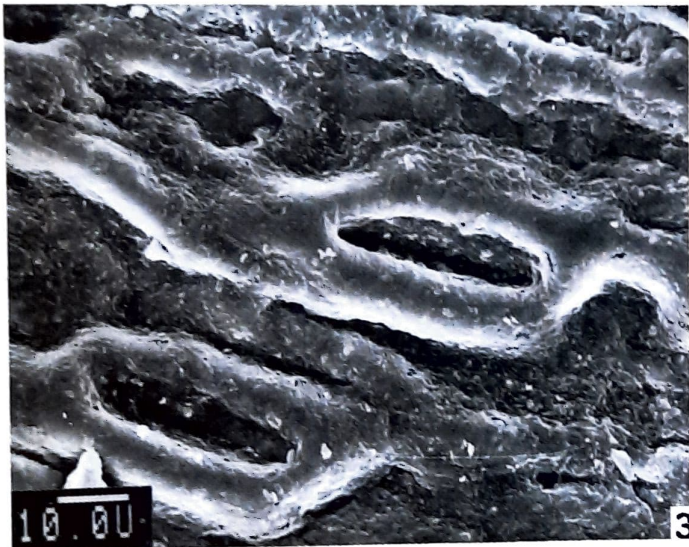
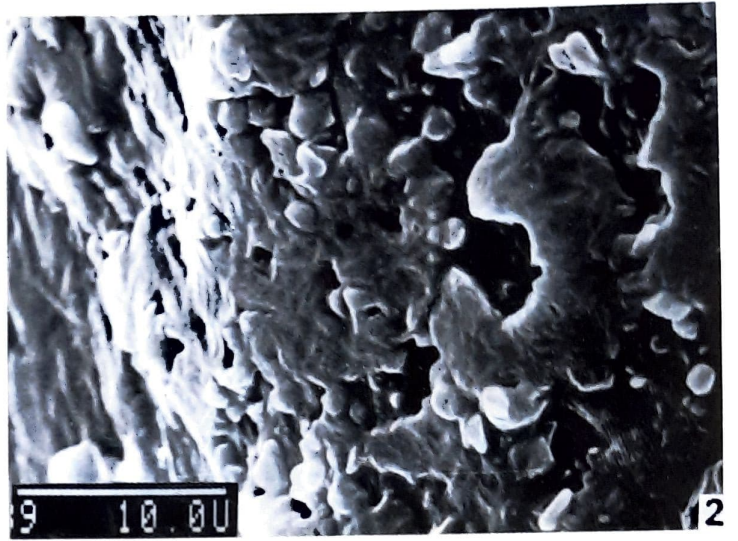
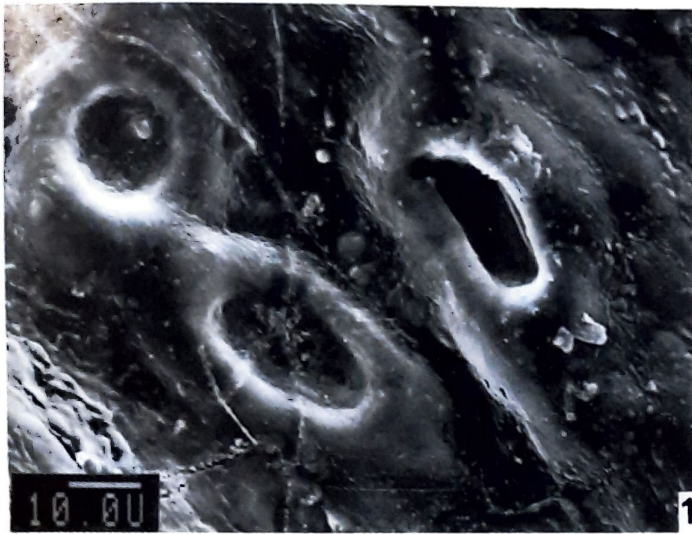


Plate 2

Outer layer consisting of thin walled cells having deep sinuosity. This is followed by single-layered sclerenchymatous hypodermis. Mesophyll is multilayered with highly tortuous cells, 3 resin canals are present, one opposite vascular bundle and two on the lateral sides. Resin canals are lined by epithelial cells and cover cells. A single conjoint vascular bundle is present in the centre, transfusion tissue is scanty (Pl. 4, fig. 3).

6. *Sequoiadendron giganteum* Buch. Leaves homomorphic, scale like, clothing the stem, spirally arranged, tip sharp pointed, margin entire, 1/8 - 1/2" long x 1/6" wide. Cuticle thin, amphistomatic, stomata present in 2 broad zones, on either side of the vein alternating with non-stomatiferous zones. Epidermal cells over the non-stomatiferous region are thin walled and arranged in longitudinal rows, cells broader than long, 20(26)37 μm long x 28(34)42 μm wide. Epidermal cells over the stomatiferous region measure 30(82) 100 μm long x 20(31) 35 μm wide. Stomata haplocheilic surrounded by 4-6 subsidiary cells. Orientation oblique, size of guard cells 24(36) 42 μm long x 7(8) 10 μm wide, subsidiary cells 18(26)32 μm long x 6(7) 9 μm wide. Stomatal pore 14(17) 22 μm long x 0(0.5) 1 μm wide. Distinct polar and lateral lamellae present. Stomatal frequency 24.52 st/mm², stomatal index 27.22 (Pl. 1, fig. 4).

Abaxial anticlinal walls are marked by shallow furrows of varying width. Periclinal walls are prominently convex with a low relief pattern of small micropapillae. Stomata are either raised or sunken with narrow over-arching cuticular rim. Wax is found as very few small flakes. Adaxial anticlinal walls are indicated by distinctly raised ridges of variable thickness. The outer walls also bear a low relief pattern, several micropapillae are more pronounced on the periclinal walls (Pl. 2, fig. 6).

Outer layer of thin walled rectangular cells, sunken stomata are present at places. This is fol-

lowed by sclerenchymatous hypodermis which is 2 layered at places. Mesophyll is multilayered and consists of elongated cells. A single resin canal is present in the centre, lined by epithelial and cover cells. A single conjoint vascular bundle, is present and on the two lateral sides transfusion tissue consisting of tracheids and parenchyma are present (Pl. 4, fig. 2).

7. *Sequoia sempervirens* Endl. Leaves dimorphic, linear or lance shaped, spirally arranged, appressed, tip pointed, margin entire 1/4-4/5" long x 1/10" wide.

Cuticle thin, hypostomatic, stomata present on either side of the vein in broad stomatiferous zone alternating with non-stomatiferous zone. Epidermal cells over the non-stomatiferous region thin walled and arranged in longitudinal rows. Cells measuring 20(32) 40 μm long x 25(42) 50 μm wide. Epidermal cells over the stomatiferous region measure 20(48) 60 μm long x 12(18) 25 μm wide. Stomata are haplocheilic, surrounded by 4-6 subsidiary cells, measuring 18(24)30 μm long x 6(7) 9 μm wide. Guard cells 20(32) 38 μm long x 7(8) 10 μm wide, stomatal pore 14(16) 20 μm long x 0(0.5) 1 μm wide. Distinct polar and lateral lamellae present. Orientation of stomata is almost horizontal but at places oblique, stomatal frequency is 15.2 st/mm² and stomatal index 17.34 (Pl. 1, fig. 5).

Abaxial anticlinal walls are marked by slightly undulate ridges of varying height and thickness. Stomata numerous, slightly sunken with pronounced rim. Small wax flakes are sometimes irregularly scattered at places (Pl. 2, fig. 4).

Epidermis consists of thin walled cells, this is followed by sclerenchymatous hypodermis. Mesophyll is multilayered and consists of elongated cells, 3 resin canals are present lined by epithelial and cover cells. Vascular bundle single, conjoint. Scanty transfusion tissue is present.

8. *Sciadopitys verticillata* Sieb. & Zucc. Leaves dimorphic, scale like, in double whorls,

Plate 3

Fig. 1 *Metasequoia glyptostroboides* leaf shows pronounced papillae in the stomatiferous region, stomata in longitudinal rows, subsidiary cells papillate over-arching guard cells x 200.

Fig. 2 *Cryptomeria japonica* leaf shows stomatiferous and non-stomatiferous band x 200.

Fig. 3 *Athrotaxis laxifolia* leaf showing numerous sunken stomata, wax deposited on their surfaces X 200.

Fig. 4 *Taiwania cryptomerioides* leaf shows stomata in longitudinal rows, slightly sunken, wax thickly deposited on stomata x 200.

Fig. 5 *Cunninghamia lanceolata* leaf shows stomatiferous and non-stomatiferous region x 200.

Fig. 6 *Taxodium distichum* leaf shows stomata scattered in the stomatiferous region small wax flakes are also seen x 1000.

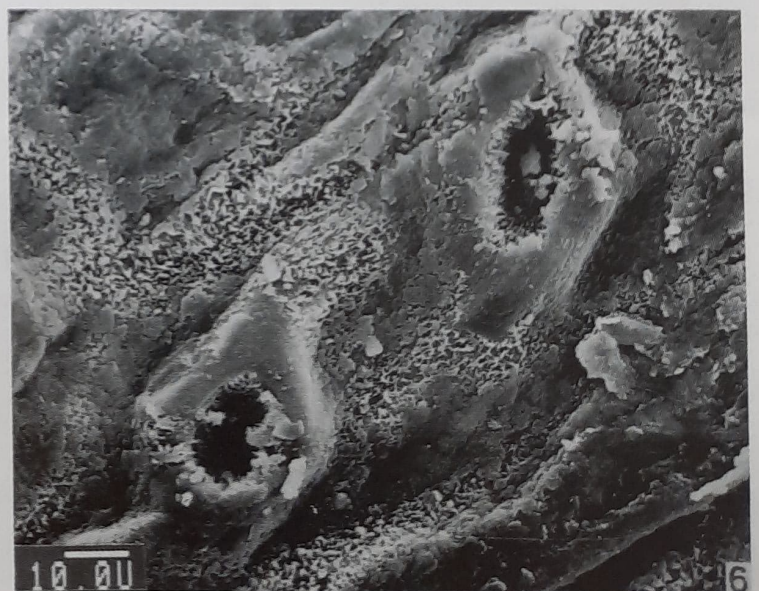
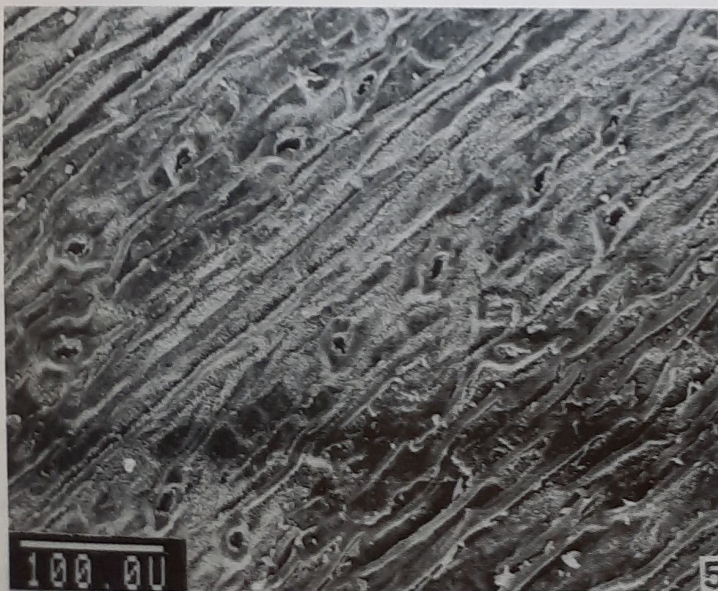
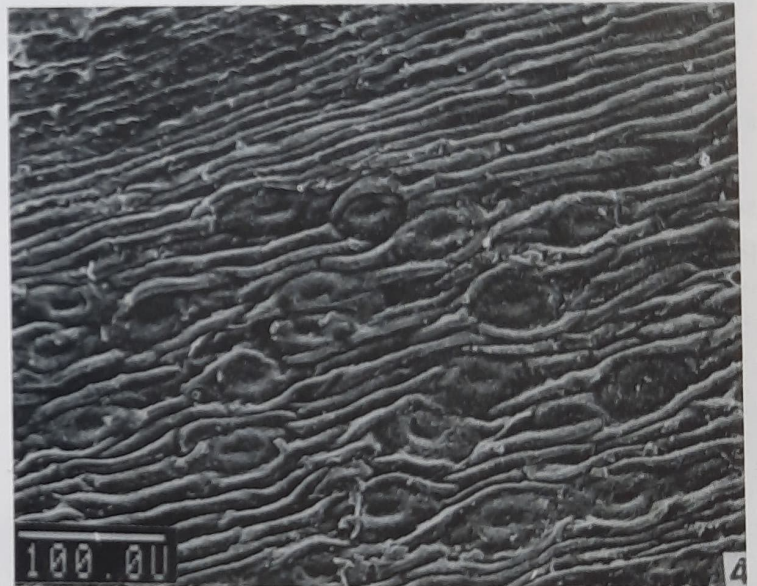
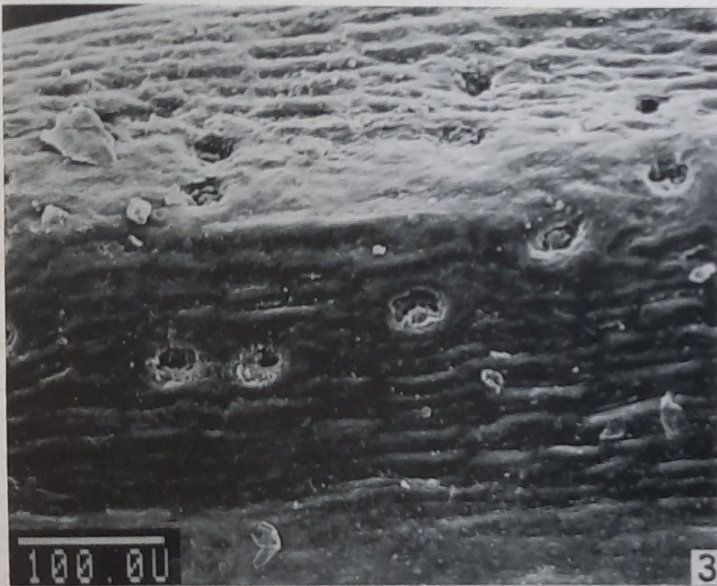
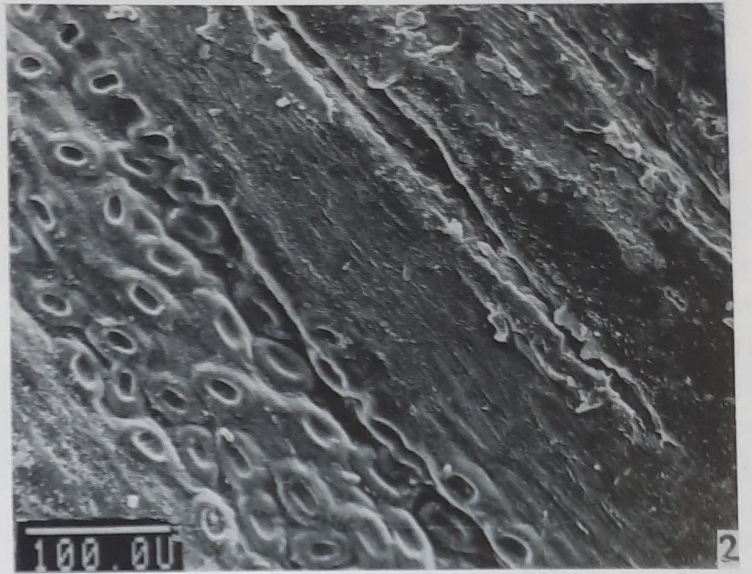
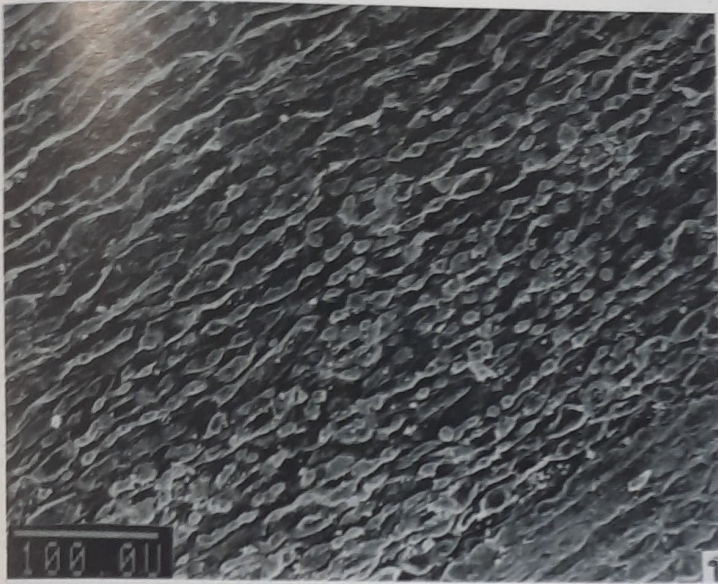


Plate 3

spreading at angles, tip obtusely pointed, margin entire 2-4" long x 1/10-1/8" wide.

Cuticle thin, hypostomatic, stomata present on either side of the vein in broad zones alternating with non-stomatiferous zone. Epidermal cells over the non-stomatiferous region thin walled arranged in longitudinal rows measuring 20(32) 28 μm long x 26(30) 40 μm wide. Epidermal cells over the stomatiferous region are similar to those of the non-stomatiferous region measuring 20(42) 52 μm long x 12(18) 22 μm wide. Stomata haplocheilic, surrounded by 4-6 subsidiary cells, measuring 16(22) 30 μm long x 6(6) 8 μm wide. Guard cells measuring 20(32) 38 μm long x 7(8) 9 μm wide. Stomatal pore 14(20) 22 μm long x 0(0.5) 1 μm wide. Distinct polar and lateral lamellae present, orientation of stomata is almost horizontal but at places oblique. Stomatal frequency 22.2 st/mm² and stomatal index 25.22.

Leaf showing numerous stomata they are sunken with pronounced cuticular rim, numerous papillae are present near the basal region of the leaf where the groove is formed due to formation of double leaf (Pl. 2, figs 2 & 5).

Outline of single-layered rectangular cells of epidermis, stomata present at places, papillae also present followed by sclerenchymatous hypodermis. Mesophyll is multilayered and consists of elongated cells with sclereids at places. Number of resin canals vary from 8-10 consisting of epithelial and cover cells.

Vascular bundles 2, conjoint, transfusion tissue scanty (Pl. 4, figs 7, 8, & 12).

9. *Taiwania cryptomerioides* R. Br. Leaves dimorphic, triangular or scale like, spirally ar-

ranged, appressed, tip pointed, margin serrate, 1/8-1/5" long, 1/10" wide.

Cuticle thin, amphistomatic, stomata present in two broad zones on either side of the vein alternating with non-stomatiferous zone. Epidermal cells over the non-stomatiferous region thin-walled and arranged in longitudinal rows. Cells broader than long, 18(26) 37 μm long x 24 (32) 40 μm wide. Epidermal cells over stomatiferous region measure 20(64) 80 μm long x 17(20) 22 μm wide. Stomata haplocheilic surrounded by 4-6 subsidiary cells measuring 16(24) 30 μm long x 6(7) 10 μm wide, guard cells measuring 20(32) 38 μm long x 7(8) 12 μm wide. Stomatal pore 14(18) 25 μm long x 0(0.5) 1 μm wide. Stomatal frequency is 25.32 st/mm² and stomatal index 27.27. Orientation of stomata is almost horizontal but at places oblique, distinct polar and lateral lamellae present (Pl. 1, figs 2 & 6).

Abaxial anticlinal walls almost straight, ridges of varying height and thickness. Stomata in longitudinal rows slightly sunken, wax deposited on the stomata. Surface showing ridges and furrows, stomata numerous, wax thickly deposited on stomata which is sunken (Pl. 3, fig. 4).

Outer layer of thin walled epidermal cells, stomata deeply sunken at places. Hypodermis sclerenchymatous single layered, stomata deeply sunken up to hypodermis. Mesophyll multilayered and consisting of elongated cells irregularly arranged, resin canal single, lined by epithelial and cover cells. Vascular bundle single, conjoint, transfusion tissue scanty (Pl. 4, fig. 6).

10. *Taxodium distichum* L. Rich. Leaves dimorphic, linear, alternate or sub-opposite, appressed, tip pointed, margin entire 1/3 - 3/4" long x 1/10" wide.

Plate 4

Fig. 1 T.S. Leaf of *Glyptostrobus linneaus* showing stomata x 140.

Fig. 2 T.S. Leaf of *Sequoiadendron giganteum* showing epidermis, double layer sclerenchymatous hypodermis x 560.

Fig. 3 T.S. Leaf of *Metasequoia glyptostroboides* showing bulging walls of epidermis and lobed mesophyll cells x 560.

Fig. 4 T.S. Leaf of *Taxodium distichum* showing bulging epidermal cells x 560.

Fig. 5 T.S. Leaf of *Athrotaxis laxifolia* showing single layer epidermis and double layered hypodermis near the margins x 560.

Fig. 6 T.S. Leaf of *Taiwania cryptomerioides* showing a single large resin canal opposite the vascular bundle x 140.

Fig. 7 T.S. Leaf of *Sciadopitys verticillata* showing two resin canals and sclereids x 140.

Fig. 8 T.S. Leaf of *Sciadopitys verticillata* showing single large vascular bundle and papillae x 800.

Fig. 9 T.S. Leaf of *Cunninghamia lancoelata* showing bordered pits of transfusion tissue x 800.

Fig. 10 T.S. Leaf of *Cryptomeria japonica* showing vascular bundle and large resin canal x 140.

Fig. 11 T.S. Leaf of *Glyptostrobus linneaus* showing bordered pits of transfusion tissue x 800.

Fig. 12 T.S. Leaf of *Sciadopitys verticillata* showing papillae near margins of double leaf x 1000.

st = stomata, hy = hypodermis, rc = resin canal
m = mesophyll, bp = bordered pits, p = papillae.

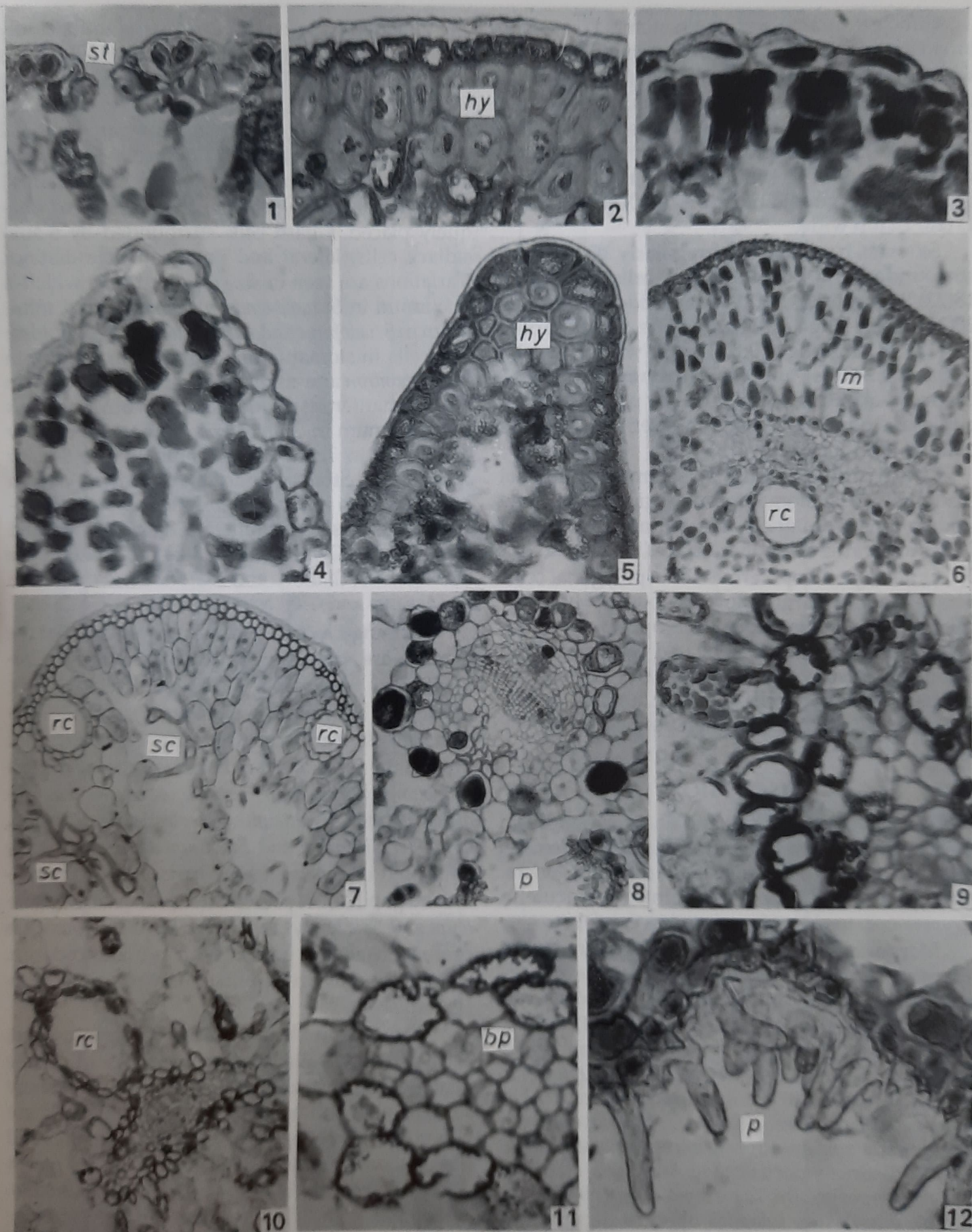


Plate 4

Cuticle thin, amphistomatic, stomata present in broad zones on either side of the vein alternating with non-stomatiferous zone. Epidermal cells over the non-stomatiferous region are thin walled and arranged in longitudinal rows, cells broader than long, 18(24)36 μm long \times 24(32) 40 μm wide. Epidermal cells over the stomatiferous region rectangular or polygonoid measure 20(60) 80 μm long \times 17(20) 22 μm wide.

Stomata haplocheilic, irregularly distributed, surrounded by 4-6 subsidiary cells measuring 18(22) 30 μm long \times 6(8) 10 μm wide, guard cells 20(32) 38 μm long \times 7(8) 10 μm wide. Stomatal pore 14(118) 25 μm long \times 0(0.5) 1 μm wide. Stomatal frequency 24.32 st/ mm^2 and stomatal index 26.52. Distinct polar and lateral lamellae present. Orientation of stomata is almost transverse, sometimes oblique (Pl. 1, figs 1 & 6).

Dorsal surface of leaf shows numerous stomata scattered in the stomatiferous region, cells show undulations throughout the surface. Small wax flakes are scattered on the surface (Pl. 3, fig. 4).

Outer layer of epidermis show polygonal cells. The cells at the margin show sinuosity. Hypodermis is sclerenchymatous, mesophyll is multi-layered and consists of elongated cells irregularly arranged. Resin canal is single and is lined by epithelial and cover cells. Vascular bundle is single, conjoint, collateral, transfusion tissue is scanty (Pl. 4, fig. 6).

DISCUSSION

The leaves are bifacial and show variations in their outline which range from linear, lanceolate, ovate lanceolate to scale like in the different genera. The tip in all the genera are pointed but acute in *Cryptomeria*, to obtusely pointed in *Sciadopitys*.

Margin in most of the genera is entire except *Taiwania*, *Cunninghamia* where it is serrate and occasional serrations in *Taxodium* and *Glyptostrobus*.

Base of the leaves is appressed in *Taxodium*, *Glyptostrobus*, *Sequoia*, *Sequoiadendron* and *Athrotaxis* whereas it is decurrent in *Cryptomeria*, broad decurrent in *Cunninghamia*, spreading in *Metasequoia* and *Sciadopitys*. Arrangement of leaves is generally spiral with few exceptions, viz. alternate or distinctly decussate in *Athrotaxis*, alternate or sub-opposite in *Taxodium*, *Glyptostrobus*, in double whorls in *Sciadopitys*, opposite decussate in *Metasequoia*. The size of leaf ranges from 1/8" to 4" long as shown in table 1.

Venation pattern is uniform in the entire family having a single vein except *Sciadopitys* which has two veins. The leaves are usually of one type (homomorphic) as in *Cryptomeria*, *Athrotaxis*, *Cunninghamia*, *Metasequoia* and *Sequoiadendron* and of 2 types (dimorphic) in *Taiwania*, *Sciadopitys*, *Taxodium*, *Glyptostrobus* and *Sequoia*. Stomata in all the genera are haplocheilic, transversely or obliquely placed. Guard cells surrounded by 6 subsidiary cells, lateral and polar lamellae distinct. Variations are seen in size of guard cells which is maximum in *Sequoiadendron giganteum* and minimum in *Sciadopitys* and *Metasequoia*. Size of epidermal cells in stomatiferous region is maximum in *Sequoiadendron* and minimum in *Sciadopitys* and in non-stomatiferous region maximum in *Metasequoia* and minimum in *Cryptomeria*. Stomatal frequency maximum in *Taiwania* and minimum in *Sequoia sempervirens*. Stomatal index maximum in *Taiwania* and minimum in *Sequoia sempervirens*. Size of subsidiary cells is maximum in *Sequoiadendron* and minimum in *Cunninghamia*. Size of stomatal pore maximum in *Taiwania* and *Taxodium* and minimum in *Taiwania* and *Glyptostrobus* (Table 2).

Scanning Electron Microscopy reveals that the stomata are numerous in *Athrotaxis laxifolia*, *Cunninghamia lanceolata*, *Sequoia sempervirens*, *Sciadopitys verticillata*, *Cryptomeria japonica*, *Glyptostrobus linneaus*, and *Taiwania cryptomerioides*. Wax in the form of small flakes is present in *Cunninghamia lanceolata*, *Sequoia sempervirens*, *Sequoiadendron giganteum*, *Glyptostrobus linneaus*, *Cryptomeria japonica* and *Taxodium distichum*, thickly deposited in *Taiwania cryptomerioides*. Micropapillae and papillae are present in *Sequoiadendron giganteum* and *Sciadopitys verticillata*. Sunken stomata is present in all the genera with pronounced rim. Subsidiary cells are papillate in *Metasequoia glyptostroboides*.

Epidermis in all the genera is single layered, cells are thin walled and rectangular in all the genera except *Metasequoia* where the cells show sinuous wall and in *Taxodium* where the cells are polygonal. Hypodermis is sclerenchymatous in all the genera, usually single layered but at places double layered in *Athrotaxis*, *Sequoiadendron*. Mesophyll is multilayered and consists of elongated cells in *Sequoiadendron*, *Sequoia sempervirens*, *Sciadopitys*, *Taiwania*, and *Taxodium*, rounded cells

TABLE I
EXTERNAL MORPHOLOGY

Name of Genera	Shape	Margin	Base	Arrangement	Size of leaf	Remarks
<i>Athrotaxis</i>	ovate-lanceolate	entire	appressed	alternate or distinctly decussate	$1/4''$ long	amphistomatic, homomorphic
<i>Cryptomeria</i>	linear, subulate	entire	thick and decurrent	spirally arranged	$1/2''$ long	amphistomatic, homomorphic
<i>Cunninghamia</i>	linear, lanceolate	serrate	broad, decurrent	spirally arranged	$1\frac{1}{2}$ - $2\frac{1}{2}''$ long	hypostomatic, homomorphic
<i>Glyptostrobus</i>	linear, scale like	occasionally serrated	appressed	alternate	$1/2''$ long	amphistomatic, dimorphic
<i>Metasequoia</i>	needles twisted	entire	spreading	opposite decussate	$1\frac{1}{2}$ - $2''$ long	hypostomatic, homomorphic
<i>Sequoiadendron</i>	scale-like	entire	appressed	spirally arranged	$1/8$ - $1/2''$ long	amphistomatic, homomorphic
<i>Sequoia sempervirens</i>	linear of lance	entire	appressed	spirally arranged	$1/4$ - $4/5''$ long	hypostomatic, dimorphic
<i>Sciadopitys</i>	scale like	entire	spreading at angles	in double whorls	2 - $4''$ long	hypostomatic, dimorphic
<i>Taiwania</i>	triangular, scale like	serrated	appressed	spirally arranged	$1/8$ - $1/5''$ long	amphistomatic, dimorphic
<i>Taxodium</i>	linear	entire but occasionally serrated	appressed	alternate or sub-opposite	$1/3$ - $3/4''$ long	amphistomatic, dimorphic

TABLE -2
EPIDERMAL CHARACTERS

Name of genera	Epidermal cells in mm			G.C.	S.C.	Stomata S.P.	S.F.	S.I.
	S.R.	N.S.R.						
<i>Athrotaxis</i>	20(60)80 x	18(24)36 x	20(32)38 x	18(24)30 x	14(16)24 x	23.25	25.32	
	17(20)22	24(32)40	07(08)10	06(08)10	00(0.5)1			
<i>Crypomeria</i>	20(62)80 x	18(32)32 x	20(32)38 x	16(22)30 x	14(18)22 x	24.20	26.12	
	17(20)22	26(32)38	07(08)12	06(07)10	00(0.5)1			
<i>Cunninghamia</i>	20(42)54 x	20(32)36 x	20(32)48 x	14(22)36 x	14(18)22 x	24.32	26.12	
	12(18)22	28(34)42	07(08)09	06(06)08	00(0.5)1			
<i>Glyptostrobus</i>	30(80)92 x	20(26)36 x	22(32)40 x	18(22)32 x	14(20)24 x	22.12	25.20	
	20(31)35	28(34)42	07(8)10	06(07)09	00(0.5)1			
<i>Metasequoia</i>	20(48)56 x	20(36)38 x	20(32)38 x	15(24)30 x	14(25)22 x	24.52	27.22	
	12(18)24	25(42)50	07(8)09	06(06)09	00(0.5)1			
<i>Sequoiadendron</i>	20(48)60 x	20(32)40 x	20(32)38 x	18(24)30 x	14(20)24 x	15.20	17.34	
	12(18)25	25(42)50	07(8)10	06(07)09	00(0.5)1			
<i>Sequoia sempervirens</i>	30(82)100 x	20(26)37 x	24(36)42 x	18(26)32 x	14(16)20 x	24.52	27.22	
	20(31)35	28(34)42	07(8)10	06(07)09	00(0.5)1			
<i>Sciadopitys</i>	20(42)52 x	20(23)38 x	20(32)38 x	16(22)30 x	14(17)22 x	22.20	25.22	
	12(18)22	26(30)40	07(8)9	06(06)08	00(0.5)1			
<i>Taiwania</i>	20(64)80 x	18(36)37 x	20(32)38 x	16(24)30 x	14(20)22 x	25.32	27.27	
	17(20)80	24(32)40	07(08)12	06(07)10	00(0.5)1			
<i>Taxodium</i>	20(60)80 x	18(24)36 x	20(32)38 x	18(22)30 x	14(18)25 x	24.32	26.25	
	17(20)22	24(32)40	07(08)10	06(08)08	00(0.5)1			

TABLE 3
ANATOMICAL CHARACTERS

Name of genera	Epidermis	Hypodermis	Mesophyll	Resin canal	Vascular bundle	Transfusion tissue
<i>Athrotaxis</i>	cells thin walled, rectangular, s+	sclerenchymatous at places double layered	multilayered, rounded cells	3	single	bordered pits present
<i>Cryptomeria</i>	same as above	sclerenchymatous single layered	multilayered, thin walled cells	1	single	bordered pits present
<i>Cunninghamia</i>	same as above	sclerenchymatous single layered	multilayered, thin walled cells	3	single	bordered pits present
<i>Glyptostrobus</i>	cells thin walled, almost rectangular s+	sclerenchymatous single layered	multilayered, thin walled cells	3	single	bordered pits present
<i>Metasequoia</i>	sinuous walled	sclerenchymatous single layered	multilayered, highly tortuous cells	3	single	scanty bordered present
<i>Sequoiadendron</i>	cells thin walled rectangular, s+	sclerenchymatous double layered at places	multilayered, elongated cells	1	single	bordered pits and parenchyma
<i>Sequoia sempervirens</i>	cells thin walled	sclerenchymatous single layered	multilayered, elongated cells	3	single	scanty bordered pits
<i>Sciadopitys</i>	cells rectangular, hairs present, s+	sclerenchymatous single layered	multilayered elongated cells, sclereides present	8-10	double	scanty bordered pits
<i>Taiwania</i>	cells thin walled, s+	sclerenchymatous single layered	multilayered elongated cells	1	single	scanty bordered pits
<i>Taxodium</i>	cells polygonal	sclerenchymatous single layered	multilayered elongated cells	1	single	scanty bordered pits

in *Athrotaxis*, *Cryptomeria*, *Glyptostrobus* and *Cunninghamia*, highly tortuous cells in *Metasequoia*. Sclereides are present only in *Sciadopitys verticillata* and absent in rest of the genera. Resin canals number vary it is mostly 3 in *Athrotaxis*, *Cunninghamia*, *Glyptostrobus*, *Metasequoia* and *Sequoia sempervirens*, 8-10 in *Sciadopitys* and 1 in *Cryptomeria*, *Taiwania* and *Taxodium*. Each resin canal is lined by epithelial and cover cells. Vascular bundle is solitary, conjoint, collateral in all the genera except *Sciadopitys* which has 2 vascular bundles. Transfusion tissue is present in all the genera (Table 3).

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