

MACRO- AND MICROMORPHOLOGY OF *GRINDELIA CAMPORUM* VAR. *CAMPORUM GREENE*. FAMILY ASTERACEAE, CULTIVATED IN EGYPT: LEAF, STEM AND ROOT

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نبات الجرينديليا كامبورم جرين التابع للعائلة المركبة ، من النباتات التي ادخلت زراعتها في مصر ويستعمل هذا النبات في الطب الشعبي لعلاج الربو والتهاب الشعب الهوائية والسعال. اذ دم في حالات المغص والحمى وبعض الامراض الجلدية المختلفة مثل الإكزيما الناتجة عن سم اللبالب والبلوط. وقد رؤى أنه من المفيد دراسة الصفات العيانية والد بهرية للساق والورقة والجذر . مكان التعرف على هذه الأجزاء سواء كانت كاملة أو على هيئة مسحوق.

The detailed macro-and micromorphological characters of the stems, leaves and roots of *Grindelia camporum* varity *camporum* Greene (syn. *Grindelia Robusta*) were studied with the aim to find out the diagnostic elements of these organs, which facilitate their identification in both entire and powdered forms.

INTRODUCTION

The genus *Grindelia* (Family: Asteraceae) comprises about 30 species, mostly native to North America, Mexico and South America^{1&2}.

D) *Grindelia camporum* Greene (syn. *Grindelia robusta*, Californian

Gumplant)^{1,3-8} is a herbaceous perennial plant, mostly native to North America, Mexico and South America^{1,2&8}. It has cylindrical stems, sessile or amplexicaule, simple leaves and resinous flower-heads, surrounded by involucre of linear-lanceolate bracts. It has a balsamic aromatic odour and a bitter taste^{1,4-8}. The herb has been

used for treatment of bronchitis, asthma and employed as a lotion for dermatitis produced by the poison ivy and toxicodendrom (Anacardiaceae). Also it has been recommended for cystitis and catarrh of the bladder, and used as expectorant, spasmolytic, stomachic and bronchospasmolytic. The typical therapeutic uses of *Grindelia* include treatment of asthma, bronchitis and whooping cough^{1,4-11}.

The *Grindelia plants* contain about 20% of resin, with numerous labdane diterpene acids termed grindelanes as well as their methyl esters. They yield about 0.2% of volatile oil containing over 100 components. The oil composition from the different species varies quantitatively with bornyl acetate and -pinene which are the major components of the monoterpenoid fraction⁸.

II) *Grindelia camporum* contains phenolic acids, flavonoids, essential oil and considerable amounts of tannin (1.5%) and L-glucose, in addition to small amount of saponin^{1,4,5,7-9&11}.

Tracing the titled plant in literatures, showed that few studies have been done concerning its chemical constituents, however, nothing could be traced concerning the macro- and micromorphological characters. This prompted us to undertake a pharmacognostical investigation of this plant.

Material

The *Grindelia camporum varity camporum Greene* was cultivated in the experimental station of faculty of Agriculture Al Azhar University, Cairo and in station of Biomy Mansour, Badrasheen-Giza. The flowering plants were collected in August 2005 and were kindly identified by Prof. Dr. Salah El Nagar (Professor of Taxonomy, Faculty of Science, Assiut University). The plants at different stages of development were collected for both botanical and chemical investigation. Fresh stems, leaves and roots were preserved, separately, in a mixture of alcohol (70%) -glycerin-water (1:1:1) and were used for this study. The air dried stems, leaves and roots were reduced to powder and kept for microscopical investigation.

Habitat

The *Grindelia camporum varity camporum Greene* (Fig. 1) is a perennial, viscid herb reaches up to 0.5-2 meters in height. The shoot system is branched with an erect glabrous main stem, bearing simple alternate lanceolate to ovate, cauline, sessile leaves. The root system consists of a tap root and rootlets. The flowers are arranged in terminal capitula surrounded by involucre. The flowering period extends from May to October. The fruit is generally 2-3 angled white to golden brown, cypsela of 2-5 mm in diameter; with generally flanged top and the pappus is of 2-8 slender caduceus paleaceous awns. The plants prefer light sandy and medium loamy soils, require



A



B

Fig. 1: (A and B) Photographs of *Grindelia camporum* variety *camporum* Greene.

well-drained soil and can grow in nutritionally poor soil. They can grow in acid, neutral, basic and saline soils, and can tolerate drought^{1, 2, 4, 5, 7&8}.

A- The stem

Macromorphology of the stem

The stem (Figs. 1,2A&2B) is herbaceous to woody erect cylindrical and glabrous, it acquires about 0.5-2 meters in length and about 1.25-1.5 cm in diameter. It is branched, carrying several branches terminating with captula. The nodes are slightly swollen and the internodes are about 2.5-5-6 cm in length. The stem is flexible when fresh and breaks with fibrous fracture when dried. It has a greenish yellow colour with resinous bitter taste and balsamic odour.

Micromorphology of the stem

A transverse section **in the moderately old stem** (Fig. 3A,B&C) is circular in outline. It shows an epidermis with occasional glandular hairs. The cortex is comparatively narrow with 1-4 outer layers of collenchyma and the remaining layers are of parenchymatous cells with wide intercellular spaces. The inner most layer of the cortex shows schizogenous secretory oleo-resin canals abutting on the endodermal region (especially in the region of the pericyclic fibers). The endodermis is distinct and surrounding the central stele. The pericycle shows lignified groups of fibers interrupted by masses of pericyclic parenchyma. The vascular tissues are collateral and formed of a band of phloem elements

with groups of phloem fibers especially those adjacent the pericyclic fibers and a wide zone of xylem elements separated by a cambial zone and traversed radially by wide lignified medullary rays. The xylem consists mainly of vessels with spiral, scalariform and pitted thickenings. The primary xylem is abutted by a zone of lignified fibers towards the pith. The pith is wide and shows slightly lignified pitted and moderately thickened walled parenchymatous cells especially near the xylem mostly with narrow intercellular spaces and contain acicular prisms of calcium oxalate.

In the young stem the epidermis shows numerous glandular hairs. The hypodermis is mainly one layer of collenchymatous cells. The primary cortex is mainly parenchymatous with wide intercellular spaces and few secretory canals. The endodermis is well distinct with casperian strips while the pericycle is mainly parenchymatous cells. The vascular bundles are separated by wide primary medullary rays and the primary phloem is separated from the xylem by collapsed intrafascicular cambium. The xylem vessels are mainly of spiral thickenings; the medullary rays are nonlignified parenchymatous cells. The pith is represented by central wide region of parenchyma with wide intercellular spaces.

In very old stem cork is not observed. The majority of the primary

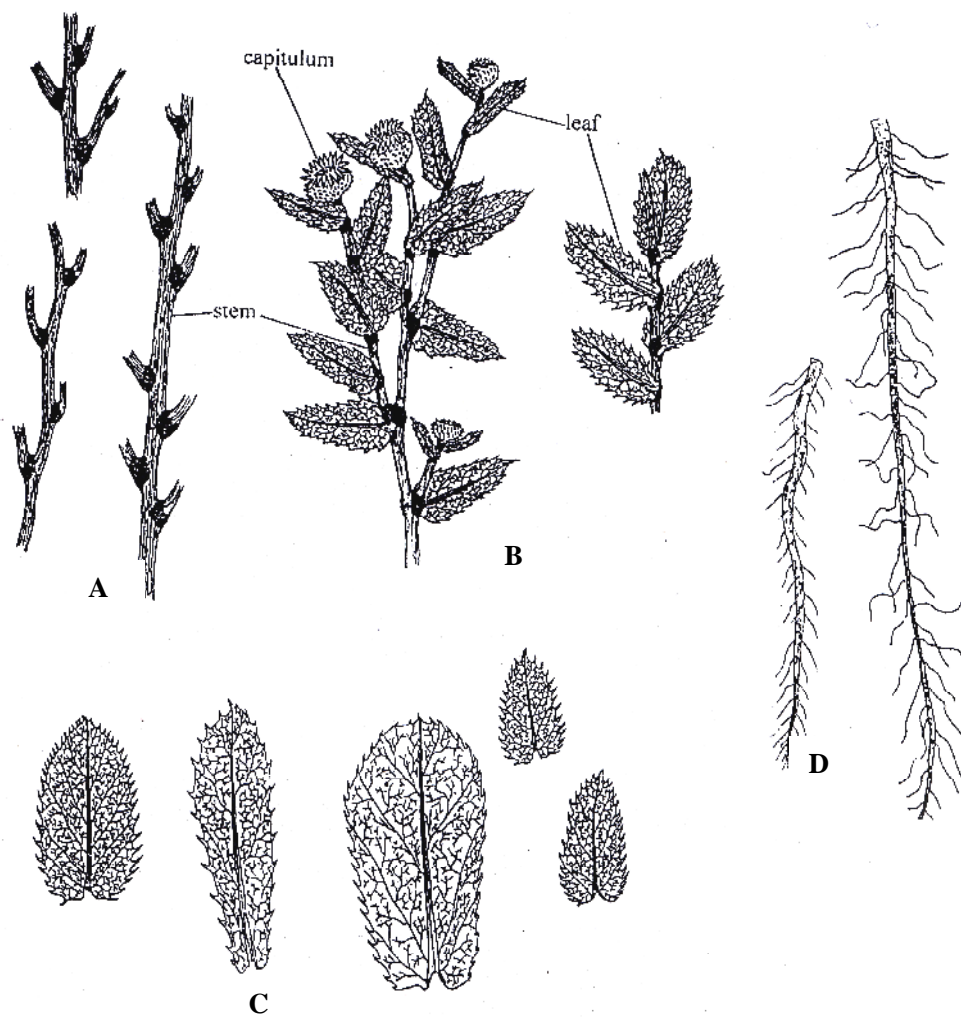


Fig. 2: Macromorphology of leaf, stem and root.

- A) Morphology of the stem (x 0.32)
- B) Morphology of a branch (x 0.32)
- C) Morphology of the leaf (x 0.32)
- D) Morphology of the root (x 0.32)

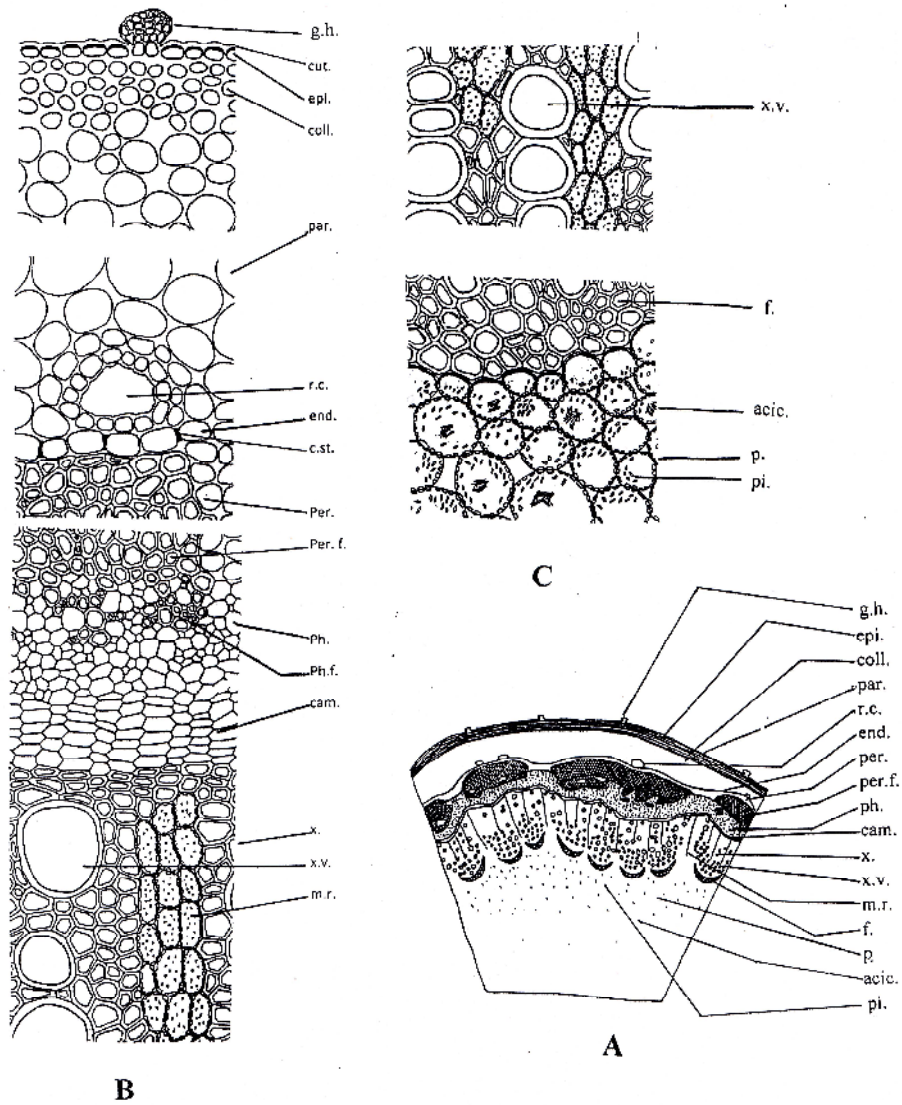


Fig. 3: Micromorphology of the stem.

A: T.S. Diagram of the moderate stem (x 45.25)
 B & C: Detailed T.S. of the moderate stem (x 154)

acic., acicular crystal of calcium oxalate; c.st., casparian strips; cam., cambium; coll., collenchyma; cu., cuticle; end., endodermis; epi., epidermis; f., fiber; g.h., glandular hair; m.r., medullary rays; par., parenchyma; per., pericycle; per.f., pericyclic fibers; ph., phloem; ph.f., phloem fibers; p., pith; pi., pits; r.c., resin cannal; x., xylem; x.v., xylem vessels.

cortical cells shows wide lumena with wavy collapsed walls, and those towards the endodermis are lignified. The endodermis and pericycle are still present. The phloem forming a wide zone and shows groups of secondary phloem fibers. The primary phloem becomes collapsed and forming ceratenchyma. The xylem is represented by a wide zone and consists mainly of vessels with spiral, scalariform and pitted thickenings. The trachiedal vessels show bordered pits. There are primary medullary rays of several layers of lignified pitted cells and the secondary medullary rays are uni- to triseriate with lignified pitted cells. In comparison to young stem, the pith becomes narrow with lignified pitted parenchymatous cells.

The epidermis

The epidermis (Figs. 3A,3B&4B) consists of one layer of subrectangular cells with thick outer tangential walls as seen in transverse section. In surface view the cells are polygonal mainly axially elongated rarely isodiametric with straight sometimes slightly curved anticlinal walls. The cells are covered with thick smooth cuticle and measure about 6.6-12-14.6 μ in width, 6.6-10-13.3 μ in height and 37.3-50.6-78.6 μ in length. Stomata are of anomocytic type, rarely anisocytic, being oval to rounded, surrounded usually by 3-4 epidermal cells and measure about 48-50.6-52 μ in diameter. The epidermis bearing glandular hairs, formed of short bicellular stalks and

multiseriate multicellular heads, covered with thick smooth cuticle and measure 6.6-9.3-12 μ in diameter and 3.3-6.6-13.3 μ in height, the epidermal cells and the first row of the collenchyma cells contain brownish yellow contents that stained yellow with iodine, dissolved in boiling alkali and turned turbid when soaking in alcohol.

The cortex

The primary cortex (Fig. 3A&B) is formed of an outer continuous region of collenchymatous cells followed by inner parenchymatous region. The collenchymae consists of 3-5 rows of thick walled cellulosic cells, the outer most layer of which consists of small cells with narrow lumena similar to the epidermal cells. The remaining collenchymae are shining with wide lumena, the cells being round to ovoid in shape. The parenchymatous region consists of about 3-7 rows and the cells show wide intercellular spaces. The innermost layer of cortex shows schizogenous oleo- resin canals abutting on the endodermis especially in the pericyclic fibers region. The parenchymae surrounding the schizogenous canals show brownish yellow content of oleo resin.

The endodermis

The endodermis (Fig. 3A&B) is distinct and formed of one layer of thin-walled tangentially elongated parenchymatous cells with casparian strips, but starch granules are not observed.

The pericycle

The pericycle (Figs. 3A,3B&4C) consists of groups of lignified fibers interrupted with thin-walled parenchymatous cells. The fibers (Fig. 4C) have thick lignified pitted walls mostly with wide lumena, but some fibers show narrow lumena. They have blunt to rounded apices sometimes acute and tapering with slightly bent apices (peak like). It measures about 10-13.3-23.3 μ in diameter and 176.6-406.6-610 μ in length.

The vascular system

The vascular system (Fig. 3A,B&C) is formed of a continuous ring of phloem followed internally with a ring of cambium and xylem.

The phloem

The phloem (Figs. 3A,3B&4C) consists of a narrow band of sieve tubes, companion cells, phloem parenchyma and scattered groups of phloem fibers especially near the pericyclic region. The phloem parenchymae are polygonal to subrectangular. The phloem fiber (Fig. 4C) has thick lignified wall, wide lumen and blunt to round sometimes acute to acuminate apex. It measures about 133.3-343.3-460 μ in length and 10-13.3-20 μ in diameter.

The cambium

The cambium (Fig. 3A&B) forms a wide band of cambiform cells (cambial zone) consists of 6-8 rows of thin-walled cellulosic subrectangular, tangentially elongated and radially arranged cells.

The xylem

The xylem (Figs. 3A,3B,3C, 4A&4C) consists of radiating zone of lignified vessels, wood parenchyma, wood fibers and tracheids. The vessels are lignified with pitted, spiral and scalariform thickenings; measuring about 13.3-23.3-26.6 μ in diameter. The wood fibers have thick lignified walls, wide lumena and mainly acute sometimes acuminate or rounded apices. The fiber measures about 150-316.6-436.6 μ in length and 10-13.3-20 μ in diameter. The vessels are accompanied by pitted lignified tracheides, tracheidal vessels and tracheidal fibers which measure about 6.6-10-13.3 μ , 13.3-16.6-20 μ and 10-11.6-13.3 μ in diameter respectively. The wood parenchyma are mainly vasocentric paratracheidal and consists of subrectangular cells with lignified pitted walls and measure about 8-12-22 μ in diameter and 140-154-198 μ in length.

The medullary rays

The primary medullary rays (Figs. 3A,3B&4A) are usually multiseriate of 4-7 layers but the secondary medullary rays are usually uniseriate to triseriate. The medullary rays are formed of radially elongated, subrectangular cells with thick lignified pitted walls.

The pith

The pith (Figs. 3A,3B&4A) is formed of a wide zone of rounded to oval parenchymatous cells, with thick pitted slightly lignified walls especially those adjacent to the

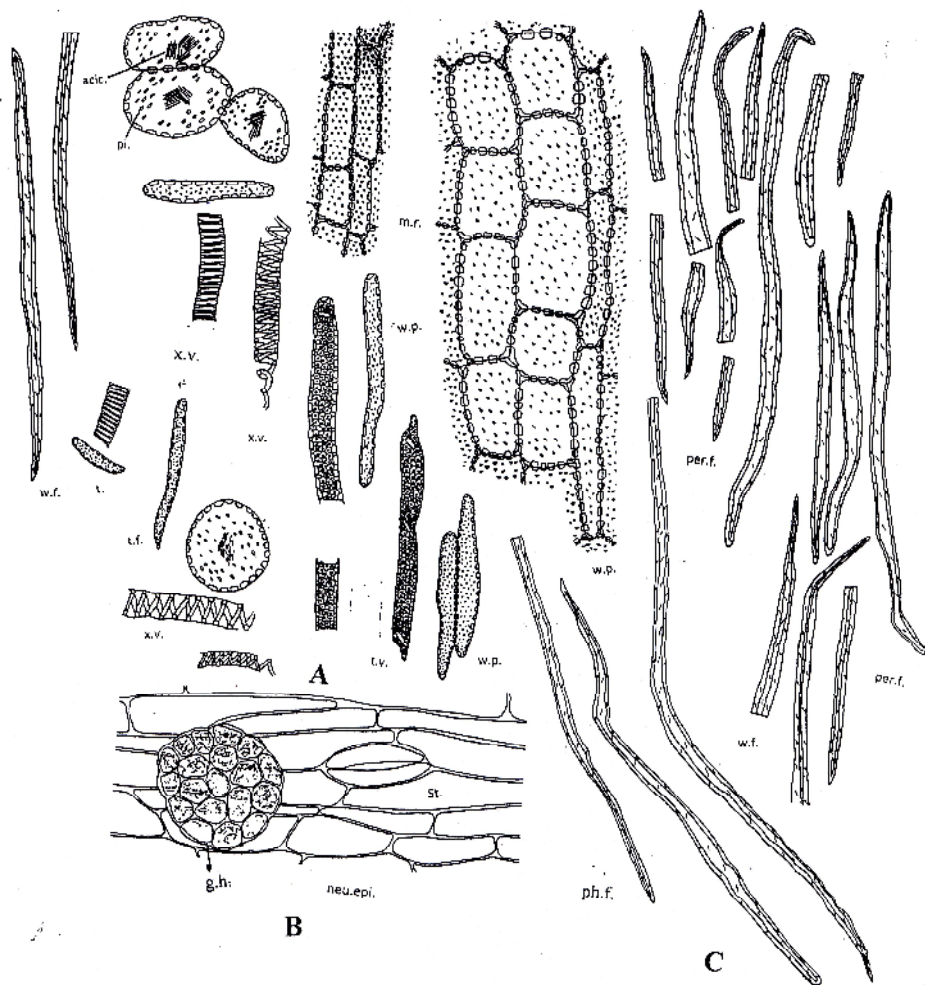


Fig. 4: Diagnostic elements of powdered stem.

A : (x 144)
 B : (x 356)
 C : (x 144)

acic., acicular crystal of calcium oxalate; g.r., glandular hair; m.r., medullary rays; neu.epi., neural epidermis; par., parenchyma; per.f., pericyclic fibers; ph.f., phloem fibers; pi., pits; st., stomata; t., tracheids; t.f., tracheidial fibers; t.v., tracheidial vessels; w.f., wood fibers; w.p., wood parenchyma; x.v., xylem vessels.

xylem. The size of the cells increase towards the center, showing large pits and contain small acicular crystal of calcium oxalate, especially near the xylem region. The crystal of calcium oxalate measures about 6-10-16 μ in length and 1.6-2-2.4 μ in width.

The Powdered stem

It is yellowish green in color with balsamic odour, and bitter taste. It is characterized microscopically by the following (Fig. 4A,B&C):

- 1- Fragments of epidermal cells with anomocytic stomata surrounded usually by 3-4 epidermal cells. The cells are polygonal with straight anticlinal walls and covered with smooth thick cuticle. Some fragments carry few glandular hairs.
- 2- Fragments of lignified fibers from pericycle, phloem and wood with thick lignified pitted walls and mostly possess wide lumina and blunt to round sometimes acute and tapering, slight bent apices (peak like).
- 4- Fragments of thick lignified xylem vessels showing spiral, scalariform and pitted thickenings.
- 5- Fragments of wood parenchyma and medullary rays with thick lignified pitted walls.
- 6- Fragments of tracheidal vessels, tracheids and trachiedal fibers showing pitted lignified walls.
- 7- Fragments of parenchymae of pith with pitted lignified walls and containing acicular crystal of calcium oxalate prisms.

(B) The leaf

Macromorphology of the leaf

The leaf (Figs. 1,2B&2C) is simple sessile, ovate sometimes obovate to lanceolate in shape with sharply serrate margin. It has a symmetric base, acute to acuminate apex and pinnate-reticulate venation. The midrib and lateral veins are slightly prominent on the lower surface. The upper surface is dark green in colour while the lower one is paler. The texture is sticky resinous on both surfaces. The leaf measures from 1.9 to 6-12 cm in length and from 0.3 to 3-6 cm in width and has a bitter taste and balsamic odour.

Micromorphology of the leaf

A transverse section in the leaf (Figs. 5A&6) through the midrib appears more or less slightly plano-convex in outline. It reveals an isobilateral structure with a heterogeneous, symmetric mesophyll showing an upper and a lower palisade, enclosing a scanty spongy tissue. The upper palisade consists of 4 to 7 rows of columnar cells, usually compact and the lower palisade consists of 4 to 6 rows of columnar cells, usually loose, with air gaps. The vascular system is formed of three main rounded to oval collateral vascular bundles crowned by two arcs of upper and lower lignified pericyclic fibers. The cortical tissue surrounds the vascular bundle shows at the abaxile side schizogenous oleo-resin canals abutting on the endodermis especially in the region of pericyclic fibers.

The epidermis

The upper epidermis

The upper epidermis (Figs. 5A,5B,5C&7) is formed of one row of subrectangular cells as seen in transverse section while in surface view (Fig. 5C) the cells appear polygonal usually isodiametric to slightly elongated with wavy or curved anticlinal walls and covered with smooth thick cuticle. They measure 28-56-100 μ in length, 16-24-44 μ in width and 4-12-16 μ in height. Stomata of anomocytic type are oval to rounded, surrounded by 3-4 epidermal cells one of them is rarely smaller than the others and measure 44-48-52 μ in diameter. Glandular hair is formed of bicellular stalk and multicellular head, covered with thick smooth cuticle and measures 7.6-10-12 μ in length and 4-8-10 μ in diameter.

The lower epidermis

The lower epidermis (Figs. 5A,5B,5D&7) is formed of one row of subrectangular to square cells as seen in the transverse section while in surface view (Fig. 5D) the cells appear polygonal usually isodiametric to slightly elongated with sinuous anticlinal walls and covered with thick smooth cuticle. They measure 28-60-88 μ in length, 12-24-48 μ in width and 8-12-16 μ in height. Stomata and glandular hairs are similar to those on upper epidermis but stomata are more abundant.

The neural epidermal cells

The neural epidermal cells appear in surface view (Figs. 5A,5E&6)

polygonal, axially elongated usually with straight, slightly curved, beaded anticlinal walls and covered with thick smooth cuticle. In the intercostal regions the cells are polygonal sometimes elongated but usually isodiametric with wavy anticlinal walls. The cells measure 44-104-148 μ in length and 8-24-28 μ in width.

The mesophyll

The mesophyll (Fig. 5A&B) is isobilateral, differentiated into upper and lower palisade, enclosing scanty spongy tissues. The upper palisade consists of 4 to 7 rows of columnar cells, usually compact, abutting on the upper epidermis and interrupted in the midrib region by a small mass of 3-5 rows of collenchymatous cells. The palisade cells are cylindrical with straight to slightly wavy walls, being rich in chloroplasts and measure 12-24-32 μ in length and 8-10-12 μ in width. The lower palisade consists of 4 to 6 rows of columnar cells, usually loose, with air gaps and extends over the lower epidermis below the vascular bundles forming bands of palisade cells alternated with bands of spongy parenchyma and measure 12-24-28 μ in length and 4-8-12 μ in width. The lower palisade is interrupted in the midrib region by a small mass of 3-4 rows of collenchymatous cells. The narrow spongy tissue consists of 2-3 rows of thin-walled rounded or slightly irregular chlorenchymatous cells with fairly wide intercellular spaces and contains chloroplasts.

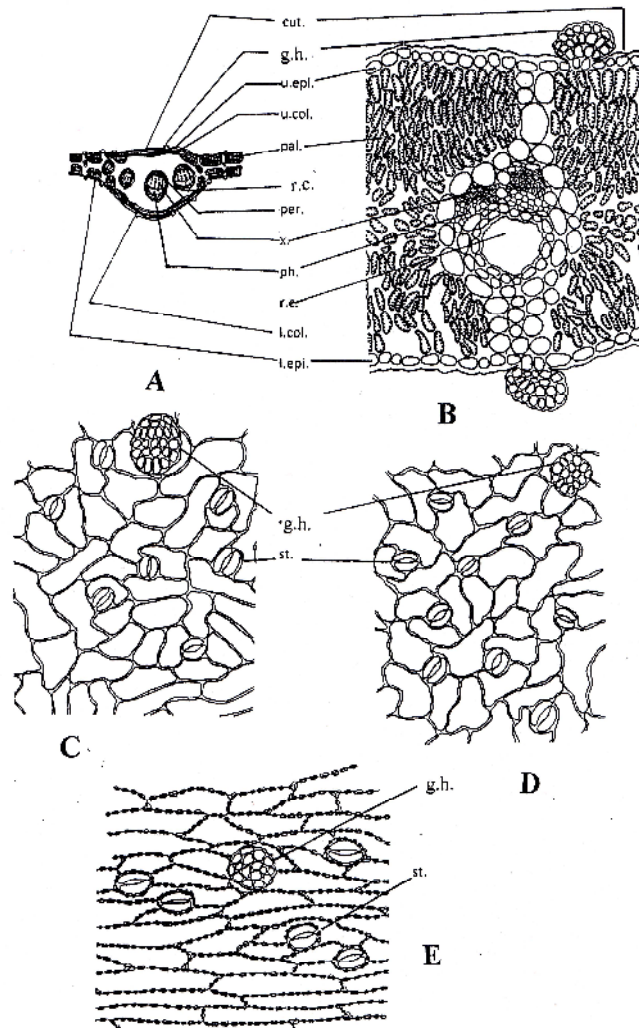


Fig. 5: Micromorphology of the leaf.

- A: T.S. Diagram of the leaf (x 10.5)
- B: Detailed T.S. in the lamina (x 125)
- C: Surface preparation of upper epidermis (x 125)
- D: Surface preparation of lower epidermis (x 125)
- E: Surface preparation of neural epidermal cells (x 125)

coll., collenchyma; cu., cuticle; g.h., glandular hair; l.coll., lower collenchyma; l.epi., lower epidermis; neu.epi., neural epidermis; pal., palisade; per., pericycle; ph., phloem; r.c., resin cannal; st., stomata; u.coll., upper collenchyma; u.epi., upper epidermis; x., xylem.

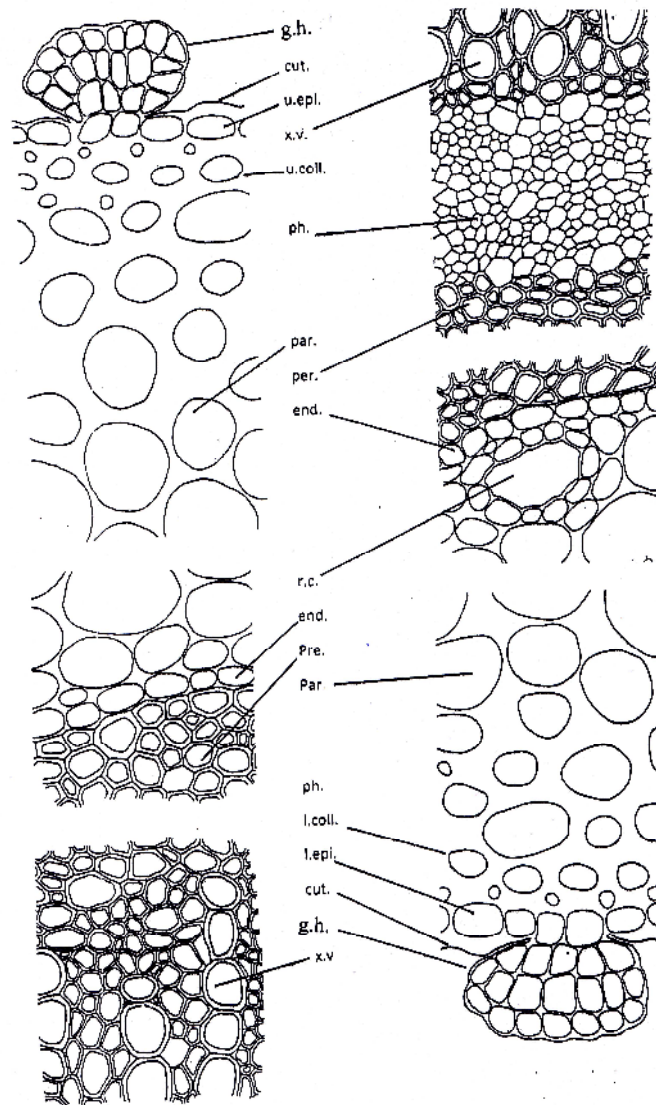


Fig. 6: Micromorphology of the leaf.

Detailed T.S. in the midrib

(x 352)

cu., cuticle; end., endodermis; g.h., glandular hair; l.coll., lower collenchyma; l.epi., lower epidermis; par., parenchyma; per., pericycle; ph., phloem; r.c., resin canal; u.coll., upper collenchyma; u.epi., upper epidermis; x., xylem; x.v., xylem vessels.

The cortical tissues

The cortical parenchyma (Figs. 5A&6) consists of few rows of oval to rounded thin-walled cellulosic cells with wide intercellular spaces and they measure 11.2-25.6-43.2 μ in diameter. The innermost layer of the parenchyma shows schizogenous oleo-resin canals abutting on the endodermis especially at the lower pericycle. The cells are free of contents.

The vascular tissue

The vascular tissue (Figs. 5A&6) is represented by three main collateral vascular bundles in the midrib region, in addition to other lateral vascular bundles of the veins. Each vascular bundle consists of a radiating upper xylem and a lower phloem region and crowned by upper and lower arcs of pericyclic fibers.

The pericycle (Figs. 5A,6&7)

It is formed, mainly, of 2 arcs, one upper above the xylem and another lower below the vascular bundle. Both arcs consist, mainly, of lignified fibers. The upper arc is usually smaller than the lower one. The fiber has a thick wall with slit-like pits, a fairly wide lumen and a rounded blunt to acute or acuminate tapering apex. Many fibers show forked tips. The fiber measures 8-22-32 μ in diameter and 240-360-730 μ in length.

The xylem (Figs. 5A,6&7)

The xylem consists of xylem vessels, wood parenchyma, wood fibers, tracheids, tracheidal vessels and tracheidal fibers. The xylem

vessels show lignified walls with spiral, scalariform, reticulate and pitted thickenings, some has bordered pits and measure 16-24-32 μ in diameter. The wood parenchyma show lignified pitted walls and measure 32-36-48 μ in diameter and 110-120-164 μ in length. The wood fibers are few with thick lignified walls, wide lumina, acute and rounded sometimes branched apices and measure 216-320-552 μ in length and 12-16-20 μ in diameter. The tracheids are numerous with scalariform and pitted thickenings and measure 12-14-16 μ in diameter. The tracheidal vessels are few, mainly with pitted lignified walls and measure 18-22-24 μ in diameter. The tracheidal fibers are few with pitted lignified walls and measure 6-10-12 μ in diameter. The xylem is traversed by uniseriate to triseriate rectangular elongated medullary rays.

The phloem (Figs. 5A&6)

The phloem zone consists of soft cellulosic elements below the xylem. It includes sieve tubes, companion cells and phloem parenchyma. The phloem parenchyma measure 4-12-32 μ in diameter. The cells are free of contents.

The powdered leaf

The powdered leaf (Fig. 7) is dark green in colour with a balsamic odour and a characteristic bitter taste. It is characterized microscopically by the following fragments.

- 1- Fragments of both upper and lower epidermis of the lamina which appear in surface view

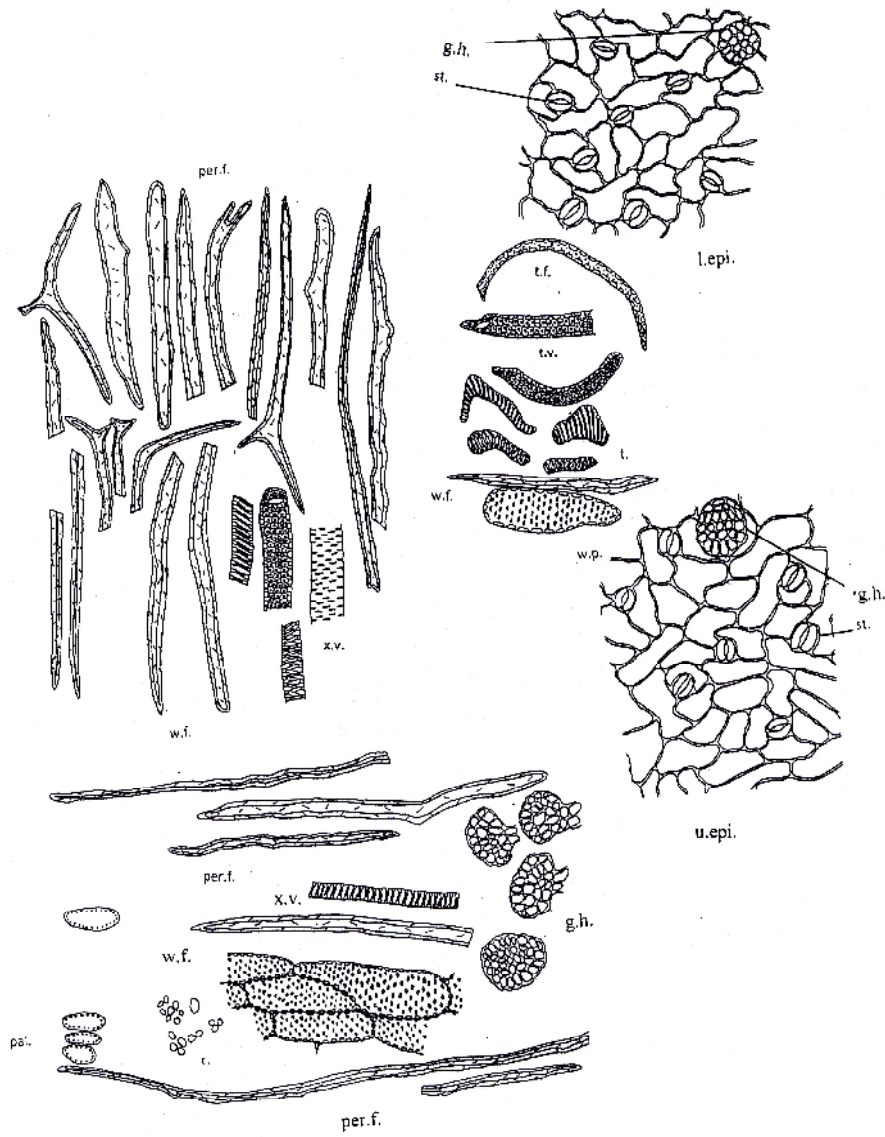


Fig. 7: Diagnostic elements of powdered leaf (x 126)

g.h., glandular hair;l.epi., lower epidermis; pal., palisade; per.f., pericyclic fibers; r., resin; st.,stomata; t., tracheids; t.f., tracheidial fibers; t.v., tracheidial vessel; u.epi., upper epidermis; w.f., wood fibers; w.p., wood parenchyma; x., xylem; x.v., xylem vessels.

polygonal usually isodiametric to slightly elongated cells with wavy and curved anticlinal walls and covered with smooth thick cuticle. The cells of the lower epidermis show more sinuated walls than those of the upper one. Stomata of anomocytic type are surrounded by 3-4 epidermal cells rarely one of them is smaller than the others. Glandular hairs are also present and each hair is formed of bicellular stalk and multicellular head and covered with smooth thick cuticle.

- 2- Fragments of cortical parenchyma, palisade and chlorenchyma cells.
- 3- Fragments of lignified xylem vessels with spiral, scalariform, pitted and reticulate thickenings. Some have bordered pits
- 4- Fragments of wood fibers with lignified thick walls, wide lumena, acute and rounded apices.
- 5- Fragments of tracheids, tracheidal fibers and tracheidal vessels with scalariform and pitted lignified walls.
- 6- Fragments of pericyclic fibers with thick lignified walls with slit-like pits, and, mostly wide lumena and rounded, blunt, acute and acuminate apices. The majority of the fibers are with projections on the surfaces.

(C) The root

Macromorphology of the root

The root system (Fig. 2D) consists of a main cylindrical, tap root bearing

several lateral rootlets. It has a characteristic odour, a slightly bitter taste and yellowish brown colour. It is flexible in fresh state and has fibrous fracture when dried. It measures about 4-14-35 cm in length and 0.2-0.35-0.6 cm in diameter.

Micromorphology of the root

A transverse section in **the old root** (Fig. 8A,B&C) is more or less circular in outline. It shows cork cells originating from the pericyclic region. The secondary cortex is a wide parenchymatous zone with few air spaces (aerenchyma) towards the outer layers. The vascular cylinder consists of a narrow ring of phloem to the outside and a wide ring of xylem to the inside enclosing a cambial zone in between.

In **young stage** the transverse section shows thick, suberised epidermal cells. The first cork originates early superficially in the subepidermal region. Large air spaces (aerenchyma) are common in the primary cortex; the endodermis is a very well distinct layer with clear casparian strips on the radial walls. The pericycle consists of a ring of few layers of collapsed parenchyma below the endodermis and surrounding the phloem and xylem. At the beginning of secondary thickening large groups of precyclic fibers (mainly 2) are observed on opposite sides and embedded in the phloem and xylem regions. The cambial zone at first is stellate in shape (zigzag like) and consists of very thin narrow collapsed layers. The primary xylem shows mainly tri-arches.

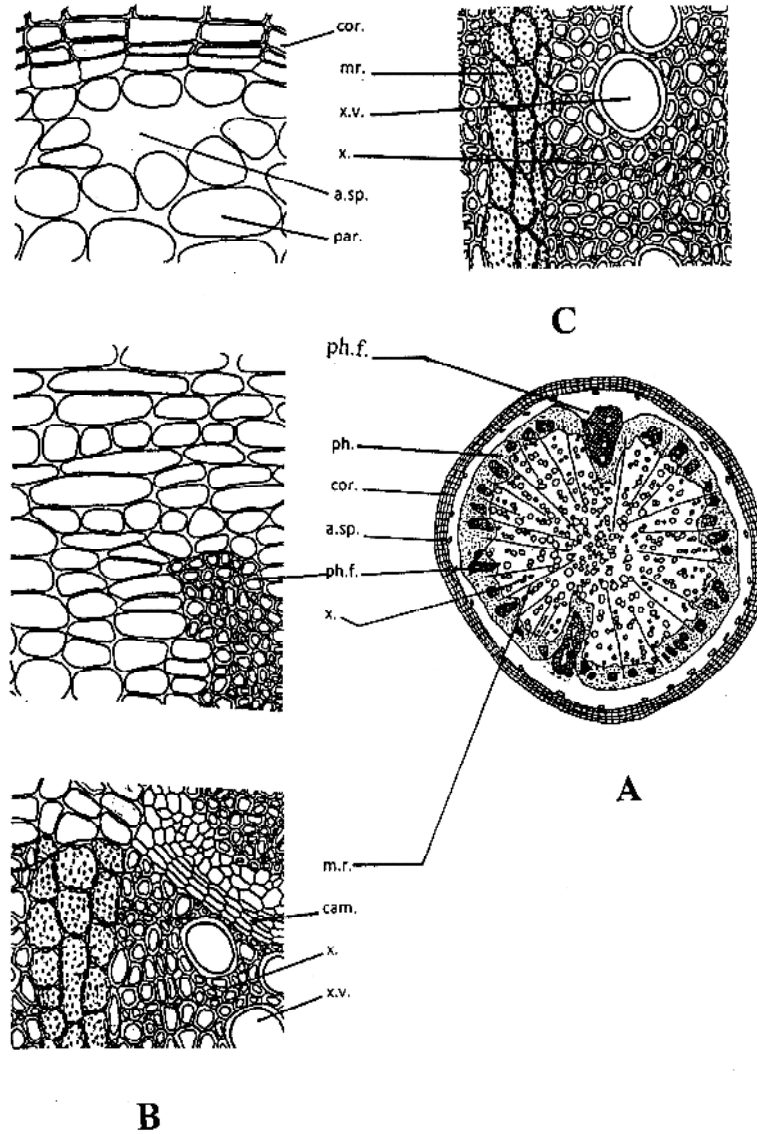


Fig. 8: Micromorphology of the root.

A: T.S. Diagram of the old root

(x 20.5)

B&C: Detailed T.S. of the old root

(x 187)

a.sp., air space; cam., cambium; cor., cork; m.r., medullary rays; par., parenchyma; per.f., pericyclic fibers; ph., phloem; ph.f., phloem fibers; x., xylem; x.v., xylem vessels.

In **moderate stage** a subsequent cork cambium of deep-seated origin arises beneath the first cork i.e. in the pericyclic region and replaced it. As the root continues to increase in growth, the primary cortex becomes collapsed and dead. The vascular cylinder is accompanied in pericyclic region by mainly 2 large strands of fibers situated on opposite side of the cylinder and embedded in the phloem and xylem.

A detailed transverse section in the old root shows:

The cork (Figs. 8A,8B&9)

The first cork arises early superficially in the subepidermal region and lately in the pericyclic region of old root. It appears regular in transverse section being formed of several rows 2-8 of subrectangular radially and tangentially arranged elongated cells. The cells show suberised non-lignified walls and contain dark brown pigments. The cork cells appear in surface view polygonal with straight, slightly curved anticlinal walls mostly of camera like shape.

The cortex

The primary cortex is sloughed off as a result of the formation of the subsequent cork in the pericycle region. The secondary cortex (Fig. 8A&B) is formed of about 3-8 rows of rounded to subrectangular tangentially elongated parenchymatous cells with thin walls and large intercellular spaces. The cells show air spaces (aerenchyma) an indication

of excess moisture. The secondary cortex is devoid of contents.

The phloem

The secondary phloem (Figs. 8A,8B&9) is formed of several small groups of fibers, phloem parenchyma, sieve tubes and companion cells. The phloem fibers show thick lignified pitted walls with slit-like pits and wide lumina and the majority of the fibers have tapering acuminate apices but some fibers with acute and rounded to blunt apices. The fiber measures 13.3-16.6-26.6 μ in diameter and 216.6-400-576.6 μ in length. The primary phloem shows collapsed cells forming ceratenchyma (keratenchyma).

The cambium

The cambial zone (Fig. 8A&B) consists of 3-5 layers of thin-walled meristematic, subrectangular tangentially elongated and radially arranged cells.

The xylem

The secondary xylem (Figs. 8A,8B&9) is formed of a wide zone of lignified radially arranged elements traversed by uniseriate to triseriate medullary rays. The xylem elements consist of vessels, tracheids, tracheidal vessels, tracheidal fibers, wood parenchyma and wood fibers. The vessels show thick lignified walls with spiral, scalariform and pitted thickenings. Some vessels have bordered pits and measure about 16.6-50-86.6 μ in diameter. The tracheids, tracheidal vessels and tracheidal fibers show thick lignified

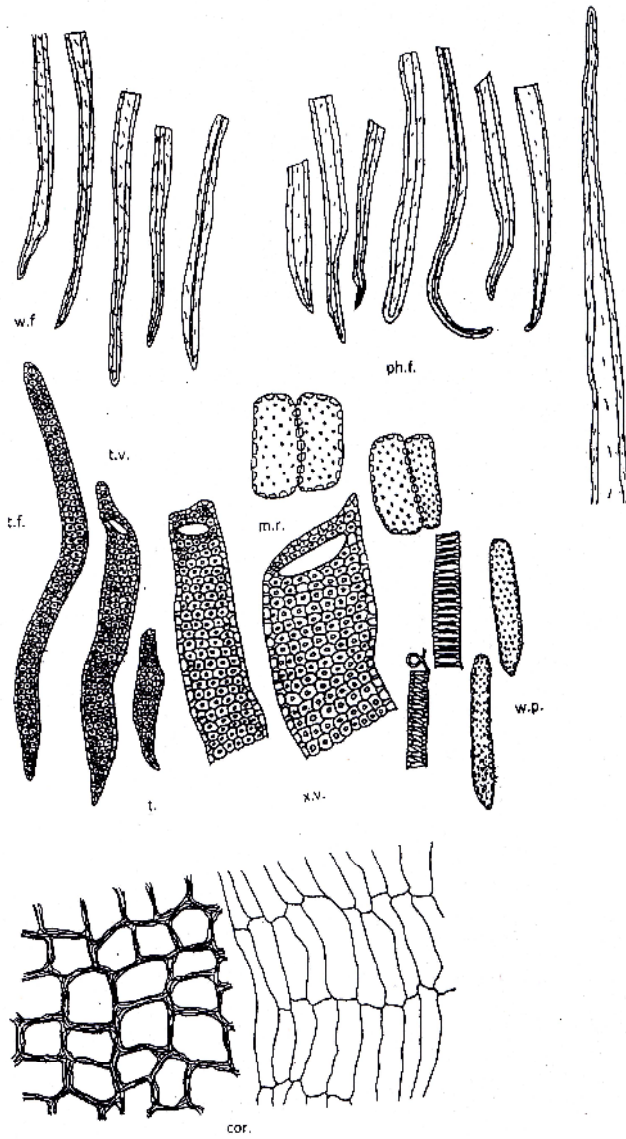


Fig. 9: Diagnostic elements of powdered root (x 170)

cor., cork; m.r., medullary rays; ph.f., phloem fibers; t., tracheids; t.f., tracheidial fibers; t.v., tracheidial vessels; w.f., wood fibers; w.p., wood parenchyma; x.v., xylem vessels.

pitted walls with simple and bordered pits and measure about 13.3-16.6-20 μ , 16.6-23.3-26.6 μ and 15-16.6-20 μ in diameter respectively. The wood fibers are the main constituent and show thick lignified walls with slit-like pits. They have mostly wide lumena and tapering acuminate, sometimes acute and blunt apices and measure about 6.6-10-16.6 μ in diameter and 200-333.3-433.3 μ in length. The wood parenchyma shows polygonal to subrectangular cells with thick lignified pitted walls and measure about 13.3-16.6-20 μ in diameter and 108-114-120 μ in length.

The medullary rays

The secondary medullary rays (Figs. 8A,8B,8C&9) are numerous, being uniseriate to triseriate and consisting of radially elongated subrectangular cells with moderately thick lignified pitted walls and measuring about 70-73.3-80 μ in length and 20-31.6-38.3 μ in width. The primary medullary rays are few and of about 3- 7 cells wide. They are free of contents.

The powdered root

The powdered root (Fig. 9) is yellowish brown in color with slight characteristic odour and bitter taste characterized microscopically by the presence of the following:

1- Fragments of cork cells usually of camera like-shaped. They are polygonal in surface view with straight, slightly curved anticlinal walls.

- 2- Fragments of phloem and wood fibers possessing thick lignified walls, with slit-like pits and mostly with wide lumena. Some fibers with acute and rounded to blunt apices but the majority of the fibers show tapering acuminate apices.
- 3- Fragments of polygonal to subrectangular wood parenchyma and medullary rays with pitted lignified walls.
- 4- Fragments of thick lignified xylem vessels with spiral, scalariform and pitted thickenings; some have bordered pits.
- 5- Fragments of thick lignified pitted tracheids, tracheidal vessels and tracheidal fibers with simple and bordered pits on their walls.

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