ANATOMY OF PETIOLE

Metcalf and Chalk in 1950 stated ‘Different types of petiole structure are of diagnostic value because of their restricted occurrence and relative stability’. It therefore assumed that the petiole anatomical feature can be good source for identification of species as a taxonomic tool. Valuable histological features dealing with study of specific petiole anatomy for 12 species of genus *Terminalia* L. used in this work are listed below.

i) **Epidermis:**

Structure of epidermis and its cell type, presence of hypodermis and presence of hairs.

ii) **Cortex:**

Collenchymatous, chlorenchymatous or parenchymatous, cell types with their arrangement and dimensions.

iii) **Sheath:**

Presence of sheath, continuous or in patches, number of layers, sizes and shapes of the cells.

iv) **Endodermis and pericycle:**

Number of layers, their cell types, etc.

v) **Vascular bundle:**

Conjoint, collateral or concentric, open or closed, shape of xylem tissue, orientation of protoxylem. Position of phloem, size and shape of the sieve elements, continuous or in patches. Presence of cambium, number of layers, shape of the cells.

vi) **Pith:**

Type of cells, shape of the cells.

All these characters along with other anatomical feature are used to differentiate species.
1. **Terminalia bellirica** (Gaertn.) Roxb.

Transverse section of petiole showed hemispherical outline with wavy margin. Epidermis is the glabrous outer most layer covered with thick cuticle. Cells of epidermis circular, ovate or vertically elongate, rarely squarish or rectangular. Hypodermis single layered cells oblong, barrel shaped, ovate-elliptic or polygonal. Cortex differentiated into outer and inner cortex. Outer cortex collenchymatous, 3 – 6 layered, cells polygonal, irregular and angular, ca 14.4 – 49.6 × 13.4 – 20.3 µm. Inner cortex 4 – 8 layered, composed of large circular, polygonal or irregular, thin walled parenchymatous cells ca. 16.8 – 55.4 × 15.2 – 42.2 µm. Rhytidome 1 – 3 layered, sandwiched between inner and outer cortex. Cortex followed by 3 – 5 layered continuous, sclerenchymatous bundle sheath. Bundle sheath cells circular, oval, polygonal and compactly arranged ca 33.6 – 117.4 × 30.5 – 55.6 µm. Endodermis single layered, cells irregular, tangentially elongated, elliptic or elliptic oblong, barrel shaped may be angular. Pericycle 1 – 2 layered in patches. Vascular bundle conjoint, bicollateral, open and endarch. Peripheral phloem 3 – 6 layered, ca 3.7 – 15.0 × 3.0 – 10.0 µm, cells polygonal, squarish, sieve elements large, circular or polygonal, sometimes with druces ca 22.9 in diameter. Druces more common in the peripheral phloem. Vascular cambium 1 – 2 layered, cells rectangular. Metaxylem circular to polygonal 3 – 5 layered ca 26.8 – 45.9 × 20.4 – 41.5 µm. Protoxylem circular to polygonal ca 12.3 – 21.8 × 11.3 – 18.2 µm. Inner phloem 2 – 6 layered, in patches. Pith parenchymatous. Two lateral vascular bundles, conjoint, concentric, amphi-critical with included phloem, situated at the corners on eighter side. Druces common in inner phloem and pith (Plate- 25).

2. **Terminalia bialata** (Roxb.) Steud.

Transverse section of petiole showed circular outline. Epidermis is outermost layer covered with thick cuticle and combretaceous trichomes. Cells of
epidermis barrel shaped, rectangular, squarish or polygonal. Hypodermis single
layered, cells polygonal, barrel shaped, circular or oval. Cortex differentiated into
outer and inner cortex. Outer cortex collenchymatous, 2 – 4 layered, cells
polygonal and angular, ca 17.2 – 55.5 × 14.0 – 39.2 µm. Druses common in
collenchyma. Inner cortex 5 – 9 layered, composed of large circular, polygonal
or irregular, thin walled parenchymatous cells ca 20.1 – 89.9 × 10.8 – 62.4 µm.
Some cortical cells showed prismatic, irregular crystals and druses. Cortex
followed by 3 – 4 layered patches of parenchymatous bundle sheath. Bundle
sheath cells polygonal, angular and compactly arranged, ca 33.6 – 117.4 × 30.5 –
55.6 µm. Endodermis single layered, cells irregular, tangentially elongated, elliptic
or elliptic oblong and curved, barrel shaped may be angular. Pericycle 1 – 2
layered in patches. Vascular bundle conjoint, bicollateral, open and endarch.
Peripheral phloem 5 – 7 layered, ca 2.2 – 15.8 × 1.8 – 7.4 µm, cells polygonal,
squarish, sieve elements large, circular or polygonal. Some phloem cells contains
tannin. Vascular cambium 1 – 2 layered, cells rectangular. Metaxylem circular to
polygonal 2 – 4 layered ca 15.0 – 58.1 × 13.9 – 41.4 µm. Protoxylem circular to
polygonal ca 12.9 – 12.9 × 8.3 – 12.7 µm. Inner phloem 2 – 5 layered, in patches.
Pith parenchymatous, druses common (Plate- 25).

3. *Terminalia catappa* L.

Transverse section of petiole showed spherical, triangular outline. Epidermis is the outer most layer covered with thin cuticle and dense, very long,
combretaceous trichomes. Cells of epidermis circular, oval. Hypodermis single
layered, composed of radially elongated, upright, hyaline cells. Cortex
differentiated into outer and inner cortex. Outer cortex collenchymatous, 8 – 10
layered, cells polygonal, irregular and angular, ca 8.9 – 29.3 × 7.4 – 24.6 µm. Inner
cortex 20 – 25 layered, composed of large circular, polygonal or irregular, thin
walled parenchymatous cells ca. 26.6 – 78.7 × 17.8 – 63.3 µm. Cortex followed by
3 – 5 layered, parenchymatous patches of bundle sheath. Bundle sheath cells
polygonal and compactly arranged ca. 33.6 – 117.4 × 30.5 – 55.6 µm. Endodermis single layered composed of large polygonal cells, barrel shaped or irregular. Pericycle 1 – 2 layered in patches. Vascular bundle conjoint, bicollateral, open and endarch. Peripheral phloem 4 – 6 layered, ca. 3.7 – 15.0 × 3.0 – 10.0 µm, cells polygonal, squarish. Vascular cambium 1 – 2 layered, cells rectangular. Metaxylem circular to polygonal 3 – 5 layered ca 20.2 – 41.2 × 19.9 – 30.2 µm. Protoxylem circular to polygonal ca 11.2 – 18.6 × 11.7 – 13.9 µm. Inner phloem 4 – 8 layered, continuous. Three large patches of phloem developed at three corners, with mucilage canal in center. Pith parenchymatous, cells large, polygonal. Two lateral vascular bundles, conjoint, collateral and closed, situated at the corners on either side towards adaxial surface. Single mucilage canal may present in each vascular bundle. Drues very common in both the cortical regions (Plate- 26).

4. **Terminalia chebula** Retz.

Transverse section of petiole showed hemispherical or oblong outline. Epidermis is the outer most layer covered with thin cuticle and combretaceous trichomes. Cells of epidermis circular, oval, ca. 5.6 – 12.2 × 9.1 – 12.0 µm. Hypodermis single layered, composed of circular to polygonal cells. Cortex differentiated into outer and inner cortex. Outer cortex collenchymatous, 4 – 6 layered, cells polygonal, irregular and angular, ca. 13.5 – 58.7 × 9.8 – 53.5 µm. Inner cortex 8 – 12 layered, composed of large circular, polygonal or irregular, thin walled parenchymatous cells ca. 25.0 – 82.1 × 23.9 – 70.5 µm. Cortex followed by 3 – 5 layered, sclerenchymatous patches of bundle sheath. Bundle sheath cells polygonal and compactly arranged ca. 6.7 – 28.6 × 4.2 – 12.1 µm, in patches. Endodermis single layered composed of large polygonal cells, barrel shaped or irregular. Pericycle 1 – 2 layered in patches. Vascular bundle conjoint bicollateral, open and endarch. Peripheral phloem 4 – 6 layered, ca. 3.7 – 15.0 × 3.0 – 10.0 µm, cells polygonal, squarish. Vascular cambium 1 – 2 layered, cells rectangular. Metaxylem circular to polygonal 3 – 5 layered ca. 17.6 – 32.7 × 16.8

5. **Terminalia citrina** Roxb. ex Flem.

6. **Terminalia cuneata** Roth.

Transverse section of petiole showed spherical and laterally compressed outline. Epidermis ruptured because of lenticels and periderm. Epidermis the outermost layer covered with thick cuticle and combretaceous trichomes. Cells of epidermis circular, rhomboid, rarely barrel shaped or rectangular, ca 6.8 – 19.2 × 6.2 – 8.9 \( \mu \text{m} \). Hypodermis single layered, composed of circular, oval, polygonal cells, filled with tannin. Cortex differentiated into outer and inner cortex. Outer cortex collenchymatous, 4 – 6 layered, cells polygonal and angular, ca 16.8 – 57.3 × 15.9 – 50.3 \( \mu \text{m} \), few cells in outer layers tanniferous. Inner cortex 4 – 6 layered, composed of large, circular, polygonal or irregular, thin walled parenchymatous cells ca. 19.2 – 82.1 × 16.8 – 59.3 \( \mu \text{m} \). Cortex followed by 3 – 5 layered, sclerenchymatous patches of bundle sheath. Bundle sheath cells polygonal, irregular and compactly arranged ca 4.3 – 22.2 × 2.9 – 14.9 \( \mu \text{m} \), in patches. Endodermis single layered composed of elliptic or elliptic oblong or barrel shaped cells. Pericycle 1 – 2 layered in patches. Vascular bundle conjoint, bicollateral, open and endarch. Peripheral phloem 8 – 12 layered, ca 6.0 – 14.6 × 4.1 – 7.7 \( \mu \text{m} \), cells polygonal, squarish. Group of druces common in phloem. Vascular cambium 1 – 2 layered, cells rectangular. Metaxylem circular to polygonal 3 – 4 layered ca 14.7 – 41.7 × 9.5 – 30.6 \( \mu \text{m} \). Protoxylem circular to polygonal ca 12.5 – 18.1 × 10.8 – 14.0 \( \mu \text{m} \). Inner phloem 12 – 15 layered, in patches. Druces common in cortex and pith. Pith parenchymatous, cells large, elliptic and oblong elliptic. Mucilage canals 3 – 4, found in pith. Two lateral vascular bundles, conjoint, concentric, amphicribal and closed, situated at the corners on either side towards adaxial surface, with mucilage canal at center in developed lateral vascular bundles. Druces common in cortex (Plate- 27).
7. **Terminalia elliptica** Willd.

Transverse section of petiole showed spherical and adaxially compressed outline. Epidermis is the outer most layer covered with thin cuticle and combretaceous trichomes. Cells of epidermis circular, rhomboid, rarely barrel shaped or rectangular, ca 9.8 – 21.9 × 7.4 – 10.1 µm. Hypodermis single layered, composed of squarish, rectangular, rhomboid and rarely polygonal, some cells filled with tannin. Cortex differentiated into outer and inner cortex. Outer cortex collenchymatous, 4 – 6 layered, cells polygonal, rhomboid, squarish, barrel shaped and angular, ca 15.8 – 39.7 × 11.6 – 34.6 µm, few cells in outer layers tanniniferous. Inner cortex 12 – 15 layered, composed of large, circular, polygonal, rhomboid, squarish, barrel shaped or irregular, thin walled parenchymatous cells ca. 22.0 – 96.8 × 20.7 – 79.2 µm. Large irregular crystals up to 100 µm, randomly distributed throughout the cortex. Cortex followed by 3 – 4 layered, sclerenchymatous patches of bundle sheath. Bundle sheath cells polygonal, irregular and compactly arranged ca 8.0 – 26.7 × 6.4 – 17.9 µm, in patches. Endodermis single layered composed of polygonal, elliptic or elliptic oblong or barrel shaped cells. Pericycle 1 – 3 layered in patches, cells polygonal, oblong and ovate. Vascular bundle conjoint, bicolateral, open and endarch. Peripheral phloem 10 – 15 layered, ca 4.3 – 14.6 × 3.4 – 9.1µm, cells polygonal, squarish. Group of drucses common in phloem. Vascular cambium 2 – 4 layered, cells rectangular. Metaxylem circular to polygonal 3 – 4 layered ca 31.1 – 43.0 × 27.2 – 37.6 µm. Protoxylem circular to polygonal ca 13.9 – 24.2 × 10.8 – 17.7µm. Inner phloem 12 – 15 layered, in patches. Drucses common in cortex and pith. Pith parenchymatous, cells large and polygonal. Mucilage canals 4 – 6 found in pith, epithelial layers very prominent. Large irregular crystals randomly distributed in the pith. 2 – 4 lateral vascular bundles, conjoint, concentric, amphicribal and open, situated at the corners on eighter side towards adaxial surface, with mucilage canal.
at the center in developed lateral vascular bundles. Druces and prismatic crystals common in cortex (Plate- 28).

8. **Terminalia myriocarpa** Van Heurck & Mull.-Arg.

Transverse section of petiole showed spherical and adaxially compressed outline. Epidermis is the outer most layer covered with thin cuticle and combretaceous trichomes. Cells of epidermis circular, rhomboid, rarely barrel shaped or rectangular, ca 8.6 – 16.5 × 7.8 – 8.1 µm. Hypodermis 2 – 4 layered, composed of squarish, rectangular, rhomboid and rarely polygonal, collenchymatous cells, some cells filled with tannin and prismatic crystals. Cortex differentiated into outer and inner cortex. Outer cortex collenchymatous, 3 – 4 layered, cells polygonal, rhomboid, barrel shaped and angular, ca 15.2 – 39.4 × 12.5 – 34.2 µm, few cells in outer layers tanniniferous. Inner cortex 12 – 15 layered, composed of large, circular, polygonal, rhomboid, squarish, barrel shaped or irregular, thin walled parenchymatous cells ca. 22.0 – 96.8 × 20.7 – 79.2 µm. Cortex followed by 4 – 8 layered, sclerenchymatous patches of bundle sheath. Bundle sheath cells polygonal compactly arranged ca 7.1 – 21.4 × 5.1 – 13.0 µm, in patches. Endodermis 2 – 3 layered composed of oval, oblong, circular, elliptic or elliptic oblong or barrel shaped cells in patches and filled with tannin. Pericycle 1 – 3 layered in patches, cells polygonal, oblong and ovate and filled with tannin. Vascular bundle conjoint, bicollateral, open and endarch. Peripheral phloem 11 – 15 layered, ca 6.1 – 15.7 × 3.9 – 8.2 µm, cells polygonal, squarish. Group of druces common in phloem. Vascular cambium 2 – 3 layered, cells rectangular. Metaxylem circular to polygonal 3 – 4 layered, ca 51.4 – 81.6 × 31.0 – 42.6 µm. Protoxylem circular to polygonal, ca 20.2 – 45.6 × 17.8 – 25.6 µm. Inner phloem 12 – 16 continuous layered. Druces common in cortex and pith. Pith parenchymatous, cells large and polygonal, some cells filled with tannin. 4 – 6 mucilage canals found in pith, epithelial layers very prominent. Large irregular crystals randomly distributed in the pith. 4 – 6 lateral vascular bundles, conjoint,
concentric, amphicribal and open, situated at the corners on either side towards adaxial surface, with mucilage canal at center in developed lateral vascular bundles. Druces and prismatic crystals common in cortex (Plate- 28).

9. **Terminalia pallida** Brandis

Transverse section of petiole showed spherical and laterally compressed outline. Epidermis is the outer most layer covered with thick cuticle. Cells of epidermis circular, oval, rhomboid, barrel shaped or rectangular, ca 8.6 – 18.2 × 7.0 – 8.2μm. Hypodermis single layered, tanniniferous, cells barrel shaped, oblong, ovate and polygonal and parenchymatous. Cortex differentiated into outer and inner cortex. Outer cortex collenchymatous, 4 – 6 layered, cells polygonal, rhomboid and angular, ca 11.6 – 52.5 × 10.4 – 40.0 μm, few cells in outer layers tanniniferous. Inner cortex 12 – 15 layered, composed of large, polygonal, circular, rhomboid, squarish, thin walled parenchymatous cells ca. 17.8 – 67.6 × 15.0 – 57.6μm. Cortex followed by 2 – 6 layered, sclerenchymatous patches of bundle sheath. Bundle sheath cells polygonal, circular, oval and compactly arranged ca 6.0 – 24.7 × 3.5 – 18.4 μm, in patches. Endodermis single layered composed of elliptic oblong or ovate elongate cells in patches. Pericycle 1 – 2 layered in patches, cells elliptic oblong or ovate elongate and polygonal. Vascular bundle conjoint, biconnected, open and endarch. Peripheral phloem 10 – 15 layered, ca 3.3 – 14.4 × 3.9 – 10.1 μm, cells polygonal, rectangular and squarish. Group of druces common in phloem. Vascular cambium 2 – 3 layered, cells rectangular. Metaxylem circular to polygonal 3 – 4 layered, ca 20.5 – 34.0 × 15.5 – 21.6 μm. Protoxylem circular to polygonal ca 9.9 – 12.3 × 8.6 – 9.6 μm. Inner phloem 11 – 12 layered in irregular patches present only on adaxial side. Druces common in cortex. Pith parenchymatous, cells large and polygonal. Lateral vascular bundles 2 – 4, conjoint, concentric, amphicribal and open, situated at the corners on either side towards adaxial surface. Druces common in cortex (Plate-29).

Transverse section of petiole showed spherical and adaxially compressed outline. Epidermis is the outer most layer covered with thin cuticle. Cells of epidermis circular, rhomboid, rarely barrel shaped or rectangular, ca 11.0 – 22.8 × 9.5 – 16.2 μm, every cell filled with tannin appeared dark black or purple. Hypodermis single layered, composed of squarish, rectangular, irregular and rarely polygonal, parenchymatous cells, some cells filled with tannin. Cortex differentiated into outer and inner cortex. Outer cortex collenchymatous, 5 – 6 layered, cells polygonal, rhomboid, barrel shaped and angular, ca 21.9 – 70.2 × 17.6 – 55.9 μm, few cells in outer layers tanniniferous. Inner cortex 8 – 10 layered, composed of large, circular, polygonal, rhomboid or irregular, thin walled parenchymatous cells ca 24.3 – 93.8 × 18.3 – 87.2 μm, some cells filled with large irregular crystals. Cortex followed by 5 – 7 layered, contineous, parenchymatous bundle sheath. Bundle sheath cells polygonal compactly arranged ca 5.2 – 18.2 × 5.2 – 11.7 μm. Endodermis single layered, cells polygonal, oval, circular, oblong elliptic, pericycle 1 – 2 layered. Vascular bundle conjoint, bicollateral, open and endarch. Peripheral phloem 4 – 7 layered, ca 2.6 – 15.7 × 2.6 – 8.7 μm, cells polygonal, squarish. Group of irregular druces common in phloem. Vascular cambium 2 – 3 layered, cells rectangular. Metaxylem circular to polygonal 3 – 4 layered, ca 26.2 – 42.7 × 19.8 – 41.5 μm. Protoxylem circular to polygonal ca 20.9 – 25.8 × 13.4 – 23.4 μm. Inner phloem 10 – 13 layered in patches only on adaxial side. Druces common in cortex and pith. Pith parenchymatous, cells large and polygonal, some cells filled with tannin. Single, large mucilage canal with prominent epithelium found in pith. Large irregular crystals randomly distributed in the pith. Lateral vascular bundles, two, conjoint, concentric, amphicribal and open, situated at the corners on either side towards adaxial surface. Druces common in cortex (Plate- 29).
11. **Terminalia procera** Roxb.

Transverse section of petiole showed hemispherical outline on abaxial side and convex on adaxial side. Epidermis is the outer most layer covered with thin cuticle and combretaceous trichomes. Cells of epidermis circular, rhomboid, rarely barrel shaped or rectangular, ca 8.3 – 17.7 × 7.5 – 8.3 μm. Hypodermis single layered, composed of squarish, rectangular, rhomboid and rarely polygonal, parenchymatous cells. Cortex differentiated into outer and inner cortex. Outer cortex collenchymatous, 5 – 7 layered, cells polygonal, rhomboid, barrel shaped and angular, ca 13.9 – 54.3 × 11.6 – 37.9 μm, few cells in outer layers tanniniferous. Inner cortex 12 – 15 layered, composed of large, circular, polygonal, rhomboid, squarish, barrel shaped or irregular, thin walled parenchymatous cells ca 22.9 – 81.7 × 15.5 – 23.9 μm. Cortex followed by 4 – 8 layered, sclerenchymatous patches of bundle sheath. Bundle sheath cells polygonal and compactly arranged ca 8.0 – 28.3 × 7.3 – 14.5 μm. Some cells show deposition of tannin. Endodermis single layered cells, barrel shaped and elliptic. Pericycle 1 – 2 layered cells, barrel shaped, elliptic, oblong – elliptic or polygonal. The main vascular bundle reniform, conjoint, bicolateral and open and endarch. Peripheral phloem 5 – 8 layered, ca 7.3 – 18.1 × 7.2 – 11.7 μm, cells polygonal, squarish. Group of druces common in phloem. Vascular cambium 2 – 3 layered, cells rectangular. Metaxylem circular to polygonal 3 – 4 layered ca 49.3 – 51.9 × 38.9 – 50.2 μm. Protoxylem circular to polygonal ca 13.3 – 27.5 × 13.3 – 21.4μm. Inner phloem 5 – 10 contineous layered. Druces common in cortex and pith. Pith composed of parenchyma, 6 – 8 mucilage canals found in the pith region. Six lateral vascular bundles distributed adaxially three on each side, larger lateral vascular bundle situated towards center and smaller, developing lateral vascular bundles situated towards periphery. The larger vascular bundles conjoint, collateral and open and smaller, developing lateral vascular bundles conjoint, concentric and amphicribal. Druces and prismatic crystals common in cortex (Plate- 30).
12. **Terminalia travancorensis** Wight & Arn.

Transverse section of petiole showed reniform outline. Epidermis is the outer most layer covered with thin cuticle and combretaceous trichomes. Cells of epidermis circular, rhomboid, squarish or rectangular, ca $6.8 - 16.0 \times 5.7 - 7.8 \mu m$ and tanniniferous. Hypodermis single layered, composed of squarish, rectangular, rhomboid and irregular and taninniferous. Cortex differentiated into outer and inner cortex. Outer cortex collenchymatous, 3 – 4 layered, circular, oval, irregular with angular thickning, ca $18.1 - 64.4 \times 16.1 - 49.1 \mu m$, few cells in outer layers tanniniferous. Inner cortex 12 – 13 layered, composed of large, circular, polgonal, rhomboid or irregular, thin walled parenchymatous cells ca. $18.4 - 82.6 \times 16.2 - 54.1 \mu m$. Cortex followed by 3 – 5 layered sclerenchymatous bundle sheath, continuous on abaxial surface, in patches on adaxial surface. Bundle sheath cells circular, oval, polygonal and compactly arranged ca $5.0 - 29.3 \times 4.3 - 18.5 \mu m$. Endodermis single layered, cells oblong, elliptic ovate or rarely barrel shaped. Casparion strips inconspicuous. Pericycle 1 – 2 layered, inconspicuous at certain places, cells polygonal, elongate or ovate elongate. Cambium two layered; the main vascular bundle conjoint, bicollateral and open; the vascular strand curved on eighter side. Peripheral phloem 12 – 17 layered, ca $3.6 - 15.7 \times 3.1 - 9.7 \mu m$, cells polygonal, squarish. Group of druces common in phloem. Vascular cambium 2 – 3 layered, cells rectangular. Metaxylem circular to polygonal 4 – 6 layered ca $20.2 - 37.5 \times 14.9 - 30.9 \mu m$. Protoxylem circular to polygonal ca $10.8 - 12.1 \times 7.0 - 7.5 \mu m$. Inner phloem 12 – 14 irregular layered in patches. Druces common in cortex and pith. Pith parenchymatous, cells large and polygonal (Plate- 30).