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A Review on Anatomy of Plants in Verbenaceae

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ABSTRACT

Socioeconomically the plants of Verbenaceae are very important, are distributed worldwide mostly grown in tropical and subtropical regions with only a few grown in the temperate regions. The anatomical studies are preliminary research prior and prerequisite learning to critical studies like chemical inspection though it is few in the plants of this family. Most likely twenty six species of Verbenaceae have been studied anatomically till now. In this review, a detail view on anatomical studies in plants of this family is discussed.

Key words: Anatomical studies, Angiosperm, Flowering plant, Review, Verbenaceae family

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1. INTRODUCTION

This family is commonly called Verbena family. The genera and species number in the Verbenaceae family explained different by many scientists in various time. It includes about 100 genera and 2,600 species (Kyhos & Carr, 1994). It is described 77 genera with 3,020 species (Yashsvi, 2008). According to Elpel's (2013), there are about 75 genera and 3,000 species exist in the Varbeneceae. Shou-liang & Gilbert (1994) reported 91 genera and ca. 2000 species in the Varbeneceae family. On the basis of phylogeny, Verbenaceae family is about 35 genera includes 1000 species worldwide (Atkins, 2004), mostly grown in tropical and subtropical regions, with only a few grown in the temperate regions. The plant habit varies from trees to lianas to shrubs and herbs.

The flowers of the plants in this family are aggregated in spikes, clusters, or racemes and usually consist of a tube flaring into four or five almost equally cut lobes, are mostly important for their flowers. The genus, *Verbena*, contains some 200 to 250 species, almost all of them native to the Western Hemisphere. Among the 30 *Petrea* species, all tropical American, is a woody evergreen vine called purple wreath, or sandpaper vine (*Petrea volubilis*). The 220 species of the genus *Lippia* bear clusters of white, rose, or purplish flowers. *Lippia canescens* of South America is a matting ground cover with oblong leaves and small heads of yellow-throated, lilac flowers. *Caryopteris,* with 15 East Asian species, is exemplified by bluebeard (*Caryopteris incana*), an oval-leaved shrub with clusters of bright blue flowers in the autumn. Other tropical plants such as the Chinese hat plant (*Holmskioldia sanguinea*) and species of pigeon berry, or golden dewdrop (*Duranta*), and glory-bower (*Clerodendrum*) are cultivated as ornamentals.

The plants of Verbenaceae are well known for their uses in traditional medicine systems. Quite a number of the plants have been reported to contain bioactive phytochemicals with important pharmacological effects. Essential oil obtained from *Lippia* spp. possessed antinociceptive, anti-inflammatory activities inhibited diarrheal disease (Machado et al., 2010), anthelmintic activity against sheep gastrointestinal nematodes (Camurça-Vasconcelos et al., 2007; Camurça-Vasconcelos et al., 2008), spasmodic activity (Görnemann et al., 2008). A new anthraquinone, named tectone (3,8-dihydroxy-2-methyl anthraquinone) with

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anti-hyperglycemic properties has been isolated from leaves of *Tectona grandis* L.f. (Shukla et al., 2010). Anti-oxidant and anti-fungal properties have been shown of various solvent extracts of leaves of *V. officinalis* (Casanova et al., 2008). Ethanol extract of *Stachytarpheta jamaicensis* reportedly demonstrated anti-inflammatory properties in animal models of nociception and inflammation (Sulaiman et al., 2009). Anti-inflammatory phenylpropanoid glycosides have been reported from leaves of *Clerodendron trichotomum* (Kim et al., 2009). The plant, *Clerodendrum umbellatum* is used in the traditional medicinal system of Cameroon for treatment of intestinal helminthiasis (Jatsa et al., 2009). *Acantholippia deserticola*, used in traditional northern Chilean medicine, has been shown to have anti-oxidant properties (Morales et al., 2008). *Verbana officinalis*, a European native, is widely used for teas and herbal remedies.

Trees of the Verbenaceae are yielded timber. The wood of *Avecennia marina* is used for poles in house building, boat construction, especially the ribs, furniture, handles and beehives making. The wood of *Gmelina arborea* is suitable for general utility purposes, especially light construction and structural work, general carpentry, packaging, carvings, utility furniture and decorative veneers, with excellent woodworking properties. Teak (*Tectona grandis*) is a well known timber yielding tree from India to Java. The wood is valued for heavy construction as well as fine furniture.

Plant anatomy or phytotomy is the general term for the study of the internal structure of plants. While originally it included plant morphology, which is the description of the physical form and external structure of plants, since the mid-20th century the investigations of plant anatomy are considered a separate, distinct field, and plant anatomy refers to just the internal plant structures. Plant anatomy is now frequently investigated at the cellular level, and often involves the sectioning of tissues and microscopy. Anatomical studies have much significance in different sectors of investigation. Studies on anatomy of plants can explain where, what, when and how chemical components are produced. The anatomical studied can be explanted the qualities of the wood properties. The anatomical structure was investigated in order to resolve the taxonomical problems of critical species and genera (Duletić-Lašević et al., 1997). There are many reports available on the anatomical studies of many plant families like Asteraceae (Hadad et al., 2013), *Cleomaceae* (Thenmozhi et al., 2013), and Malvaceae (Garica et al., 2014). The anatomical studies were carried out on some species of the Verbenaceae completely or partially, are discussed in this report.

The plants of Verbenaceae are commercially importance in the yield of flowers, production of biochemicals and use of folk medicines. The trees are produced wood using for paper making, furniture, poles etc. To consider the view of these points in the economical uses, it is important to anatomical study of the plants for better understanding pharmacists, tree growers and furniture makers. This review study clarifies anatomical characteristics of plants of Verbenaceae family already carried out completely or partially. This review is to sum up the anatomical study of plants in Verbenaceae family which have already been studied anatomically.

2. GENERA AND SPECIES OF VERBENACEAE FAMILY

Verbenaceae commonly known as the verbena family or vervain family, was a largest. Recent phylogenetic studies (Cantino et al., 1992) have shown that numerous genera traditionally classified in Verbenaceae belong instead in mainly Lamiaceae and others (Table 1 and 2). The new narrowly circumscribed Verbenaceae family includes some 38 genera and 1,200 species (Table 1) (Heywood, 2007).

3. DESCRIPTION ON ANATOMY OF PLANTS IN VERBENACEAE FAMILY

3.1. Anatomical features of plants of genus *Avicennia*

Avicennia spp. are Mangrove plants. Mangrove forests are generally distributed along tropical coastlines of Asia, Africa and America, although this range extends beyond due to the movement of unusually warm waters from the equator, including the east coast of Africa, Australia, and New Zealand (Hogarth, 1999; McLeod & Salm, 2006). The plants of this genus are evergreen shrub or small tree; roots with many vertical breathing roots above soil level; trunk usually low-branching, sometimes with small prop roots; bark surface smooth to slightly fissured or flaky, brownish or yellowish green; crown dense and rounded. Leaves decussately opposite, simple acute or acuminate at apex, leathery. Flowers bisexual, regular, sessile. Fruit is a slightly asymmetrical, broadly ellipsoid to ovoid capsule. Seeds are compressed (Ball & Farquhar, 1984). These plants have developed complex physiological, morphological and anatomical adaptations allowing survival and success in the high stress habitat where they inhabit (Hogarth, 1999).

The development and anatomical structure of pneumatophores in *Avicennia marina* (Forsk.) Vierh were elicited by Purnobasuki & Suzuki (2005) and stated that the cortex cells wider parallel to the root axis, elongate parallel to the root radius and shrank in the plane perpendicular to the radius leaving long and thin row of cortex cells during gas space formation. They also reported aerenchyma pronounced tubular structure, run parallel to the root axis, relatively straight and the walls of the tubes being made up of single layers of cells in regular rows, which appeared to be interconnections between tubes, and no perforated membrane or transverse septa on the tip, and connected each other create as a continuum. There are redial pores at the corner of the cortical cells.

The anatomical responses were evaluated in the water logging of mangrove seedlings of *A. marina* grown in experimentally simulated semidiurnal tides (Xiao et al., 2009). They observed the leaf thickness, mesophyll thickness, palisade parenchyma thickness, palisade–spongy

Table 1. The genera in the new narrowly circumscribed family (Germplasm Resources Information Network, 2004).

1	Acantholippia Griseb.	14	Hierobotana Briq.	27	Recordia Moldenke
2	Aloysia Palau	15	*Junellia* Moldenke	28	Rehdera Moldenke
3	Baillonia Bocq.	16	*Lampayo* F.Phil. ex Murillo	29	Rhaphithamnus Miers
4	Bouchea Cham.	17	Lantana L.	30	Stachytarpheta Vahl
5	Burroughsia	18	Lippia L.	31	Stylodon Raf.
6	*Casselia* Nees & Mart.	19	*Mulguraea* N.O'Leary & P.Peralta	32	Tamonea Aubl.
7	Chascanum E. Mey	20	*Nashia* Millsp.	33	Ubochea
8	Citharexylum L.	21	Neosparton Griseb.	34	Urbania
9	Coelocarpum Balf. f.	22	Parodianthus Tronc.	35	Verbena L.
10	Diostea Miers	23	Petrea L.	36	Verbenoxylum Tronc.
11	Dipyrena Hook.	24	*Phyla* Lour.	37	Xeroaloysia Tronc.
12	Duranta L.	25	Pitraea Turcz.	38	Xolocotzia Miranda
13	Glandularia J.F.Gmel.	26	*Priva* Adans.		

Table **2.** Various genera formerly included in the family Verbenaceae are now treated under other families (Germplasm Resources Information Network, 2004).

Moved to Acanthaceae					
1	*Avicennia* L.				
Moved to Lamiaceae					
2	*Amasonia* L.f.	17.	*Hemiphora* (F.Muell.) F.Muell.	32.	*Physopsis* Turcz.
3	*Brachysola* (F.Muell.) Rye	18	*Holmskioldia* Retz.	33	*Pityrodia* R.Br.
4	*Callicarpa* L.	19	*Hosea* Ridl.	34	*Premna* L.
5	*Caryopteris* Bunge	20	*Hymenopyramis* Wall. ex Griff.	35	*Pseudocarpidium* Millsp.
6	*Chloanthes* R.Br.	21	*Kalaharia* Baill.	36	*Pseudocaryopteris* P.D.Cantino
7	*Clerodendrum* L.	22	*Karomia* Dop	37	*Rotheca* Raf.
8	*Congea* Roxb.	23	*Lachnostachys* Hook.	38	*Schnabelia* Hand.-Mazz.
9	*Cornutia* L.	24	*Mallophora* Endl.	39	*Spartothamnella* Briq.
10	*Cyanostegia* Turcz.	25	*Monochilus* Fisch. & C.A.Mey.	40	*Sphenodesme* Jack
11	*Dicrastylis* J.Drumm. ex Harv.	26	*Newcastelia* F.Muell.	41	*Symphorema* Roxb.
12	*Discretitheca* P.D.Cantino.	27	*Oncinocalyx* F.Muell.	42	*Tectona* L.f.
13	*Faradaya* F.Muell.	28	*Oxera* Labill.	43	*Teijsmanniodendron* Koord
14	*Garrettia* H.R.Fletcher	29	*Peronema* Jack	44	*Teucridium* Hook.f.
15	*Glossocarya* Wall. ex Griff.	30	*Petitia* Jacq.	45	*Tripora* P.D.Cantino
16	*Gmelina* L.	31	*Petraeovitex* Oliv.	46	*Vitex* L.
Moved to Oleaceae					
47	*Dimetra* Kerr.	48	*Nyctanthes* L.		
Moved to Orobanchaceae					
49	*Asepalum* Marais	50	*Cyclocheilon* Oliv.	51	*Nesogenes* A. DC.
Moved to Phrymaceae					
52	*Phryma* L.				
Moved to Stilbaceae					
53	*Campylostachys* Kunth	54	*Euthystachys* A. DC.	55	*Stilbe* P.J.Bergius
56	*Thesmophora* Rourke				

ratio and hypodermis thickness decreased with increasing water logging. The mesophyll to leaf thickness ratio, stem and pith diameter, and cortex thickness increased on that time. The tangential vessel diameter, vessel wall thickness in stem and leaf and fiber wall thickness in stem showed a similar tendency in response to water logging, remaining constant between 0 and 4 h water logging duration, but decreasing with more prolonged water logging. When the water logging duration exceeded 4 h, no sclerenchyma cells in leaves or gelatinous fibers in stems were observed. The response of these leaf and stem features indicated that water transport and mechanical support could remain relatively stable in the 0–4 h water logging duration, but they would be negatively influenced by longer flooding. Tissues for gas exchange were stimulated by water logging, while the functions of water storage, photosynthesis, mesophyll conductance were weakened with increasing water logging. Borkar et al. (2009) was noticed on anatomy of *A. marina* under the conditions of higher salinity, showed increased thickness of hypodermal water storage tissue in leaf and produced taller salt extruding glands at the lower epidermis to eliminate more salt; whereas, the thickness of the photosynthetic mesophyllic tissue significantly reduced. At lower salinity or with reduction in salinity in monsoon, contrary to above occurred. The effect of salinity levels on anatomy of *A. marina* has reported by Ghowail et al. (1993). There were not notable differences in the anatomical structures of stems, roots and leaves of *A. marina* individuals grown on the three levels 0% (tap water), 50% and 100% of sea water studied. The vessel characteristics such as grouping and diameters of vessels together with vessel element length of *A. marina* reported in stem (Robert et al. 2009). Higher vessel density, higher vessel grouping, smaller vessel diameters and shorter vessel element lengths of *A. marina* were found in higher salinity. Safdari and Shadman (2015) studied wood anatomy of *A. marina*. The concentric included phloem was present which was surrounded by lignified conjunctive parenchyma (axial parenchyma) and scleroid bands are also found in axial parenchyma cells of stems.

The anatomy of leaves and the pneumatophores of *A. marina* were changed by the oil pollution (Diab & Bolus, 2014). The oil pollutants are deposited inside the tissues of leaves and aerial roots which lead to obvious changes on the anatomical features of the plant. The effects of Slicon (Si) on the anatomy of the roots in *A. marina* and it was prompted the development of the apoplastic barrier with casparian trips formation in the roots (Zhang et al., 2013). El-Tarabily & Youssef (2010) reported the application of *Oceanobacillus picturae* bacterium to sediments amended with rock phosphate (RP) significantly promoted the growth of roots and shoots of seedlings of *A. marina*. Significantly increased available sediment phosphate, decreased sediment pH, positively enhanced nutrient uptake parameters in roots and shoots, increased stem circumference, number of xylem vessels, mean xylem diameter, and the hydraulically weighted xylem vessel diameter. The wood anatomical traits asvesseldensity, grouping, diameter and length, as well as fiber wall thickness,are affected by variations on salinity and flooding level (Yáñez-Espinosa & Flores, 2011). The study has demonstrated that *Avicennia* trees stem vascular system, particularly wood anatomical traits as vessel density, grouping, diameter and length, as well as fiber wall thickness, is affected by variations on salinity and flooding level (Yáñez-Espinosa et al., 2009).

3.2. Anatomical features of plant of genus *Gmelina*

Gmelina arborea is a short-lived tree, which reaches an age of about 30 years. It is a deciduous medium-sized tree. Under optimal conditions the bole is straight with good natural pruning in dense stands. Isolated trees develop very large branches. The tree is deciduous except in the first year, and flowering occurs when new leaves have just begun to develop, but intensity of flowering varies. Leaves decussately opposite, simple; stipules absent; acuminate at apex, entire to toothed at margin. Inflorescence consisting of cymes arranged in a terminal or axillary panicle. Fruit a globose to obovoid, fleshy drupe and they are ripe when the color changes from green to yellow (Fuwape et al., 2001).

Wood anatomical description of *Gmelina arborea* has been carried out (Lamb, 1968). In this plant, i) Growth ring: growth ring boundaries distinct or indistinct or absent, ii) Vessels: wood diffuse-porous; simple perforation plates; intervessel pits alternate; shape of alternate pits polygonal; intervessel pits medium; vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell; vessel-ray pits with much reduced borders to apparently simple: pits rounded or angular; mean tangential diameter of vessel lumina 100–200 µm; (mean tangential diameter of vessel lumina ≥ 200 µm); ≤ 5 vessels per square millimetre; 5–20 vessels per square millimetre; tyloses common. iii) Tracheids and fibres: fibres with simple to minutely bordered pits; septate fibres present; fibres very thin-walled; fibres thin- to thick-walled. iv) Axial parenchyma: (axial parenchyma diffuse); axial parenchyma scanty paratracheal; axial parenchyma vasicentric; two cells per parenchyma strand; four (3–4) cells per parenchyma strand; eight (5–8) cells per parenchyma strand. v) Rays: larger rays commonly 4 - to 10-seriate; all ray cells procumbent; body ray cells procumbent with one row of upright and/or square marginal cells; ≤ 4 rays per mm; 4–12 rays per mm. Mineral inclusions: acicular crystals.

3.3. Anatomical features of plant of genus *Lantana*

Lantana camara is a rugged evergreen shrub. Stems are quadrangle in profile with small prickles. The leaves are arranged in opposite pairs. They are broadly oval, rough with short hairs with finely toothed edges. When crushed they have a smell. Flowers are a mixture of cream, pink or orange numerous small rounded heads often in two colors, yellow and red. Fruits are fleshy berries in clusters, green ripening to black. *L. camara* is poisonous to stocks and humans. In Australia, it is a weed of national significance and must continuously be suppressed and destroyed. Other *Lantana* species and hybrids are cultivated as ornamental under hundred of cultivar names (Sharm et al., 1988; Roy & Barua, 1985).

The leaves of *L. camara* were anatomically examined by light microscopy and scanning electron microscopy (Passos et al., 2009). The secretory idioblasts were observed in the petiole and the leaf blades. Abaxial and adaxial leaf epidermal anatomy was studied based on leaf epidermal characters of *L. camara* (Munsif et al., 2007). These species showed variations in stomata types and size, epidermal cell

Table 3 Summarized reports on anatomical study of plants in Verbenaceae.

Species	Anatomical characteristics	References
Avicennia marina	**Stem** a) vessel density, b) vessel diameter, c) vessel grouping, d) vessel length	Robert et al., 2009
	a) phloem, b) axial parenchyma	Safdari & Shadman, 2015
	a) vessel density, b) vessel grouping, c) vessel diameter and d) vessel length	Yáñez-Espinosa & Flores, 2011
	Stem a) tangential vessel diameter, b) vessel wall thickness, c) fiber wall thickness, d) gelatinous fibers	Zhang et al., 2013
	Leaf a) thickness, b) mesophyll thickness, c) palisade parenchyma thickness, d) palisade–spongy ratio, e) hypodermis thickness, f) tangential vessel diameter, g) vessel wall thickness, h) sclerenchyma cells	Xiao et al., 2009
	Pneumatophores a) cortex cells	Purnobasuki & Suzuki, 2005
	Leaf a) extruding glands at the lower epidermis, b) mesophyllic tissue, c) hypodermal water storage tissue	Borkar et al., 2009
	Leaf, Pneumatophores, Aerial root	Diab and Bolus, 2014
	Root a) apoplastic barrier with casparian trips	Zhang et al., 2013
	Stem, Root, Leaf	Ghowail et al., 1993
	Shoots and Roots a) stem circumference, b) number of xylem vessels, c) xylem diameter, d) hydraulically weighted xylem vessel diameter	El-Tarabily &Youssef, 2010
Avicennia germinans	**Stem** a) vessel density, b) fiber wall thickness	Yáñez-Espinosa et al., 2009
Gmelina arborea	**Stem** a) growth rings, b) vessels, c) tracheids and fibres, d) axial parenchyma, e) rays	Lamb, 1970
Lantana camara	**Petiole and the leaf blades** a) secretory idioblasts	Passos et al., 2009
	Leaf a) epidermal cell shape size, b) trichomes shape, c) glandular hairs, d) Trichomes 5 basal-cells	Munsif et al., 2007
	Inflorescence a) meristematic differentiation	Caroprese et al., 2011
	Leaf a) unicellular nonglandular trichomes	Francino et al., 2006; Hallahan & Gray, 2000; Valkama et al., 2003
	Stem a) epidermis, b) cortex, c) xylem and phloem, d) cambium, e) pith **Leaf** a) mesophyll, b) secretory idioblasts, c) vascular system	Sultana, 2016
Lantana indica	**Leaf** a) trichomes one basal-cells	Munsif et al., 2007
Lippia alba	**Leaf**	Jezler, 2013

	a) epidermis, b) mesophyll, c) trichomes	
Lippia origanoides	**Leaf** a) trichomes	Tozin et al., 2015
Lippia stachyoides	**Leaf** a) trichomes	Tozin et al., 2015
Lippia scaberrima	**Leaf** a) trichomes	Combrinck et al., 2007
Lippia citriodora	**Leaf** a) trichomes	Argyropoulou et al., 2010
Tectona grandis	**Stem** a) fiber length, b) fiber diameter, c) fiber lumen width and d) cell wall thickness	Izekor & Fuwape, 2011
	Stem a) wood density	Moya et al., 2009
	Leaf a) epidermal cells, b) palisade	Junior et al., 2009
	Stem a) vessels b) xylem rays	Sanghvi et al., 2013
	Stem a) vessels	Nordahlia et al., 2014
	Stem a) wood texture, b) tyloses, c) pits	Josue & Imiyabir, 2011
	Stem a) fibers	Wheeler et al., 1989
	Stem, Leaf and Root a) most of the microscopic features.	Ogata et al., 2008
Citharexylum myrianthum	**Stem and Root** a) semi-ring porous wood, b) vessels- simple perforation plates, c) fibers - bordered small pits	Marcati et al., 2014
	d) parenchyma and sclerenchyma bands	Vergílio et al. 2017
	Stem a) Acicular calcium oxalate crystals were found in cambial fusiform and ray cell initials	Marcati & Angyalossy, 2005
	Leaf a) Stomata of the anomocytic type, occur on both surfaces of the leaf, stomata predominantly on the abaxial surface, b) Simple and glandular trichomes, palisade parenchyma reveals two layers of cells, epidermis of the abaxial surface exhibits sinuates anticlinal walls	Juck et al. 1997
Citharexylum montevidense	**Stem** a) Vessels - solitary and short radial multiple pores, bordered pits, b) Fibers – septate	Siegloch et al., 2013
Vitex lucens	**Stem**	
	a) Vessels - round to oval, also angular; solitary, perforation plates simple, b) Rays - homogeneous type III, occasionally heterogeneous type II, c) Fibers - thick-walled; pits simple	Patel, 1974
Vitex agnus-castus	**Stem**	
	a) Young stem - Nonglandular hairs, epidermis, cuticle, sclerenchymatous b) Mature stem - epidermis, collenchymatous tissue, starch in pith	Watson & Dallwitz, 1992
	c) Vessels - tylosis	Richter & Dallwitz, 2000
	d) quadrangular, Nonglandular hairs, cuticle, periderm replaces the epidermis, cork cells are thin-walled, peripheral part collenchymatous tissue, cortex, phloem tissue, cambium tissue, xylem tissue	Watson & Dallwitz, 1992

	e) starch deposition in the pith	Metcalfe & Chalk, 1957
	Root	
	a) cork, periderm, cortex, Sclerenchyma, xylem and phloem	Dogan et al., 2008
	b) root showed a parallelism	Metcalfe & Chalk, 1957
	Leaf	
	a) stomata were found only in the lower surface, anomocytic type, palisade parenchyma, spongy parenchyma, Oxalate sands	Metcalfe & Chalk, 1957
	b) prismatic cyristals present	Metcalfe & Chalk, 1957; Özörgücü et al. 1991; Richter & Dallwitz, 2000
Teucridium parvifoliu	**Stem**	
	a) Vessels more or less evenly distributed, tyloses absent, Vascular tracheids occasional, Rays heterogeneous type II and multiseriates and uniseriates, sheath cells irregularly distributed, pits simple	Patel, 1974
Verbena gracilescens	**Stem** a) internal structure **Leaf** a) type and density of stomata, b) glandular and nonglandular trichomes	Moecelle et al., 2012
Verbena bonariensis	Do	Moecelle et al., 2012
Verbena intermedia	Do	Moecelle et al., 2012
Verbena litoralis	Do	Moecelle et al., 2012
Verbena montevidensis	Do	Moecelle et al., 2012
Verbena rigida	Do	Moecelle et al., 2012
Stachytarpheta glabra	**Stem** a) semi-diffuse porous wood, radial multiple, pores, heterogeneous rays, short libriform fibers	Siegloch et al., 2014
Stachytarpheta angustifolia	**Leaf and petiole** a) Epidermis, b) Chlorenchyma, c) the palisade layer was one to three cells thick	Okeke et al., 2015
Stachytarpheta cayannensis	Do	Okeke et al., 2015
Stachytarpheta jamaicensis	Do	Okeke et al., 2015

shape size and trichomes shape. Most of the characters especially trichomes were diagnostic and used for distinguishing taxa. Glandular hairs were observed. Trichomes of *L. camara* on abaxial surface had aggregates of 5 basal-cells, in *L. indica* there was just one basal-cell.

Transversal and longitudinal sections of three stages of inflorescence were observed (Caroprese et al., 2011). It was microscopically characterized by an immature development in which the meristematic differentiation begins with a mass of cells.

The unicellular nonglandular trichomes observed in *Lantana* have been described for plants of this genus. The largest frequency of these trichomes in the adaxial surface of *L. camara* can be related to several factors such as protection against excessive radiation and high temperatures, as reported in the literature (Francino, 2006; Hallahan & Gray, 2000; Valkama, 2003).

The fresh hand sections of stem and leaf of *Lantana camara* L. were studied to find out identical characteristics (Sultana, 2016). Epidermis of the stem section was the outermost layer covering with a single layer barrel-shaped parenchyma cells. Cortex was represented by several layers of loosely setup parenchyma cells with prominent intercellular spaces. Xylem and phloem tissues were located upper and lower of meristematic cambium, respectively. The meristematic cambium was composed of 3 cells layers. Pith was the innermost part of the stem formed by a group of loosely constructed parenchyma cells. Leaf blades presented uniseriate epidermis cells with thin periclinal walls and a relatively thick cuticle on the adaxial surface. The mesophyll was dorsiventral and having secretory idioblasts. The vascular system is open, forming a flattened arch in the "V" shape with two accessory bundles located dorsally and groups of secretory idioblasts located laterally in the cortical parenchyma.

3.4. Anatomical features of plant of genus *Lippia*

The genus *Lippia*, which encompasses approximately 200 species, is native to South America, Central America and Africa (Brummitt, 1992), and is widespread in the Brazilian savannas (cerrados) and rocky grasslands (Salimena, 2010) is commonly employed in the form of a leaf infusion or

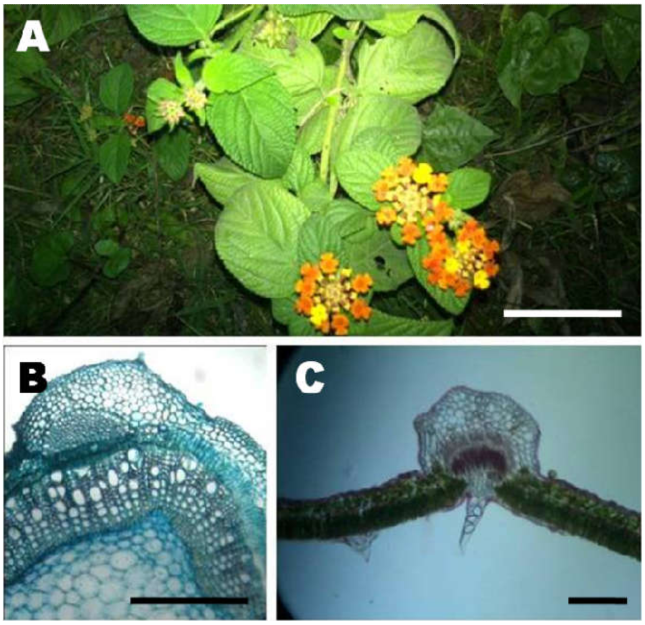

Fig. 1 Anatomical features of lantana camera L., A) a plant with flowering, scale bar 3cm. B) Cross section of stem, Scale bar 500um. C) Cross section of leaf, Scale bar 500um.

decoction in the treatment of colds, bronchitis, coughs, asthma, and stomach and intestinal disorders (Lorenzi & Matos, 2008). Furthermore, the essential oil of *Lippia alba* exhibits antispasmodic and analgesic properties that have been attributed to the presence of the terpenoids citral, myrcene and limonene (Vale et al., 2002).

In *Lippia alba*, the leaves of cidreira and melissa displayed similar anatomical patterns in that they were amphistomatic. The epidermis on both surfaces was composed of a monolayer of rectangular cells covered with a thin cuticle, and the external periclinal cell walls were thicker on the adaxial compared with the abaxial surface. The mesophyll was dorsiventral, but in cidreira the palisade parenchyma was biseriate while in melissa it was uniseriate. In cidreira, it was possible to observe the occurrence of angular collenchyma in the sub-epidermal region of the mid-vein, but this feature was not present in melissa (Jezler et al., 2013).

Simple tector and glandular trichomes, the latter with variable morphology, were observed on the surfaces of the leaf blades of the two morphotypes. The abaxial surfaces of the leaves exhibited a greater density of trichomes than the adaxial sides, and the glandular trichomes were partially covered by the larger and more abundant simple tector trichomes. Capitate glandular trichomes could be classified into six different morphological types: Types I (large unicellular secretory head, collar cell present, short stalk) and II (bicellular secretory head, collar cell present, short unicellular stalk), were present in both morphotypes, type III (small bicellular secretory head, collar cell present, long stalk) occurred only in cidreira, and types IV (bulb-shaped bicellular secretory head, short stalk), V (unicellular secretory head, collar cell present, long stalk) and VI (large tricellular secretory head, collar cell present, short stalk) were observed only in melissa (Table 1). Simple tector trichomes were of variable size, with an acute curved apex and a large basal disc comprising eight radial cells (Jezler et al., 2013).

The morphology and histochemistry of glandular trichomes in *L. origanoides* Kunth and *L. stachyoides* Cham., using conventional methods in anatomy, histochemistry, scanning and transmission electron microscopy, and ultracytochemical techniques were analyzed (Tozin et al., 2015). Five morphotypes (I–V) of glandular trichomes were identified in *L. origanoides*, and four morphotypes (I, III–V) in *L. stachyoides*. Morphotype I is the most abundant in both species.

The morphology of the glandular trichomes was investigated and observed that three types of trichomes were distinguished on the mature leaves of *Lippia scaberrima* Sond (Combrinck et al., 2007). Leaves of *L. citriodora* possess one type of setae (non-glandular) and at least five types of glandular trichomes, with the latter differing anatomically and in the composition of their secondary metabolites (Argyropoulou et al., 2010).

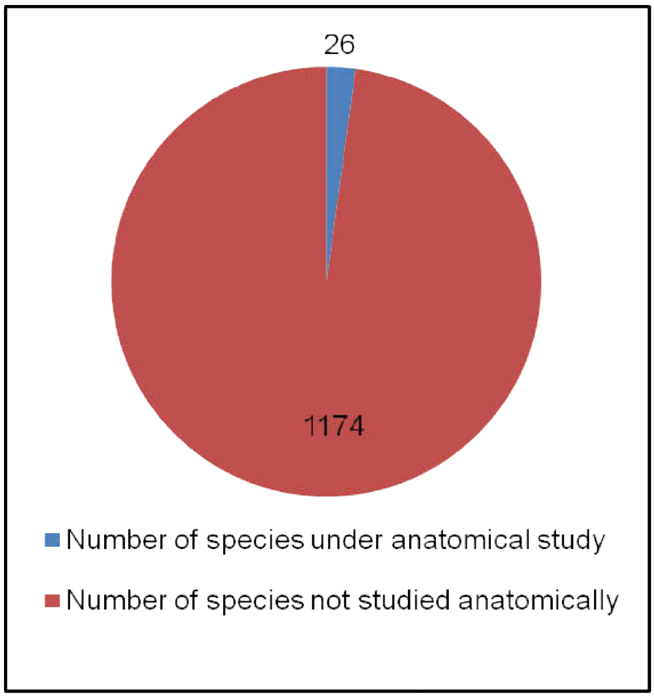

Fig. 2 A real feature of anatomical research on plants of Verbenaceae.

3.5. Anatomical features of plant of genus *Tectona*

Tectona grandis is native to south and southeast Asia, mainly India, Sri Lanka, Indonesia, Malaysia, Thailand, Myanmar and Bangladesh but is naturalized and cultivated in many countries in Africa and the Caribbean. Myanmar's teak forests account for nearly half of the world's naturally occurring teak. Molecular studies show that there are two centers of genetic origin of teak: one in India and the other in Myanmar and Laos (Vaishnaw et al., 2015; Verhaegen et al., 2010).

The variations in anatomical characteristics namely fiber length, fiber diameter, fiber lumen width and cell wall thickness of *Tectona grandis* wood age 15, 20 and 25-year old were investigated by Izekor & Fuwape (2011). Six trees from each even aged stand and similar class diameter selected from Edo State Forestry plantations were used. Wood samples were systematically collected from the outer, middle and inner wood sections of the radial and longitudinal positions at 10, 50 and 90% of the tree height. Fiber length, fiber diameter and cell wall thickness increased with increase in age while fiber lumen width decreased with increase in age. However all the anatomical characteristics were examined in this study increased from inner wood to outer wood but decreases from the base to top.

The radial variation of some anatomic characteristics, wood density and natural durability of teak (*Tectona grandis* L.F.) growing in Costa Rica were reported (Moya et al., 2009). Samples of trees 13 years old were obtained from two growing sites (high and low growing) of plantations established in a humid tropical climate (CHT) and drytropical climate (CST). The variables measured of the fibers as well as for the rays were not affected by the climate or the type of growing site, except for the length of the fibers. The fibers of teak wood from the best growing site were significantly larger. Vessels were found with a greater frequency for the CST but mostly solitary in comparison with the CHT. Average density, maximum density and the variation within the ring presented a light higher magnitude for the CST. The quality of the growing site did not affect these variables. Radial variation of anatomical features, wood density and decay resistance in teak (*T. grandis*) from two qualities of growing sites and two climatic regions of Costa Rica were found.

The changes of anatomical features in plants were to compare in *in vitro* culture and *ex vitro* of leaves of *T. grandis* (Junior et al., 2009). The stomata in *ex vitro* culture showed smaller dimensions, while the thickness of cuticle, the epidermal cells and parenchyma of palisade were thicker leaves developed in *ex vitro*. The results indicate adaptive plasticity of *T. grandis*, which could allow the acclimatization of micro propagated plants.

Structural alterations induced in response to fungal invasion are described (Sanghvi et al., 2013). At the outset, fungal mycelia entered into wood tissue through vessels and xylem rays, invading all cell types by ramifying through pits on lateral walls. Fungal invasion commenced from the cell corners and the middle lamellae of the fiber wall, without any pronounced effect on the primary and secondary wall layers. Xylem cells were separated due to dissolution of middle lamella in the early stage, but in the advanced stages of decay all cell types showed formation of erosion channels and bore holes. In the advanced stage of infection, vessels were deformed due to explicit degeneration and eventually collapsed due to loss of rigidity. Xylem rays were more vulnerable to degradation than axial elements.

The anatomical characteristics with porosity is ring-porous and semi-ring porous distinct in *T. grandis* (Nordahlia et al., 2014). Growth rings are distinct, straight, wavy or slightly interlocked, rather coarse to coarse, predominantly solitary and some with radial multiples of 2–3. Vessels diffuse, sometimes arrange in radial series, mainly oval, sometimes round, yellow deposits or tyloses are common. Axial parenchyma is sparsely vasicentric in latewood, in marginal or in seemingly marginal bands. Multiseriate rays are 3–6 cells and homocellular. The ring porous and semi ring porous wood are also described (Josue & Imiyabir, 2011). The wood textured is rather coarse with the grain straight to shallowly interlocked. The arrangements of the vessels, rays and parenchyma cells were characterized. The vessels are diffuse, moderately few, mainly oval, sometimes round, predominantly solitary and some with radial multiples 2 to 3. Yellow deposits or tyloses are common. The tangential diameters of solitary vessels in ring porous wood. Rays are 1 to 3 seriates but predominantly 3 to 5 seriates. All ray cells are procumbent. Axial parenchyma is sparsely vasicentric in latewood, in marginal or in seemingly marginal bands. The perforation plate is simple with intervessel pits alternate. Fibers are exclusively septet with two to several septa per fiber. The fibers can be classified as thin to thick-walled (Wheeler et al., 1989). Most of the microscopic features of the teak also observed (Ogata et al., 2008).

3.6. Anatomical features of plant of genus *Citharexylum*

The *Citharexylum* is a genus, contains shrub and tree species (Whistler, 2000), commonly known as fiddlewoods or zitherwoods (Quattrocchi, 2000). They are native to the Americas, ranging from southern Florida and Texas in the United States to Argentina. The highest diversity occurs in Mexico and the Andes (Aymard & Ricardo, 1997). *C. caudatum* and *C. spinosum*, are cultivated as ornamentals (Whistler, 2000).

Marcati et al. (2014) reported that the qualitative anatomical features of *Citharexylum myrianthum* did not vary between stem and root wood; differences between the organs were found only in quantitative features. Growth rings distinct, delimited by marginal bands, semi-ring-porous wood, and slightly distended rays in early wood, and radially flattened fibers with thick walls in the latewood. In addition, the axial parenchyma pattern varied through the growth ring, with marginal bands and confluent irregular bands in the earlywood, and confluent and lozenge-aliform in latewood. Vessels: predominantly solitary, in multiples of 2 and of 3–6; fine helical thickenings throughout the body of vessel element in both earlywood and latewood; vessel element tails of different shapes in one or both tips; simple perforation plates, radiate, and foraminate-reticulate perforation plates, transverse or inclined; intervessel pits alternate, circular; vessel-ray pits similar to intervessel pits in shape and in size. Rays: predominantly multiseriate, heterocellular, body ray cells procumbent with one row of upright and/or square marginal cells. Axial parenchyma: paratracheal aliform, confluent forming irregular bands, and initial marginal bands; variable from 3–4 cells per strand mostly, occasionally more than 6 cells per strand; cells forked, with projections, and undulations. Fibres: thin- to thick- walled; simple to minutely bordered small pits only in radial walls; septate fibres and nonseptate fibres present; fibres with wall interruptions; forked and with a wide range of tip shapes. Mineral inclusions: acicular calcium oxalate crystals in ray parenchyma cells (procumbent, upright and/or square cells). Vessel element parameters including length, tangential diameter, and frequency, as well as ray height were significantly different between root and stem. Root wood had lower vessel frequency, longer and narrower vessel elements when compared to stem wood. Root wood had taller rays than stem wood. Stomata of the anomocytic type occur on both surfaces of the leaf, having stomata predominantly on the abaxial surface of *C. myrianthum*. Simple and glandular trichomes occur on both surfaces of the leaf. The leaf blade has dorsiventral organization, in which of the palisade parenchyma reveals two layers of cells. The epidermis of the abaxial surface exhibits sinuates anticlinal walls. The anatomy features were studied using both light and scanning electron microscopy (Juck et al., 1997).

Acicular calcium oxalate crystals were found in cambial fusiform and ray cell initials, as well as in their daughter cells in *C. myrianthum*. An abundance of crystals was observed during periods of water deficit and leaf fall (July). Fewer crystals were found in the beginning of the wet season and bud swelling (September). When trees were ftowering and the soil was wet (November and December), acicular crystals were rarely observed in differentiating phloem and xylem parenchyma cells, in fully differentiated phloem cells, but not in fully differentiated xylem cells (Marcati & Angyalossy 2005).

Both the qualitative and quantitative features of all secondary phloem cell types, and compared the quantitative features. The same percentage of sieve tubes in the conducting phloem between the organs indicates a similar conducting efficiency between stem and roots, even though sieve tubes have wider diameters in the stems of *C. myrianthum*. Overall, stems had a higher portion of non-conducting secondary phloem than the roots, with a higher number of both parenchyma and sclerenchyma bands, likely indicating a higher storage and support potential of the phloem in stems (Vergílio et al., 2017).

Siegloch et al. (2013) reported the wood anatomy of *Citharexylum montevidense* Moldenke is described. The wood structure presents: small diameter vessels; solitary and short radial multiple pores; medium length vascular elements, with appendices; simple perforation plates; medium size intervascular pits, with alternate-ornamented bordered pits; scanty paratracheal parenchyma; heterogeneous rays; and septate fibers.

3.7. Anatomical features of plant of genus *Vitex*

Vitex genus has about 250 species (Raymond et al., 2004), common names include "chaste tree" or "chastetree". Species of *Vitex* are native throughout the tropics and subtropics, with a few species in temperate Eurasia (David, 2008). About 18 species are known under cultivation. *V. agnus-castus* and *V. negundo* are often grown in temperate climates (Anthony et al., 1992). About six others are frequently grown in the tropics (George & Derral, 2005).

Indistinct to distinct growth rings observed in *Vitex lucens* (Patel, 1974). Vessels evenly distributed; round to oval, also angular; solitary, or in radial multiples and occasionally as oblique tangential pairs; slight tendency towards oblique pattern in areas with predominantly radial multiples; perforation plates simple; intervascular pits randomly arranged, angular, extremely fine spiral thickening present; tyloses and dark brown deposits sometimes present; pits to rays in different forms i.e., somewhat similar to intervascular pits, also radially elongated with border, or round to axially and radially elongated without border. Vascular tracheids are absent. Axial parenchyma moderately frequent to infrequent; initial, scanty paratracheal to vasicentric. also diffuse. diffuse-in-aggregates, rarely banded. Rays homogeneous to heterogeneous· type III. occasionally heterogeneous type II; dissected rays often present; axially united rays occasional; sheath cells absent. Fibers thin to very thick-walled; pits simple to almost simple, more numerous on radial walls than on tangential walls.

Dogan et al. (2008) reported anatomical studies made on *V. agnus-castus* showed similar characteristics of other species of the Verbenaceae to which this species belongs (Metcalfe & Chalk, 1957). In the cross-section of the secondary root, it was seen that, derived from the cork, the periderm tissue is formed, which replaces the epidermis in the outer layer. The next tissue identified inwards was the cortex. Sclerenchyma was seen as a ring in the secondary roots, while as a group, formed from a group of cells, in the mature ones. In the middle, xylem tissue occupies a large area, just below the phloem tissue.

The observations concerning the root showed a parallelism with the results of Metcalfe & Chalk (1957). The stem, as a typical characteristic of the Verbenaceae, is quadrangular (Watson & Dallwitz, 1994). Nonglandular hairs take place on the epidermis. In the outer layer of the young stem, the epidermis covered by a cuticle was observed. In the mature stem, the periderm replaces the epidermis, and the cork cells are thin-walled. In the peripheral part of the stem, collenchymatous tissue is seen as a layer. The sclerenchymatous tissue is found as a continuous ring in the young stem, while it is found as cell groups in the mature stem. Just below the cortex, phloem tissue is seen. Beneath the phloem tissue, cambium tissue from 3 to 5 cell layers is found. Under the cambium tissue, xylem tissue takes place. Wood parenchyma is similar, simple and elongated. Rays become much broader in the mature wood. The pith of the plant stem is formed from parenchymatous cells. On the other hand, the existence of the starch was determined in the pith cells. Richter & Dallwitz (2000) studied the *Vitex* species used as commercial timbers. Since *V. agnus-castusis* not used as a timber, they did not include the species in their study. They reported that they saw tylosis in the vessels of the species that they studied, and they concluded that this was the characteristics for the entire *Vitex* genus.

However, in this study, the same structure is not seen in *V. agnus-castus*. They also concluded that there is no stored structure in *Vitex* genus, but it was found as a result of our study that *V. agnus-castushas* starch deposition in the pith of the stem. The anatomical structure in the cross section of the stem is in accord with the general characteristics of the members of the Verbenaceae (Metcalfe & Chalk, 1957). In the leaves, the outer surface of the upper epidermis is covered by a cuticle with non-glandular hairs on its surface. These hairs are short and conical. These results show a parallelism with the record of Metcalfe & Chalk (1957). However, two-celled, non-glandular longer hairs in the lower epidermis (Fig. 5) were not mentioned by Metcalfe & Chalk (1957). The stomata were found only in the lower surface of the leaf, on the same level with the epidermis. It was observed that leaves of *V. agnus-castus* do not have subsidiary cells, and the epidermis cells surround the stomata (anomocytic type). Beneath the upper epidermis, a single layer hypodermis is found. The next layer is the palisade parenchyma. Its cells are arranged very tightly in three to four rows and are rich with chlorophyll. The intercellular spaces are rare. In the records of Metcalfe & Chalk (1957), we do not find any information about the thickness of the palisade parenchyma. Just beneath the palisade parenchyma, the spongy parenchyma is found. Its cells contain less chlorophyll in comparison to the palisade parenchyma cells and their air spaces are larger. Oxalate sands were found in the transverse section of the leaves. Described as prismatic cyristals, the existence of oxalate sands in the anatomic sections of the leaf is also reported by Metcalfe & Chalk (1957) and Özörgücü et al. (1991). Similarly, Richter & Dallwitz (2000) reported that some *Vitex* species have prismatic crystals, while others do not. In *V. agnus-castus*, they were seen only in the cross sections of the leaf.

3.8. Anatomical features of plant of genus *Teucridium*

Teucridium is a genus of flowering plant in this family. It contains only one known species, *Teucridium parvifolium*, endemic to New Zealand (Allan, 1961; Moldenke, 1981).

Patel (1974) reported in *Teucridium parvifoliu*, observed growth rings indistinct to distinct in the stem. Vessels more or less evenly distributed; considerably larger in early wood than in latewood; slight tendency towards radial and oblique patterns; solitary or in radial multiples, or in longer chains; perforation plates simple; intervascular pits round; sometimes angular; randomly arranged; more or less uniform in diameter; spiral thickening conspicuous; tyloses absent; dull yellow deposits occasional; pits to rays similar to intervascular pits; also simple, round, angular. Vascular tracheids occasional; spiral thickening conspicuous. Axial parenchyma sparse; scanty paratracheal; diffuse; also diffuse-in-aggregates with tendency towards being boundary type: 2-4 cells/strand; also fusiform. Rays heterogeneous type II. sometimes also type I; composed almost entirely of upright cells; I-S cells wide; multiseriates; uniseriates; dissected and axially united rays often present; sheath cells irregularly distributed. Fibers mostly thick to very thick-walled; rarely septate; pits simple to almost simple, more numerous on radial walls than on tangential walls.

3.9. Anatomical features of plant of genus *Verbena*

Verbena is a genus, contains about 250 species of annual and perennial herbaceous or semi-woody flowering plants. The majority of the species are native to the Americas and Asia. *Verbena officinalis*, the common vervain or common verbena, is the type species and native to Europe (Botta et al., 1995).

Six species of Verbena like as *Verbena gracilescens* (Cham.) Verter; *V. bonariensis* L.; *V. intermedia* Gillies and Hook; *V. litoralis* Kunth; *V. montevidensis* Spreng. and *V. rigida* Spreng were studied (Moecelle et al., 2012). The stems and leaves of these species were fixed and transverse sections were cut for observation with a light microscope in order to differentiate their anatomical features. Likewise a scanning electron microscope and an environmental scanning electron microscope were used to study the leaf surface of these species. The type and density of stomata and glandular and nonglandular trichomes were analyzed in all species, as well as the internal structure of the leaf and stem.

3.10. Anatomical features of plant of genus *Stachytarpheta*

Stachytarpheta is a plant genus in this family. The flowers are rich in nectar and popular with many butterflies, such as the South Asian crimson rose, Malabar banded swallowtail, and grass yellow and humming birds. Several species in this genus are known as porter weeds (Natural Resources Conservation Services, 2015).

Siegloch et al. (2014) reported that the wood structure presents: semi-diffuse porous wood; radial multiple pores; medium length vascular elements, with appendices; simple and scalar form perforation plates; small altemate vestured pits; scanty par tracheal parenchyma; heterogeneous rays; and short libriform fibers in *Stachytarpheta glabra* Cham. Investigations on the anatomical features of the leaf and petiole of three species of Stachytarpheta (*S. angustifolia*, *S. cayannensis* and *S. jamaicensis*) were reported by Okeke et al. (2015), was made with the aid of a light microscope. Anatomical significant features were found in the leaf and petiole. The leaves and petioles were dorsiventral. The epidermis was conspicuous but one cell thick. The epidermal cells in the leaves were not of uniform size in both surfaces. Chlorenchyma was present as a very narrow portion of the leaves and petiole tissue while the palisade layer was one to three cells thick. These features however, could not proffer any taxonomic relevance to the delimitation of any of the species in this genus.

4. CONCLUSION

Twenty six species of Verbenaceae deliberated anatomically among 1200 species newly narrowed by phylogenetic study. Among 26 species, a few species studied anatomically heavily and rest of them studied partially. *Avicennia marina,* *Lantana camara, Tectona grandis, Citharexylum myrianthum* and *Vitex agnus-castus* studied profoundly. The point of view it is stated the maximum species of this family were not undertaken anatomical studies. The more anatomical studies were needed on the plants of this family on the basis of importance and socioeconomic aspects.

5. REFERENCES

Siegloch, A. M., Marchiori, J. N. C., Santos, S. R. D. (2014) Estudo Anatomico Do Lenho De *Stachytarpheta* glabra Cham. (Verbenaceae). *Balduinia*, 44, 17-20.

Allan, H.H. (1961). *Flora of New Zealand*. R.E. Owen, Government Printer, Wellington.

Anthony, J. H., Mark G. & Margot L. (1992). *The New Royal Horticultural Society Dictionary of Gardening*. The Stockton Press, New York.

Argyropoulou, C., Akoumianaki-Ioannidou, A., Christodoulakis, N. S. and Fasseas, C. (2010). Leaf anatomy and histochemistry of *Lippia citriodora* (Verbenaceae). *Australian Journal of Botany*, 58, 398–409.

Atkins, S. (2004). Verbenaceae. *In*: The Families and Genera of Flowering Plants, Kadereit J. W. (ed.), Springer-Verlag, Berlin, Germany, pp. 449 – 468.

Aymard, G. A. & Ricardo M. R. (1997). A new species of *Citharexylum* (Verbenaceae) from Ecuador. *Novon*, 7(2), 95–97.

Ball, M. C. & Farquhar G. D. (1984). Photosynthetic and stomatal responses of two mangrove species, *Aegiceras corniculatum* and *Avicennia marina* to long term salinity and humidity conditions. *Plant Physiology January*, 74, 1-6.

Borkar, M. U., Athalye, R. P. & Goldin, Q. (2009). Salinity induced changes in the leaf anatomy of the mangrove *Avicennia marina* along the anthropogecically stressed tropical creek. *Journal of Coastal Development*, 14(3), 191-201.

Botta. S. M., Martinez, S. & Romero, M. E. M. D. (1995). Nomenclatural revisions in Verbenaceae. *Hackney*, 2, 127–128.

Brummitt, R. K. (1992). *Vascular Plants: Families and Genera*. Kew: Royal Botanic Gardens.

Camurça-Vasconcelos, A. L., Bevilaqua, C. M, Morais, S. M, Maciel, MV, Costa CT, Macedo IT, Oliveira LM, Braga RR, Silva RA, Vieira LS & Navarro AM (2008). Anthelmintic activity of *Lippia sidoides* essential oil on sheep gastrointestinal nematodes. *Veterinary Parasitology*, 154,167-170.

Camurça-Vasconcelos, A. L., Bevilaqua, C. M., Morais, S. M., Maciel, M. V., Costa, C. T., Macedo, I. T., Oliveira, L. M., Braga, R. R., Silva, R. A. & Vieira, L. S. (2007). Anthelmintic activity of *Croton zehntneri* and *Lippia sidoides* essential oils. *Veterinary Parasitology*, 148,288-294.

Cantino, P. D., Harley, R. M. & Wagstaff, S.J. (1992). Genera of Labiatae: status and classification. *In:* Advances in Labiate Science, Harley RM & Reynolds T (Eds.), Richmond, Royal Botanic Gardens, Kew, pp. 511-522.

Caroprese, A. J. F, Parra, G. M. I., Arrieta, P. D. & Stashenko, E. (2011). Microscopic anatomy and volatile secondary metabolites at three stages of development of the inflorescences of *Lantana camara* (Verbenaceae). *Rev. Biol. Trop.*, 59(1), 473-86.

Casanova, E., García-Mina, J. M. & Calvo, M. I. (2008). Antioxidant and antifungal activity of *Verbena officinalis* L. leaves. *Plant Foods for Human Nutrition*, 63, 93-97.

Combrinck, S., Plooy, G. W. D., McCrindle, R. I. & Botha, B. M. (2007). Morphology and histochemistry of the glandular trichomes of *Lippia scaberrima* (Verbenaceae). *Annals of Botany*, 99, 1111–1119.

David, J. M. (2008). *Mabberley's Plant-Book*, Third Edition. Cambridge University Press, UK.

Diab, E. A. & Bolus, S. T. (2014). The effect of petroleum pollutants on the anatomical features of *Avicennia marina* (Forssk.) Vierh. *Intl. J. Sci. Res.*, 3(12), 2503-2515.

Dogan, Y., Ay, G. & Kozuharova, E. (2008). A study on the anatomical characteristics of *Vitex agnus-castus* (Verbenaceae). *Phytologia Balcanica*, 14(1), 95-101.

Duletić-Laušević, S., Marin, P. D., Marin, M. & Grujić-Jovanović, S. (1997). Laboratory of plant anatomy, chair of plant morphology and systematic. *Helia*, 20, 17.

Elpel's, T. J. (2013). *Botany in A Day*, Sixth Edition. HOPS Press, LLC, Arizona.

El-Tarabily, K. A. & Youssef T. (2010). Enhancement of morphological, anatomical and physiological characteristics of seedlings of the mangrove *Avicennia marina* inoculated with a native phosphate solubilizing isolate of *Oceanobacillus picturae* under greenhouse conditions. *Plant Soil*, 332,147–162.

Francino, D. M. T. (2006). Anatomia foliar e caulinar de Chamaecrista trichopoda (Caesalpinioideae) e histoquímica do nectário extrafloral. *Planta Daninha*, 24(4), 695-705.

Fuwape, J. A., Onyekwelu, J. C. & Adekunle, V. A. J. (2001). Biomass equations and estimation for *Gmelina arborea* and *Nauclea diderrichii* stands in Akure forest reserve. *Biomass and Bioenergy*, 21, 401–405.

George, W. S., & Derral, R. H. (2005) *A Tropical Garden Flora*, Bishop Museum Press, Honolulu.

Germplasm Resources Information Network (2004). "GRIN Genera of Verbenaceae, Germplasm Resources Information Network. United States Department of Agriculture", available at: https://en.wikipedia.org/wiki/Verbenaceae/(accessed 10 October 2011).

Ggarcia, T. B., Potigura, R. C. D. V., Kikuhi, T. Y. S., Demarco, D. & Aguiar-Dias, A. C. A. (2014) Leaf anatomical features of three *Theobroma* species (Malvaceae *s.l.*) native to the Brazilian Amazon, *Acta Amazonica*, 44(3), 291 – 300.

Ghowail, S. I., Abdel-Monem, A. M , El-Ghamry, W. M. & Saber N. E. (1993). Preliminary studies on the effect of different salinity levels on germination, growth and anatomy of mangrove (*Avicennia marina*). *Tasks for Vegetation Science*, 27, 237-244.

Görnemann, T., Nayal, R., Pertz, H. H. & Melzig, M. F. (2008). Antispasmodic activity of essential oil from *Lippia dulcis* Trev. *Journal of Ethnopharmacology*, 117, 166-169.

Hadad, M., Susana, G., Martha, G., Gabriela, F. & Alejandro, T. (2013). Anatomical studies of *Baccharis grisebachii* Hieron. (Asteraceae) used in folk medicine of San Juan province, Argentina. *Dominguezia*, 29(2), 41-47

Hallahan, D. L. & Gray, J. C. (2000). *Advances in Botanical Research: Plant Trichomes*. Academic Press, Botanical Research Society, Germany.

Heywood, V. H., Brummitt, R. K., Culham, A. & Seberg, O. (2007). *Flowering Plant Families of the World*. Royal Botanic Gardens, Kew.

Hogarth, P. J. (1999). *The Biology of Mangroves*, Oxford University Press, New York, USA

Izekor, D. N. & Fuwape, J. A. (2011). Variations in the anatomical characteristics of plantation grown *Tectona grandis* wood in Edo State, Nigeria. *Archives of Applied Science Research*, 3(1), 83-90.

Jatsa, H. B., Ngo-Sock, E. T., Tchuem-Tchuente, L. A. & Kamtchouing, P. (2009). Evaluation of the *in vivo* activity of different concentrations of *Clerodendrum umbellatum* Poir against *Schistosoma mansoni* infection in mice. *African J. Traditional Complementary and Alternative Medicines*, 6, 216-221.

Jezler, C. N., Ariana, R. M. F., Oliveira, A. R. M. F., Batista, R. S., Oliveira, R. A., Silva, D. C. & Costa, L. C. B. (2013). *Lippia alba* morphotypes cidreira and melissa exhibit significant differences in leaf characteristics and essential oil profile Brazilian. *Journal of Pharmacognosy*, 23(2), 217-223.

Josue, J. & Imiyabir, Z. (2011). Anatomical features, quality and mechanical properties of 15-year-old *Tectona grandis* (Teak) planted in Sabah. *In:* ITTO Project on Improving Utilization and Value Adding of Plantation Timbers from Sustainable in Malaysia, Tan YE, Gan KS & Lim SC (Eds.), Reka Cetak Sdn. Bhd., Klang, Selangor Darul Ehsan. pp. 1-33.

Juck, D. B. F., Nakashima, T., Alquini, Y. & Cervi, A. C. (1997). Leaf anatomy of *Citharexylum myrianthum* Cham. (Verbenaceae). *Plant Anatomy*, 78, 69-72.

Junior, F., Poeta, P. C., Pereira, S. & Everson, J. (2009). Anatomical characteristics of leaves from Teak (*Tectona grandis* L.f.) developed under *in vitro* and *ex vitro* culture conditions. *Evidência Joaçaba*, 9, 17-28.

Kim, K. H., Kim, S., Jung, M. Y., Ham, I. H. & Whang. W. K. (2009). Anti-inflammatory phenylpropanoid glycosides from *Clerodendron trichotomum* leaves. *Archives of Pharmacal Research*, 32, 7-13.

Kyhos, D. W. & Carr, G. D. (1994). Chromosome stability and liability in plants. *Evolutionary Theory*, 10, 227-248.

Lamb, A. F. A. (1968). *Fast Growing Timber Trees of the Lowland Tropics No. 1: Gmelina arborea*. University of Oxford and Commonwealth Forestry Institute, Oxford, England.

Lorenzi, H. & Matos, F. J. A. (2008). *Plantas Medicinais no Brasil - Nativas e Exóticas*. Nova Odessa: Instituto Plantarum de Estudos da Flora.

Machado, M., Dinis, A. M., Salgueiro, L., Cavaleiro, C., Custódio, J. B. & Sousa-Mdo, C. (2010). Anti-Giardia activity of phenolic-rich essential oils: effects of *Thymbra capitata*, *Origanum virens*, *Thymus zygis* subsp. *sylvestris*, and *Lippia graveolens* on trophozoites growth, viability, adherence, and ultrastructure. *Research*, 106, 1205-1215.

Marcati, C. R. & Angyalossy, V. (2005). Seasonal presence of acicular calcium oxalate crystals in the cambial zone of *Citharexylum Myrianthum* (Verbenaceae). *IAWA Journal*, 26(1), 93-98.

Marcati, C. R., Longo, L. R., Wiedenhoeft, A. & Barros, C. F. (2014). Comparative wood anatomy of root and stem of *Citharexylum myrianthum* (Verbenaceae). *Rodriguésia*, 65(3), 567-576.

McLeod, E. & Salm, R.V. (2006). *Managing Mangroves for Resilience to Climate Change,* IUCN, Gland, Switzerland.

Metcalfe, C. R. & Chalk, L. (1957). Anatomy of the Dicotyledons. II. Claredon Press, Oxford.

Moecelle, M. R. M., Gattuso, M. A. & Apóstolo, N. M. (2012). Stem and leaf anatomy of six species of Verbena native to Buenos Aires province, Argentina. *New Zealand Journal of Botany*, 50(1), 3-14.

Moldenke, H. N. (1981). Notes on the genus Teucridium (Verbenaceae). *Phytologia*, 48, 439-444.

Morales, G., Paredes, A., Sierra, P. & Loyola, L. A. (2008). Antioxidant activity of 50% aqueous-ethanol extract from *Acantholippia deserticola*. *Biological Research*, 41, 151-155.

Moya, R., Berrocal, A., Serrano, J. R. & Tomazello, M. (2009). Radial variation of anatomical features, wood density and decay resistance in teak (*Tectona grandis*) from two qualities of growing sites and two climatic regions of Costa Rica. *Investigación Agraria: Sistemas Recursos Forestales*, 18(2), 119-131.

Munsif, S., Khan, M. A., Ahmad, M., Zafar, M., Shah, G. M. & Shaheen, N. (2007). Leaf epidermal anatomy as an aid to the identification of genera *Lantana*, *Verbena* and *Vitex* of family Verbenaceae from Pakistan. *J. Agri. Soc. Sci*., 3(2), 43-46.

Natural Resources Conservation Services (2015). "Stachytarpheta. Natural Resources Conservation Service Plant Database USDA", available at: https://en.wikipedia.org/wiki/Stachytarpheta(accessed 30 November 2015).

Nordahlia, A. S., Lim, S. C., Hamdan, H. & Anwar, U. M. K. (2014). Wood properties of selected plantation species: *Tectona grandis* (Teak), *Neolamarckia cadamba* (Kelempay/ Laran), *Octomeles sumatrana*

(Binuang) and *Paraserianthes falcataria* (Batai). *Technology*, 54, 1-7.

Ogata, K., Fujii, T., Abe, H. & Bass, P. (2008). *Identification of the Timbers of Southest Asia and the Western Pacific*. Kaiseisha Press, Japan.

Okeke, C. U., Iroka, C. F., Izundu, A. I. & Nkumah, O. C. (2015). Comparative systematic leaf and petiole anatomical studies of the genus Stachytarpheta found in Awka Nigeria, *Journal of Medicinal Plants Studies*, 3(4), 82-84.

Ozorgucu, B., Gemici, Y. & Turkan, I. (1991). *Kar Jlat Jrmal J Bitki Anatomisi*. Ege Üniv. Fen Fak. Yay. No. 129. zmir.

Passos, J. L., Meira, R. M. S. A. & Barbosa, L. C. A. (2009). Oliar anatomy of the speies *Lantana camara* and *L. radula* (Verbenaeae). *Planta Daninha, Viçosa-MG*, 27(4), 689-700.

Patel, R. N. (1974). Wood anatomy of the dicotyledons indigenous to New Zealand 5. Verbenaceae. *New Zealand Journal of Botany*, 12, 33-44.

Purnobasuki, H. & Suzuki, M. (2005). Functional anatomy of air conducting network on the pneumatophores of a mangrove plant, Avicennia marina (Forsk.) Vierh. *Asian J. Plant Sci*., 4(4), 334-347.

Quattrocchi, U. (2000). *CRC World Dictionary of Plant Names: A-C*. CRC Press, Australia.

Raymond, M. H., Sandy, A., Andrey, L. B., Philip, D. C., Barry, J. C., Renée, J. G.r, Madeline, M. H., Rogier, P. J. de K., Tatyana, V. K., Ramón, M., Alan, J. P., & Ryding, P.O. (2004). Labiatae. *In:* The Families and Genera of Vascular Plants, *Kubitzki K. & Kadereit JW (Eds.), Springer-Verlag, Berlin, Heidelberg, Germany, pp.* 167-275.

Richter, H. G. & Dallwitz, M. J. (2000). “Commercial timbers: descriptions, illustrations, identification and information retrieval”, available at: http://biodiversity.uno.edu/delta/(accessed 4th May 2000).

Robert, E. M. R., Koedam, N., Beeckman, H. & Schmitz, N. (2009). A safe hydraulic architecture as wood anatomical explanation for the difference in distribution of the mangroves *Avicennia* and *Rhizophora*. *Functional Ecology*, 23, 649–657.

Roy S. & Barua A. K. (1985). The structure and stereochemistry of a triterpene acid from *Lantana camara Phytochemistry,* 24(7), 1607-1608.

Safdari, V. & Shadman, P. (2015). Wood anatomy of an Iranian Mangrove plant, *Avicennia marina* (Forsk) Vierth growing in mangrove forests (Ghashem Island). *Iranian Journal of Wood and Paper Science Research*, 29(4), 560-570.

Salimena, F. R. (2010). Uma nova espécie de *Lippia* L. (Verbenaceae) do cerrado brasileiro. *Acta. Bot. Bras*., 24, 232-234.

Sanghvi, G. V., Koyani, R. D. & Rajput, K. S. (2013). Anatomical cahractersation of teak (*Tectona grandis*) wood decayed by fungus *Chrysosporium asperatum. Journal of Tropical Forest Science*, 25(4), 547–553.

Sharma, O. P., Makkar, H. P. S., Dawra, R.K. (1988). A review of the noxious plant *Lantana camara*. *Toxicon*, 26(11), 975-987.

Shou-liang, C. & Gilbert, M. G. (1994). Verbenaeae. *Flora of China*, 17, 1–49.

Shukla, N., Kumar, M., Akanksha, A. G., Rahuja, N., Singh, A. B., Srivastava, A. K., Rajendran, S. M. & Maurya, R. (2010). Tectone, a new antihyperglycemic anthraquinone from *Tectona grandis* leaves. *Natural Product Communications*, 5, 427-430.

Siegloch, A. M., Marchiorp, J. N. C. & Santos, S. R. D. (2013). Estudo Anatomico Da Madeira De *Citharexylum* Montevidense Moldenke (Verbenaceae), *Balduinia*, 42, 27-32,

Sulaiman, M. R., Zakaria, Z. A., Chiong, H. S., Lai, S. K., Israf, D. A. & Azam, S. T. M. (2009). Antinociceptive and anti-inflammatory effects of *Stachytarpheta jamaicensis* (L.) Vahl (Verbenaceae) in experimental animal models. *Medical Principles and Practice*, 18, 272-279.

Sultana, R. S. (2016). Stem and leaf anatomy of *Lantana camara* L. - a plant of the Verbenaceae family. *Int. J. Curr. Res. Biosci. Plant Biol.*, 3(1), 27-31.

Thenmozhi, S., Subasini, U., Kameshwaran, S., Dhanalakshmi, M. & Victor-Rajamanickam, G. (2013). Morpho-anatomical and preliminary phytochemical studies of leaves of *Gynandropsis pentaphylla* Linn. *Intl. J. Pharmacy & Life Sci*. 4(7), 2800-2809.

Tozin, L. R. D. S., Carvalho, S. F., Machado, S. R. & Rodrigues, T. M. (2015). Glandular trichome diversity on leaves of *Lippia origanoides* and *Lippia stachyoides* (Verbenaceae): morphology, histochemistry, and ultrastructure . *Botany*, 93(5), 297-306.

Vaishnaw, V. V., Naseer M., Wali, S. A., Kumar, R., Tripathi, S. B., Singh, N. M., Akhtar, A. S. (2015). AFLP markers for analysis of genetic diversity and structure of teak (*Tectona grandis*) in India. *Canadian Journal of Forest Research*, 45(3), 297–306.

Vale, T. G., Furtado, E. C. & Santos, J. G. (2002). Central effects of citral, myrcene and limonene, constituents of essential oil chemotypes from *Lippia alba* (Mill.) N.E. Brown. *Phytomedicine*, 9, 709-714.

Valkama, E. (2003) Comparative analysis of leaf trichome structure and composition of epicuticular flavonoids in Finnish Birch species. *Ann. Bot*., 91(6), 643-655.

Vergílio, P. C. B., Silva, J. R. D. S., Blagitz, M., Longo, L. R., Marcati, C. R. (2017). Structural differences in the secondary phloem suggests higher support and storage potential in stems than roots of *Cytharexylum myrianthum* Cham. (Verbenaceae). *Journal of Botany*, 95(9), 953-960.

Verhaegen, D., Fofana, I. J.; Logossa, Z. A. & Ofori, D. (2010). What is the genetic origin of teak (*Tectona grandis L.*) introduced in Africa and in Indonesia? *Tree Genetics & Genomes,* 6(5), 717–733.

Watson, L. & Dallwitz M. J. (1994). The families of flowering plants: descriptions, illustrations, identification, and information retrieval on CD-ROM version 1.0 1993, and colour illustrated manual. *Nordic Journal of Botany*, 14(5), 486.

Wheeler, E. A., Baas, P., Gasson, P. E. (1989). IAWA list of microscopic features for hardwood identification. *IAWA Bulletin*, 10(3), 219-332.

Whistler, W. A. (2000). *Tropical Ornamentals: A Guide*. Timber Press, Taxas, USA. pp. 128–130.

Xiao, Y., Zuliang, J., Wang, M., Lin, G. & Wang, W. (2009). Leaf and stem anatomical responses to periodical waterlogging in simulated tidal floods in Mangrove *Avicennia marina* seedlings. *Aquatic Botany*, 91(3), 231-237.

Yáñez-Espinosa, L. & Flores, J. (2011). A review of sea-level rise effect on Mangrove forest species: anatomical and morphological modifications. *In:* Global Warming Impacts - Case Studies on the Economy, Human Health, and on Urban and Natural Environments, Stefano Casalegno S. (Ed.), InTech China, Shanghai, China, pp. 23-78.

Yáñez-Espinosa, L., Angeles, G., López-Portillo, J. & Barrales, S. (2009). Variación Anatómica de la Madera de *Avicennia germinans* en la Laguna de La Mancha, Veracruz, México. *Boletín de la Sociedad Botánica de México*, 85, 7-15.

Yashsvi, B. (2008). "Verbenaceae: Characters, Distribution and Types", available at: http://www.biologydiscussion.com/angiosperm/dicotyledons/verbenaceae-characters-distribution-and-types/48476/(accessed 10 September 2003).

Zhang, C., Jose, M., Pereira, M., Correia, C., Coutinho, J., Goncalves, A., Guedes, A. & Laranjo, J. G. (2013). Foliar application of Sili-K increases chestnut growth and photosynthesis, simultaneously increasing susceptibility to water deficit. *Plant Soil*, 365, 211-225.