

MACRO- AND MICROMORPHOLOGICAL STUDY OF THE LEAF, STEM & ROOT OF *JUGLANS NIGRA* LINN. (BLACK WALNUT) CULTIVATED IN EGYPT

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في هذا البحث تمت دراسة الصفات العيانية والمجهريّة لأوراق وسيقان وجذور نبات الجوجلانس نجرا (الجوز الأسود) (ل) عائلة الجوجلانديسي (العائلة الجوزية) المنزرع في مصر وذلك للتعرف على هذا النبات في حالته الصحيحة وعلى هيئة مسحوق.

The detailed macro- and micromorphological characters of the leaf, stem and root of juglans nigra Linn. (Black Walnut) cultivated in Egypt have been studied in order to find out the diagnostic features which can help in the identification of the plant in both entire and powdered forms.

INTRODUCTION

Juglans nigra Linn. (Black Walnut) family Juglandaceae (Walnut family) is a large tree growing abundantly in eastern united states, mountain's region of north Africa and in East Asia. It's cultivated in Egypt.¹⁻³ The leaves of *Juglans nigra* Linn. are used in folk medicine as antihypertensive and antidiabetic, while the stem bark is used as astringent and anthelmintic.⁴ Also the root bark of *Juglans mandshurica* is reported to show cytotoxic activity.^{5,6} Naphthoquinones, naphthanyl glucosides and flavonoids were isolated from the genus *Juglans*.⁷⁻¹⁰

In Continuation of our work on black walnut we report here the macro- and micromorphology of the leaf, stem and root of the plant to reveal the diagnostic features by which the plant can be identified in the entire and powdered forms.

Habitat

Juglans nigra Linn. (Figs. 1&2) is a large, deciduous tree. It attains a height of 4-6 meters. It shows monopodial branching and carries alternate, exstipulate, compound, imparipinnate leaves. The plant is monoecious where both the

staminate and pistillate flowers are usually in pendulous branched catkins. The fruit is a large drupe like nut, the outer part is fleshy or leathery, while the inner one is stony.^{1,11} The plant prefers temperate temperature, sandy soils with moderate moisture contents.

PLANT MATERIAL

Juglans nigra Linn. was collected from the Assiut university campus. Its identity was confirmed by Dr. Salah M. El-Nagar Associate Professor of Taxonomy, Department of Botany, Faculty of Science, Assiut University, Assiut, Egypt.

Fresh samples of the plant were collected (during flowering and fruiting stages) in the period from October to December 1999. Fresh stems, leaves, and root, as well as, samples preserved in a mixture of alcohol (70%) - glycerin - water (1:1:1) were used. The powdered material was obtained from air dried leaves, stems and root.

MACROMORPHOLOGY

1- The leaf (Figs. 1B&2B)

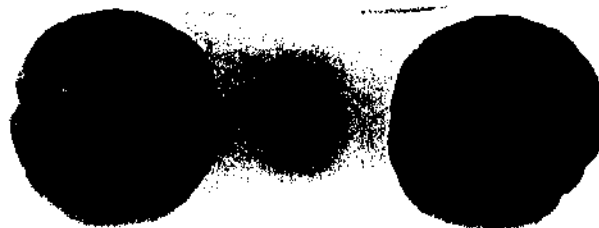
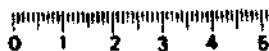
The leaves are alternate, compound,



A



B



C

Fig. 1: A, Photo of the plant x 1/50
B, Photo of a branch x 0.7
C, Photo of the fruit x 0.7

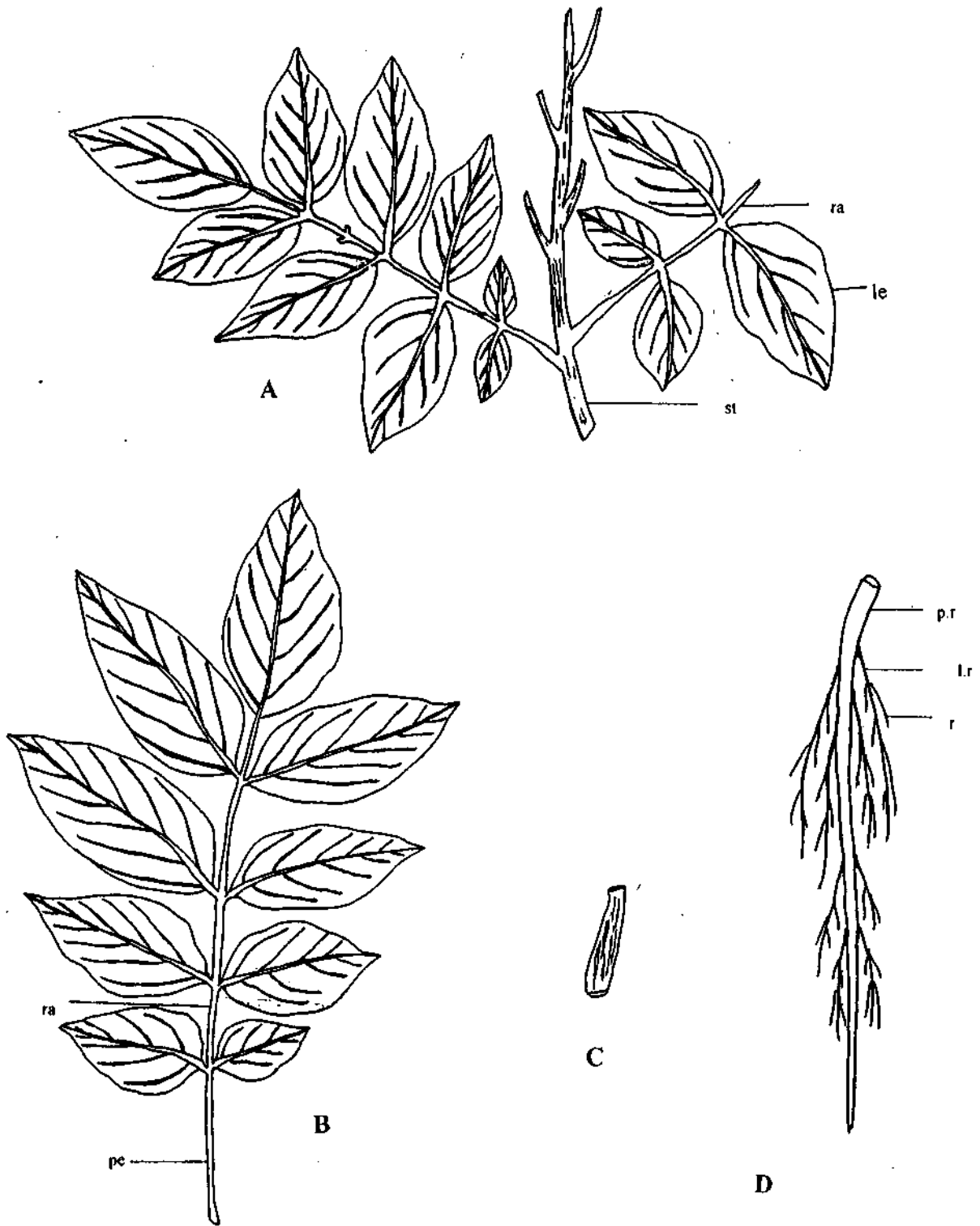


Fig. 2: A, *Juglans nigra* Linn. x 0.7

B, The leaf x 0.7

C, The stem x 0.7

D, The young root x 0.7

l., leaf; le., leaflet; l.r., lateral root; pe., petiole; p.r., primary root; r., rootlets; ra., rachis; st., stem.

imparipinnate and exstipulate. Each leaf is formed of about 7-15 leaflets. The leaflet is ovate to lanceolate in outline, with entire sinuate margin, acute to acuminate apex and symmetric base. Both surfaces are hairy especially the lower surface. The leaflets show dark green upper surface and a paler lower ones. Venation is pinnate, reticulate and the midrib is more prominent on the lower surface. The leaflets measure from 2-6.5 cm in length and about 1-3.5 cm in width at the middle part. The dry leaves are almost odourless, with unpleasant slightly bitter taste. The petiole is cylindrical in shape, green in colour, with hairy surface and measuring about 2-4 cm in length and about 2-3.5 mm in diameter. The leaf rachis is sub-cylindrical in outline, green in colour, with hairy surface, bearing about 7-15 leaflets and reaching about 5-10 cm in length and 1-2 mm in diameter.

2- The stem (Figs. 1A&2C)

The main trunk of the plant is erect, cylindrical in shape, solid, monopodially branched and measuring from 4-6 meters in height and about 40-50 cm in diameter near the ground.

The terminal and lateral branches are narrower with short internodes measuring from 10-15 cm in length and about 0.4-1 cm in diameter. The surface of these branches are brown, rough and covered with brownish cork, except the young portions just below the apical buds, are green in colour and hairy. The stem has a faint odour and a slight bitter taste.

3- The root System (Fig. 2D)

The root is obtained from a very young plant (nurseling that attains about 50-60 cm in height) and cultivated in a flower pot. It consists of a long cylindrical fusiform tap root, bearing few lateral roots and numerous rootlets. Externally it's dark brown in colour, with somewhat rough longitudinally wrinkled surface. The root is solid flexible when fresh, and breaks with a fibrous fracture, exposing a yellowish white woody interior when dry. It measures up to 10-14 cm in length and 0.5-0.7 cm in

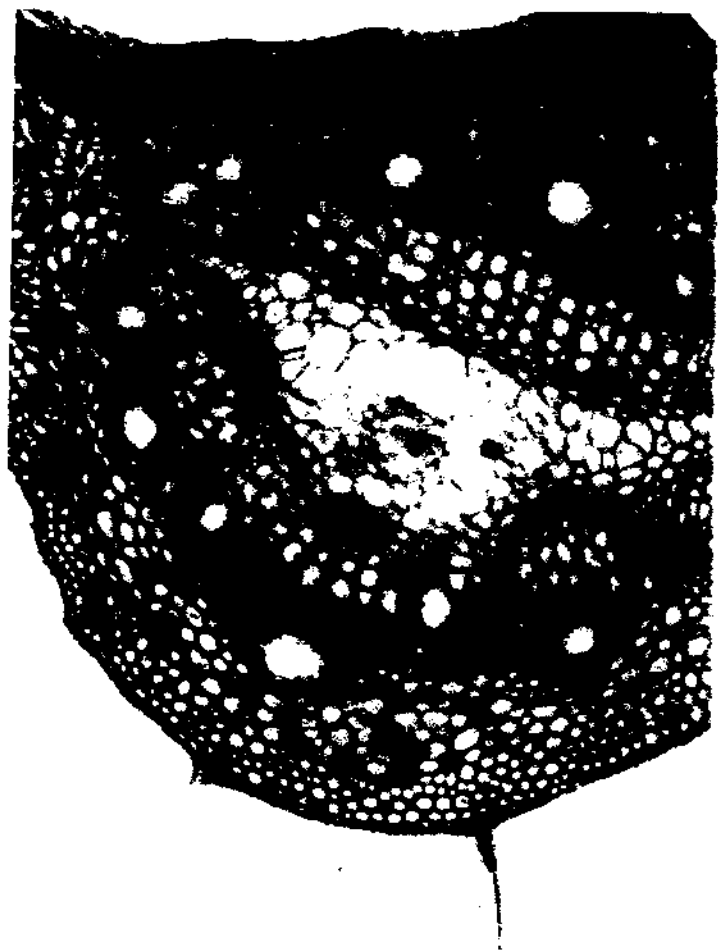
diameter at the top portion. It's odourless with a slight bitter taste.

MICROMORPHOLOGY

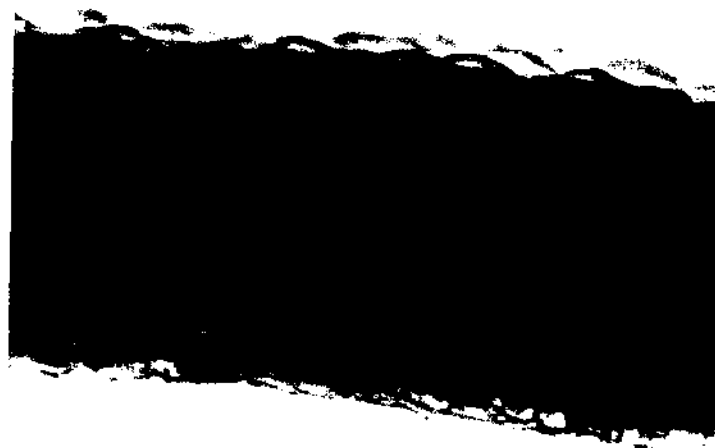
1- Micromorphology of the leaflet (Figs. 3,4,5&6)

A transverse section in the lamina through the midrib of the leaflet appears more or less biconvex in outline. The midrib is more prominent on the lower surface and showing a small ridge on the upper one. It shows a dorsiventral structure, with an upper layer of palisade cells, interrupted by a small mass of collenchyma, another mass of collenchyma is present on the lower part of the midrib. Large clusters of calcium oxalate are common in the palisade layer. The spongy zone is moderately wide formed of several rows of parenchymatous cells and showing numerous clusters of calcium oxalate, as well as, many schizogenous glands. The bundle of the main vein is concentric showing a central pith surrounded by a continuous ring of xylem, phloem and pericycle. Numerous schizogeneous glands are abundant in the pith and phloem. Many resinous secretory canals are present in the phloem.

The upper epidermis: It consists of one layer of square to rectangular cells as seen in T.S. being polygonal, usually isodiametric sometimes axially elongated subrectangular in surface view. The cells have more or less straight beaded anticlinal walls and covered with smooth cuticle. They measure about 20-42 μ in length, about 13-34 μ in width and about 12-27 μ in the height. Stomata are rare on the upper surface. They are of anomocytic type, and surrounded by 4-6 epidermal cells. The stomata are oval to rounded in outline and measuring about 20-25 μ in width and about 33-46 μ in length. The neural epidermal cells are rectangular axially elongated, with straight beaded anticlinal walls and covered with smooth cuticle. Trichomes of non-glandular type are present, being stiff, unicellular, showing swollen base, covered with smooth cuticle, having a wide lumen, acute apex and many of them show granular contents. They

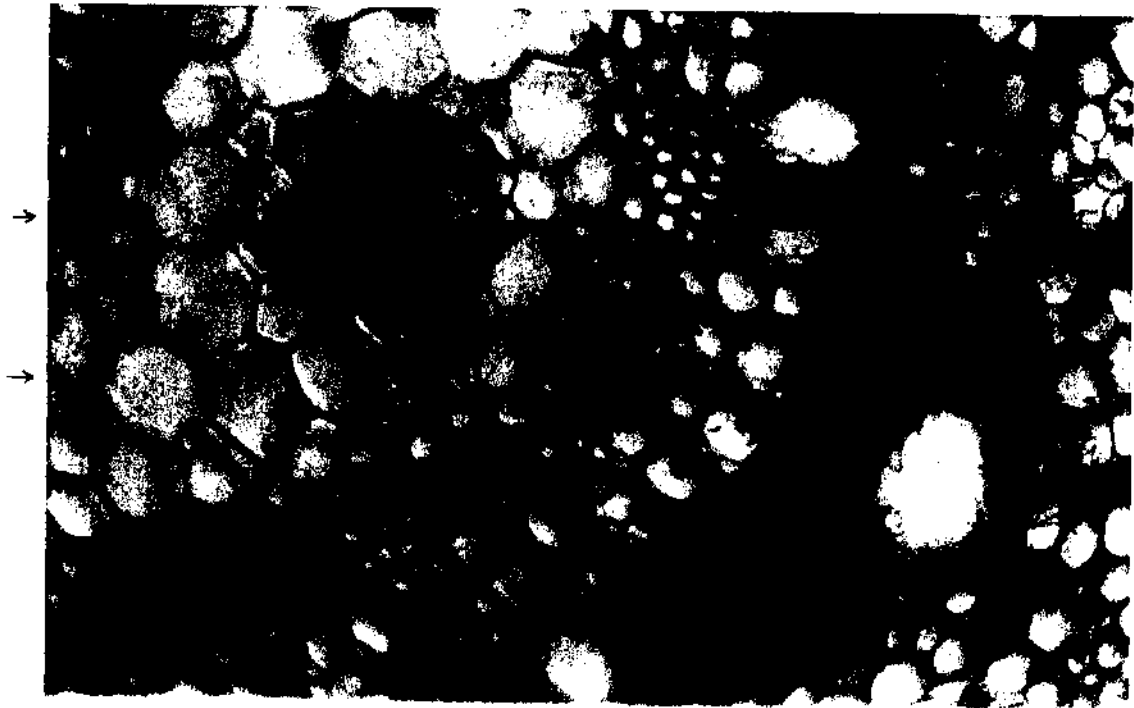


A



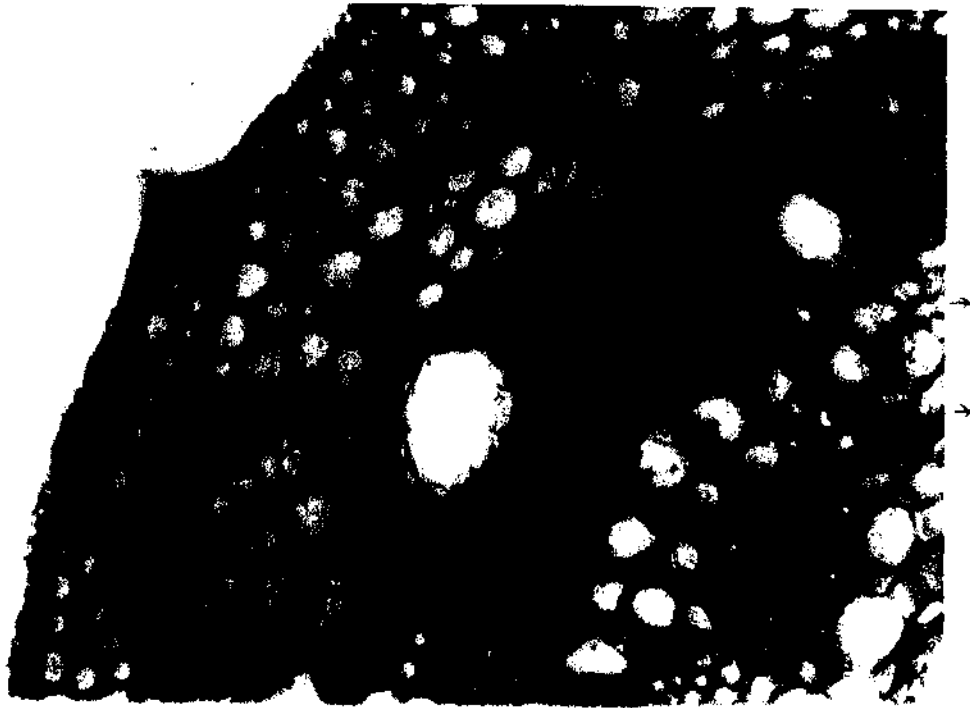
B

Fig. 3: A, Photo of T.S. of leaf at midrib region x 160
B, Photo of T.S. of leaf at lamina x 252



x 252

Fig. 4: A photo of T.S. of leaf at the midrib region



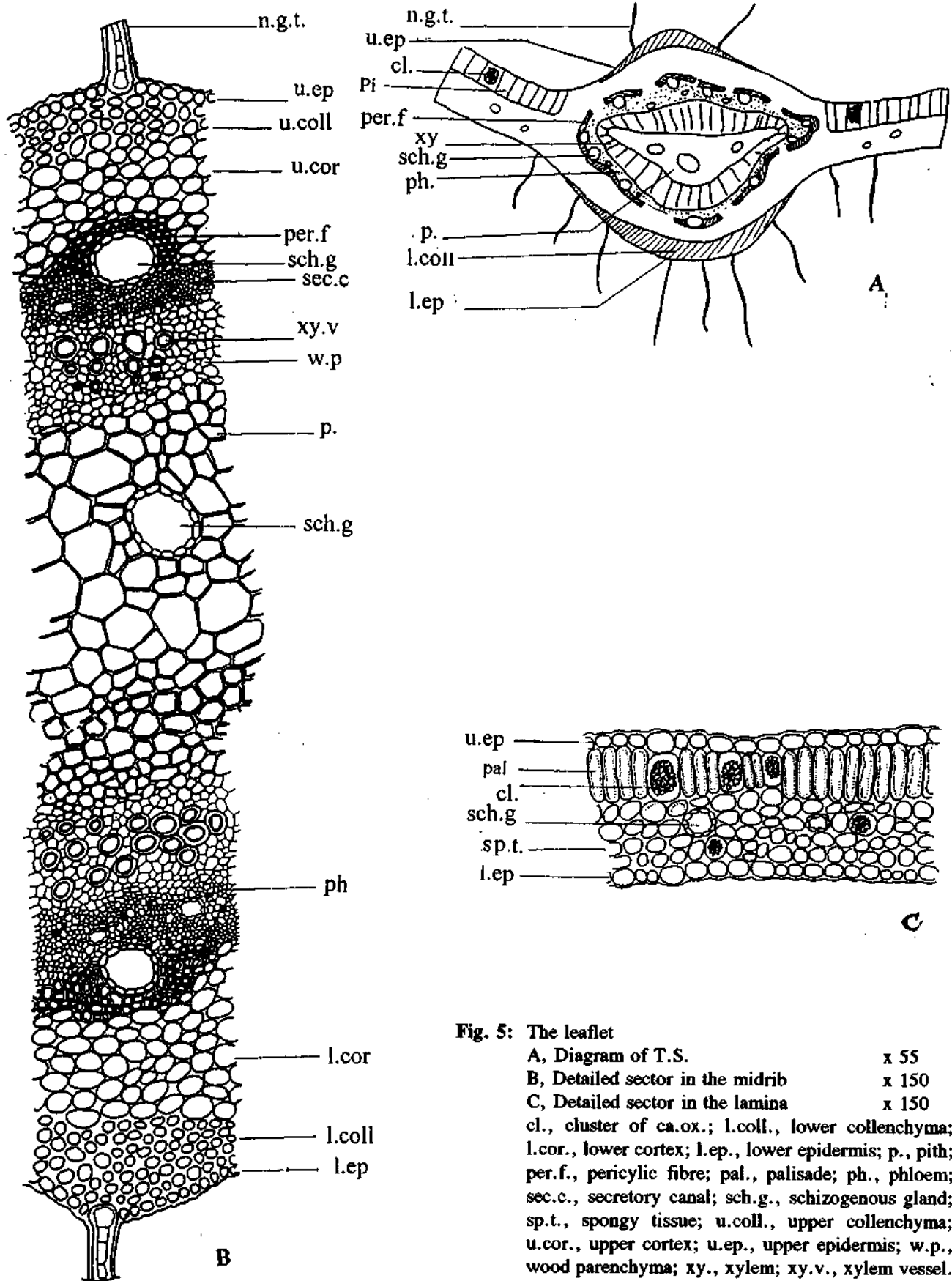


Fig. 5: The leaflet

A, Diagram of T.S. x 55
 B, Detailed sector in the midrib x 150
 C, Detailed sector in the lamina x 150

cl., cluster of ca.ox.; l.coll., lower collenchyma;
 l.cor., lower cortex; l.ep., lower epidermis; p., pith;
 per.f., pericylic fibre; pal., palisade; ph., phloem;
 sec.c., secretory canal; sch.g., schizogenous gland;
 sp.t., spongy tissue; u.coll., upper collenchyma;
 u.cor., upper cortex; u.ep., upper epidermis; w.p.,
 wood parenchyma; xy., xylem; xy.v., xylem vessel.

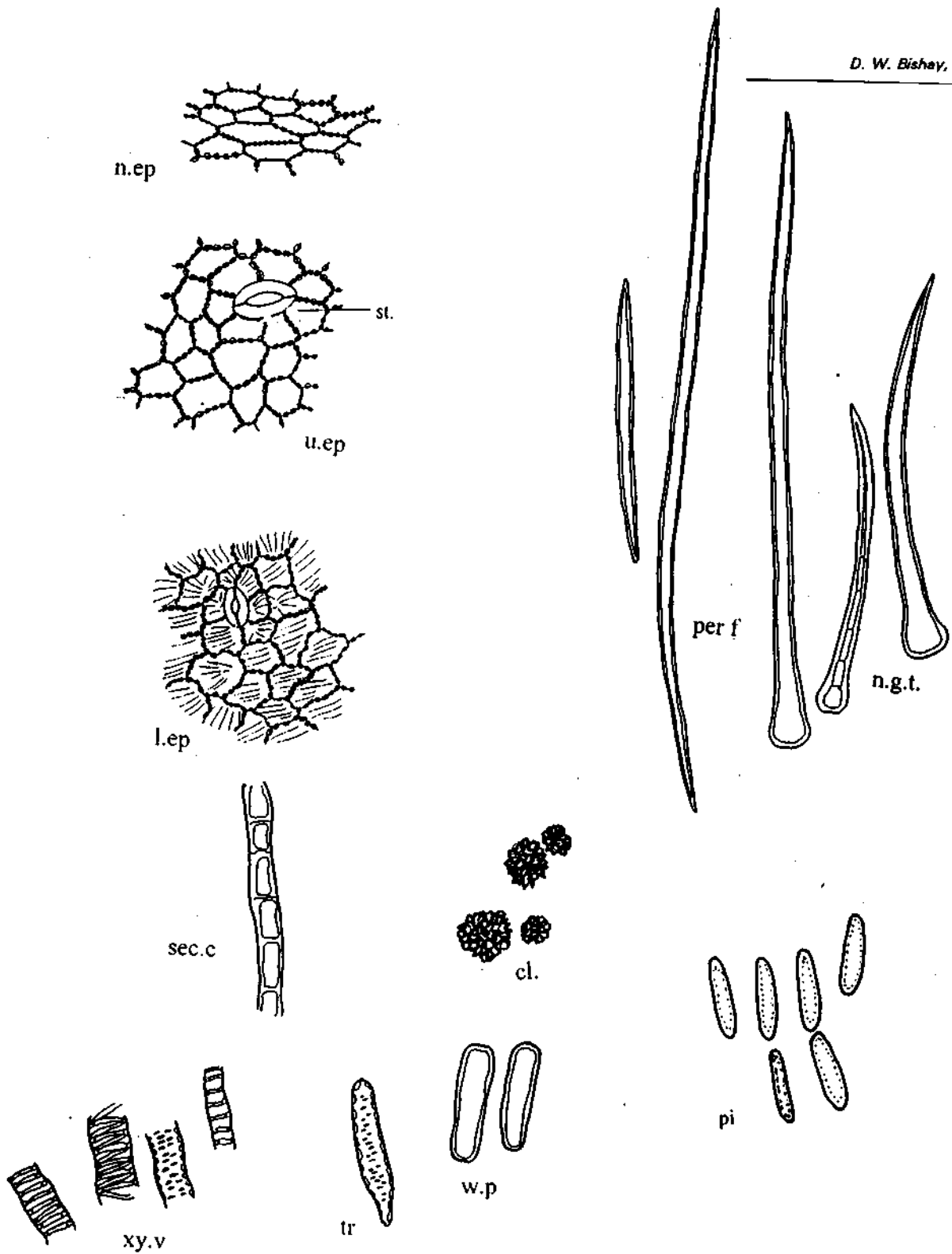


Fig. 6: Powdered leaflet

cl., cluster of ca.ox. (x 500); l.ep., lower epidermis (x 240); n.ep., neural epidermis (x 300); n.g.t., non glandular trichome (x 300); pi., palisade (x 240); per.f., pericyclic fibre (x 300); st., stomata (x 240); sec.c., secretory canal (x 500); tr., tracheid (x 500); w.p., wood parenchyma (x 500); u.ep., upper epidermis (x 240); xy.v., xylem vessel (x 240).

measure about 180-368 μ in length and about 23-30 μ in diameter at the basal portion.

The lower epidermis: It consists of one layer of square or subrectangular cells as seen in T.S. In surface view the epidermal cells appear polygonal usually isodiametric sometimes subrectangular with beaded anticlinal walls and covered with thin striated cuticle. The cells are slightly smaller than those of the upper epidermis, measuring about 17-38 μ in length, 10-27 μ in width and about 10-20 μ in height. Stomata of the same type, but more numerous are present, measuring about 28-31 μ in length and about 15-17 μ in width. Non-glandular hairs exactly similar to those of the upper surface are present, but they are more numerous.

The mesophyll: It is heterogenous, the upper palisade is formed of one row of columnar cells containing chloroplasts and measuring about 46-67 μ in length and 13-20 μ in width. Some palisade cells are larger reaching 26-40 μ in width and containing large clusters of calcium oxalate measuring about 20-40 μ in diameter. The spongy parenchyma are arranged in about 3-4 layers containing many clusters of calcium oxalate that measure 20-27 μ in diameter, as well as, numerous schizogenous glands measuring about 20-47 μ in diameter.

The cortical tissue: There are an upper and a lower subepidermal collenchymatous masses. The upper mass being formed of about 2-4 rows, while the lower is formed of about 4-6 rows. The cells are rounded in outline. The cortical parenchymatous cells surrounding the vascular bundle are formed of about 3-4 layers above the bundle and about 4-6 layers below it, being rounded to oval in shape with moderately wide intercellular spaces. They are free of any contents.

The vascular system: It is represented by a main central large vascular bundle of the midrib and few smaller ones on each side representing the veins. The main vascular bundle of the midrib region is concentric, showing a central pith surrounded by a complete ring of xylem,

phloem and pericycle. The pericyclic ring consists of isolated groups of lignified pericyclic fibres that interrupted by pericyclic parenchyma. The fibre has a moderately thin lignified wall, a wide lumen and an acute apex, and measuring about 163-470 μ in length and about 8-10 μ in diameter.

The phloem surrounds the xylem and consists of thin walled sieve elements and showing numerous schizogenous glands embedding in the pericyclic ring, where the pericyclic fibres appears as a crown over the glands. In addition, the phloem shows other secretory resinous canals measuring about 7-10 μ in diameter.

The xylem consists of lignified mostly spiral, scalariform and sometimes pitted xylem vessels measuring about 13-34 μ in diameter. The vessels are separated by thin walled cellulosic parenchyma, as well as, few lignified pitted tracheids that measure 50-54 μ in length and about 8-10 μ in width. The pith forms a relatively wide zone of parenchymatous cells and contains numerous schizogenous glands measuring about 92-100 μ in diameter.

2- The petiole

A transverse section of the petiole (Figs. 7&8) is somewhat circular in outline, showing a small ridge on its upper side. It shows an epidermis surrounding a cortex followed by a circle of pericycle that enclosing the main vascular bundle which arranged in a circle and surrounding a parenchymatous pith. Many schizogenous glands are present in the phloem and pith. Those of the phloem are imbedded in the pericyclic region. Clusters of calcium oxalate are present in the cortex, phloem and pith.

The Epidermis: It consists of one layer of square to rectangular cells in T.S. In surface view the epidermal cells are polygonal, axially elongated some isodiametric but mainly subrectangular. The cells show straight beaded anticlinal walls and covered with thin smooth cuticle. They measure about 23-57 μ in length, 13-34 μ in width and about 7-16 μ in height. Stomata of anomocytic type are rarely present.

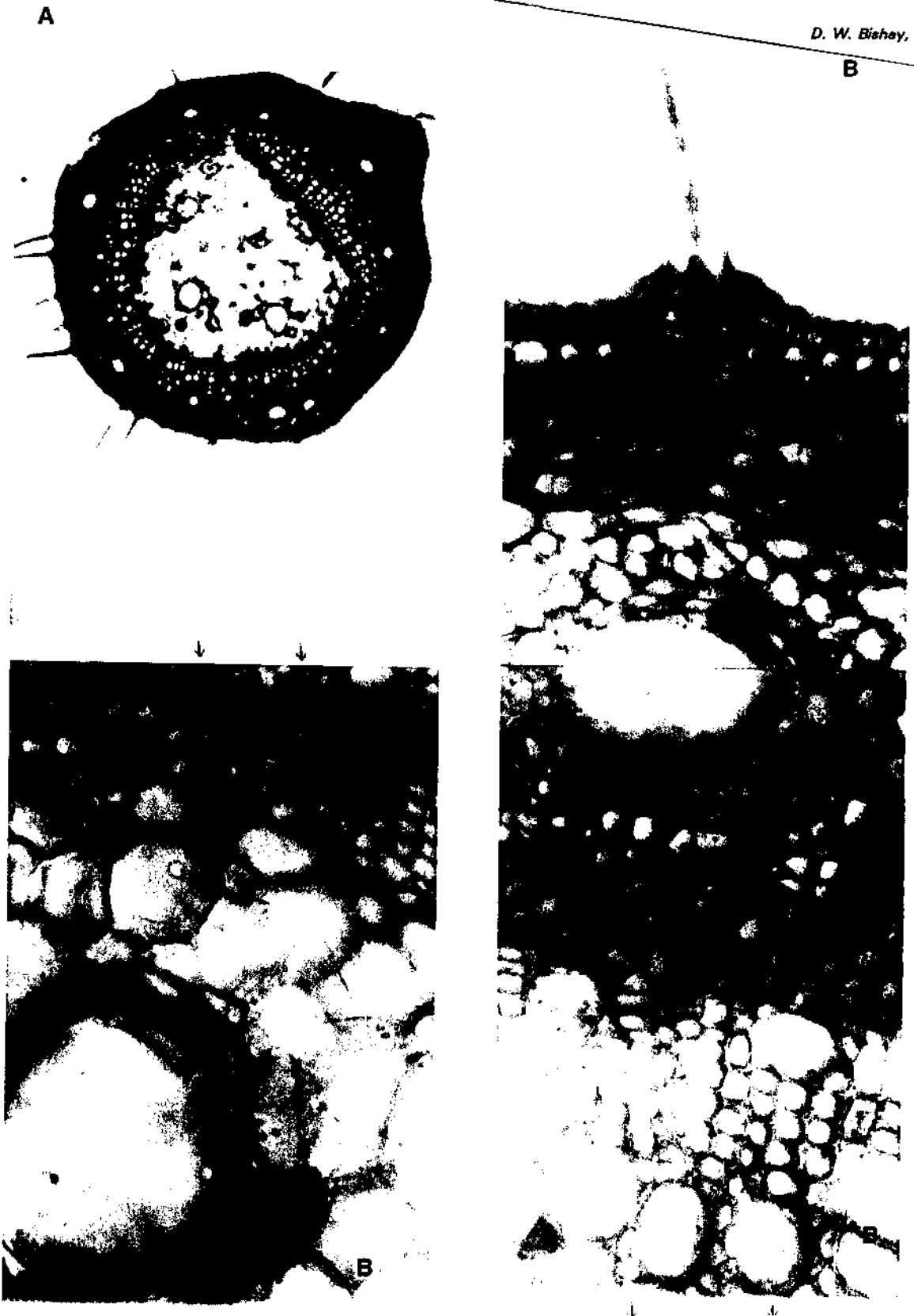


Fig. 7: A, Photo of T.S. of the petiole
B, Photo of T.S. of the petiole

x 70
x 320

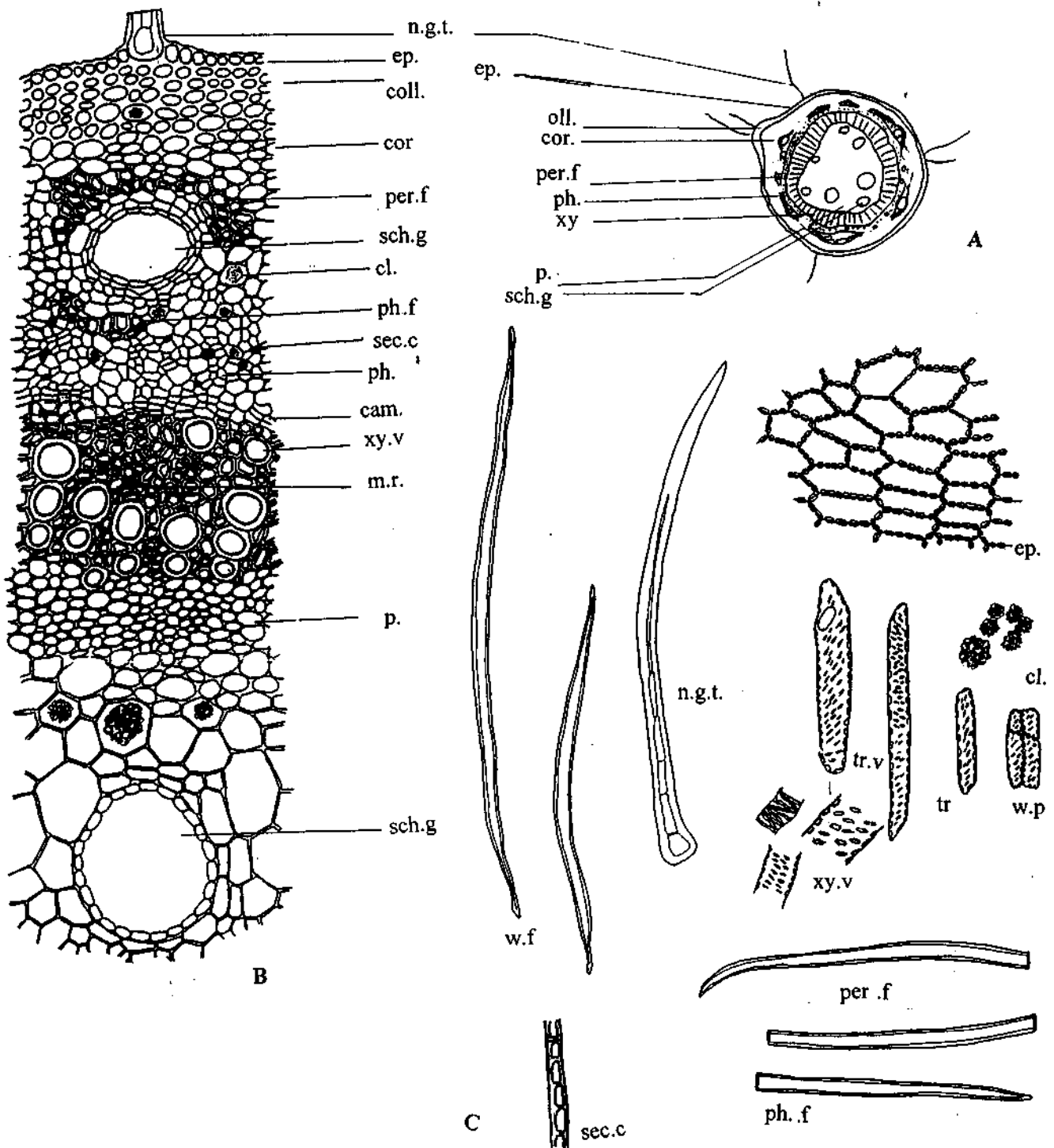


Fig. 8: The petiole

A, Diagram of T.S.

x 30

B, Detailed sector

x 240

C, Powdered petiole

x 300

cam., cambium; cl., cluster of ca.ox.; coll., collenchyma; cor., cortex; ep., epidermis; m.r., medullary ray; n.g.t., non glandular trichome; p., pith; per.f., pericylic fibre; ph., phloem; ph.f., phloem fibre; sec.c., secretory canal; sch.g., schizogenous gland; tr., tracheid; tr.v., tracheidal vessel; w.f., wood fibre; w.p. wood parenchyma; xy., xylem; xy.v., xylem vessels.

Non-glandular trichomes similar to those of the leaf blade are also present.

The cortical tissue: Consists of 2-3 rows of outer collenchymatous cells, followed by 3-4 rows of thin walled parenchymatous cells with moderately wide intercellular spaces. The endodermis is indistinct. Few clusters of calcium oxalate are present in the parenchyma and measuring about 12-17 μ in diameter.

The pericycle: Is formed of a continuous ring of isolated groups of lignified pericyclic fibres. The fibre shows more or less thin lignified walls, a moderately wide lumen and an acute apex, measuring about 500-750 μ in length and about 8-10 μ in diameter.

The phloem: Consists of a relatively wide zone that surrounding the xylem and formed of sieve tubes, companion cells, phloem parenchyma and phloem fibres. The fibre shows a thin lignified wall, a wide lumen and an acute apex, and measuring about 460-730 μ in length and about 8-10 μ in diameter. The phloem parenchyma contains numerous clusters of calcium oxalate measuring about 8-21 μ in diameter, as well as, numerous secretory resinous canal similar to those of the leaf blade. In addition, the phloem shows numerous schizogenous glands that arranged in the form of a ring and imbedding in the pericyclic layer, where the pericyclic fibres form an arc over them.

The cambium: Is clear forming a cambiform zone.

The xylem: Is a wide radially arranged zone and formed of lignified vessels, fibres, wood parenchyma, tracheids and few tracheidal vessels traversed by medullary rays. The vessels are lignified with pitted, sclariform or spiral thickenings and measuring about 12-38 μ in diameter. The wood fibre has a thin lignified wall, a wide lumen and an acuminate tapering apex. They measure about 240-420 μ in length and about 8-10 μ in diameter at its middle portion. The wood parenchyma is formed of

polygonal axially elongated cells with pitted lignified walls and measuring about 6-10 μ in width and about 13-34 μ in length. Tracheids and tracheidal vessels with lignified pitted walls are present. Medullary rays are usually uniserriate. They are elongated subrectangular in outline, with lignified walls, while in the phloem region the cells of medullary rays are rectangular with thin unlignified walls.

The pith: Is formed of a comparatively wide zone of polygonal parenchymatous cells, containing numerous schizogenous glands measuring about 120-125 μ in diameter and clusters of calcium oxalate measuring about 16-30 μ in diameter.

3- Leaf rachis

The transverse section of the leaf rachis is exactly similar to that of the petiole, but smaller in diameter.

The powdered leaf

The powdered leaf (Figs 6&8c) is green in colour, possessing a faint odour and an unpleasant taste. It is characterized microscopically by the following features:

- 1- Fragments of upper epidermal cells of the lamina, being polygonal, showing more or less straight beaded anticlinal walls, covered with smooth cuticle and carrying anomocytic stomata.
- 2- Fragments of lower epidermal cells of the lamina, being, polygonal, with wavy beaded anticlinal walls, carrying anomocytic stomata and covered with striated cuticle.
- 3- Fragments of polygonal beaded parenchymatous cells of the petiole epidermis with straight anticlinal walls and rarely show anomocytic stomata.
- 4- Numerous non-glandular trichomes which are unicellular, showing acute apex, wide lumen, a swollen base and covered with smooth cuticle.
- 5- Fragments of neural epidermal cells.
- 6- Fragments of lignified xylem vessels with spiral, sclariform and pitted thickenings.

- 7- Abundant tracheids and tracheidal vessels with lignified pitted walls.
- 8- Fragments of wood fibres with thin lignified walls, wide lumens and acuminate tapering apices (from the petiole).
- 9- Fragments of both phloem fibres (from the petiole) and pericyclic fibres (from the petiole and leaf blade) usually with thin lignified walls, wide lumens and acute apices.
- 10- Numerous clusters of calcium oxalate, either free or imbedded in parenchyma cells.
- 11- Scattered palisade cells.
- 12- Tracheids with pitted lignified walls
- 13- Fragments of wood parenchyma showing either thin cellulosic walls (from the leaf), or lignified pitted walls (from the petiole).
- 14- Fragments of resinous secretory canals.

4- Stem (Figs. 9,10&11)

A transverse section in the young stem, just below the apical bud is more or less circular in outline. It's formed of an epidermis carrying abundant non-glandular trichomes exactly similar to those of the leaf. The cortex is formed of about 7-10 layers of rounded to oval parenchymatous cells with narrow intercellular spaces. The endodermis is indistinct. The pericycle is parenchymatous, surrounding a narrow central stele that encloses a wide parenchymatous pith. Many clusters of calcium oxalate, as well as, schizogenous glands are abundant in the cortex and pith. However, a transverse section in the old stem is more or less circular in outline, showing cork cells that arises early and subepidermally. The pericycle forms a more or less complete ring of about 2-3 layers of isolated groups of lignified pericyclic fibres. The primary phloem begins below the pericycle showing large and wide schizogenous glands usually bulging the pericyclic region, where the pericyclic fibres form an arc around them. The secondary phloem consists of soft and hard bast, showing mainly uniseriate medullary rays, as well as, scattered resinous canals. The parenchymatous cells surrounding both phloem and pericyclic fibres contains prisms of calcium oxalate forming crystal sheath. The xylem is a wide zone of secondary lignified elements, the main constituents is represented by lignified

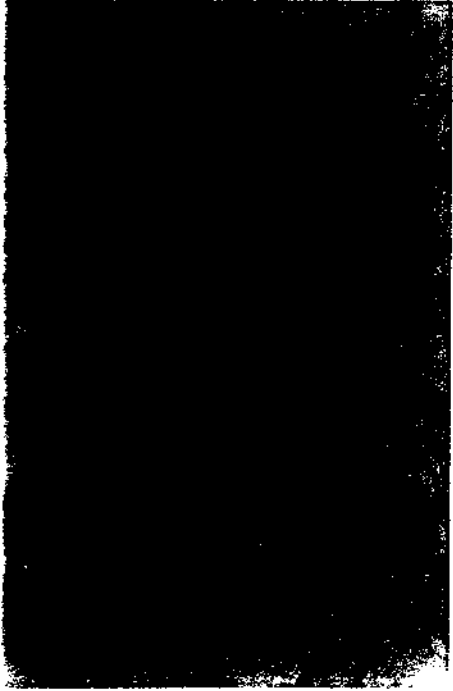
fibres and traversed by medullary rays. The primary xylem is clear and consists of several arcs. The pith is a wide centric parenchymatous zone showing scattered large secretory glands in addition to numerous clusters & prisms of calcium oxalate. Minute starch granules are present in the cortex, medullary ray and the pith.

The cork: It is formed of several layers of yellowish brown suberized tabular radially and tangentially arranged cells as seen in T.S. From top view, they appear polygonal usually isodiametric with straight anticlinal walls. They measure about 16-28 μ in length, 12-20 μ in width and about 8-13 μ in height. The phellogen originates early in the subepidermis layer and usually collapsed and indistinct.

The cortex: The secondary cortex consists of several layers of thin walled parenchymatous cells with narrow intercellular spaces and containing clusters of calcium oxalate measuring about 16-28 μ in diameter, as well as, few minute starch granules. The remaining of the primary cortex is followed internally the secondary cortex and is a comparatively wider zone of thin walled parenchymatous cells with moderately wide intercellular spaces and showing the same contents as the secondary cortex. The endodermis is indistinct.

The pericycle: It is formed of a continuous zone of about 2-4 rows of lignified pericyclic fibres that is interrupted by pericyclic parenchyma. The pericyclic fibres form an arc over the schizogenous glands. Each fibre has a thin lignified wall, a wide lumen and acute apex. They measure about 460-960 μ in length and about 8-10 μ in diameter at the middle portion. The parenchyma surrounding the fibres contains prisms of calcium oxalate forming crystal sheath.

The phloem: It is formed of a moderately wide zone of primary and secondary elements. It consists of sieve tubes, companion cells and phloem parenchyma. At the periphery of the primary phloem large schizogenous glands are present. They are arranged in the form of a ring



B



C

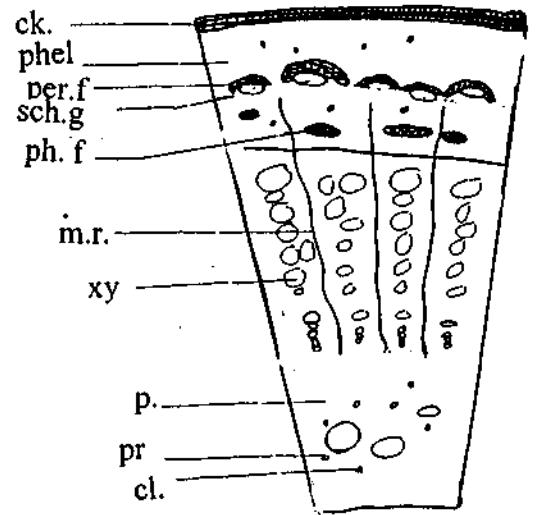
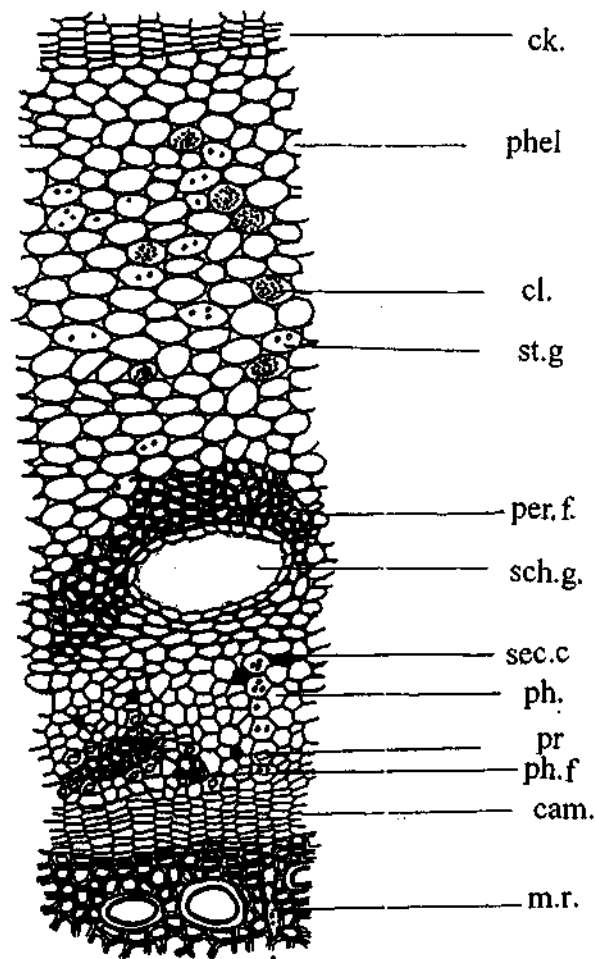


A

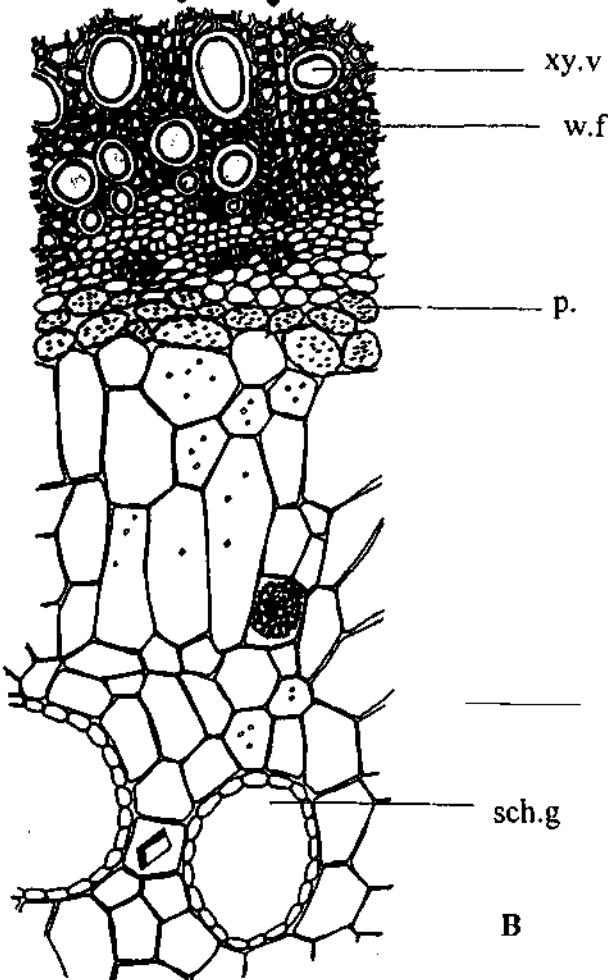
Fig. 9: A, Photo of T.S. of the stem
 B,C, Photo of the pith of the stem showing large cluster and large prisms of calcium oxalate

x 170

x 240



A



B

Fig. 10: The stem

A, Diagram of T.S.

x 75

B, Detailed sector

x 180

cam., cambium; ck., cork; cl., cluster of ca.ox.; m.r., medullary ray; p., pith; per.f., pericyclic fibre; phel., phelloderm; ph., phloem; ph.f., phloem fibre; pr., prism of ca.ox.; sec.c., secretory canal; sch.g., schizogenous gland; st.g., starch granule; w.f., wood fibre; w.p., wood parenchyma; xy., xylem; xy.v., xylem vessel.

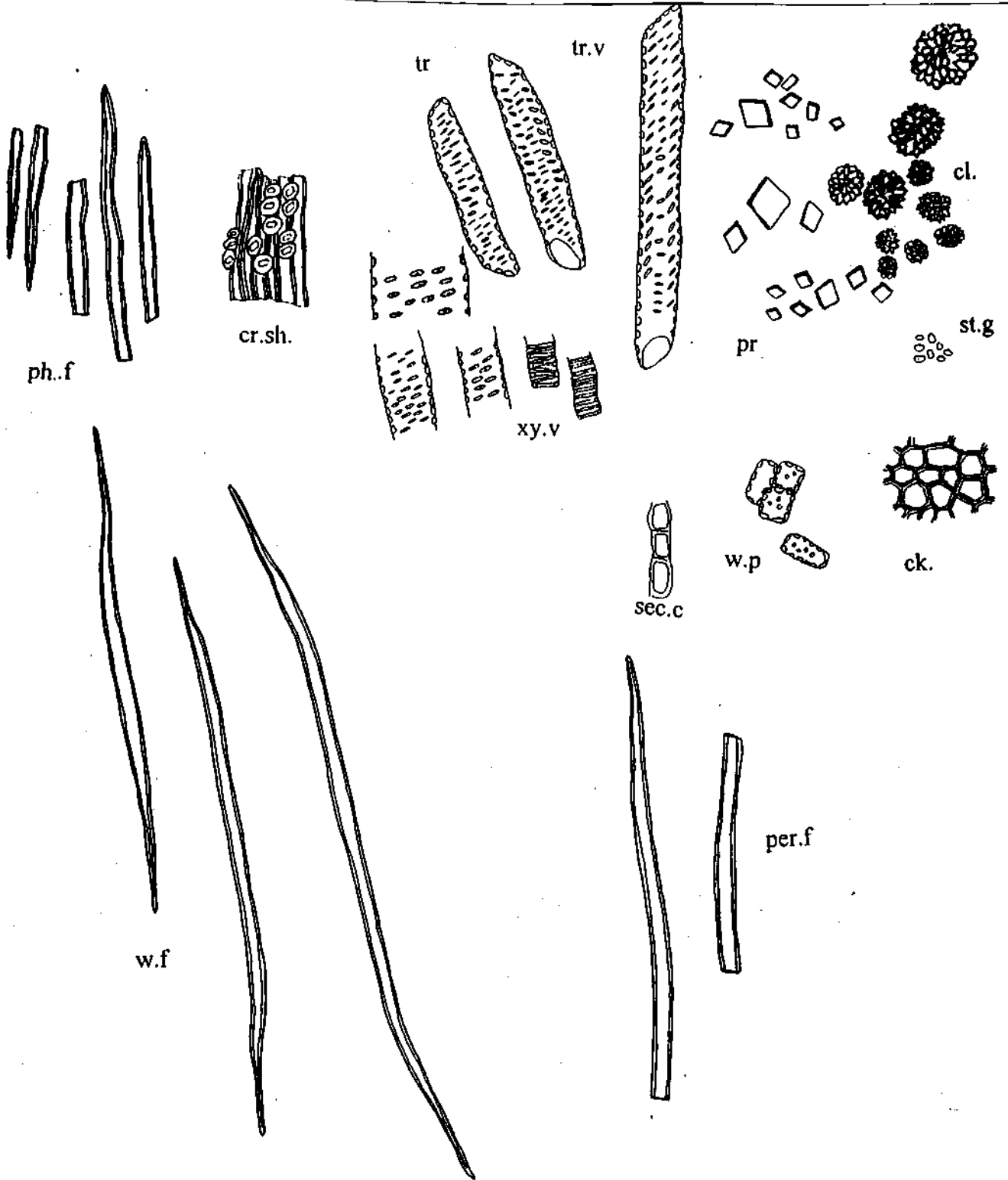


Fig. 11:

Powdered stem (x 300); ck., cork; cl., cluster of ca.ox.; cr.sh., crystal sheath; per.f., pericyclic fibre; ph.f., phloem fibre; pr., prism of ca.ox.; sec.c., secretory canal; st.g., starch granule; tr., tracheid; tr.v., tracheal vessel; w.f., wood fibre; w.p., wood parenchyma; xy.v., xylem vessel.

and bulging the pericyclic region, where pericyclic fibres form a crown over them. They measure about 85-115 μ in diameter. Patches of lignified phloem fibres occur in the secondary phloem and accompanied with crystal sheath. The prisms of calcium oxalate forming crystal sheath measure about 5-9 μ in width and about 11-14 μ in length. The phloem fibre shows a thin lignified wall, a narrow lumen and acute apex. They measure about 460-955 μ in length and about 8-10 μ in diameter at the middle portion. The phloem contains numerous resinous secretory canals measuring about 4-9 μ in diameter.

The Cambium: Forms wide band of cambiform cells consisting of several layers of thin-walled cellulosic cells which are subrectangular tangentially elongated and radially arranged.

The xylem: Is represented by a ring of wide radiating lignified secondary elements of vessels, fibres, tracheids and wood parenchyma. The vessels are usually solitary with pitted, scalariform and spiral thickening. The pitted vessels show both simple and bordered pits, while the primary xylem shows mainly spiral and some pitted vessels. The vessels measure about 15-62 μ in diameter. Wood fibres are the main constituents of the xylem. The fibre shows a thin lignified straight wall, a moderately wide lumen and an acuminate tapering apex. They measure about 280-490 μ in length and about 8-10 μ in diameter. Tracheids with tapering ends and pitted lignified walls are present and measuring about 110-115 μ in length and about 18-20 μ in width. Tracheidal vessels are also present with long segment and clear lateral perforation. The wood parenchyma is subrectangular in outline with thick pitted lignified walls, containing minute and few starch granules and measuring about 18-28 μ in length and about 12-14 μ in width. The medullary rays are radially elongated, subrectangular in outline, with pitted lignified walls and containing prisms of calcium oxalate, as well as, minute starch granules. They are usually uniseriate and sometimes biseriate. However, the medullary ray in the phloem region is not lignified showing the same contents.

The pith: Is formed of a comparatively wide central zone of parenchymatous cells. The first few layers are rounded to oval in outline with pitted lignified walls. The remaining layer consists of elongated polygonal thin walled cellulosic parenchymatous cells. They contain clusters of calcium oxalate measuring about 40-65 μ in diameter, as well as, prisms of calcium oxalate measuring about 27-34 μ in length and about 16-20 μ in width. In addition, the pith contain large numerous schizogenous glands measuring about 110-195 μ in diameter.

The powdered stem

The powdered stem (Fig. 11) is yellowish brown in colour, with faint odour and having unpleasant taste. It is characterized microscopically by the presence of:

- 1- Fragments of polygonal isodiametric suberized, nonlignified cork cells. They contain dark brown pigments.
- 2- Fragments of wood parenchyma with thick, pitted and lignified walls.
- 3- Fragments of tracheids and tracheidal vessels with pitted lignified walls.
- 4- Fragments of both lignified pericyclic and phloem fibres surrounded by crystal sheath with prismatic crystals of calcium oxalate. The fibre possesses a thin lignified wall, a wide lumen and an acute apex.
- 5- Numerous scattered prisms and clusters of calcium oxalate.
- 6- Fragments of wood fibres with thin lignified walls, wide lumens and acuminate tapering apices.
- 7- Fragments of lignified vessels with spiral, scalariform and pitted thickenings. The pitted vessels show both simple and bordered pits.
- 8- Fragments of secretory resinous canals.

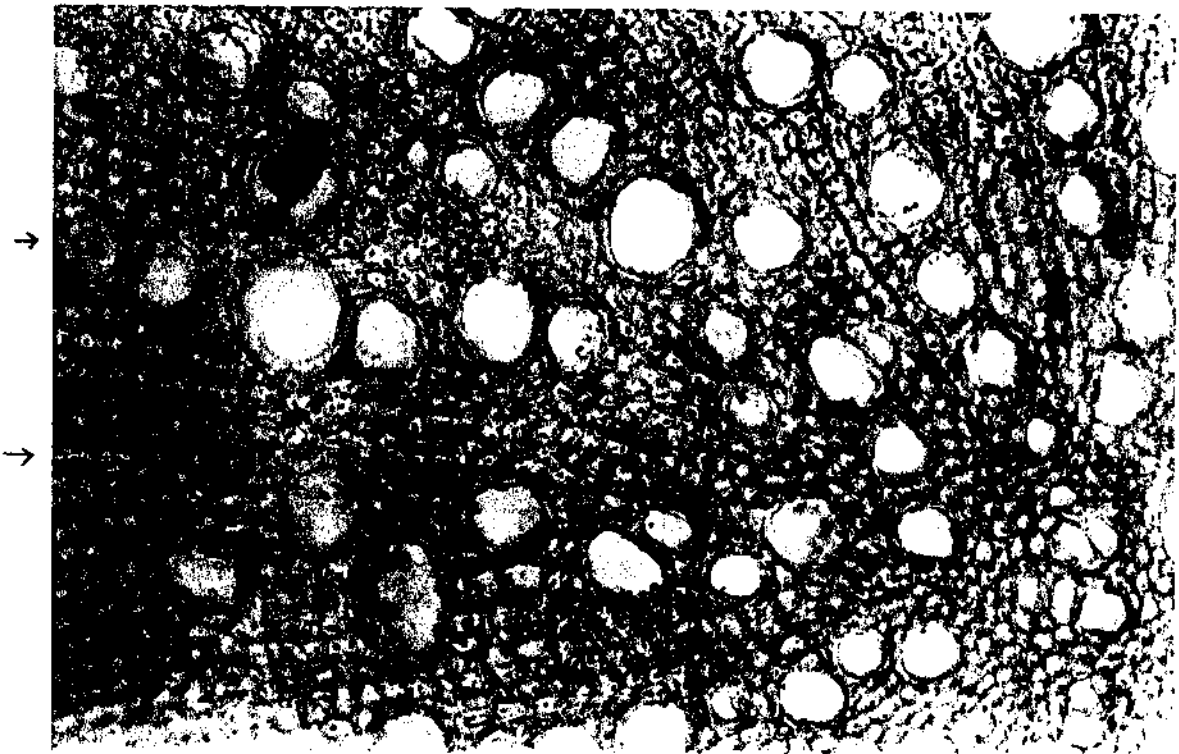
5- The root

A transverse section in the root (Fig. 12&13) is circular in outline. It shows reddish brown cork followed by a comparatively wide parenchymatous cortex surrounding a central cylinder of vascular bundle. The vascular bundle composed of narrow phloem and a wide xylem traversed by usually uniseriate or sometimes



x 400

Fig. 12: Photo of T.S. of the root



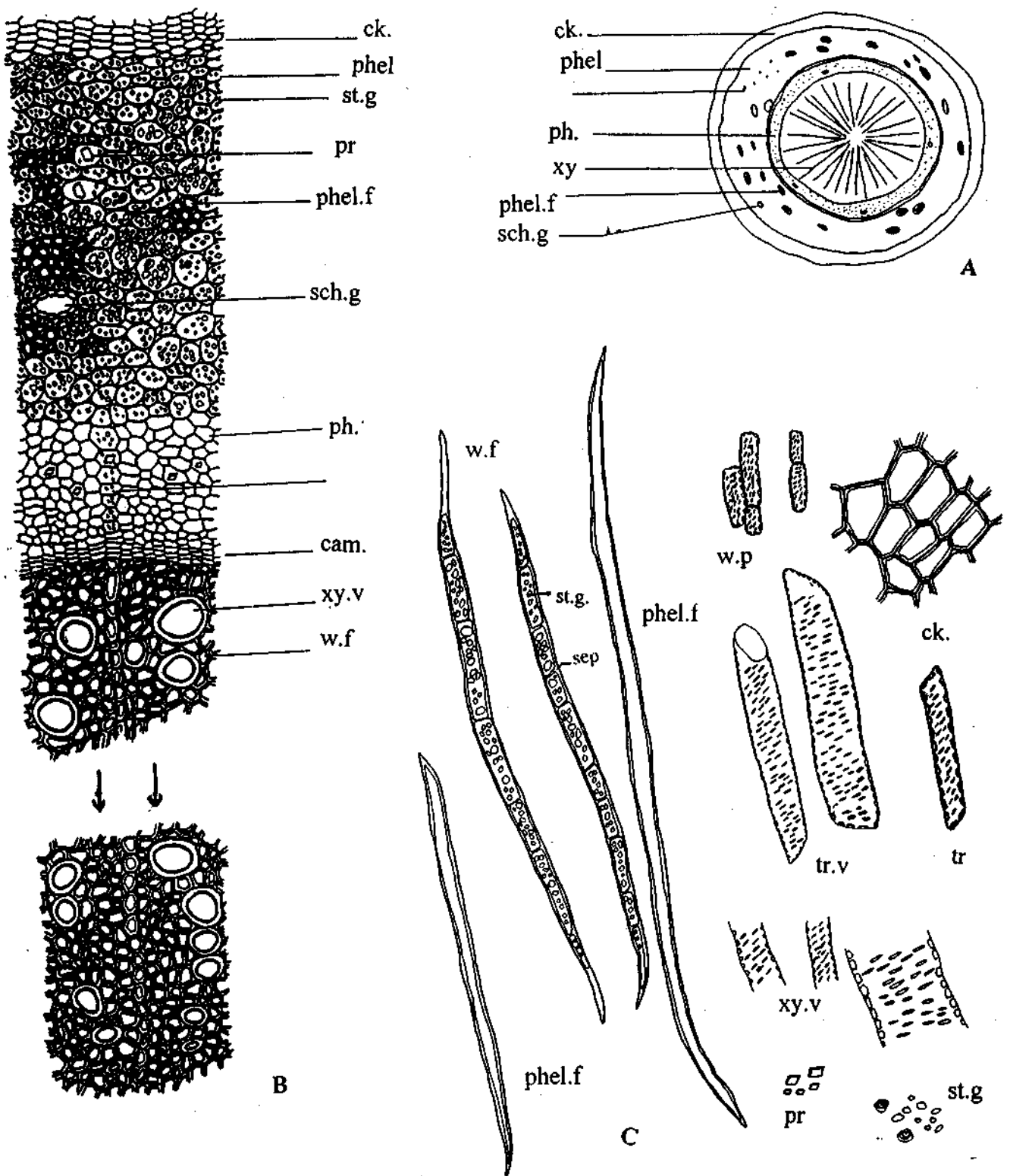


Fig. 13: The young root

A, Diagram of T.S.

x 30

B, Detailed sector

x 240

C, Powdered root

x 300

cam., cambium; ck., cork; m.r., medullary ray; ph., phloem; phel., phelloderm; phel.f., phelloderm fibre; pr., prism of calcium oxalate; sep., septa; sch.g., schizogenous gland; st.g., starch granule; tr., tracheid; tr.v., tracheal vessel; w.f., wood fibre; w.p., wood parenchyma; xy., xylem; xy.v., xylem vessels.

biserriate medullary rays. Minute strach granules, as well as, prisms of calcium oxalate are scattered in the parenchymatous cells.

The cork: The cork originates early in the pericyclic region replacing all the outer tissue. It consists of several rows of tabular cells as seen in T.S. and containing reddish brown pigment. In surface view the cells being polygonal isodiametric with straight thin walls. They measure about 27-40 μ in length 12-21 μ in width and about 6-11 μ in height.

The phelloderm: It consists of a comparatively wide zone of thin walled parenchymatous cells about 15-20 rows, being oval to rounded in outline. The cells contain abundant rounded to oval mainly simple starch granules with centric hilum appearing as a dot and occasionally concentric striations appear. The granules measure about 3-7 μ in diameter. Occasionally compound starch granules of 2 to 4 components are observed. Minute prisms of calcium oxalate measuring about 6-9 μ in width and about 10-13 μ in length are observed. Few schizogenous glands measuring about 29-35 μ in diameter are present. Groups of lignified fibres are scattered in the phelloderm. The fibre shows thin lignified wall, wide lumen and acute apex. They measure about 250-460 μ in length and about 8-10 μ in diameter.

The phloem: It consists of a narrow ring of thin walled cellulosic elements that include sieve tube, companion cells and phloem parenchyma. Phloem fibres are not observed. The phloem is traversed by numerous uniserriate or sometimes biserriate medullary rays. Phloem parenchyma and medullary ray contain numerous prisms of calcium oxalate and starch granules which are identical to those of the phelloderm.

The cambium: The cambium forms a cambiform zone of several rows of thin walled cells that are tangentially elongated and radially arranged.

The xylem: It is a wide cylinder of lignified

radiating elements. As the secondary xylem is well developed and very compact, it is difficult to trace the primary arches. However, in the young root the primary xylem being tetra to penta-arch. The vessels are mainly solitary showing lignified reticulated, spiral and pitted thickenings. They measure about 14-50 μ in diameter. Tracheids with pitted lignified walls, as well as, tracheidal vessels of large segment and lateral perforation are present. Wood parenchyma are usually rectangular with pitted lignified walls and measuring about 16-40 μ in length and about 8-12 μ in width. The wood fibre is straight regular in the outline with thin lignified wall, a wide lumen and an acuminate tapering apex. The fibre is septated and containing numerous starch granules. They measure about 250-360 μ in length and about 10-13 μ in diameter. The xylem region is traversed by usually uniserriate or sometimes biserriate medullary rays. The cells are rectangular radially elongated with lignified walls and containing starch granules.

The powdered root

The powdered root (Fig. 13C) is yellowish brown in colour, with faint odour and having unpleasant taste. It is characterized microscopically by the presence of:

- 1- Fragments of polyogonal thin walled suberized cork cells containing yellowish brown pigment.
- 2- Fragments of spiral, pitted, reticulated and sclariform thickened xylem vessels.
- 3- Fragments of wood parenchyma which are rectangular in outline with pitted lignified walls and containing starch granules.
- 4- Fragments of tracheids and tracheidal vessels with pitted lignified walls.
- 5- Fragments of phelloderm fibres, with thin lignified walls, wide lumens and acute apices.
- 6- Fragments of wood fibres with thin lignified walls, wide lumens and acuminate tapering apices, the fibres are septated and containing starch granules.
- 7- Abundant scattered starch granules. The granules are rounded to oval in outline with

centric hilum that appearing as a dot and occasionally concentric striations appear. Rarely compound starch granules of 2-4 components are observed.

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