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All Authors	Naw Al Shar Phaw and Soe Myint Aye
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Morphological and Anatomical Studies on *Persea americana* Miller cultivars from Pyin Oo Lwin Area

Naw Al Shar Phaw[1]& Soe Myint Aye[2]

Abstract

In the present study, the morphological and anatomical characters of *Persea americana* Miller growing in Pyin Oo Lwin were studied. The pronounced morphological characters of *P. americana* Miller were perennial evergreen trees, simple and spirally arranged leaves, axillary paniculate cymose inflorescences and baccate fruits. The significantly different morphological characters are the shapes and sizes of the fruits. The fruits and seeds are globoid in shape in cv. a. The fruits of cv. b are oval in shape and the seeds are subgloboid with a pointed beak at the apex. The fruits of cv. c are pyriform in shape and the seeds are ovoid in shape. According to the anatomical characters, the stomata are paracytic or rubiaceous type. The vascular bundles of leaves, stems, fruits and roots are conjoint collateral and closed. In addition, it was observed that mean length and width of macerated elements are different from one another in three cultivars.

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Introduction

Persea americana Miller belongs to the family Lauraceae, together with laurel and cinnamon. Three ecological races (subspecies) are recognized: Mexican, Guatemalan and West Indian; in that order we may regard them as subtropical, semitropical and tropical. Despite the name the West Indian race did not originate on the Caribbean Islands, but in the lowlands of Central America. The other races were inhabitants of the highlands (Samson 1980).

Persea americana Mill. (Avocado) is native to the neo-tropics. Cultivars of Guatemalan, Mexican, and West Indian origin have spread, becoming important crops in many tropical and subtropical regions around the world (Knight 2002 as cited in Arnon *et al.* 2006). However, avocado is a popular fruit in Mexico, Central America, Greater Antilles, Chile, Spain, Canaries, Israel, South Africa, Sri Lanka, India, Indonesia, Philippines, Thailand, Vietnam and other countries (Anonymous 2003).

All avocado belong to the science genus/ species group called *Persea americana*. Over 50 different commercial varieties of avocado exist within this basic group. Avocados are also often categorized as belonging to three basic types (sometimes called "races") according to their place of origin (Anonymous 2001 - 2015).

The Lauraceae are distinguished by the small, undifferentiated perianth, the trimerous stamens in several whorls, the valvated anther dehiscence, and the drupaceous fruit whose single seed lacks endosperm (Lawrence 1968).

The plant is tolerant to a wide range of soil types (acidic and alkaline) with the exception of saline conditions. It does require well aerated soils and will not survive in areas with poor drainage due to excess water. It tends to grow well on hillsides but should never be

[1] PhD Candidate, Department of Botany, University of Mandalay
[2] Professor, Department of Botany, University of Mandalay

grown near stream beds. The plant can be grown in the shade but is productive only in full sun (Finau 2011).

The tree is grown for its nutritious fruit that has long been important in the diets of the people of Central America. Consumption is most often as an uncooked savoury dish mixed with herbs and / or spices, as an ingredient of vegetable salads, or as a sweetened dessert (Indonesia, the Philippines). However, its texture and colour can be used to enhance the presentation and consumption of many foods. The oil is used by the cosmetic industry in soaps and skin moisturizer products. The flesh is also used in traditional medicine (Verheij & Coronel 1992).

Bergh (1992) as cited in Finau (2011) described the avocado fruit to be nutrition-rich while others in the industry call it a functional food due to its additional health benefits from certain phytochemicals. It contains high amounts of vitamins A, B,C, E and other nutrients like folacin, niacin, iron (Fe), magnesium (Mg), folate, pantothenic acid and contains 60% more potassium than bananas. Most of these nutrients are deficient in most typical diets and are all abundantly present in avocado. In its unmodified natural state the avocado represents a more balanced and wholesome diet than most food or even concentrated supplement pills (Finau 2011).

Morphological and anatomical characters are very essential in determining the right species. Moreover, internal structures of plants provide correct identifications of plants which possess similar morphological characters. Therefore, anatomical characters are very useful to identify the plants. The aims and objectives of this study are to examine the morphological characters and to identify the anatomical characters of *Persea americana* Miller.

Materials and Methods

In the present study, the specimens were collected from Pyin Oo Lwin Township in the flowering and fruiting season from January to November, in the year 2011-2014. After collecting the specimens, the vegetative and floral parts of fresh specimens were studied.

For histological studies, free-hand sections of the fresh specimens were cut by using razor blades to obtain the thin sections. Some of the thin sections were cleaned in chloral hydrate solution on a glass slide and stained with safranin solution for microscopic examination, and they were mounted in dilute glycerine solution and observed under the microscope. For microtome sections. The killing and fixation, dehydration, infiltration, embedding, staining and mounting were performed according to Johansen's (1940) method. Maceration of the specimens were done by boiling in equal proportion of 50% acetic acid and 50% hydrogen peroxide according to Jeffery's method (1940). The permanent slides and macerated materials were photographed, measured and described.

Results

1. Taxonomical studies

1.1 Morphological characteristics of *Persea americana* Miller, Gard. Dict. Abr. ed. 8:1759. (Figure 1)

Family : Lauraceae
Myanmar name : Htaw pat thi
English name : Avocado
Flowering period : December to June

Perennial evergreen trees; stems and branches terete. Leaves simple, spirally arranged, exstipulate; blades elliptic to lanceolate or ovate, green, glabrous and dark green above, more

or less glaucous with the venation prominent below, cuneate at the base, entire along the margin, acute at the apex; petioles terete, canaliculate above; reddish, coriaceous, densely hairy when young, turning dark green and glabrous at maturity. Inflorescences axillary paniculate cymes, many-flowered; primary peduncle terete, yellowish white to cream, pubescent; secondary peduncle terete, yellowish white to cream, pubescent. Flowers hypogynous, bisexual, actinomorphic, small, about 1 cm across at anthesis, yellowish white to cream, fragrant; shortly bracteate, pedicellate; bracts elliptic lanceolate, hairy; pedicels terete, about 0.5 cm, hairy. Tepals 6 in two whorls, erect, obtuse, the outer ones usually smaller, about 3 mm long, the inner ones about 4 mm long, yellowish white to cream, densely tomentose. Stamens 9, in three whorls, the outermost ones modified into 3 staminodes, the inner ones fertile, bear 2 glands at the base; filaments white, hairy, about 1 mm long; anthers dithecous, basifixed, dehiscing by upturning flap-like valves, oblong, pale green, glabrous. Gynoecium composed of solitary pistil, unicarpellary; ovary superior, unilocular, with one ovule in the locule on the pendulous placenta; style terminal, slender, about 1.5 mm long; stigma papillate, about 0.5 mm in diameter. Fruit indehiscent, baccate, large, fleshy, 1-seeded, green when young, maroon or purple at maturity.

Cultivar a -globoid, 9.5 - 10.3 cm by 8.9 - 9.2 cm, the flesh about 2 cm thick; seeds globoid

Cultivar b- oval, 12 - 14 cm by 8.0 - 8.8 cm, the flesh about 2 cm thick; seeds subgloboid with a pointed beak at the apex

Cultivar c- pyriform, 12.8 - 13.0 cm by 6.7 - 7.3 cm, the flesh about 1. 5 cm thick; seeds ovoid.

2. Anatomical Studies

2.1 Anatomical Characteristics of *P. americana* Miller, Gard. Dict. Abr. ed. 8:1759

Petiole

In transverse section, the petiole of *Persea americana* Miller studied was shield shape in outline (Table 1). Distinguishable into dermal, ground and vascular tissue systems (Figure 2 A-C).

Dermal Tissue System: Composed of epidermal cells and trichomes. In surface view, the epidermal cells parenchymatous, rectangular or polygonal, cell walls thin, anticlinal walls straight, crystals present. In transverse section, epidermis one layer on both surfaces, cell barrel in shape, cells compact.

Ground Tissue System: Composed of collenchymatous and parenchymatous tissues. Collenchymatous cells above the lower epidermal layer and upper epidermal layer were lacunar type, cells oval or rounded; parenchymatous cells above the vascular bundle and below the vascular bundle were oval or rounded (Table 1).

Vascular Tissue System: Vascular bundle crescent shaped in outline, collateral type; bundle sheath absent, xylem on the adaxial side and phloem on the abaixal side; phloem cells polygonal, phloem composed of sieve tubes and companion cells; xylem polygonal, composed of vessel elements, tracheids and fibers (Table 6).

Figure 1. Fruits and Seeds of *Persea americana* Miller cultivars

A. Fruit of cv.a B. Seed of cv.a

C. Fruit of cv.b D. Seed of cv.b

E. Fruit of cv.c F. Seed of cv.c

Lamina

In transverse section, the lamina of *Persea americana* Miller studied was dorsiventral with reticulate venation (Table 2). Distinguishable into dermal, ground and vascular tissue systems (Figure 2 D-F).

Dermal Tissue System : Composed of epidermal cells and guard cells of stomata. Subsidary cells also present. In surface view, upper and lower epidermal cells parenchymatous, irregular polygonal, stomata present only on lower surface, rubiaceous or paracytic type, trichome present, non-glandular, unicellular. In transverse section, both upper and lower epidermise one layered, cells barrel shaped; cuticle thin on both surfaces.

Ground Tissue System: Mesophyll differentiated into palisade and spongy parenchyma. Palisade parenchyma cells elongated, cells compact; spongy parenchyma cells rounded or oval or irregular (Table 2).

Vascular Tissue System : Vascular bundle embedded in the ground tissue; collateral, cresent shaped, xylem on the adaxial side and phloem on the abaxial side; phloem cells polygonal, phloem composed of sieve tubes and companion cells; xylem cells polygonal, composed of vessel elements, tracheids and fibers (Table 7).

Midrib

In transverse section, the midrib of *Persea americana* Miller studied was semicircular at the abaxial side and concave at the adaxial side (Table 3). Distinguishable into dermal, ground and vascular tissue system (Figure 2 G-I).

Dermal Tissue System : Composed of epidermal cells and trichomes. In surface view, the epidermal cells parenchymatous, rectangular or polygonal in shape, crystals present. In transverse section, both upper and lower epidermis one layered, cells barrel shaped.

Ground Tissue System : Composed of collenchymatous and parenchymatous tissues. Collenchymatous cells above the lower epidermis and below the upper epidermis were lacunar type, cells oval or rounded; parenchymatous cells above the vascular bundle and below the vascular bundle were oval or rounded (Table 3).

Vascular Tissue System: The vascular bundle crescent shaped in outline, collateral type, bundle sheath absent, xylem on the adaxial side and phloem on the abaxial side; phloem cells polygonal, phloem composed of sieve tubes and companion cells; xylem cells polygonal, xylem composed of vessel elements, tracheids and fibers (Table 8).

Stem

In transverse sections, the stem of *Persea americana* Miller was circular in outline. Distinguishable into dermal, ground and vascular tissue systems (Figure 3 A-F).

Dermal tissue system : In transverse sections, epidermis one layered, cells parenchymatous, barrel shaped or tabular in shape.

Ground tissue system : Composed of cortex, endodermis, pericycle and pith. The cortex differentiated into outer collenchymatous tissue and inner parenchymatous tissue; outer collenchymatous cells polygonal in shape, lacunar type, inner parenchymatous cells polygonal in shape. Endodermis indistinct. Pericycle forming discontinuous in primary body. In secondary body, the pericyclic fiber, located on the outer periphery of the vascular region originating outside the primary phloem, 3 to 9 - layered in cv. a, 4 to 9 - layered in cv. b and 3 to 7 -layered in cv. c. Pith composed of parenchymatous cells, cells isodiametric, thin walled with several intercellular spaces (Table 4).

Vascular tissue system : Collateral vascular system in the form of discrete bundle, separated each other by interfascicular region in primary body. Secondary growth of vascular tissue within the bundle becomes as continuous cylinder. Vascular cambium forming a continuous

ring between secondary phloem and secondary xylem, vascular cambium cells radially arranged and tangentially flattened (Table 4). Secondary phloem cell polygonal in shape, composed of sieve tubes, companion cells and phloem parenchyma. Secondary xylem form a continuous cylinder, transversed by narrow medullary rays, the rays 1 to 12 seriate in cv. a, 2 - 6 seriate in cv. b and 1 - 19 seriate in cv. c, xylem cells polygonal, xylem composed of vessel elements, tracheids and fibers (Table 9).

Root

In transverse section, the root of *Persea americana* Miller was circular in outline. Distinguishable into dermal, ground and vascular tissue system (Figure 3 G-L).

Dermal tissue system : The epiblema cells typically uniseriate, parenchymatous cells, cells 15 - 30 μm in length, 15 - 25 μm in width in cv. a, 10 - 30 μm in length, 10 - 20 μm in width in cv. b and 15 - 25 μm in length, 10 - 20 μm in width in cv. c.

Ground tissue system : Composed of cortex, endodermis and pericycle. The root cortex homogenous, parenchymatous cell rounded or irregular in shape. A continuous concentric layer of innermost cortical layer formed endodermis, cells parenchymatous, barrel shaped. Pericycle one layered, continuous, cells barrel shaped. Pith parenchymatous, 100 - 115 μm in tangential diameter, 100 - 115 μm in radial diameter in cv. a, 65 - 125 μm in tangential diameter, 50 - 75 μm in radial diameter in cv. b, 75 - 85 μm in tangential diameter, 50 - 65 μm in radial diameter in cv. c (Table 5).

Vascular tissue system : The central part of the root was occupied by the vascular cylinder composed of the vascular system and the associated parenchyma. In transverse section, vascular cylinder triarch to hexarch, 3 - 6 xylem strands alternating with the phloem strands. Xylem elements in exarch condition, with protoxylem towards periphery and metaxylem towards centre. The development of xylem in centripetal direction. In secondary vascular tissue system; vascular cambium arises in the pericycle, the cortex is still intact; phloem distributed at the periphery of the xylem, composed of sieve tubes, companion cells and phloem parenchyma; xylem arranged as a continuous cylinder and in the form of radiate group, cells polygonal or rounded, composed of vessel elements, tracheids and fibers (Table 10).

Fruit

Fruits of *Persea americana* Miller studied were berry of one carpel containing a single seed. Distinguishable into dermal, ground and vascular tissue systems (Figure 4 A-F).

Dermal tissue system : Composed of two types of cells, namely epidermal cells and guard cells of stomata. In surface view, epidermal cells parenchymatous, irregular polygonal, intercellular space present; stomata rubiaceous or paracytic type. In transection, epidermis one-layered, cell barrel shaped. Cuticle present.

Ground tissue system : Composed of parenchymatous and sclerenchymatous cells. Parenchymatous many layered, cells rounded or irregular, oil droplets present, intercellular spaces present; an interrupted layers of sclerenchyma tissue limiting the exocarp and mesocarp, this layer consisting of lignified stone cells, cells brachysclereids.

Vascular tissue system : The vascular or conducting system of the fruit permeates the mesocarp in an asymmetrical pattern. Composed of xylem and phloem. Xylem composed of vessel elements, tracheids and fibers (Table 11).

Seed

The seed of *Persea americana* Miller was composed of two fleshy cotyledons and a centrally attached plumule, hypocotyl and radicle, the whole surrounded by seed coats (Figure 4 G-L).

The seed coats : Made up of tannin cell, sclereid and vascular system. Sclereid, irregular in shape with heavy, deeply pitted, lignified walls. Vascular system composed of xylem and phloem. Xylem composed of vessel elements, tracheids and fibers. Phloem composed of sieve tubes and companion cells (Table 12).

In transection of the seed : Epidermis one layered, cell barrel shaped; cuticle present. Parenchymatous many layered, cells rounded or polygonal, starch present, intercellular spaces present.

The vascular system of the seed : Consisting of several strands running in groups to the surface of the cotyledon. Composed of xylem and phloem; xylem composed of vessel elements, tracheids and fibers (Table 13).

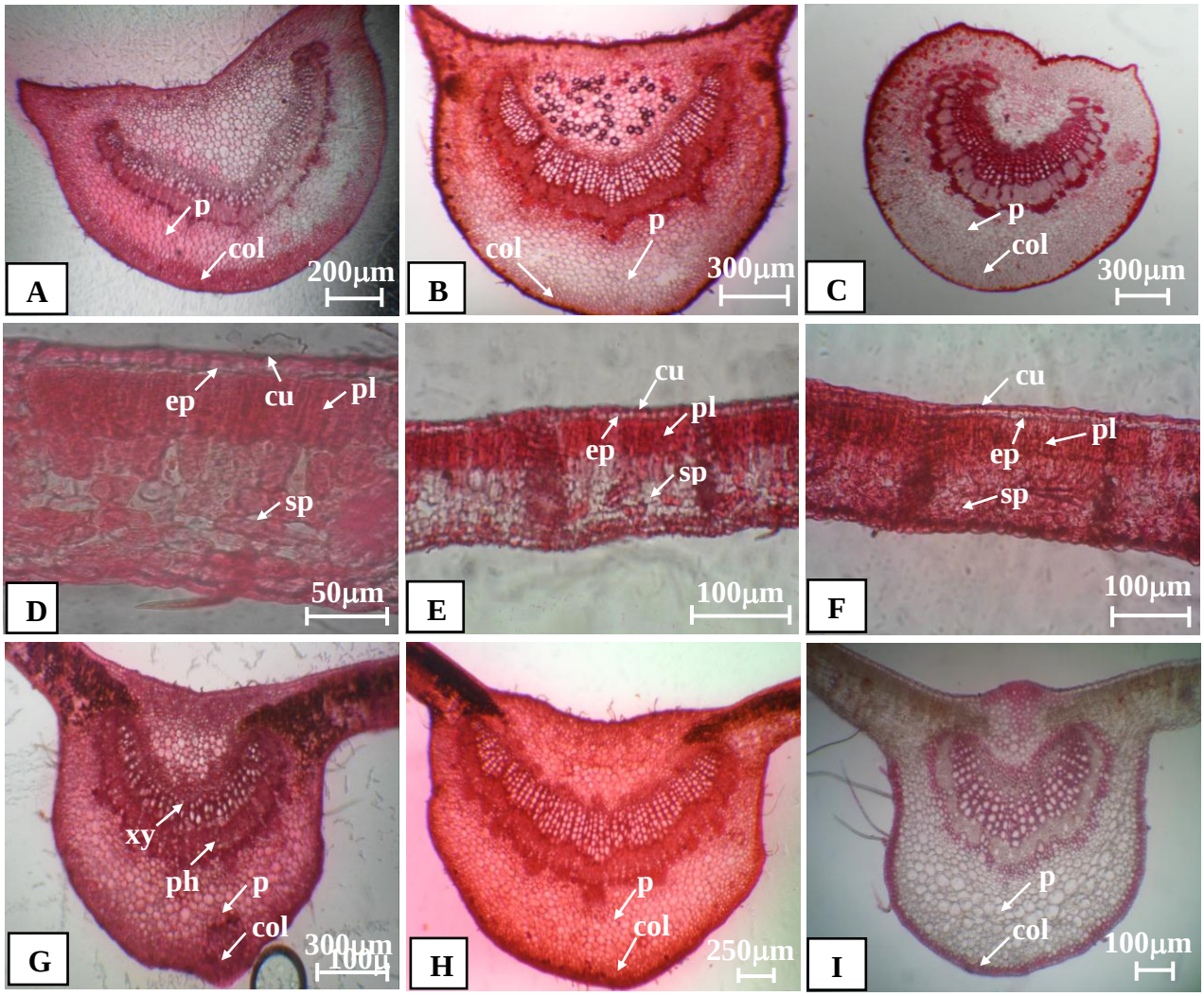

Figure 2. Internal structure of the leaves of *Persea americana* Miller cv.a, b, c
T.S of petiole showing ground tissue and vascular bundle of **A**- cv. a, **B**- cv.b, **C**- cv.c;
T.S of lamina showing palisade & spongy parenchyma of **D**- cv. a, **E**- cv.b, **F**- cv. c;
T.S of midrib showing vascular bundle of **G**- cv. a, **H**- cv.b, **I**- cv.c;
(p - parenchyma, col - collenchyma, ep - epidermic cell, cu - cuticle, pl - palisade, sp - spongy)

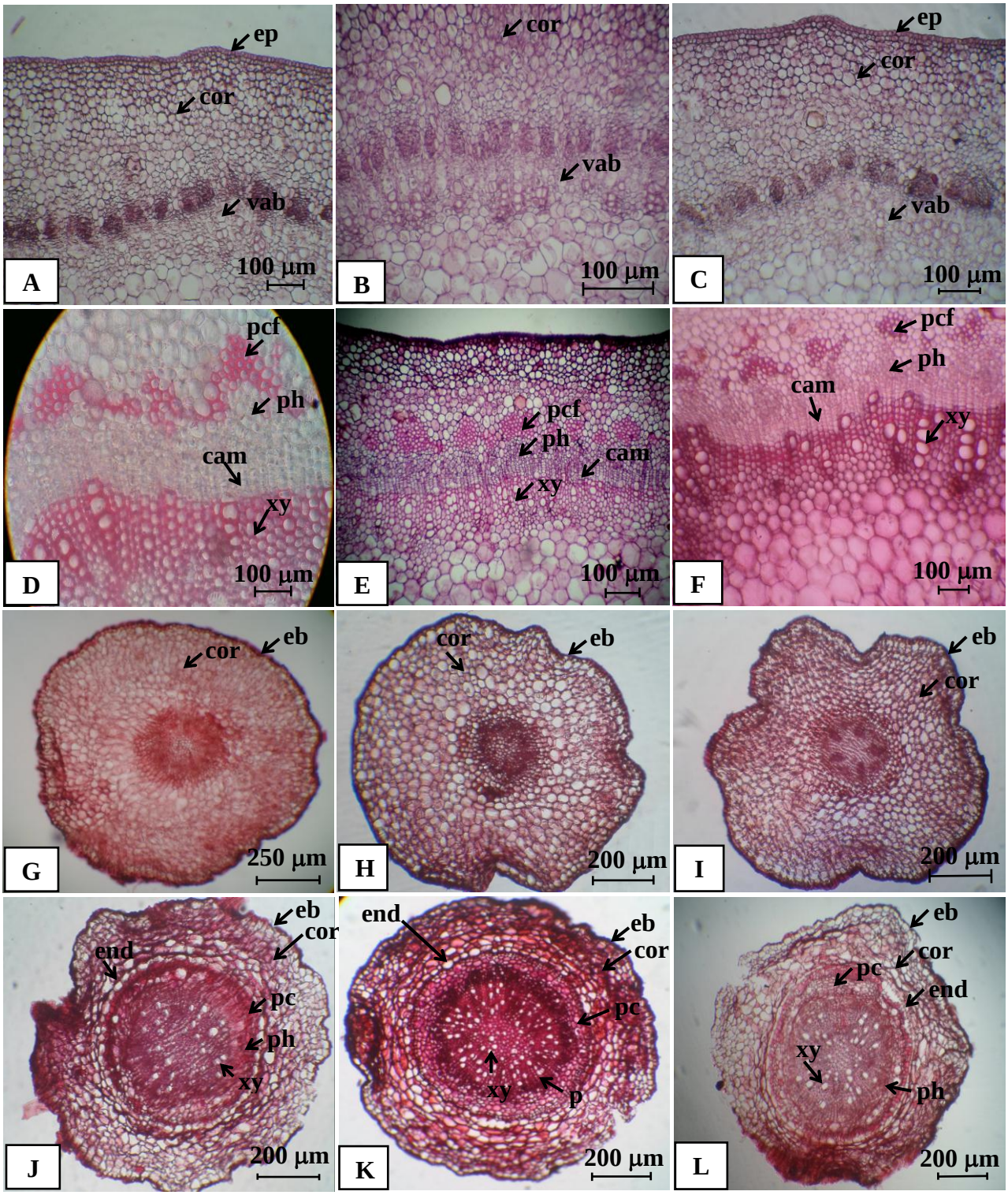

Figure 3. Internal structure of the stems and roots of *Persea americana* Miller cv. a, b, c
Close up view of pirmary stem of **A-** cv. a, **B-** cv.b, **C-** cv. c;
Close up view of secondary stem showing vascular bundle of **D-** cv. a, **E-** cv.b, **F-** cv.c
T.S of root showing primary body of **G-** cv. a, **H-** cv.b, **I-** cv.c
T.S of root showing secondary body of **J-** cv. a, **K-** cv.b, **L-** cv.c
(ep - epidermal, cor - cortex, vab - vascular bundle pcf - pericyclic fibers, ph -phloem, xy - xylem, cam - cambium, eb - epiblema, end - endodermis, pc - pericycle)

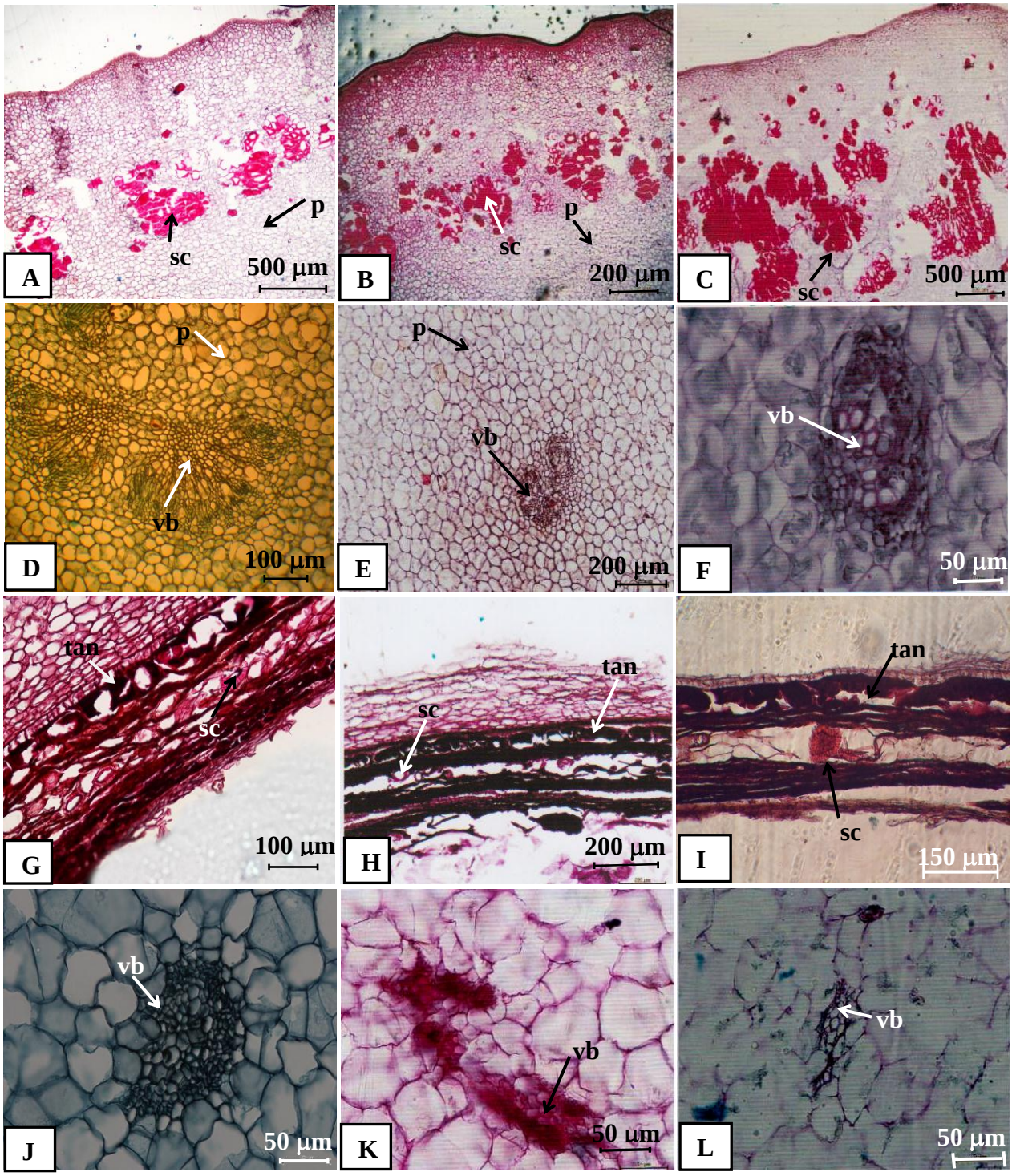

Figure 4. Internal structure of the fruits and seeds of *Persea americana* Miller cv. a, b, c
T.S of exocarp showing epidermis and sclereid layer of **A**- cv. a, **B**- cv.b, **C**- cv. c
Close up view of mesocarp showing vascular bundle of **D**- cv. a, **E**- cv.b, **F**- cv.c
T.S of seed coat of **G**- cv. a, **H**- cv. b, **I** – cv.c
T.S of seed showing vascular bundle of **J**- cv. a, **K**- cv. b, **L**- cv.c
(ep - epidermal, p - parenchyma, sc -sclereid, vb - vascular bundle, tan - tannin)

Table 1. Anatomical characters of the petioles of *P. americana* Miller

Cultivar names	Petiole size		Collenchyma		Parenchyma	
	Length (μm)	Width (μm)	Above the lower epidermis	Below the upper epidermis	Above the vascular bundle	Below the vascular bundle
Cultivar a (ah waine myo)	2437.5-2500.0	1562.5-1625.0	6 to 10-layered	7 to 11-layered	7 to 14- layered	6 to 10-layered
Cultivar b (ah shae myo)	2125-2750	1875.0-2312.5	6 to 10-layered	6 to 9-layered	6 to 14-layered	4 to 12-layered
Cultivar c (buthi pon myo)	1687.5-2375.0	1437.5-2125.0	8 to 12-layered	6 to 13-layered	6 to 11-layered	7 to 15-layered

Table 2. Anatomical characters of the lamina of *P. americana* Miller

Cultivar names	Lamina thickness (μm)	Palisade parenchyma	Spongy parenchyma
Cultivar a (ah waine myo)	130 - 775	1 to 2- layered	3 to 6-layered
Cultivar b (ah shae myo)	175 - 700	2 to 3-layered	3 to 7-layered
Cultivar c (buthi pon myo)	200 - 700	1 to 3-layered	4 to 6-layered

Table 3. Anatomical characters of the mdribs of *P. americana* Miller

Cultivar names	Midrib size		Collenchyma		Parenchyma	
	Length (μm)	Width (μm)	Above the lower epidermis	Below the upper epidermis	Above the vascular bundle	Below the vascular bundle
Cultivar a (ah waine myo)	1375-1600	1125.0-1337.5	6 to 12- layered	4 to 10 -layered	5 to 9-layered	2 to 8-layered
Cultivar b (ah shae myo)	1750.0-2062.5	1250-1500	5 to 9-layered	6 to 10-layered	6 to 10-layered	6 to 12-layered
Cultivar c (buthi pon myo)	1250-1550	975-1125	2 to 4-layered	5 to 10-layered	5 to 10-layered	5 to 12-layered

Table 4. Anatomical characters of the stems of *P. americana* Miller

Cultivar names	Pericyclic fiber		Cambium		Pith cell	
	Layer	Thickness (μm)	Layer	Thickness (μm)	Length (μm)	Width (μm)
Cultivar a (ah waine myo)	3 to 9-layered	30 - 100	5 to 7-layered	20 - 35	20 - 100	20 - 75
Cultivar b (ah shae myo)	4 to 9-layered	45 - 125	4 to 6-layered	25 - 40	30 - 110	25 - 80
Cultivar c (buthi pon myo)	3 to 7-layered	40 - 100	3 to 7-layered	15 - 45	25 - 85	20 - 75

Table 5. Anatomical characters of the roots of *P. americana* Miller

Cultivar names	Epiblema		Cortex		Pith cell	
	Length (μm)	Width (μm)	Layer	Thick (μm)	Length (μm)	Width (μm)
Cultivar a (ah waine myo)	15 - 30	15 - 25	10 to 12-layered	275 - 350	100 - 115	100 - 115
Cultivar b (ah shae myo)	10 - 30	10 - 20	10 to 20- layered	150 - 320	65 - 125	50 - 75
Cultivar c (buthi pon myo)	15 - 25	10 - 20	9 to 12- layered	125 - 250	75 - 85	50 - 65

Table 6. Mean length and width of vessel elements, tracheids and fibers found in petioles of *P. americana* Miller cultivars

Mean / Cultivar names	Vessel elements		Tracheids		Fibers	
	Length (μm)	Width (μm)	Length (μm)	Width (μm)	Length (μm)	Width (μm)
Cultivar a (ah waine myo)	384.0 (250-550)	44.8 (25-65)	1322.0 (850-2000)	37.6 (25-50)	969.2 (325-2250)	23.6 (15-40)
Cultivar b (ah shae myo)	991.0 (700-1275)	69.6 (50-150)	1148.4 (475-2000)	35.6 (25-50)	1162.4 (500-2875)	23.0 (15-35)
Cultivar c (buthi pon myo)	349.2 (175-600)	42.6 (30-50)	978.0 (550-1900)	30.4 (20-40)	1184.0 (550-2500)	23.0 (15-35)

Table 7. Mean length and width of vessel elements, tracheids and fibers found in lamina of *P. americana* Miller cultivars

Mean / Cultivar names	Vessel elements		Tracheids		Fibers	
	Length (μm)	Width (μm)	Length (μm)	Width (μm)	Length (μm)	Width (μm)
Cultivar a (ah waine myo)	484.8 (85-690)	31.0 (15.50)	951.6 (190-1550)	25.0 (10-40)	895.0 (375-1750)	18.4 (10-20)
Cultivar b (ah shae myo)	463.0 (175-725)	26.4 (25-40)	961.6 (350-1700)	19.8 (15-25)	998.0 (350-1700)	16.4 (15-25)
Cultivar c (buthi pon myo)	575.6 (290-975)	32.2 (25-50)	807.0 (450-1000)	20.4 (15-25)	748.0 (225-1500)	17.0 (15-20)

Table 8. Mean length and width of vessel elements, tracheids and fibers found in midrib of *P. americana* Miller cultivars

Mean / Cultivar names	Vessel elements		Tracheids		Fibers	
	Length (μm)	Width (μm)	Length (μm)	Width (μm)	Length (μm)	Width (μm)
Cultivar a (ah waine myo)	417.0 (275-625)	38.6 (25-50)	835.0 (625-1375)	39.2 (35-50)	1141.0 (450-2350)	21.0 (15-30)
Cultivar b (ah shae myo)	324.2 (175-500)	36.4 (20-50)	903.0 (500-1150)	32.0 (25-50)	1126.0 (750-2200)	18.8 (15-25)
Cultivar c (buthi pon myo)	524.0 (275-1000)	38.6 (30-50)	839.6 (415-1000)	29.6 (15-50)	1188.0 (425-1950)	16.0 (10-20)

Table 9. Mean length and width of vessel elements, tracheids and fibers found in stem of *P. americana* Miller cultivars

Mean / Cultivar names	Vessel elements		Tracheids		Fibers	
	Length (μm)	Width (μm)	Length (μm)	Width (μm)	Length (μm)	Width (μm)
Cultivar a (ah waine myo)	354.8 (150-600)	33.6 (20-45)	560.0 (300-1150)	20.6 (5-25)	733.5 (437.5-1187.5)	20.0 (12.5-25.0)
Cultivar b (ah shae myo)	559.0 (175-1150)	33.6 (20-45)	907.2 (375-1750)	29.6 (15-40)	2060.0 (600-4750)	26.0 (12.5-50.0)
Cultivar c (buthi pon myo)	410.2 (225-550)	36.4 (20-55)	501.0 (300-875)	33.4 (15-35)	814.5 (462.5-1375.0)	15.5 (12.5-25.0)

Table 10. Mean length and width of vessel elements, tracheids and fibers found in roots of *P. americana* Miller cultivars

Mean / Cultivar names	Vessel elements		Tracheids		Fibers	
	Length (μm)	Width (μm)	Length (μm)	Width (μm)	Length (μm)	Width (μm)
Cultivar a (ah waine myo)	500.4 (200-1425)	19.0 (15-25)	651.4 (200-1550)	15.4 (10-25)	921.0 (437.5-1887.5)	20.5 (12.5-25.0)
Cultivar b (ah shae myo)	535.6 (150-1125)	28.2 (20-45)	807.8 (340-1525)	20.0 (15-25)	945.5 (500.0-1437.5)	18.5 (12.5-25.0)
Cultivar c (buthi pon myo)	451.4 (275-750)	45.6 (30-55)	470.0 (300-625)	28.8 (25-35)	721.9 (562.5-1312.5)	18.0 (12.5-25.0)

Table 11. Mean length and width of vessel elements, tracheids and fibers found in mesocarp of *P. americana* Miller cultivars

Mean / Cultivar names	Vessel elements		Tracheids		Fibers	
	Length (μm)	Width (μm)	Length (μm)	Width (μm)	Length (μm)	Width (μm)
Cultivar a (ah waine myo)	203.2 (80-400)	30.0 (20-45)	268.4 (100-700)	25.8 (15-45)	774.0 (375-1500)	20.0 (15-25)
Cultivar b (ah shae myo)	162.4 (75-240)	26.8 (20-35)	292.8 (75-525)	23.8 (10-40)	597.4 (225-1550)	13.6 (10-20)
Cultivar c (buthi pon myo)	178.2 (100-300)	30.4 (25-35)	227.4 (90-550)	21.0 (15-35)	895.8 (450-1600)	17.8 (15-25)

Table 12. Mean length and width of vessel elements, tracheids and fibers found in seed coat of *P. americana* Miller cultivars

Mean / Cultivar names	Vessel elements		Tracheids		Fibers	
	Length (μm)	Width (μm)	Length (μm)	Width (μm)	Length (μm)	Width (μm)
Cultivar a (ah waine myo)	186.6 (100-375)	30.2 (25-40)	179.6 (65-550)	23.0 (15-50)	1060.0 (500-1750)	17.6 (10-35)
Cultivar b (ah shae myo)	203.2 (125-130)	27.4 (20-35)	186.4 (75-700)	18.4 (10-25)	967.0 (425-1800)	16.8 (10-20)
Cultivar c (buthi pon myo)	256.6 (170-430)	30.0 (20-40)	169.6 (50-475)	22.4 (15-50)	954.6 (175-2500)	19.2 (15-25)

Table 13. Mean length and width of vessel elements, tracheids and fibers found in seed of *P. americana* Miller cultivars

Mean / Cultivar names	Vessel elements		Tracheids		Fibers	
	Length (μm)	Width (μm)	Length (μm)	Width (μm)	Length (μm)	Width (μm)
Cultivar a (ah waine myo)	180.6 (75-275)	22.2 (20-25)	218.0 (110-475)	14.2 (10-20)	1052.0 (450-2100)	16.6 (10-25)
Cultivar b (ah shae myo)	190.0 (50-300)	21.8 (20-25)	252.2 (95-400)	12.4 (10-15)	1052.6 (500-2000)	16.0 (10-25)
Cultivar c (buthi pon myo)	196.2 (40-325)	23.0 (20-25)	217.8 (75-490)	20.2 (10-40)	1100.6 (350-2300)	19.6 (10.25)

Discussion and Conclusion

Persea americana Miller belongs to the family Lauraceae and its fruit is delicious and nutritious. In this research, morphological characters of vegetative and reproductive parts and anatomical characters of its leaves, stems, roots and fruits had been studied on three cultivars.

In the morphological studies, the flowers of three cultivars are perennial evergreen tree, leaves alternate, coriaceous and evergreen, various nerved; flowers small, greenish or yellowish, cymose, bisexual, actinomorphic; perianth tube shallow, tepals 6, often unequal, not enlarged or indurate, persistent with fruit or caducous; stamens typically in 4 whorls, often the fourth row suppressed or reduced to staminodes; filaments sometimes glandular at the base, very rarely the glands fused into a disk; anthers continuous with the filament, 2- or 4-valved, opening from the base upwards by flaps; ovary of 1 carpel, superior, 1-locular; style terminal; stigma small; ovule solitary, anatropous, pendulous. These characters are in agreement with those stated by Hutchinson (1960), Lawrence (1968), Zomlefer (1994) and Dassanayake (1995).

According to the anatomical characters of leaves, leaves are dorsiventral. Palisade tissue more strongly developed towards the abaxial than towards the adaxial surface of the leaf. Mesophyll, including 1-3 layers of palisade cells. Stomata are the parasitic (rubiaceous) type. In transverse section, the petiole usually shows a single, cresent shaped vascular bundle. Crystals are in the form of small needles or spindles, tablet-shaped. These characters are in accordance with those described by Metcalfe & Chalk (1957), Kubitzki *et al.* (1993) and Bhattacharyya & Johri (1998).

In anatomical characters of stem, the epidermis is one cell in thickness in the young stem and contains stomata scattered irregularly along the axis. A large amount of pith is present in younger stems, this tissue being made up of thin walled, lignified parenchyma cells. The bulk of the xylem tissue is made up of xylem fibers and tracheal tubes that are simply pitted, the latter having elongated perforations in the end plates. The vessel end walls scalariform, or simple, or scalariform and simple. These characters are coincided with those mentioned by Schroeder (1935), Gomez (1971) and Watson & Dallwitz (1992).

According to the anatomical structures of the roots, at the beginning of the secondary growth, cambium originates as bands of meristems between the groups of primary phloem and the center of the stele. The periclinal divisions in the pericycle occur not only outside the xylem poles but spread around the circumference of the root. These are divisions preparatory for the formation of the periderm. These characters are agreed with those stated by Heismann (1939) and Mylius (1913) as cited in Esau (1965).

In anatomical characters of the fruits, the fruit type is berry type and consists of three parts, namely exocarp, mesocarp and endocarp. In the exocarp, it was found that it was composed of stomata, epidermal cells and cuticle, but stomata can be found only when the fruits are young. The exocarp is made up of epidermal, parenchyma and sclerenchyma tissues and is the layer which is removed when the fruit is peeled. Limiting the exocarp on the inner surface is an interrupted layer of sclerenchymatous tissue. This layer consists of a few isolated, slightly lignified stone cells separated by parenchyma. The mesocarp consists mainly of parenchyma cells with evenly dispersed oil cells (idioblasts). The vascular system forms a network throughout this region. The endocarp consists of a few rows of parenchyma cells which are smaller and somewhat more flattened than the adjoining cells of the mesocarp. These cells lie directly against the outer seed coat and may adhere to it when the seed is removed from the fruit. The outer layer of the seed coat consists of stone cells which are irregular in shape with heavy, deeply pitted, lignified wall. The cotyledons are formed of undifferentiated parenchyma tissue interspersed with occasional idioblasts. Starch is the main storage material of the cotyledons and is present in great abundance. These characters are in agreement with those mentioned by Cummings & Schroeder (1942), Storey (1974) and Luza & Lizana (1992).

With regard to the distinctly different mean length and width of vessel elements, tracheids and fibers, in petiole, cultivar b possessed the highest mean length and width of vessel elements (Table 6). In lamina, cultivar c possessed the highest mean length of vessel elements (Table 7) and also in midrib (Table 8). The highest mean length of vessel elements, tracheids and fibers of stem was found in cultivar b (Table 9). In seed coat, cultivar a contained the highest mean length of fibers (Table 12). Except the facts described above, it was found that the other mean length and width of three cultivars differed slightly.

According to the present morphological and anatomical studies, the vegetative parts, flowers including its parts, and anatomical characters were found to be similar in every cultivars. But, the shape and sizes of the fruits are significantly different. The fruits of cultivar a are globoid in shape and the seeds are also globoid in shape. The fruits of cultivar b are oval in shape and the seeds are subgloboid with a pointed beak at the apex. The fruits of cultivar c are pyriform in shape and the seeds are ovoid in shape. That can be used for the identification of cultivars.

The detailed characteristics of the plants from the present research will provide the useful information for further studies of determination on chemical constitutions, analysis on nutritional components and their value, and evaluation of the fruits for commercial products.

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