



## Morphological and Anatomical Studies on Selected Lamiaceae Medicinal Plants in Bani Matar District, Sana'a (Yemen)

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### Abstract

Morphological and anatomical characters of stem, petiole and leaves of 16 selected medicinal taxa of family Lamiaceae collected from Bani Matar district, Sana'a (Yemen) were examined using both stereo- and light microscopes. The obtained macro- and micromorphological characters (298) were analysed using the software *jmp* version 13. The resulted dendrogram was discussed on the light of the current taxonomic treatments of Lamiaceae. The measurement of the quantitative characters of macro- and micromorphological characters for the studied taxa was established by multivariate analysis of variance (ANOVA). Evaluation of obtained results revealed that, many characters viz. leaf composition, stomatal types and distribution, number of stamens, stem and petiole vasculature, types of trichomes, nutlet features, number of palisade and spongy layers and types of crystals are of diagnostic value in species identification and delimitation and are potentially valuable at different taxonomic levels. All the quantitative macro- and micromorphological characters except nutlet length are highly significant in species delimitation.

**Key words:** Anatomy, ANOVA, cluster analysis, Lamiaceae, medicinal plants, morphology, Yemen.

### Introduction

Lamiaceae is the sixth largest angiosperm family with about 236 genera and 7173 species distributed throughout the world in both temperate and tropical regions; its main distribution is in the Mediterranean (Harley *et al.*, 2004 & Singh, 2010).

In Yemen, Lamiaceae is one of the most important families due to use in folk medicine and for the commercial production of essential oils. It includes 23 endemic species, (AL-Khulaidi, 2013).

The members of Lamiaceae are generally aromatic, including a number of widely used culinary herbs, such as basil, lavender, marjoram, mint, oregano, rosemary, sage, savory and thyme (Wink, 2003; Celiktas *et al.*, 2007, Hussain *et al.*, 2008).

Traditionally, plant taxonomy has depended mainly upon comparative morphological features because the help in taxa delimitation and identification (Pandey & Misra 2014). Many publications pointed out on the importance of morphological characters in delimitation and identification in some Lamiaceae species ( Satil *et al.*, 2007; Baran

*et al.*, 2008; Kahraman *et al.*, 2009; Celep *et al.*, 2011 & Kiliç, 2014).

The anatomical characters of vegetative organs are important for characterization of Lamiaceae taxa (Metcalf & Chalk, 1950; Abu-Asab & Cantino, 1987; Kahraman *et al.*, 2009, 2010). The glandular hairs and their distribution (Werker, 2006), stomatal distribution and other anatomical features provide significant taxonomic information (Dinç & Öztürk., 2008; Celep *et al.*, 2011 and Venkateshappa & Sreenath, 2013). In addition, these features play an important role in elucidating phylogenetic relationships in many taxa (Pandey & Misra, 2014).

The aim of the present work is to investigate the different morphological and anatomical features of the taxa under study in Bani Matar district Sana'a (Yemen) and evaluate them in taxa identification and delimitation.

### Material and Methods:

#### 1. Plant Materials

Sixteen selected medicinal Lamiaceae taxa belonging to 13 genera were collected

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from their natural habitats except two species from cultivated fields in Bani Mater district, Sana'a Governorate, Yemen; during their flowering and fruiting seasons 2014-2016.

Table (1) represents the data of collection. The identification of the specimens was achieved by utilizing the available taxonomic and floristic literature (Wood 1997; Chaudhary 2001; Boulos 2002; Ibrahim 2013). Nomenclature of taxa followed IPNI. The specimens are kept in Herbarium of Botany Department, Faculty of Science, Ain Shams University and Biology Department, Faculty of Science, Sana'a University.

### 2. Macromorphological Investigation

The macromorphological characters of the studied taxa; stem, leaf, inflorescence, flower and fruit were described from the living specimens and photographed by using digital Sony camera (HRD- CX 700 -12.3 Mega pixels).

### 3. Micromorphological Investigation

Cross sections of the stem, petiole and lamina were made using the embedding paraffin wax technique (Johanson, 1940). The sections were examined using Bel. BIO3 T-PL light microscope and photographs were taken by digital camera power =shot G12, 10 Mega pixels.

### 4. Lamina Epidermal Characters

For leaf epidermal study, at least five leaves were cut at the median portion and soaked in concentrated Nitric acid for two - ten hrs. The appearance of air bubbles indicated the readiness of epidermises to be separated. The samples were transferred to Petri dishes containing water and with the use of fine forceps and dissecting needle the adaxial and the abaxial epidermises were separated (Ibrahim & Ayodele, 2013). The two epidermal layers (Adaxial & Abaxial) were stripped and stained with Saffranin and mounted in glycerin (Sreelakshmi *et al.*, 2014). Photomicrographs were taken using light microscope and camera (Canon power-shot G12, 10 mega pixels), the magnification power was expressed by (X). Terminology of epidermal characteristics based on Dilcher (1974).

### 5. Macro - and Micromorphological Measurements

Measurements of ten quantitative macromorphological characters for the studied taxa viz. stem length, leaf length & width, calyx, corolla, stamen, bract and seed were taken. Also, the micromorphological measurements (viz. thickness of cuticle, epidermal cells size (length x width), cortex, secondary phloem and xylem, pith width, palisade and spongy cells were determined by the ocular micrometer.

### 6. Statistical Analysis

The obtained macro- and micromorphological data were used to construct a data matrix for numerical analysis. The presence or absence of the obtained characters was coded as 1 and 0 respectively to determine the relationship between the different studied taxa using the software *jmp* version 13 for Sas Institute Inc (2017) through hierarchical cluster method average linkage modules (Sokal & Michener, 1958). For each of the quantitative measurements, the significant differences between the taxa studied was established by multivariate analyses of variances (ANOVA).

## Results and Discussion

### 1. Qualitative macromorphological characters

Macromorphological characters and their states of all studied taxa were summarized in (Table 2 & Plate 1-3). The most diagnostic characters are: the habit; shrub in *Meriandra dianthera*, undershrub in the three *Lavandula* spp. and *Otostegia fruticosa* or herb in the remaining examined taxa. All taxa studied are aromatic except *Lavandula coronopifolia* and *Marrubium vulgare*. This result agreed with that of Harley *et al.*, (2004); Chaudhary, (2001); Wood, (1997).

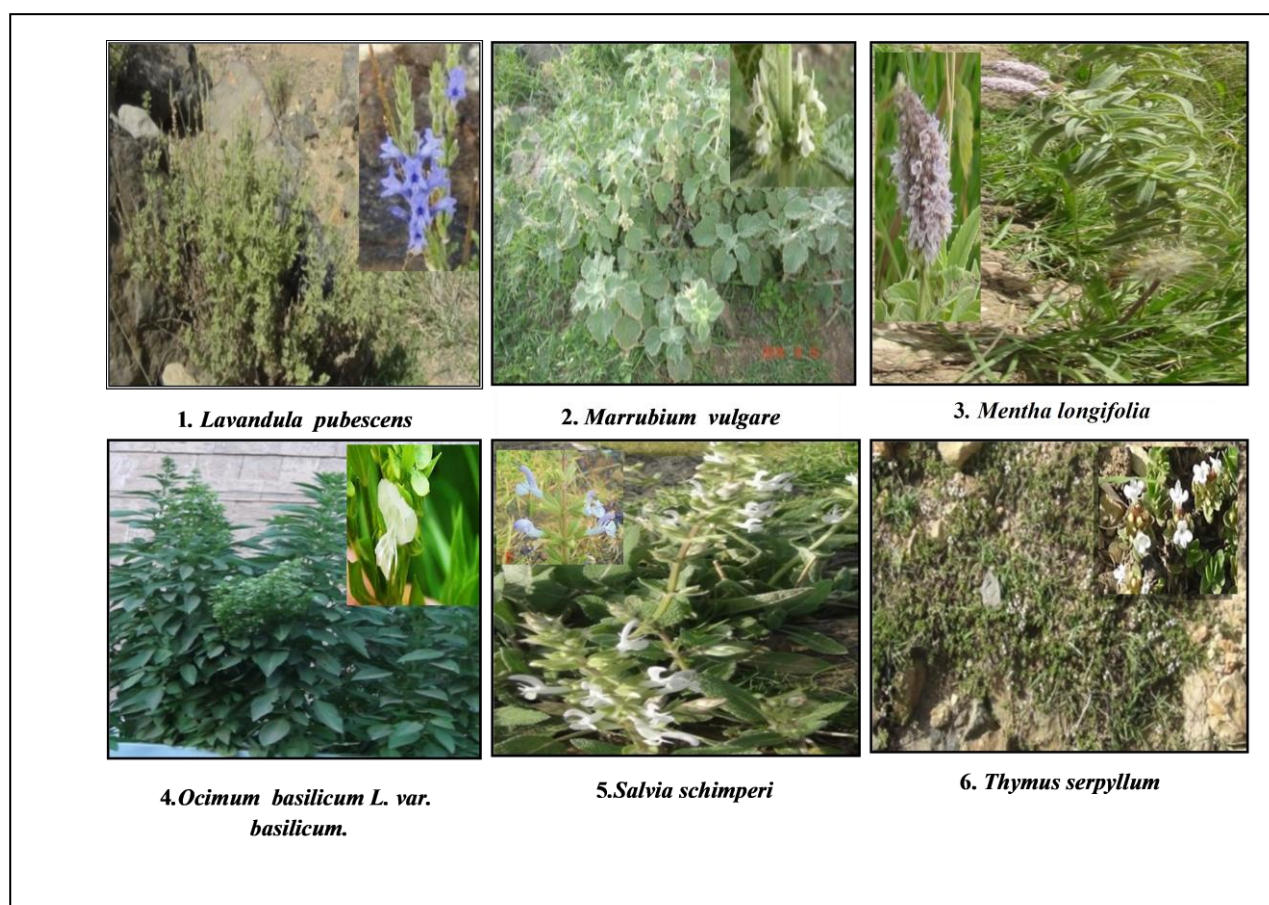
All studied taxa are erect except *Thymus serpyllum* is procumbent. The stem is semicircular in *Leucas inflata* and *Thymus serpyllum*, circular in *Meriandra dianthera*, *Otostegia fruticosa*, *Teucrium yemense* and squared in all other taxa. The leaves are simple in all studied taxa except, *Lavandula* spp. are pinnatisect. Leaves petiolate in seven taxa

while sessile-subsessile in the remaining nine taxa. Other leaf morphological features viz., arrangement, shape, margin, apex, base, texture presented variations between taxa and useful at the interspecific relationships.

In most of the studied taxa, the position and the number of flowers per inflorescence varied. In addition, the corolla color shows great variations among studied taxa. The corolla is four lobed in *Mentha longifolia*, bilobed in 13 taxa while bilobed densely villous in *Leucas inflata* and *Otostegia fruticosa*. Bract was present in all studied taxa except *Leucas inflata* and *Mentha longifolia* while bracteoles are absent in all studied taxa except five. Calyx had different shapes and with teeth in all studied taxa except *Otostegia fruticosa* and *Origanum majorana*. The basic number of stamens is four, but in *Salvia schimperi* and *Meriandra dianthera* being two.

It was clear that some macromorphological characters viz. lamina shape, flower position and number, corolla color and stamen number are taxonomically significant for Lamiaceae taxa identification and delimitation. This result is in accordance with that of Wood (1997); Chaudhary (2001); Kahraman *et al.*, (2009) and Ibrahim, (2013).

The areole is present, in *Lavandula coronopifolia*, *L. pubescens* and *Nepeta deflersiana* and absent in the remaining taxa. The nutlets showed different shapes, color and size between the studied taxa. The taxonomic value of nutlet characteristics of Lamiaceae as diagnostic character had been discussed by many authors (Husain *et al.*, 1990; Hussein, 1995; Marin *et al.*, 1998; Moon *et al.*, 2009; Salimpour *et al.*, 2014; Hassan & AL-Thobaiti, 2015 and Badamtsetseg, 2016).



**Plate 1 (Figs. 1-6):** Whole plants of some studied taxa.

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**Table (1).** Vernacular name, localities and collection data of the studied taxa

No	Medicinal taxa	Vernacular name	Village	Elevation (m)	Longitude E	Latitude N	Date of collection
1	<i>Lavandula citriodora</i> A. G. Mill.	Sh'at ran	Nimran	2700	44°10'24.24	15°11'0.14	1/10/2015
2	<i>Lavandula coronopifolia</i> Poir. = <i>L. stricta</i> Delile.	Ha'naz	Hamil	2402	44° 11 11.9	15° 13 44 .5	10/8/2014
3	<i>Lavandula pubescens</i> Decne.	Va'heia	Kusher	2681	44 °66 32 9	15° 15 37 .8	14/9/2015
4	<i>Leucas inflata</i> Benth. = <i>physoleucas acrodonta</i> Jaub.& Spach	Ba'udh	Artil	2402	44 °12 06 .3	15 °14 18 .6	20/5/2016
5	<i>Marrubium vulgare</i> L.	Hei' wjazzp	AL saih	3353	435741.8	15 15 5 8.1	20/5/2016
6	<i>Mentha longifolia</i> L. = <i>M. sylvestris</i> L.	Na'ud	Subahah	2567	44° 9'9.75	15°16'25.89	19/9/2015
7	<i>Meriandra dianthera</i> (Roem. & Schult.)Briq. = <i>Meriandra bengalensis</i> (Roxb.) Benth.	darū	Kusher	2681	44° 66 32 9	15° 15 37 .8	10/9/2015
8	<i>Nepeta deflersiana</i> Schweinf. ex Hedge	Ad'hat alnoub	Al- saih	3355	43° 57 41.8	15° 15 5 8.1	9/8/2015
9	** <i>Ocimum basilicum</i> L. var. <i>basilicum</i>	Ra'ehan ahmer	Kusher	2681	44° 66 32 9	15° 15 37 .8	20/8/2015
10	** <i>Ocimum basilicum</i> var. <i>purpurascens</i> Benth.	Rahan abudh	Kusher	2681	44° 66 32 9	15° 15 37 .8	20/8/2015
11	** <i>Origanum majorana</i> L.	ba'rduqsh	Kusher	2681	44° 66 32 9	15° 15 37 .8	20/5/2016
12	<i>Otostegia fruticosa</i> (Forssk.) Schwienf. ex. Penzing subsp. <i>schimperi</i> (Benth.) Sebald	Sh'iqub	Baty naamah	2686	44° 9'9.75	15°16'25.89	28/8/2015
13	<i>Salvia schimperi</i> Benth.	Ma'smes	Kusher	2958	44°10'32.90	15°15'37.80	20/5/2016
14	* <i>Stachys yemenensis</i> Hedge	Ha'lal	Bayt al-ahmer	2958	43° 5 81 6.5	15° 14 53.6	12/8/2015
15	* <i>Teucrium yemense</i> Deflers	As'abai merem	Bayt al-ahmer	2958	43° 5 81 6.5	15° 14 53.6	22/8/2015
16	<i>Thymus serpyllum</i> L. = <i>Thymus laevigatus</i> Vahl	Za'tar, Sa'tar	Al- Bald	3353	43° 5657.2	15° 16 09.3	15/8/2015

\*\*cultivated taxa,\* Endemic taxa.

Table (2). Qualitative macromorphological characters of the studied taxa

Character & Character state		Taxa																
		LC	LCO	LP	LI	MV	ML	MD	ND	OBB	OBP	OM	OF	SS	SY	TY	TS	
Duration	Perennial	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
	Annual	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	
Habit	Undershrub	+	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	
	Herb	-	-	-	+	+	+	-	+	+	+	+	-	+	+	+	+	
	Shrub	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	
Aromatic		+	-	+	+	-	+	+	+	+	+	+	+	+	+	+	+	
Stem	Strength	Erect	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
		Procumbent	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
	External Appearance	Square	+	+	+	-	+	+	-	+	+	+	+	-	+	+	-	-
		Semicircular	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-
		Circular	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-
	Internal appearance	Solid	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
		Hollow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
	Texture	Sub- glabrous	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Glabrous	-	+	-	-	-	-	-	-	+	+	-	-	-	-	-	-
		Tomentose	-	-	-	+	-	-	+	+	-	-	+	+	-	+	+	+
		Woolly	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-
		Pubescent	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
		Densely pubescent	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
	Leaf	Arrangement	Opposite decussate	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Clustered			-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Opposite- whorled			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Composition		Pinnatisect	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
		Simple	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+
Shape		Oblong-linear	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
		Orbicular	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
		Lanceolate	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-
		Ovate	-	-	-	-	-	-	-	+	-	+	+	-	-	-	-	-
		Elliptic	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
		Oblong-elliptic	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
		Oblong – lanceolate	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
		Oblanceolate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Margin		Obovate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
		Dentate	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
		Entire	+	-	-	+	-	-	-	-	+	+	+	-	-	+	-	+
		Crenate	-	-	-	-	+	-	-	+	-	-	-	+	-	-	-	-
		Sharply serrate	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
		Denticulate	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
		Irregularly serrated	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Apex		Serrate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
		Obtuse	+	+	+	-	-	-	-	+	-	-	-	-	+	-	-	+
		Cleft & crenate	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
		Obtuse - acute	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
		Acute	-	-	-	-	-	+	+	-	+	+	-	+	-	+	-	-
		Rounded	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Base		Subacute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
	Truncate	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Subcordate	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	
	Cuneate	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	
	Rounded	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	
	Cordate	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	
	Cuneate-Truncate	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	
	Acute	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	
	Attenuate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	
	Oblique	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Color	Adaxial surface	Green	+	+	+	+	-	-	-	+	+	+	+	-	-	-	-	
		Dark green	-	-	-	-	+	+	+	-	-	-	-	+	-	-	-	+
		Green - white	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
		Grey	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
	Abaxial surface	White	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
		Green	+	+	+	+	-	-	-	+	+	+	+	-	-	-	-	-
		Grey	-	-	-	+	-	+	-	+	-	-	-	-	-	-	-	+
		White	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-
	Dark green	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	
	Green – white	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	

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**Table 2. Cont'd.**

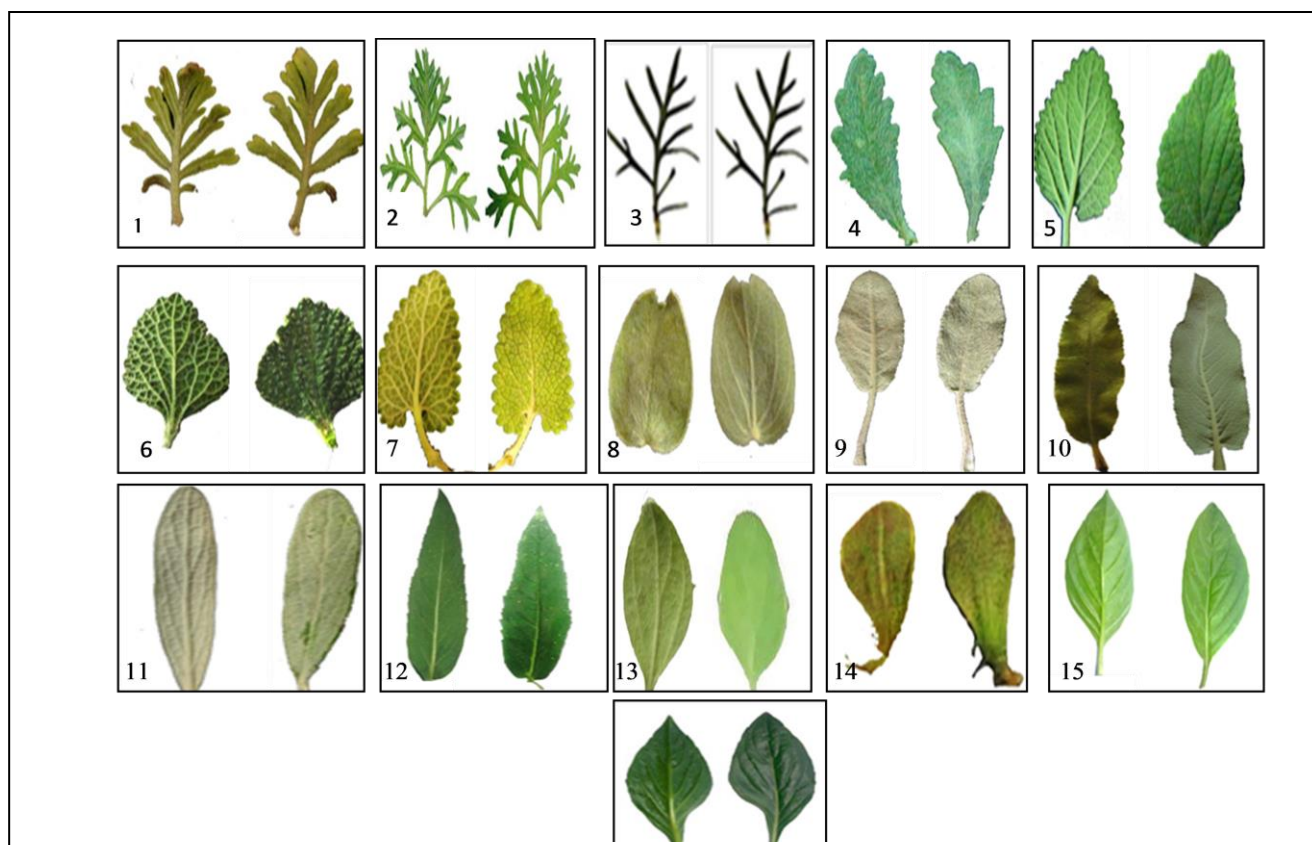
Character & Character state		Taxa																	
		LC	LCO	LP	LI	MV	ML	MD	ND	OBB	OBP	OM	OF	SS	SY	TY	TS		
<b>Leaf</b>	<b>Texture</b>	Thinly tomentose	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
		Thinly pubescent	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Densely pubescent	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Tomentose	-	-	-	+	-	+	-	-	-	-	-	-	-	+	+	-	
		Tomentose & wrinkled	-	-	-	-	+	-	+	+	-	-	-	-	+	+	-	-	
		Slightly pubescent	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	
		Densely tomentose	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	
	<b>Position</b>	Ciliated & Punctate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	
		Terminal panicle	+	+	+	-	-	+	-	-	+	+	-	-	-	-	-	-	
		Whorl	-	-	-	+	+	-	+	+	-	-	-	+	+	+	-	-	
		Axial spicates	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	
	<b>Number</b>	Dense terminal heads	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	
		2	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	
		6-10	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	
		3-7	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
		5-8	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	
		Many	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-	+	
	<b>Bract</b>	<b>Present</b>	Present	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	
			Absent	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	
		<b>Shape</b>	Ovate Acute	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
			Orbicular	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
			Ovate	-	-	-	-	-	-	+	-	+	+	-	+	-	-	-	-
			Linear-setaceous	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
			Obovate	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+
			Broadly ovate	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
			Oblong lanceolate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
	Lanceolate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+		
	<b>Bracteoles</b>	<b>Present</b>	Present	-	-	-	+	+	+	-	-	-	-	-	+	-	+	-	
			Absent	+	+	+	-	-	-	+	+	+	+	+	-	+	-	+	+
		<b>Shape</b>	Minut	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
			Subulate- hooked	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
			Linear-setaceous	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
			Spinose pubescent subulate	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
			3- unequal spinose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
			Cylindrical	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
		<b>Calyx</b>	<b>Shape</b>	Tubular -obconical	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
				Tubular prickley	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Campanulate with 2 lippes	-			-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	
Obconical & bilabiate	-			-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	
Tubular	-			-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	
Sea-shell shaped with flat limb	-			-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	
Tubular with 2 lippes	-			-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	
bladder like	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	+		
<b>Teeth</b>	Present	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+		
	Absent	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-		
<b>No. Teeth</b>	5	+	+	+	-	-	+	-	+	-	-	-	-	+	+	+	+		
	10	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-		
	More than 10	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-		
	2	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-		
<b>Corolla</b>	<b>Color</b>	Blue -violet	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
		Blue	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	
		White	-	-	-	+	+	-	+	-	+	-	+	+	-	-	-	+	
		Lilac	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	
		Blue with dark blue spots	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	
		Purple	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	
		White with purple markings	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	
		Pink	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	
	Rosy pink	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	
	<b>Shape</b>	Bilobed	+	+	+	-	+	-	+	+	+	+	+	-	+	+	+	+	
		Bilobed with densely villous	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	
		Four lobed	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	
	<b>Stamens No.</b>	4	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	
2		-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-		

Table 2. Cont'd.

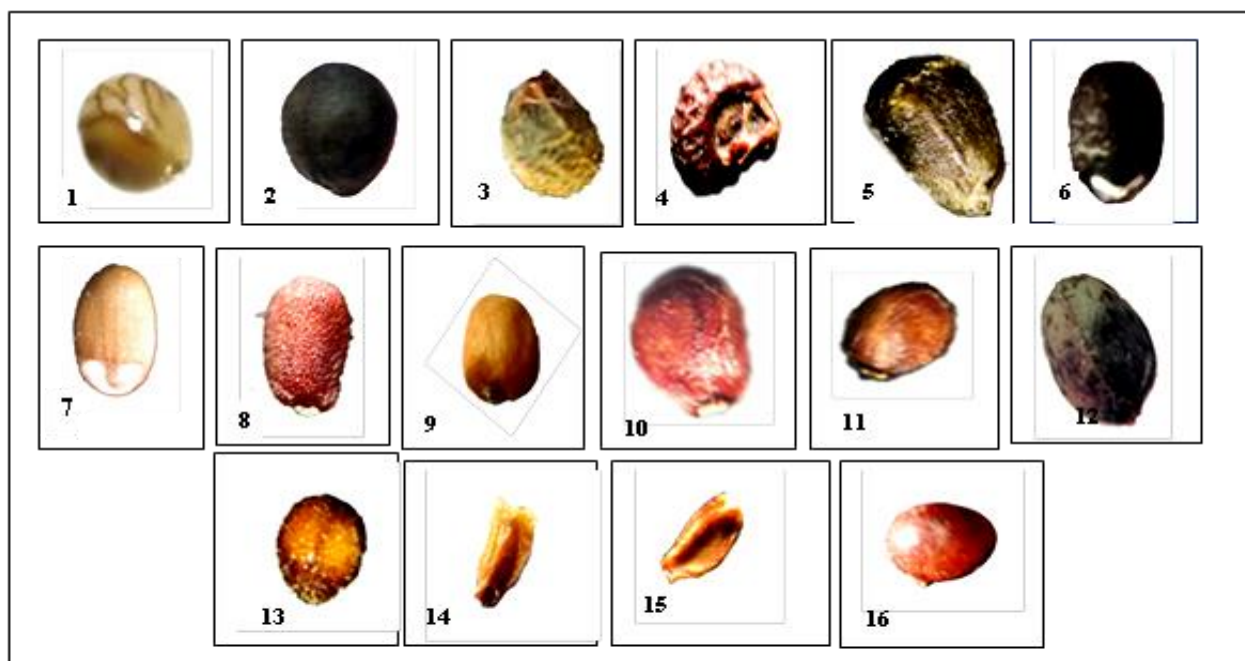
Character & Character state		Taxa																
		LC	LCO	LP	LI	MV	ML	MD	ND	OBB	OBP	OM	OF	SS	SY	TY	TS	
Nutlet	Shape	Trigonus – ovoid	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Ovoid	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-
		Oblong- ovoid	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
		Obovoid	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+
		Oblong-Trigonus	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
		Obovoid-elliptic	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
		Ellipsoid	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
		Semi –spherical with small hilum	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
		Trigonus	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
		Rounded-trigonus with dark strips	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
		Trigonus-obovoid	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
	Kidney –irregular	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	
	Color	Brown	+	+	+	-	+	+	-	-	+	+	+	-	-	-	+	+
		Grey	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
		Black	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
		Shiny green	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
		Greenish brown	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
		Gray with black spot	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
	Areole	Present	-	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-
		Absent	+	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+
Texture	Smooth	+	-	-	-	-	-	+	-	-	-	-	-	+	+	-	-	
	Warty	-	+	+	-	+	+	-	+	+	+	+	+	-	-	-	+	
	Reticulate & minute hairs	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	
	Reticulate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	

**Taxa abbreviations:** (LC) *Lavandula citriodora*, (LCO) *Lavandula coronopifolia*, (LP) *Lavandula pubescens*, (LI) *Leucas inflata*, (MV) *Marrubium vulgare*, (ML) *Mentha longifolia*, (MD) *Meriandra dianthera*, (ND) *Nepeta deflersiana*, (OBB) *Ocimum basilicum* var. *basilicum*, (OBP) *Ocimum basilicum* var. *purpurascens*, (OM) *Origanum majorana*, (OF) *Otostegia fruticosa*, (SS) *Salvia schimperii*, (SY) *Stachys yemenensis*, (TY) *Teucrium yemense*, (TS) *Thymus serpyllum*.

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**Plate 2. The leaves of the 16 studied taxa;** (1) *Lavandula citriodora*, (2) *L. pubescens*, (3) *L. coronopifolia*, (4) *Teucrium yemense*, (5) *Otostegia fruticosa*, (6) *Marrubium vulgare*, (7) *Nepeta deflersiana*, (8) *Leucas inflata*, (9) *Salvia schimperi*, (10) *Meriandra dianthera*, (11) *Stachys yemenensis*, (12) *Mentha longifolia*, (13) *Origanum majorana*, (14) *Thymus serpyllum*, (15) *Ocimum basilicum* var. *basilicum*, (16) *Ocimum basilicum* var. *purpurascens*



**Plate 3 (Figs. 1-16): Nutlet of 16 studied taxa;** (1) *Salvia*, (2) *Meriandra dianthera*, (3) *Leucas inflata*, (4) *Teucrium yemense*, (5) *Otostegia*, (6) *Nepeta deflersiana*, (7) *Lavandula coronopifolia*, (8) *L. pubescens*, (9) *Origanum majorana*, (10) *Ocimum basilicum* var. *purpurascens*, (11) *O. basilicum* var. *basilicum*, (12) *Stachys yemenensis*, (13) *Mentha longifolia*, (14) *Lavandula citriodora*, (15) *Marrubium vulgare*, (16) *Thymus serpyllum*.



## 2. Qualitative micromorphological characters

The qualitative anatomical characters of the studied taxa are presented here for the first time and summarized in Table (3)

### a. Stem (Table 3; Plate 4)

The epidermal cells are covered with a thick cuticle in eight taxa and thin cuticle in the other eight taxa. **Stomata** are observed in the three *Lavandula* spp. only while absent in the remainder taxa. Cortex including patches of sclerenchyma cells in three studied *Lavandula* spp., *Meriandra dianthera* and *Stachys yemenensis*. In addition, the endodermis well defined in all studied taxa except *Meriandra dianthera*, *Otostegia fruticosa* and *Salvia schimperi*. Vascular system is dissected or in the form of continuous siphonostele. Pith is solid in all taxa except *Thymus serpyllum* and including polyhedral parenchyma in 12 taxa or pentagonal and hexagonal cells in three *Lavandula* spp. and *Leucas inflata*. The crystals are needles, solitary, tuft like or druses were observed in the cortex of stem. In the obtained results, the pith is solid in all studied taxa except *Thymus serpyllum* while, Dinç *et al.* (2008) reported that some species of genus *Stachys* are with hollow pith and others with solid pith. Metcalfe & Chalk, (1979) stated that stems of many genera and species of the family Lamiaceae are quadrangular with well-defined collenchyma in four angles. In addition, they reported that sclerenchymatous tissue surround the phloem groups of vascular bundles. This report in accordance with the present results. Also, presence of sclerenchyma cells in a few studied species agree with Salmaki *et al.* (2011) who reported that the bundle sheath can be sclerenchymatous in a few species of *Stachys*. Solereder (1908) and Ryding (2010), mentioned that calcium oxalate crystals occur in leaves, stems, flowers and fruits of Lamiaceae in forms of needle-shaped or polyhedral crystals, druses and prismatic. The present results agree with these findings and

shows that crystals of great importance in identification and taxa delimitation.

### b. Petiole (Table 4; Plate 5)

Present in seven taxa while absent in the remaining taxa. In cross sections five types can be categorized; kidney shape (*Marrubium vulgare*), trigonometrica (*Nepeta deflersiana*), arc shape (two *Ocimum* varieties), half circle with wings (*Meriandra dianthera*), half circle (*Otostegia fruticosa* and *Salvia schimperi*). The epidermal cells are radially arranged in seven taxa while tangentially elongated in *Nepeta deflersiana* and *Meriandra dianthera*. The epidermal cells covered with a thick cuticle in five taxa except *Otostegia fruticosa* and *Salvia schimperi*. Ground system including one type of tissue in *Otostegia fruticosa* while the other taxa have two types. The angular collenchyma cells found in *Nepeta deflersiana* and two *Ocimum* varieties, Lamellar in *Marrubium vulgare*, *Meriandra dianthera* and *Salvia schimperi*. The shape of the petiole central vascular bundle has diagnostic value in species characterization in Lamiaceae (Shahri *et al.*, 2016; Akçin *et al.*, 2011; Shaheen, 2007; Eric *et al.*, 2007; Metcalfe & Chalk, 1979). In this study, the anatomical petiole characters of the examined seven taxa showed high variation which helped in species delimitation.

### c. Lamina (Table 5; Plate 6)

Characterized by isobilateral or dorsiventral, and there are variation in aspects of midrib region, only *Thymus serpyllum* and *Meriandra dianthera* characterized by presence of sclerenchyma cells while lamellar and angular collenchyma found in *Lavandula pubescens* and *Stachys yemenensis* and the other taxa have lamellar or angular. Midrib region cross sections can be categorized into five types: V shape, circular, flat (ribbon) shape, half circle and U shape. There are differences in vascular system aspects; rounded in *Origanum majorana*, *Lavandula coronopifolia* and *L. pubescens*, crescent in *L. citriodora*, *Leucas inflata*, *Marrubium vulgare*, *Salvia schimperi* and *Teucrium yemense* or arc shape in the remaining nine taxa. The number of vascular bundles in midrib region are, two in *Lavandula pubescens*, three

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in *Salvia schimperi* and one in the remaining 14 taxa. Crystals found only in eight taxa as tuft-like in *Nepeta deflersiana*, *Mentha longifolia* and *Teucrium yemense*, needle and solitary in *Marrubium vulgare*, duress in the three *Lavandula* spp. and *Leucas inflata*.

The results of the present work showed great differences in the studied taxa regarding lamina structure in dermal system, mesophyll tissue, midrib region and crystals. These parameters were used in studying the relationship among species of Lamiaceae and can be considered for different taxonomic purposes at the genus or species level (Metcalf & Chalk, 1950; Inyama *et al.*, 2016). Lamina epidermal surfaces are generally amphistomatic but hypostomatic in *Stachys yemenensis* only. The stomatal types are anisocytic in *Nepeta deflersiana* and *Otostegia fruticosa*, pericytic in *Mentha longifolia* and *Thymus serpyllum*, but more commonly dianisocytic in most taxa studied. Anticlinal wall is rounded in *Thymus serpyllum*, wavy in *Marrubium vulgare*, *Mentha longifolia*, two *Ocimum* varieties, *Origanum majorana*, *Salvia schimperi* and *Teucrium yemense* while straight in the eight remaining taxa. Inamdar & Bhatt (1972) found that in majority of species, the stomata occurred exclusively on the lower leaf surfaces. However, Cantino (1990) mentioned that both amphistomatic and hypostomatic lamina are found in the members of the family. The present results in accordance with Cantino (1990) finding. The results showed also, three types of stomatal development within the studied species; diacytic, anisocytic and pericytic and this result agree with EL-Gazzar & Watson (1970), Inamdar & Bhatt, (1972) and Grozeva *et al.* (2016). While Metcalfe & Chalk (1979), stated that, diacytic stoma type was the most common in Lamiaceae.

### d. Trichomes morphology (Table 6 and Plates 8 & 9)

In the present results, the types of trichomes observed among studied taxa are summarized in table (6) and selected micrographs of all types of trichomes are presented in plates (8 & 9). The types of trichomes showed considerable variation among the studied taxa and therefore are potentially valuable for

different levels of classification. This result agree with Ascensão *et al.*, (1995); Bokhari & Hedge, (1976); Xiang *et al.* (2010) and Hu *et al.* (2012).

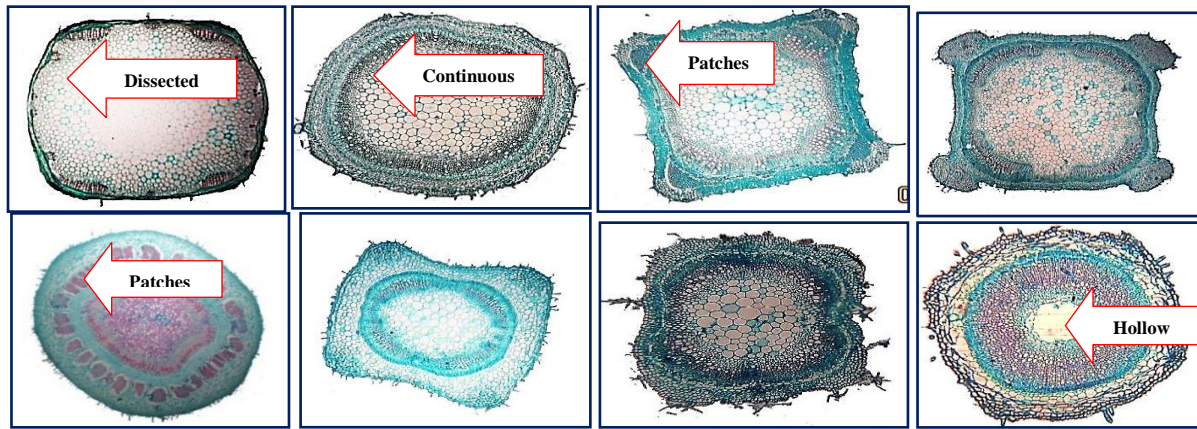
All taxa studied have eglandular and/or glandular trichomes. Peltate, capitate trichomes are the most diagnostic, and the stellate type is unique in *Marrubium vulgare* while capitate biramous in *Meriandra dianthera*. In some genera of Lamiaceae, trichome morphology is helpful in infrageneric classification (Marin *et al.*, 1994; Navarro & El-Oualidi, 2000; Yousefi *et al.*, 2015), as well as at specific levels (Bruni *et al.*, 1987; Giuliani *et al.*, 2008).

### 2. Quantitative macromorphological measurements (Table 7)

The mean measurements of ten quantitative macromorphological characters of the stem length, leaf, nutlet length and width, calyx, corolla, stamen, bract length for the studied taxa and the analysis of variance (ANOVA) are summarized in Table (7).

The results showed highly significant differences at  $P \geq 0.05$  between studied taxa in all characters except nutlet length. On the other hand, the stem length and leaf size of *Teucrium yemense*, *Thymus serpyllum* have the smallest values (12,17 cm), (1 X 0.5 & 0.9 X 0.4 mm) respectively while *Meriandra dianthera* and *Otostegia fruticosa* have the largest values of stem (200 & 150 cm), also *Meriandra dianthera* and *Salvia schimperi* have the largest values of leaf size (10 X 3.5 & 7.5 X 2.8 cm) respectively. The calyx, corolla, stamen, bract length of both *Otostegia fruticosa* and *Salvia schimperi* have the largest values: (12 and 19 mm), (22 and 35 mm), (15 and 25 mm) and (7 and 18 mm) respectively among 16 taxa while the remainder taxa show smallest and moderate length.

The nutlet length showed no significant differences  $P = 0.6$  among the studied taxa while nutlet width showed significant differences with  $P = 0.0001$ . The *Marrubium vulgare* and *Mentha longifolia* showed the smallest nutlet width.



**Plate 4. (Figs. 1-8).** Stem microphotographs showing different outline in T.S. , type of tissues in cortex, type of vascular system of the studied taxa of Lamiaceae (LM), (X=10-20). 1 & 7: Square, 2 &8: Semicircular, 5: Circular, 6: Square with two concave & two convex lateral sides. 3 & 4: Square with four bulging angles. 1. *Salvia schimperii*, 2. *Ostostegia fruticosa*, 3. *Lavandula pubescens*, 4. *Mentha longifolia*, 5. *Meriandra dianthera*, 6. *Origanum majorana*, 7. *Stachys yemenensis*, 8. *Thymus serpyllum*.

**Table (3):** Stem micromorphological characters of the studied taxa

Character and character states		Taxa															
		LC	LCO	LP	LI	MV	ML	MD	ND	OBB	OBP	OM	OF	SS	SY	TY	TS
Outline in T.S.	Square	+	+	+	-	+	+	-	+	+	+	+	+	+	+	-	-
	Semicircular	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
	Circular	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+
Cuticle	Thick	+	+	+	-	-	+	+	+	-	-	-	+	+	-	+	+
	Thin	-	-	-	+	+	-	-	-	+	+	+	+	-	-	+	-
Epidermal cells	Tangentially & radially	+	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-
	Tangentially	-	+	+	-	-	+	+	+	-	-	-	-	+	+	-	-
	Radially	-	-	-	-	+	-	-	-	+	+	+	-	-	-	+	-
Stomata	Present	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
	Absent	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+
No. of Tissues	3	+	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-
	2	-	-	-	+	+	+	-	+	+	+	+	+	+	+	+	+
	1	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	+
Type of tissues	Parenchyma	-	-	-	+	+	-	+	-	+	+	+	+	+	-	-	+
	Chlorenchyma	+	+	+	-	-	+	-	+	-	-	-	-	-	+	+	-
	Lamellar	+	+	+	-	+	+	+	+	+	+	+	+	-	-	-	+
	Angular & lamellar	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+	-
	Angular	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-
Sclerenchyma		+	+	+	-	-	-	+	-	-	-	-	-	-	+	-	-
Endodermis		+	+	+	+	+	+	-	+	+	+	+	-	-	+	+	+
Crystals	Duress	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
	Needles & solitary	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
	Tuft like	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
	Solitary	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
Pith cell wall	Thick	+	+	+	+	-	+	+	+	-	-	-	+	-	+	+	-
	Thin	-	-	-	-	+	-	-	-	+	+	+	-	+	-	-	+
Type of pith cells	Penta- hexagonal	+	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-
	Polyhedral	-	-	-	+	+	+	+	+	+	+	+	-	+	+	+	+
Pith section	Hollow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
	Solid	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
Type of vascular system	Continuous	+	+	+	+	-	-	+	-	+	+	-	+	-	-	+	+
	Dissected	-	-	-	-	+	+	-	+	-	-	+	-	+	+	-	-
Fascicular	Vessels	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Fibers	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Parenchyma	-	-	-	+	-	+	+	+	+	+	+	+	+	+	+	-
Interfascicular	Vessels	-	-	-	-	-	+	-	-	-	-	+	-	-	+	+	+
	Fibers	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Parenchyma	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-

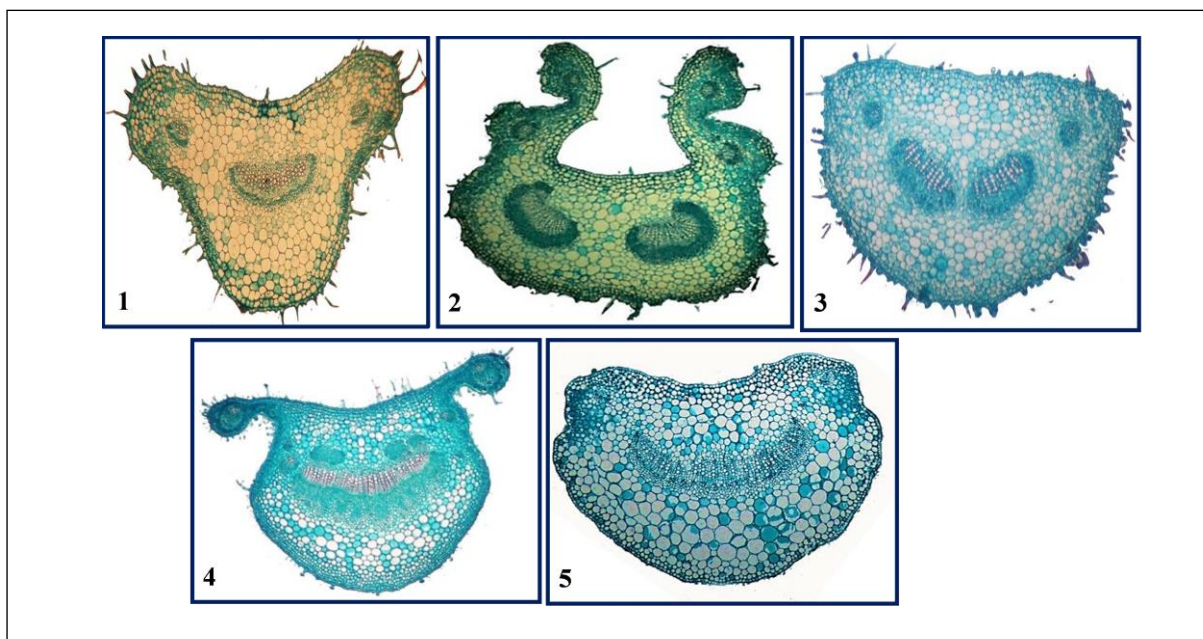
Taxa abbreviations: (LC) *Lavandula citriodora*, (LCO) *Lavandula coronopifolia*, (LP) *Lavandula pubescens*, (LI) *Leucas inflata*, (MV) *Marrubium vulgare*, (ML) *Mentha longifolia*, (MD) *Meriandra dianthera*, (ND) *Nepeta deflersiana*, (OBB) *Ocimum basilicum* var. *basilicum*, (OBP) *Ocimum basilicum* var. *purpurascens*, (OM) *Origanum majorana*, (OF) *Ostostegia fruticosa*, (SS) *Salvia schimperii*, (SY) *Stachys yemenensis*, (TY) *Teucrium yemense*, (TS) *Thymus serpyllum*

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**Table (4):** Petiole micromorphological characters of seven studied taxa (nine taxa sessile).

Character and character states		Taxa															
		LC	LCO	LP	LI	MV	ML	MD	ND	OBB	OBP	OM	OF	SS	SY	TY	TS
Petiole	Present	-	-	-	-	+	-	+	+	+	-	+	+	-	+	+	-
	Absent	+	+	+	+	-	+	-	-	-	-	+	-	-	-	+	+
Outline in T.S.	Kidney	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-
	Half circle with wings	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
	Trigonometric	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
	Arc	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
	Half circle	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
Cuticle	Thin	-	-	-	-	+	-	+	+	+	+	-	-	-	-	-	-
	Thick	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
Epidermal cells	Radially	-	-	-	-	+	-	+	+	+	+	-	+	+	-	-	-
	Tangentially	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
No. of Tissues	2	-	-	-	-	+	-	+	+	+	+	-	-	+	-	-	-
	1	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Parenchyma	Polyhedral	-	-	-	-	+	-	+	-	+	+	-	-	+	-	-	-
	Penta- hexagonal	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-
Collenchyma	Lamellar	-	-	-	-	+	-	+	-	-	-	-	-	+	-	-	-
	Angular	-	-	-	-	-	-	-	+	+	+	-	+	-	-	-	-
Aspect of vascular system	Arc	-	-	-	-	+	-	+	+	+	+	-	+	+	-	-	-
No. of Bundles	3	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
	6	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-
Crystals	Solitary	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-

**Taxa abbreviations:** (LC) *Lavandula citriodora*, (LCO) *Lavandula coronopifolia*, (LP) *Lavandula pubescens*, (LI) *Leucas inflata*, (MV) *Marrubium vulgare*, (ML) *Mentha longifolia*, (MD) *Meriandra dianthera*, (ND) *Nepeta deflersiana*, (OBB) *Ocimum basilicum* var. *basilicum*, (OBP) *Ocimum basilicum* var. *purpurascens*, (OM) *Origanum majorana*, (OF) *Otostegia fruticosa*, (SS) *Salvia schimperii*, (SY) *Stachys yemenensis*, (TY) *Teucrium yemense*, (TS) *Thymus serpyllum*.



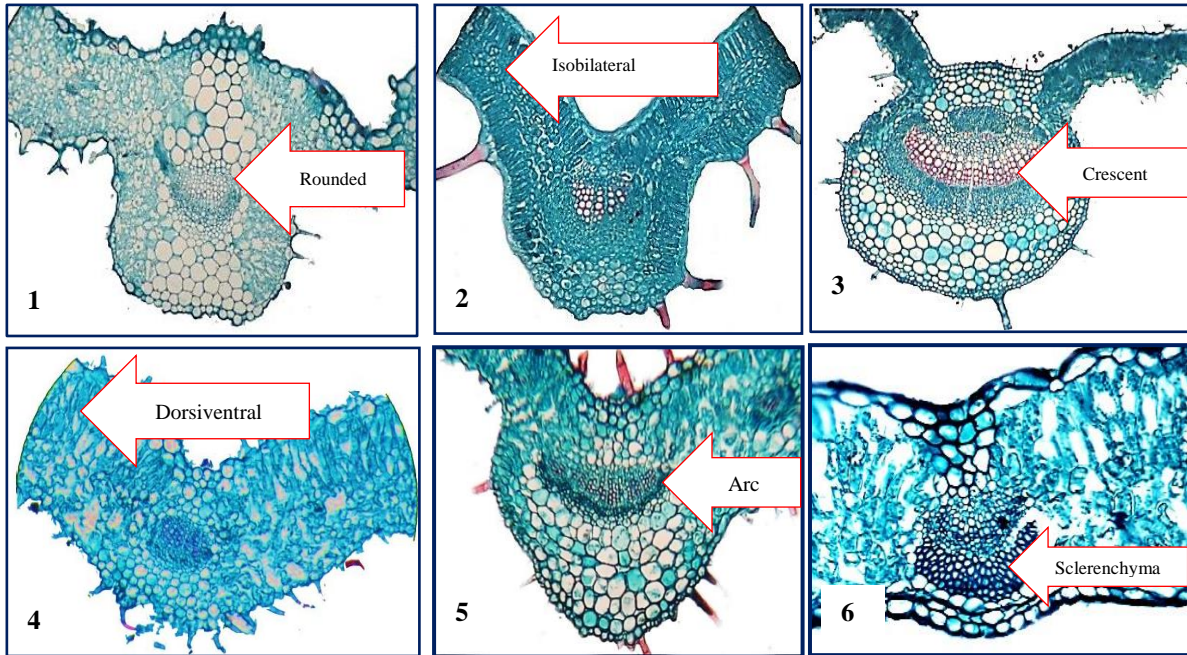
**Plate 5 (Figs. 1-5).** Petiole microphotographs showing different outline aspects of the petiole, in the studied taxa of Lamiaceae (LM), (X=20): 1: Trigonometric, 2: Kidney, 3: Half circle, 4: Half circle with wings, 5: Arc. 1: *Nepeta deflersiana*, 2: *Marrubium vulgare*, 3: *Otostegia fruticosa*, 4: *Meriandra dianthera*, 5: *Ocimum basilicum* var. *basilicum*.

Table (5): Lamina micromorphological characters of the studied taxa.

Character and character states		Taxa																
		LC	LCO	LP	LI	MV	ML	MD	ND	OBB	OBP	OM	OF	SS	SY	TY	TS	
Cuticle	Thick	+	+	+	+	-	+	+	-	-	-	-	-	-	-	-	-	
	Thin	-	-	-	-	+	-	-	+	+	+	+	+	+	+	+	+	
Epidermal Cells	Tangentially & buliform	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	
	Tangentially	+	+	-	-	-	+	+	+	+	+	-	-	-	-	+	+	
	Radially	-	-	+	-	+	-	-	+	-	+	+	+	+	-	-	-	
	Radially & tangentially	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	
Type	Dorsiventral	+	+	+	-	+	-	-	+	+	+	+	+	+	-	+	+	
	Isobilateral	-	-	-	+	-	+	+	-	-	-	-	-	-	+	-	-	
Chlorenchyma		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Palisade Rows No	2	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	
	1	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	
Spongy Rows No	3	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+	
	4-6	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	1	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	
	2	-	-	-	-	-	+	+	-	-	-	-	-	-	+	-	-	
	3-5	-	-	-	-	-	-	-	+	-	-	-	+	+	-	-	-	
	3-4	-	-	-	-	-	-	-	-	+	+	-	-	-	-	+	-	
	4-5	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	
Midrib shape	U	+	+	+	-	+	+	-	-	-	-	+	+	-	-	-	-	
	Half circle	-	-	-	+	-	-	-	+	-	-	-	-	-	+	-	-	
	Circular	-	-	-	-	-	-	+	-	+	+	-	-	-	-	-	-	
	Flat	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	
	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	
Ground System	Lamellar	+	+	-	+	+	+	+	-	-	-	-	-	+	-	-	-	
	Angular	-	-	-	-	-	-	-	+	+	+	+	+	-	-	+	+	
	Lamellar & angular	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	
	Sclerenchyma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	
Aspect of Vascular System	Crescent	+	-	-	+	+	-	-	-	-	-	-	-	+	-	-	-	
	Rounded	-	+	+	-	-	-	-	-	-	+	-	-	-	-	-	-	
	Arc	-	-	-	-	-	+	+	+	+	+	-	+	-	+	+	+	
No. of Bundles	1	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+	
	2	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	
	3	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Crystals	Duress	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	
	Needle & tuft like	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	
	Tuft like	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	
	Solitary	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	
Adaxial surfaces	Cells Shape	Pentagonal	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	
		Irregular	-	-	-	-	+	+	-	+	+	+	-	+	-	+	-	
		Tetra-pentagonal	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	-
		Penta-hexagonal	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
	Anticlinical Wall	Straight	+	+	+	+	-	-	+	+	-	-	+	-	+	-	-	-
		Wavy	-	-	-	-	+	+	-	-	+	+	+	-	+	-	+	-
Rounded		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	
Abaxial surfaces	Cells Shape	Pentagonal	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	
		Irregular	-	-	-	-	+	+	-	+	+	+	-	+	+	+	-	
		Tetra-pentagonal	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	-
		Penta-hexagonal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
	Anticlinical Wall	Straight	+	+	+	+	-	-	+	+	-	-	+	-	-	-	-	-
		Wavy	-	-	-	-	+	+	-	-	+	+	+	-	+	+	+	-
Rounded		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	
Lamina type	Amphistomatic	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	
	Hypostomatic	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	
Stomata	Dia-Anisocytic	+	+	+	+	+	-	+	-	-	-	-	-	+	+	+	-	
	Pericytic	-	-	-	-	-	+	-	-	+	+	+	-	-	-	-	+	
	Anisocytic	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	

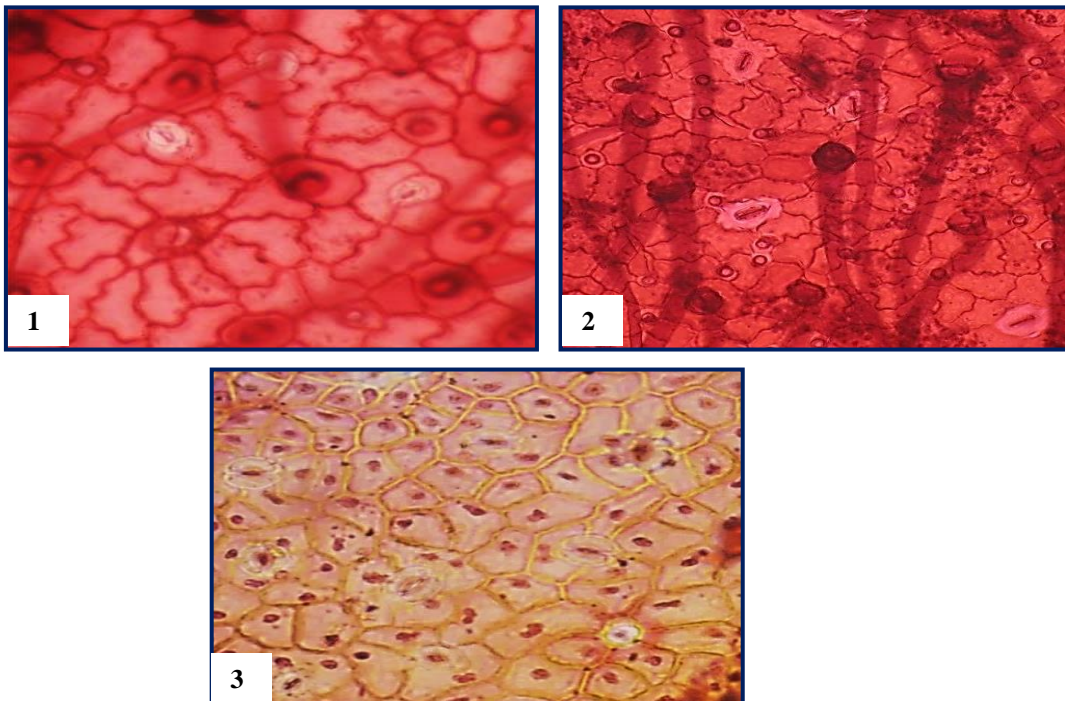
Taxa abbreviations: (LC) *Lavandula citriodora*, (LCO) *Lavandula coronopifolia*, (LP) *Lavandula pubescens*, (LI) *Leucas inflata*, (MV) *Marrubium vulgare*, (ML) *Mentha longifolia*, (MD) *Meriandra dianthera*, (ND) *Nepeta deflersiana*, (OBB) *Ocimum basilicum* var. *basilicum*, (OBP) *Ocimum basilicum* var. *purpurascens*, (OM) *Origanum majorana*, (OF) *Otostegia fruticosa*, (SS) *Salvia schimperii*, (SY) *Stachys yemenensis*, (TY) *Teucrium yemense*, (TS) *Thymus serpyllum*.

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**Plate 6 (Figs. 1-6).** Lamina microphotographs showing different mesophyll characteristics in the studied taxa of Lamiaceae (LM), (X=20-40).

1. *Lavandula citriodora*, 2. *Leucas inflata*, 3. *Meriandra dianthera*, 4. *Origanum majorana*, 5. *Teucrium yemense*, 6. *Thymus serpyllum*.



**Plate 7 (Figs. 1-3).** Lamina microphotographs showing different types of stomata and anticlinal wall in *Teucrium yemense*, *Mentha longifolia*, *Leucas inflata*.

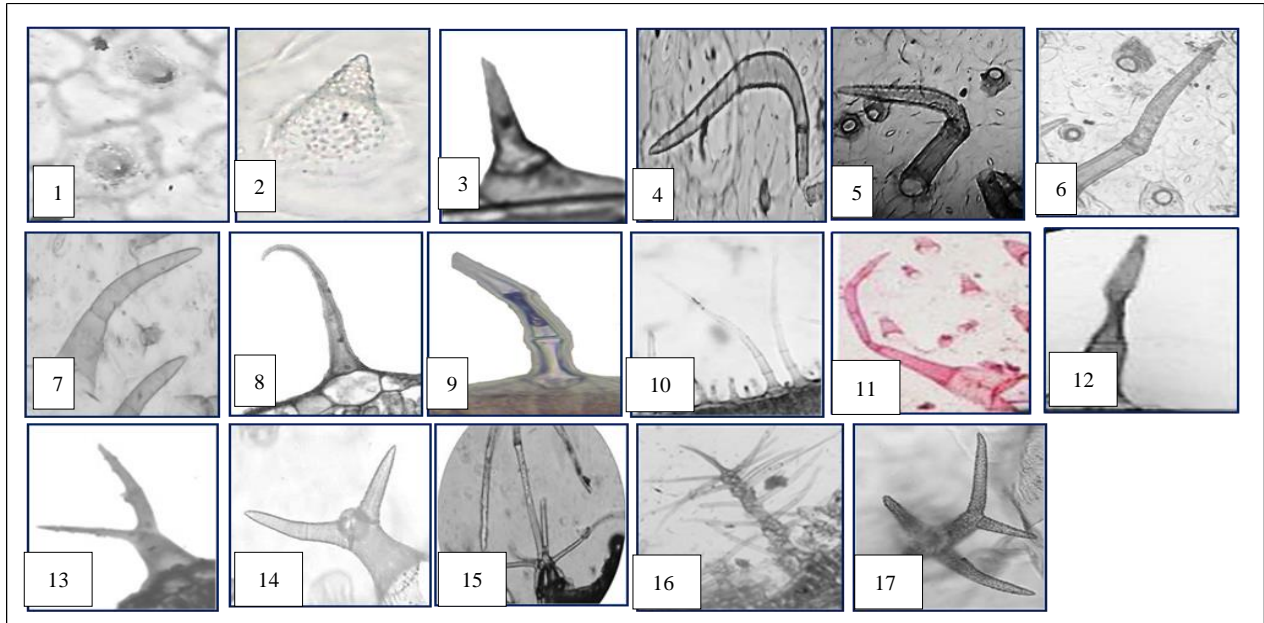
Table (6): Types of eglandular and glandular trichomes of the 16 medicinal studied taxa of Lamiaceae.

Character and character states		Taxa																			
		LC	LCO	LP	LI	MV	ML	MD	ND	OBB	OBP	OM	OF	SS	SY	TY	TS				
Trichrome	Eglandular	Papillate Smooth	-	-	-	-	-	-	-	+	-	-	-	+	+	-	-	+			
		Papillate Rough	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
		Unicellular Smooth	-	-	-	-	-	-	+	+	-	-	+	+	-	-	-	-	-		
		Unicellular Rough	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-		
		Smooth Bicellular Concave	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
		Rough Bicellular Concave	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Bicellular Smooth	-	-	-	-	-	-	+	+	-	-	+	+	-	-	-	-	-	-	
		Bicellular Rough	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Multicellular concave apex	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Multicellular Smooth	-	-	-	-	+	+	+	+	-	-	+	+	+	-	+	+	+	+	
		Multicellular Rough	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Multicellular Rough with internodes	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Biramous Smooth	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	
		Biramous Rough	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Dendritic Smooth	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	
		Dendritic Rough	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Stellate	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-		
	Glandular	Peltate	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+		
		Type I	Head	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	
			Stalk	Long	-	-	-	-	+	-	+	-	-	-	-	+	-	-	-	-	-
				Short	U	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
					B	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	+
		Type II	Head	+	+	-	+	-	+	+	-	-	-	-	+	-	-	-	-	-	
			Stalk	Long	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Short	+	+	-	+	-	+	+	-	-	-	-	+	-	-	-	-	-
			Type III	Head	+	+	+	-	+	+	+	+	-	-	-	-	+	-	-	-	-
		multicellular stalk		+	+	+	-	+	+	+	+	-	-	-	-	+	-	-	-	-	
		Type I V	Head	+	+	-	+	+	-	-	-	-	-	-	+	-	-	-	-	-	
			Stalk	Long	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Short	-	+	-	+	+	-	-	-	-	-	-	+	-	-	-	-	-
Type V			-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-		

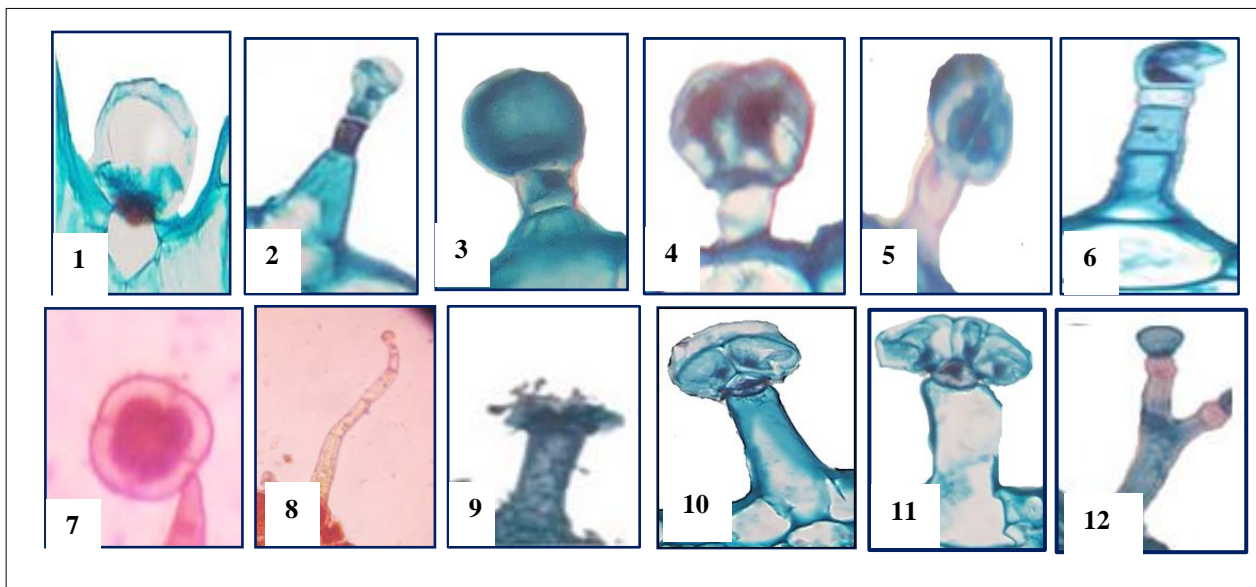
Taxa abbreviations: (LC) *Lavandula citriodora*, (LCO) *Lavandula coronopifolia*, (LP) *Lavandula pubescens*, (LI) *Leucas inflata*, (MV) *Marrubium vulgare*, (ML) *Mentha longifolia*, (MD) *Meriandra dianthera*, (ND) *Nepeta deflersiana*, (OBB) *Ocimum basilicum* var. *basilicum*, (OBP) *Ocimum basilicum* var. *purpurascens*, (OM) *Origanum majorana*, (OF) *Otostegia fruticosa*, (SS) *Salvia schimperii*, (SY) *Stachys yemenensis*, (TY) *Teucrium yemense*, (TS) *Thymus serpyllum*.

T: Taxa; C: Characters ; (+):Present; (-) :Absent . Type I :unicellular head and uni-bicellular stalk , Type II : bicellular head and uni-bicellular stalk , Type III : unicellular head and multicellular stalk , Type V : multicellular head and unicellular stalk, Type V :biramous,U:unicellular , B:bicellular .

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**Plate 8. (Figs. 1-17).** Different types of eglandular trichomes (X=40). 1: Smooth papillate, 2: Rough papillate, 3: Smooth unicellular, 4: Smooth concave bicellular, 5: Rough concave bicellular, 6: Rough bicellular, 7: Smooth bicellular, 8: multicellular with concave apex, 9: multicellular, 10: Smooth multicellular, 11: Rough multicellular, 12: Multicellular with ridges and marked internodes, 13: Smooth biramous, 14: Rough biramous, 15: Stellate, 16: Smooth dendritic, 17: Rough dendritic.



**Plate 9 (Figs. 1-12).** Different types of glandular trichomes. (X=40). 1: Peltate, Capitate; 2: Unicellular head with bicellular stalk, 3: Unicellular head with unicellular stalk, 4: Bicellular head with unicellular stalk, 5: Bicellular head with Bicellular stalk, 6: unicellular head with multicellular stalk, 7: Multicellular head and unicellular stalk, 8: Unicellular head and multicellular stalk, 9: Unicellular head with long unicellular stalk, 10: Bicellular head with long unicellular stalk, 11: Multicellular head with long unicellular stalk, 12: Biramous.



#### 4. Quantitative micromorphological measurements (Table 8)

The stem, petiole and lamina micromorphological characters showed that there are significant differences with  $P=0.0001$ , among 16 taxa (Table 8). The results showed that *Lavandula citriodora*, *L. coronopifolia*, have very thick stem cuticle (1, 2.3  $\mu\text{m}$ ) respectively while *Lavandula citriodora*, *Leucas inflata* and *Meriandra dianthera* have very thick lamina cuticle (1.5, 1, 1.2  $\mu\text{m}$ ) respectively. On other hand, the cortex, secondary phloem thickness and pith width of *Salvia schimperi* has the largest values (38.8, 13, 26.6 & 225  $\mu\text{m}$ ) respectively. *Leucas inflata*, *Meriandra dianthera*, and two *Ocimum* varieties, *Otostegia fruticosa* has the largest cortex thickness (34, 47, 28.57, 28.57 & 28  $\mu\text{m}$ ) respectively while *Thymus serpyllum* has the smallest 11.28  $\mu\text{m}$ . *Meriandra dianthera* has the largest value of secondary phloem (22.8  $\mu\text{m}$ ) while *Thymus serpyllum* has the smallest (3.6  $\mu\text{m}$ ). While, *Lavandula pubescens*, *Marrubium vulgare*, *Mentha longifolia*, *Meriandra dianthera* and *Nepeta deflersiana* have the largest values of secondary xylem thickness (40, 48.8, 45, 56 & 40  $\mu\text{m}$ ). *Thymus serpyllum* has the smallest pith width (19.2  $\mu\text{m}$ ) while *Lavandula pubescens*, *Otostegia fruticosa* have the largest values (208 & 240  $\mu\text{m}$ ) respectively. On other hand, the adaxial epidermal cell lengths and width are larger than abaxial among all studied taxa.

#### 5. Cluster analysis of macro – and micromorphological characters

In the present study, 16 medicinal taxa of family Lamiaceae belonging to 13 genera were used as the operational taxonomic units (OUT'S). A total of 298 attributes are extracted from the macro & micromorphological characters of the studied taxa. The presence or absence of each character was treated as binary character in a data matrix using the software *jmp* version 13 for Sas Institute Inc (2017) through Hierarchical cluster method average linkage modules, (Sokal & Michener, 1958) and resulted in a dendrogram (Fig.1) depending on the degree of dissimilarity of

cluster. It was compared with the current taxonomic treatments of the Lamiaceae provided by Bentham & Hooker, (1876); Briquet, (1895 – 1897); Thonner, (1962); Cantino *et al.* (1992c) and Takhtajan, (2009). The resulted data from the dendrogram are categorized in ten groups included in two clusters, two subseries and two series at relatively high-rescaled dissimilarity distance (Fig.1).

The obtained data from the dendrogram revealed that:

1. *Thymus serpyllum* was separated in (G<sub>1</sub>) under Series I, due to high dissimilarity distance 26.03 with other taxa in most morphological and anatomical characteristics. This result agrees with that of Bentham and Hooker (1876), Briquet (1895 – 1897) and Thonner, 1962 classification, who put *Thymus* under subtribe *Thymineae* and disagree with Cantino *et al.* (1992) who put *Thymus* under tribe Mentheae and Takhtajan (2009) who put it under tribe Satureieae.

2. *Salvia schimperi* was separated in (G<sub>2</sub>) under Series II, this result agrees with Thonner (1962) and Takhtajan (2009) classification who put the *Salvia* under tribe *Salvieae* and disagreed with Cantino *et al.*, (1992) who put *Salvia* under tribe Mentheae.

3. The two studied taxa *Meriandra dianthera* and *Otostegia fruticosa* were separated in one group together (G<sub>3</sub>) at dissimilarity distance (24.32). This result agrees with Thonner (1962) who put *Meriandra* and *Otostegia* under subfamily Stachyoideae. However, the results disagreed with Cantino *et al.* (1992) and Takhtajan (2009) classification who put *Meriandra* under subfamily Nepetoideae and *Otostegia* under subfamily Lamioideae. In addition, this result support the earlier views of Thonner (1962) who put the two genera *Meriandra* and *Otostegia* under the same subfamily of Stachyoideae and two separated tribes Meriandreae and Stachyeae respectively.

4. *Leucas inflata* was separated in (G<sub>4</sub>), this result agrees with Takhtajan (2009), Thonner, (1962) classification, who put it under subtribe lamieae and Cantino *et al.*, (1992c) who put the genus under subfamily lamioideae.

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5. *Stachys yemenensis* was separated in (G<sub>5</sub>), this result agrees with Bentham and Hooker (1876), Briquet (1895 – 1897) classification, who put it under tribe Stachyeae or Stachydeae alternatively, and Takhtajan (2009) who put it under lamieae tribe.

6. *Teucrium yemense* was separated in (G<sub>6</sub>), this result agrees with Cantino et al., (1992) classification, who put it under subfamily Teucrioideae and Takhtajan (2009) who put *Teucrium* under tribe Teucriae.

7. *Marrubium vulgare* was separated in (G<sub>7</sub>) this result agrees with Bentham and Hooker (1876) classification, who put it under subtribe Marrubieae and Briquet (1895 – 1897), Thonner (1962), Takhtajan (2009), classification, who put it under tribe Marrubieae while Cantino et al. (1992) put it under subfamily lamioideae.

8. *Nepeta deflersiana* was separated in (G<sub>8</sub>), this result agrees with Bentham and Hooker (1876), Thonner (1962), Takhtajan (2009) classification who put it under tribe Nepeteae or Nepetai and disagreed with Cantino et al., (1992) who put under tribe Mentheae.

9. The two *Ocimum* varieties, *Origanum majorana* and *Mentha longifolia* were grouped together in (G<sub>9</sub>), this result agrees with Cantino et al. (1992) and Takhtajan (2009) classification who put these taxa under

subfamily Nepetoideae. Among (G<sub>9</sub>), we found that the dissimilarity distance was 4.4 between the two *Ocimum* varieties due to the different flower colors.

10. *Lavandula citriodora*, *L. coronopifolia* & *L. pubescens* were separated in one group together (G<sub>10</sub>), this result agrees with Cantino et al. (1992c); Takhtajan, (2009) classification, who put them under tribe Lavanduleae and Thonner (1962) who put under subfamily Lavanduloideae. The dissimilarity distance between *Lavandula coronopifolia* and *L. citriodora* was 17.2. Therefore, the latter species separated in single branch inside (G<sub>10</sub>). The result indicates that trichomes play important role in species delimitation among genera. In this study, clustering (G<sub>8</sub>) and (G<sub>9</sub>) in one branch supporting the views of the close relation between (two *Ocimum* varieties, *Origanum majorana*, *Mentha longifolia* and *Nepeta deflersiana*) this result in accordance with Cantino et al. (1992) classification who put them under one subfamily Nepetoideae.

In **conclusion**, the classification of most of the studied taxa of family Lamiaceae is in accordance with that of Bentham and Hooker, Briquet, Thonner classification, while, agrees with Cantino et al. and Takhtajan classification to some extent for some genera. More studies on many taxa still needed for accurate assignments.

**Table (7). Quantitative macromorphological measurements of the studied taxa**

measurements Taxa	Stem		Leaf			Flower				Nutlet	
	Length cm	Lamina		Petiole Length cm	Calyx Length Mm	Corolla Length mm	Stamen Length mm	Bract Length mm	Length mm	Width mm	
		Length cm	Width cm								
LC	70±2.05	4±0.4	3±0.2	0	5±0.2	8±0.1	1±0.09	5±0.1	2±0.1	1.5±0.09	
LCO	100±2.6	4±0.5	3±0.09	0	5±0.2	8±0.1	1.5±0.2	2.5±0.1	2±0.1	1.5±0.09	
LP	100±2.6	4±0.5	3.5±0.09	0	6±0.1	8±0.1	1.5±0.2	5±0.1	2±0.1	1.5±0.09	
LI	40±2.1	2±0.1	1.7±0.08	0	6±0.1	12±0.1	5±0.08	0	2±0.04	1.5±0.04	
MV	40±2.6	3.6±0.2	3.5±0.08	5±0.08	7±0.1	8±0.08	1±0.04	4±0.1	1±0.08	0.5±0.04	
MD	200±2.8	10±0.2	3.5±0.1	1.4±0.04	5±0.1	6±0.04	4±0.1	0	2.5±0.04	1.5±0.04	
ML	50±0.8	10±0.2	3.5±0.1	0	2±0.2	3.2±0.04	1.5±0.04	5±0.09	0.9±0.04	0.5±0.04	
ND	80±2.6	3.2±0.08	1.9±0.04	1±0.09	6±0.2	12±0.23	2.5±0.08	5±0.16	1.5±0.09	1±0.09	
OBB	60±2.9	3±0.1	2.7±0.04	2±0.08	6±0.1	9±0.2	2±0.1	3±0.08	1.9±0.4	1±0.09	
OBP	60±2.9	3±0.1	2.7±0.04	2±0.08	6±0.1	9±0.2	2±0.1	3±0.08	1.9±0.4	1±0.09	
OM	35±2.6	2.5±0.6	1±0.1	2±0.08	25±0.8	2.2±0.04	2±0.08	3±0.1	1.9±0.04	1±0.08	
OF	150±3.5	2.8±0.04	2.7±0.04	5±0.1	12±0.12	22±0.1	15±0.09	7±0.2	1.2±0.08	1.7±0.09	
SS	100±1.5	7.5±0.25	2.8±0.05	5±0.1	19±0.7	35±0.2	25±0.3	18±0.2	2±0.01	2±0.05	
SY	50±2.8	3.5±0.1	0.8±0.04	0	7±0.08	22±0.2	2±0.08	3±0.2	2±0.01	1±0.09	
TY	12±1.2	1±0.1	0.5±0.04	0	8±0.08	9±0.09	4±0.04	4±0.1	1.5±0.08	1±0.08	
TS	17±1.3	0.9±0.5	0.4±0.04	0	1.5±0.08	6.5±0.06	5±0.04	4±0.2	1±0.07	1±0.08	
Prob≥05	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.6	0.0001*	

Taxa abbreviations: (LC) *Lavandula citriodora*, (LCO) *Lavandula coronopifolia*, (LP) *Lavandula pubescens*, (LI) *Leucas inflata*, (MV) *Marrubium vulgare*, (ML) *Mentha longifolia*, (MD) *Meriandra dianthera*, (ND) *Nepeta deflersiana*, (OBB) *Ocimum basilicum* var. *basilicum*, (OBP) *Ocimum basilicum* var. *purpurascens*, (OM) *Origanum majorana*, (OF) *Otostegia fruticosa*, (SS) *Salvia schimperii*, (SY) *Stachys yemenensis*, (TY) *Teucrium yemense*, (TS) *Thymus serpyllum*. (0); Absent. Mean±SD

Table 8. Quantitative micromorphological measurements of the studied taxa

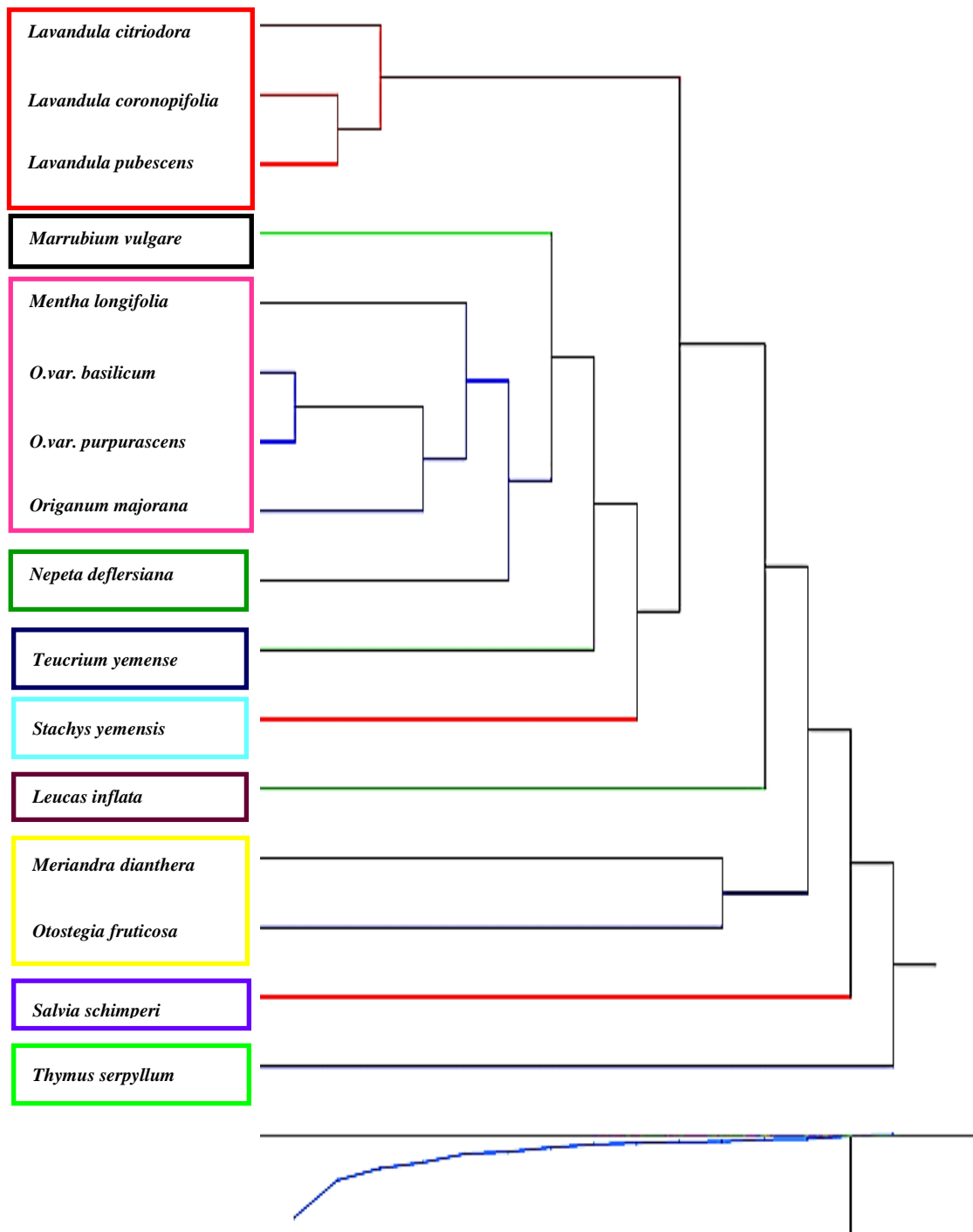
measurements Taxa	Stem							Petiole		
	Cuticle thickness µm	Epidermal cells		Cortex thickness µm	Secondary phloem thickness Mm	Secondary xylem thickness µm	Pith width µm	Cuticle thickness µm	Epidermal cells	
		Length µm	Width µm						Length Mm	Width µm
LC	1±0.04	2.9±0.08	4.5±0.01	24±0.8	14±0.2	28±0.8	188±1.2	0	0	0
LCO	2.3±0.08	3.9±0.2	6.9±0.3	16±0.4	6±0.8	10±2.5	181±0.8	0	0	0
LP	0.8±0.08	3.6±0.08	5.76±0.3	21.3±0.9	14.5±1.08	43±4.6	208±1.2	0	0	0
LI	0.4±0.04	1.6±0.04	2±0.4	34±1	9±0.4	12±0.8	88±0.8	0	0	0
MV	0.8±0.04	1.84±0.08	1.86±0.04	20±0.02	12±0.3	40±0.07	100±1.2	0.8±0.04	2.8±0.1	3.04±0.08
MD	0.56±0.04	2.16±0.2	2.8±0.1	47±2.2	22.8±0.2	48.8±0.4	104±0.8	0.64±0.04	1.2±0.04	2.24±0.08
ML	0.8±0.04	2±0.03	5.2±0.3	21±0.2	8±0.04	45±3.2	168±1.2	0	0	0
ND	0.64±0.02	1.84±0.08	3.68±0.2	14.53±1.4	14±0.2	56±3.6	125±1.3	0.3±	1.5±	1.62±
OBB	0.25±0.04	2.5±	3.5±0.2	28.75±0.8	8.75±0.4	17.5±0.8	185±1.2	0.3±	2.2±	2.4±
OBP	0.25±0.04	2.5±	3.5±0.2	28.75±0.8	8.75±0.4	17.5±0.8	185±1.2	0.3±	2.2±	2.4±
OM	0.4±0.03	1.8±0.04	2.8±0.1	20±0.5	13±0.2	24.6±1.3	196±0.5	0	0	0
OF	0.4±0.03	1.9±0.03	3.6±0.2	28±0.7	16±0.3	40±0.8	240±0.8	0.4±0.02	1.6±0.01	2±0.01
SS	0.8±0.04	2.6±0.1	3.76±0.2	38.8±2.6	13±1	26.6±2.4	225±0.2	0.4±0.008	4.08±0.04	3.68±0.3
SY	0.4±0.02	2±0.02	2±0.02	12±1.22	9.3±0.4	25±0.8	88±0.03	0	0	0
TY	0.4±0.03	1.92±0.03	1.6±0.1	16±0.1	6.7±0.6	20±0.3	76±1.2	0	0	0
TS	0.4±0.01	2.13±0.1	4.2±0.04	11.28±0.1	3.6±0.2	17.6±0.8	19.2±0.7	0	0	0
Prob≥05	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0065*	0.0004*	0.0004*

Table 8.Cont'd.

measurements Taxa	Lamina								
	Cuticle thickness µm	Adaxial		Abaxial		Palisade cells		Spongy cells	
		Epidermal cells		Epidermal cells		Length µm	Width µm	Length Mm	Width µm
Length µm	Width µm	Length µm	Width µm						
LC	1.5±0.06	9±0.08	4±2.6	5±0.04	2±0.4	15±0.2	5±0.2	8.9±0.2	8.8±0.2
LCO	0.4±0.04	2±0.5	5±1.5	1.2±0.8	3±0.2	15±0.3	5±0.2	15±0.5	5±0.07
LP	0.8±0.04	5±0.3	9±0.2	1±0.1	3±0.3	12.64±0.4	4±0.1	6.16±0.4	4.16±0.08
LI	1±0.04	3±0.5	9±0.2	2±0.1	4±0.2	8±0.1	2±0.1	8±0.2	2±0.04
MV	0.5±0.04	1.25±0.05	3.12±0.08	0.75±0.05	1.37±0.04	6.63±0.03	1.37±0.04	2.75±0.05	1.37±0.04
MD	1.2±0.04	2±0.07	4.96±0.2	2±0.1	1.2±0.04	7.5±0.02	1.84±0.02	4.5±0.06	1.84±0.04
ML	0.96±0.02	2.88±0.03	5.2±0.2	1.57±0.05	3.2±0.08	2.96±0.3	1.36±0.04	1.76±0.06	2.96±0.04
ND	0.4±0.01	3.06±0.03	3.8±0.08	1.7±0.6	1.7±0.2	1.95±0.4	0.76±0.02	0.78±0.05	0.43±0.05
OBB	0.4±0.01	5.68±0.4	6±1.2	2.16±0.1	3.04±0.1	16.64±1.2	4.8±0.2	6.4±0.001	6.8±0.07
OBP	0.4±0.01	5.68±0.04	6±1.2	2.16±0.1	3.04±0.1	16.64±1.2	4.8±0.2	1.76±	2.96±0.04
OM	0.4±0.03	1.6±0.07	1.7±0.02	0.6±0.05	0.6±0.05	3.6±0.5	1.03±0.1	0.85±	0.85±0.6
OF	0.4±0.01	3.44±0.04	4.8±0.8	1.2±0.01	2.32±0.02	8.4±0.1	1.6±0.1	3±0.05	2.4±0.2
SS	0.32±0.02	2.64±0.1	6±0.3	2.26±0.1	2.46±0.31	5.88±0.3	2.11±0.04	3.54±0.2	2.91±0.2
SY	0.4±0.02	3.73±0.2	4.8±0.4	1.4±0.05	1.93±0.03	8.5±0.2	1.9±0.04	6.5±0.01	1.9±0.03
TY	0.4±0.03	2.13±0.07	4.2±0.2	1.36±0.04	2.8±0.1	7.28±0.2	1.76±0.1	5.44±0.1	1.76±0.04
TS	0.4±0.04	2.13±0.04	4.2±0.1	1.36±0.03	2.08±0.1	7.28±0.3	1.76±0.04	5.44±0.2	1.76±0.04
Prob≥05	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*

Taxa abbreviations: (LC) *Lavandula citriodora*, (LCO) *Lavandula coronopifolia*, (LP) *Lavandula pubescens*, (LI) *Leucas inflata*, (MV) *Marrubium vulgare*, (ML) *Mentha longifolia*, (MD) *Meriandra dianthera*, (ND) *Nepeta deflersiana*, (OBB) *Ocimum basilicum* var. *basilicum*, (OBP) *Ocimum basilicum* var. *purpurascens*, (OM) *Origanum majorana*, (OF) *Otostegia fruticosa*, (SS) *Salvia schimperii*, (SY) *Stachys yemenensis*, (TY) *Teucrium yemense*, (TS) *Thymus serpyllum*. (0); Absent. Mean±SD±SD.

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**Fig(1): Dendrogram based on 298 attributes of micro-&macromorphological characters using *jmp* program, showing the interrelationships between 16 Lamiaceae taxa based on dissimilarity distance.**

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