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OCCURRENCE, DIVERSITY AND TAXONOMIC IMPLICATION OF CALCIUM OXALATE CRYSTALS IN SOME MEMBERS OF LAMIACEAE AND ALLIED TAXA

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ABSTRACT

Diversity of calcium oxalate (CaOx) crystals in stem and petiole of 46 species of Lamiaceae and allied taxa collected from different parts of Upper Gangetic Plain and adjacent Shivalik hills of Indian subcontinent have been examined with the help of electric photo-light microscope. It is interesting to notice that in genus *Ocimum,* and *Mosla dianthera* crystals are formed in epidermal tissues and trichomes. Although *Tectona* and *Callicarpa* now are supposed to be quite distinct, druses can only be seen in both these genera. The structural organization of crystal forms can be specific and distinct between taxa. The presence of different crystal forms in Lamiaceae and allied taxa provide additional diagnostic features for classification at subfamily level. The data in the present study is not large enough and can not be used as such as a rule at family level until or unless it covers a large number of taxa of this family. Anybody can add data in this study to make it large so that it may be useful at family level. On the basis of taxa studied, a possible description at subfamily level along with bracketed key have been given in the following paragraph.

Kewwords: Upper Gangetic Plain, India, Lamiaceae, Stem, Petiole, Calcium oxalatecrystal

INTRODUCTION

The definite roles of calcium oxalate crystals in plants are unknown. But on the basis of large number of studies carried out by researchers and available data concerning about biomineralization in plants, it has been observed that plants store calcium oxalate for balancing excess calcium concentration, biochemical reservoir, metabolic waste and as a defensive mechanism against herbivores (Franceschi and Nakata, 2005). The externally derived calcium is precipitated by plants into different salts forms like- calcium oxalate, calcium carbonate, calcium sulphate etc He *et al.* (2012). Calcium oxalate is the commonest form of stored calcium occurred inside plants. Calcium oxalate crystals are present into all group of plants ranging from algae, fungi and lichen to higher plants. Generally, crystals can be observed into young parenchymatous tissues of growing plant parts. Calcium ions are important for bio-signaling. The cells store extra amount of calcium into separate membrane bound compartments called idioblast (Pueschel, 2001; Sugimura *et al*., 1999). The membrane of young idioblast shows highly active role in pumping of excess calcium into the compartment and the pattern of formation of crystals inside idioblast are highly regulated process (Kostman and Franceschi, 2000; Weiner and Dove, 2003; Osuji *et al*., 2000). The formation of crystals is not a random process, instead the precipitation of calcium with internally synthesized oxalic acid occurs into definite manner to produce definite crystal forms (Faheed *et al*., 2013). On the basis of morphology, crystals can be categorized into five general types-raphides, styloids, druses, crystal sand and prismatic (Franceschi and Horner, 1980). Raphides are needle like calcium oxalate crystals with sharp points at both ends and broad at the middle portion or one end of raphide is pointed but other end blunts abruptly. Raphides produce defensive effect by creating holes into the gut of herbivores. In most of the cases the defensive mechanisms are synergistic in combination with some toxins or proteases (Konno *et al*., 2014). There are only few records of studies related to the occurrence of different crystal forms in Lamiales (Mathew and Shah, 1984; Ryding, 2010).The primary objective of the present study is to find out the morphological nature of different types of crystal forms and their taxonomical implication in Lamiaceae and allied taxa.

The synthesis of particular form of crystals during the formation of tissues can be variable and fixed for a particular species (Lersten and Horner, 2005). Calcium oxalate in plants are present in the form of either calcium oxalate monohydrate ($CaC_2O_4.H_2O$-whewellite) or calcium oxalate dihydrate ($CaC_2O_4.{}_2H_2O$-weddellite) (Frey-Wyssling, 1981; Ishii and Takiyama, 1989). Crystals of different types and their presence or absence may be utilized as a useful taxonomic character for delimiting the taxa. Among Angiosperms, dicotyledons show great diversity with respect to form, size, hydration and distribution of crystals, while monocotyledons show comparatively less diversity in crystal shape, size and forms (Prychid and Rudall, 1999). The form and size of crystals can be variable within and between genera and families. This feature is genetically controlled (the type of crystal in particular tissue of a plant is fixed) (Bouropoulas *et al*., 2001). Robert brown (1833) was an earlier worker who successfully recognized the taxonomic significance of raphides in Orchidaceae. Gulliver (1864) recognized importance of raphides for separation of Onagraceae from Hydrocharitaceae as latter lack raphides.

Mathew and Shah (1984) have showed that crystals were common in woody species of Verbenaceae *s.l* but now according to new circumscription most of woody species of this family are now part of Lamiaceae. The herbaceous and non-woody plants of Verbenaceae were seen devoid of crystal forms but in the present study we have reported great diversity of crystals in herbaceous plants of Lamiaceae. Although it is very difficult for reclassifying large numbers of taxonomically related plants only on the basis of crystal forms, the data obtained by us can provide an aid for strengthening the given classification system.

MATERIALS AND METHODS

The taxa studied belong to 41 species of Lamiaceae and 5 species of Verbenaceae. Plant materials were collected from natural habitats located in different parts of Upper Gangetic Plain (between 29.9680N to 77.5552E and 28.985N to 77.7064E), and also plants cultivated in the garden. The identification of selected plant species was done with the help of "Flora of Upper Gangetic plain, and of the adjacent Siwalik and sub-Himalayan tracts" by J. F. Duthie, (1903-1929) and other available standard literature and online floras, (https://sites.google.com/site/efloraofindia/, http://www.efloras.org/flora_page.aspx?flora_id=2 and http://legacy.tropicos.org/namesearch.aspx?projectid=32). Recent accepted names were checked with the help of different databases and online websites (https://wcvp.science.kew.org/, http://www.plantsoftheworldonline.org/ and https://www.ipni.org/). Family Lamiaceae include7 sub-families (Harley *et al*., 2004) and 12 subfamilies (Li *et al*., 2016). We studied crystal forms in 46 species collected from different parts of Upper Gangetic Plain. On the basis of Crystal forms our study falls into 7 sub-families of Lamiaceae and five species of Verbenaceae. For fresh plant material, samples were collected and immediately put in to clean plastic bags. Healthy samples were selected and washed with running fresh water to remove any dust particle. Stem and leaves were separated carefully.

The transverse sections of stems and petioles were cut with the help of double edged razor and kept separately into watch glasses filled with water. Thinnest and complete sections were selected for the microscopic examination. Selected sections were mounted in glycerin on a clear glass slide and covered with coverslip for preparation of temporary slides. The slides prepared in this way were examined for the presence or absence of different types of crystals forms in stem and petiole of each selected species with the help of binocular microscope. The pictures were captured by using Dewinter digital Microscope and Otpscopes digital microscope.

RESULTS

Table 1 : Distribution of different crystal forms in stem (S) and petiole (P) sections of taxa studied.

Sr. No.	Taxa studied	Crystal type	Remarks
1.	*Anisomeles indica* (L.) Kuntze	acicular, oblong and styloid (S, P)	Same type in both organs
2.	*Colebrookea oppositifolia* Sm.	prism, styloid and rhombic (S, P)	Same type in both organs
3.	*Leonotis nepetifolia* (L.) R.Br.	styloid and rectangular, prism (S, P)	Characteristic crystal are rectangular
4.	*Leucas cephalotes* (Roth) Spreng.	Styloid and crystal sand (S, P)	Same type in both organs
5.	*Leucas aspera* (Willd.) Link	styloid (S, P)	Characteristic crystal is Styloid
6.	*Leucas nutans* (Roth) Spreng.	Styloid (S, P)	Characteristic crystal is styloid
7.	*Leucas decemdentata* (Willd.) Sm.	styloid, prism and crystal sand (S, P)	Characteristic crystal is Prisms
8.	*Pogostemon benghalensis* (Burm.f.) Kuntze	acicular aggregate (S, P)	Acicular raphides are characteristic
9.	*Mesosphaerum suaveolens* (L.) Kuntze	prism and rectangular and crystal sand (P)	Characteristic for petiole
10.	*Isodon rugosus* (Wall. Ex Benth.) Codd	prism and crystal sand (S, P)	Same type in both organs
11.	*Mosla dianthera* (Buch.-Ham. ex. Roxb.) Maxim.	rectangular, crystal sand (S, P) styloids in trichomes of petiole	Characteristic crystal is is Styloids in trichomes
12.	*Nepeta hindostana* (B.Heyne ex Roth) Haines	crystal sand (P)	Only one type of crystal sand found
13.	*Nepeta graciliflora* Benth.	crystal sand (S, P)	Crystal sand is characteristic for both organs
14.	*Ocimum basilicum* L.	prism, crystal sand (S) and styloid in trichomes	Characteristic crystal is Styloid in trichomes
15.	*Ocimum americanum* L.	acicular, crystal sand (S, P) and styloid in trichomes	Characteristic crystal is Styloid in trichomes
16.	*Ocimum tenuiflorum* L.	rectangular (P), short prisms (S), and crystal sand (S, P)	Short rectangular are in epidermal tissue
17.	*Ocimum gratissimum* L.	Rectangular, prism, bar (S); Styloid, rectangular (P) and bar in petiole trichomes	Bars in trichomes are characteristic
18.	*Ocimum* × *africanum* Lour.	Crystal aggregate in trichomes	Crystals in trichomes are characteristics
19.	*Perilla frutescens* (L.) Britton	styloid (S, P)	Same type in both organs
20.	*Platostoma hispidum* (L.) A. J. Paton	styloid, rectangular and crystal sand (S, P)	Same type in both organs
21.	*Coleus scutellarioides* (L.) Benth.	acicular, styloid and crystal sand (S, P)	Same type in both organs

22.	*Coleus amboinicus* Lour.	acicular, styloid and crystal sand (S, P)	Same type in both organs
23.	*Salvia splendens* Sellow ex. Schult.	acicular, styloid and rhombic (S, P)	Same type in both organs
24.	*Salvia plebeia* R.Br.	rectangular and rhombic (S, P)	Characteristic crystal is Rectangular
25.	*Clerodendrum indicum* (L.) Kuntze.	crystal sand (S, P)	No other form observed
26.	*Clerodendrum infortunatum* L.	rhombic (S), styloid (P) and crystal sand (S, P)	Crystals bearing sclerenchymatous cells are characteristic
27.	*Clerodendrum splendens* G.Don	styloid, acicular, rhombic and crystal sand (S, P)	Crystals bearing sclerenchymatous cells are characteristic
28.	*Clerodendrum thomsoniae* Balf.f.	acicular, styloid, rhombic and crystal sand (S, P)	Same type in both organs
29.	*Clerodendrum chinense* (Osbeck) Mabb.	Rhombic and styloid (S, P)	Same type in both organs
30.	*Clerodendrum* × *speciosum* Dombrain	Styloid, acicular, rhombic and crystal sand (S, P)	Same type in both organs
31.	*Volkameria inermis* L.	rhombic, spherical aggregate and crystal sand (S, P)	Spherical aggregate are characteristic
32.	*Pseudocaryopteris bicolor* (Roxb.Ex.Hardw.) P.D.Cantino	prism and spherical aggregate of crystal sand (S, P)	Same type in both organs
33.	*Holmskioldia sanguinea* Retz.	acicular and rhombic (S, P)	Same type in both organs
34.	*Scutellaria repens* Buch.-Ham. ex D.Don	crystal sand (S)	Characteristic crystal is crystal sand
35.	*Vitex negundo* L.	acicular, oblong, prism and crystal sand (S)	Smaller sized prisms are characteristic
36.	*Premna mollissima* Roth	Acicular, oblong and prism (S)	Prisms are larger in comparison to *Vitex*
37.	*Gmelina asiatica* L.	styloid, prism (P) and spherical aggregate (S)	Spherical aggregate are characteristic for stem
38.	*Gmelina arborea* Roxb.	spherical aggregate, styloid and rectangular (P)	Spherical aggregate are characteristic for petiole
39.	*Tectona grandis* L.f.	druses (S), prisms, rectangular, druses and crystal sand (P)	Druses are characteristic
40.	*Tectona hamiltoniana* Wall.	druses (S), rectangular druses and crystal sand (P)	Druses are characteristic
41.	*Callicarpa macrophylla* Vahl	Druses and prism (S, P)	Druses are characteristic
42.	*Lantana camara* L.	styloid, oblong, rhombic and crystal sand (S, P)	Same type in both organs
43.	*Lantana indica* Roxb.	Dust (S, P)	Same type in both organs
44.	*Phyla nodiflora* (L.) Greene	acicular and styloid (S, P)	Same type in both organs
45.	*Duranta erecta* L.	Polygonal prisms and crystal sand (S, P)	Same type in both organs
46.	*Petrea volubilis* L.	prism and rectangular (S, P)	Crystals bearing sclerenchymatous cells are characteristic

Artificial Key: On the basis of aforesaid taxa examined, a key to sub-families of Lamiaceae for the study areais given below:
1a. Druses present in stems and petioles …..**2**
1b. Druses absent in stems and petioles ……**3**

2a. Crystal sand present in petioles - **Tectonoideae**
2b. Crystal sand absent in petioles - **Callicarpoideae**

3a. Bars present in stems and trichomes – **Nepetoideae**
3b. Bars absent/ not present…………………**4**
4a. Oblong crystals present in stems………..**5**
4b. Oblong crystals absent in stems….,……..**6**

5a. Spherical aggregate crystal sand present in stems… **Viticoideae**
5b. Rhombic crystals present in stems………………… **Lamioideae**
6a. Styloid crystals present in stems and petioles ……..**Ajugoideae**
6b. No styloid crystals in stems and petioles………… **Scutellaroideae**

Characteristics of subfamilies: On the basis of taxa studied using the character and character state of calcium oxalate Crystal, the possible description of subfamilies of Lamiaceae are given below

The Sub family Lamioideae are characterized by the presence of acicular, oblong, styloid, prism, rhombic, rectangular and crystal sand (S, P).

The Sub family Nepetoideae are characterized by presence of short prismatic and bars (S); prism (P); acicular, styloid, prism, rhombic, rectangular and crystal sand (S, P); bars and crystal aggregate in trichomes.

The Sub family Ajugoideae are characterized by the presence of rhombic (S); styloid (P); acicular, styloid, prism, rhombic, spherical aggregate and crystal sand (S).

The Sub family Scutellarioideae are characterized by the presence of crystal sand (S); acicular and rhombic (S, P).

The Sub family Viticoideae are characterized by the presence of acicular, oblong and spherical aggregate crystal sand (S); styloid, prism and rectangular (P); spherical aggregate (S, P)

The sub family Tectonoideae are characterized by the presence of prism, rectangular, crystal sand and druses (P); druses (S, P).

The sub family Callicarpoideae are characterized by the presence of prism and druses (S, P).

Family Verbenaceae are characterized by the presence of acicular, oblong, styloid, prism, rhombic, rectangular, crystal sand and polygonal prism (S, P).

S= Stem; P= Petiole

Classification:

Taxonomic arrangement of taxa studied according to Harley *et al*. (2004) & Li *et al*. (2016) is given below

Harley *et al.* (2004)	**Li *et al.* (2016)**
Lamioideae: *Anisomeles*, *Colebrookea*, *Leonotis*, *Leucas*, *Pogostemon* **Nepetoideae:** *Mesosphaerum, Isodon*, *Mosla*, *Nepeta, Ocimum, Perilla, Platostoma* *Coleus, Salvia* **Ajugoideae:** *Clerodendrum*, *Pseudocaryopteris*, *Volkameria* **Scutellarioideae:** *Scutellaria, Holmskioldia* **Viticoideae:** *Vitex, Premna*, *Gmelina* **Prostantheroideae** **Symphorematoideae** **Incertae Sedis unplaced (ten genera** *Tectona* *Callicarpa*	**Lamioideae:** *Anisomeles*, *Colebrookea*, *Leonotis*, *Leucas*, *Pogostemon* **Nepetoideae:***Mesosphaerum Isodon*, *Mosla*, *Nepeta,Ocimum, Perilla, Platostoma, Coleus, Salvia* **Ajugoideae:** *Clerodendrum*, *Pseudocaryopteris*, *Volkameria* **Scutellarioideae:** *Scutellaria*, *Holmskioldia* **Viticoideae:** *Vitex* **Premnoideae:** *Premna*, *Gmelina* **Prostantheroideae** **Symphorematoideae** **Cymarioideae** **Peronematoideae** *Tectona callicarpa*

Out of 10 genera which were remained unplaced by Harley *et al*. (2004), 8 genera were transferred to their respective sub-families by Li *et al*. (2016). On the basis of recent phylogenetic classification of Lamiaceae proposed by Li*et al*.2016; Li and Olmstead (2017) proposed two new monogeneric sub-families viz, Callicarpoideae with genus *Callicarpa*, and Tectonoideae with genus*Tectona*.

DISCUSSION AND CONCLUSION

The different type of crystals present in studied members of family Lamiaceae and allied taxa can useful to delimit the group at different taxonomic level. It is interesting to note that *Ocimum* spp and *Mosla dianthera* contain crystal forms in trichomes. In *Petrea volubilis*, *Clerodendrum splendens* and *C. infortunatum* crystal producing cells are sclerotic in nature. The following discussion deals with diversity of crystal forms and their possible taxonomic implication at different taxonomic level. Plate A-F provide detailed microscopic images of type of crystals reported in different taxa.

According to Harley *et al*. (2004) there are 63 genera in sub-family Lamioideae. We have studied 8 species of 5 genera of this subfamily. Styloids are most commonly observed crystals type in taxa of this subfamily and their shape is distinct in comparison to taxa studied of other subfamilies. In *Anisomeles* and *Leucas* styloides are same in shape, however their size is greater in *Anisomeles*. There is no difference in crystal forms of stem and petiole of *Anisomeles indica*. No prismatic and rhombic types were seen in this species. The structure of styloides in all four species of *Leucas* are similar and only in *Leucas cephalotes* some broad prismatic forms can be seen. In species of *Colebrookea* and *Leonotis* structure of prismatic crystals appear same. Only *Pogostemon benghalensis* contains needle like acicular crystals.

This sub-family Nepetoideae include 105 genera, out of which we have studied 15 species of 9 genera. In *Mesosphaerum suaveolens* prismatic, rectangular and crystal sand particles were observed. Prisms and crystal sand were seen in *Isodon*. In *Mosla dianthera* narrow rectangular crystals have been observed which are not so broad as are present in *Mesosphaerum suaveolens*. Styloids can also be seen in the trichomes of *Mosla dianthera*. Only dust particles were observed in the cross section of petiole of *Nepeta* spp. In *Ocimum* spp. crystals can be located mainly in epidermal tissues and in trichomes. Styloids, dust and rectangular bars were observed in the epidermal tissue of stem. Some narrow sized styloids were also seen in first or second cells of trichomes. In *Perilla frutescens* only styloides were seen in both stem and petiole. In *Platostoma hispidum* dust, styloids and small sized rectangular crystals were seen in petiolar section. In both the species of *Coleus* same types of acicular, styloids and crystal sand in petioles as well as in stem were seen. In *Salvia plebeia* rectangular crystal were seen larger in comparison to *Salvia splendens.*

Out of 23 genera recognized in sub-family Ajugoideae, we have studied 8 species under 3 genera. In genus *Clerodendrum* presence of rhombic and prismatic crystals were seen more prominent, but in *Clerodendrum indicum* only dust particles were seen in both petioles and stem. In *Pseudocaryopteris bicolor* prisms and spherical aggregates of crystal sand were seen. In *Volkameria inermis* some spherical aggregates were seen along with rhombic and crystal sand. In *Clerodendrum infortunatum, Clerodendrum splendens* and *Clerodendrum thomsoniae* styloides were also along with rhombic and crystal sand.

Out of 5 genera of Scutellarioideae we have studied 2 species of 2 genera. In *Scutellaria repens* only some sand like particles were seen in the sections of both parts. In *Holmskioldia sanguinea* acicular and rhombic forms were observed.

Harley *et al*. (2004) recognized 10 genera in Viticoideae, out of which we have studied 4 species of 3 genera. In *Vitex negundo* small sized prismatic cryatals and crystal sand were observed in the cross section of stem. In stem of *Premna mollissima* prisms were larger in comparison to *Vitex negundo* but their structure looks much like that of *Vitex negundo.* In the petiole of *Gmelina asiatica* only small sized prismatic crystals and in stem styloides, prisms (like in *Gmelina asiatica*) were seen. In the petiole of *Gmelina arborea* large sized styloides, prisms (like in *Gmelina asiatica*), spherical aggregate and some acicular crystals were seen. Styloids of *Gmelina asiatica* were smaller than that of *Gmelina arborea.*

In Tectonoideae there are three species of *Tectona* in world (https://wcvp.science.kew.org/search?q=tectona). We have studied *Tectona grandis* and *Tectona hamiltoniana.* In both these species druses were common in stems as well as in petioles. The shape of these druses were alike. Druses and dust particles were look same in petiole and stem of *Tectona grandis*. Beside in petiole prisms and rectangular crystals of different shapes were seen. In stem the shape of rectangular crystal was different from that of petiole in *Tectona grandis*. Similarily in *Tectona hamiltoniana* the rectangular crystals were different in structure from that of *Tectona grandis*

In Callicarpoideae there is one genera and 170 species. We have studied 1 species. In *Callicarpa macrophylla* druses are more prominent and their structure are similar in petiole and stem. In stem druses were seen with some rectangular forms, but petiole prismatic crystals, dust particles and smaller prismatic crystals forms were also seen. Druses are uniform in both the vegetative parts and their structure is similar to druses observed in both species of *Tectona.*

Family Verbenaceae include 30 genera, of which we have studied 5 species of 4 genera. In *Lantana camara* rectangular bars and crystal sand were seen in both stem and petiole. In *Phyla nodiflora* acicular crystal and styloids were seen. In *Petria volubilis* rectangular prisms and rectangular bars were seen in both vegetative parts.

Previous works of (Metcalfe and Chalk, 1950; Mathew and Shah, 1984; Ryding 2010) have provided information about presence of different types of calcium oxalate cryatals in Verbenaceae and Lamiaceae.

Present studies on anatomy of stem and petiole have suggested that distribution of crystals of specific form, size and shape (based on specific organs as stem and petiole) can be used as diagnostic character at subfamily level, generic level and their combination can also be used for infrageneric level as well. At generic level styloids are most common form in genera like *Anisomeles*, *Colebrookea*, *Leonotis* and *Leucas* and their combination with other type of crysrtal like-acicular oblong (for *Anisomeles*), prism and rhombic (for *Colebrookea*), prism and rectangular (for *Leonotis*), prism and crystal sand (for *Leucas*) are specific. Genus *Pogostemon* is characterized by presence of raphides only.

Interestingly, *Mosla* and *Ocimum* are characterized by presence of crystals in the trichomes. In *Mesosphaerum*, *Isodon*, *Nepeta*, *Platostoma* and *Coleus* crystal sand is common. Genus *Nepeta* is characterized by the presence of only crystal sand. *Coleus* and *Salvia* are characterized by Acicular and styloid forms.

All species of genus *Clerodendrum* except *Clerodendrum indicum* (in which only crystal sand was observed) exhibit rhombic and styloids in abundance in both stem and petiole. The crystal bearing sclerenchymatous cells are characteristic feature for *Clerodendrum infortunatum*, *Clerodendrum splendens* and *Petrea volubilis* (Rueda, 1994). The same feature was observed by us in these aforesaid species. Mathew and Shah (1987) and Inamdar (1968) also stated that character of sclerenchymatous cells can be of taxonomic importance. We have not observed any crystal bearing sclerenchymatous cells in genera of other subfamilies. *In Volkameria inermis* and *Pseudocaryopteris bicolor* spherical aggregates are characteristic. In *Holmskioldia sanguinea* acicular and rhombic and in *Scutellaria repens* only crystal sand were observed. In *Vitex* and *Premna* prisms are characteristic feature. Genus *Gmelina* is characterized by styloids and spherical aggregate. *Tectona* and *Callicarpa* exhibit same type of druses.

The studied genera of Verbenaceae viz. *Lantana*, *Phyla*, *Duranta* and *Petrea* (already discussed in detail above) also show crystal diversity in the form of acicular, oblong, styloid, prism, rhombic, rectangular, crystal sand and polygonal. Thus results of this anatomical study on occurrence of different type of calcium oxalate crystals in taxa studied can be used as additional diagnostic features at different taxonomic level.

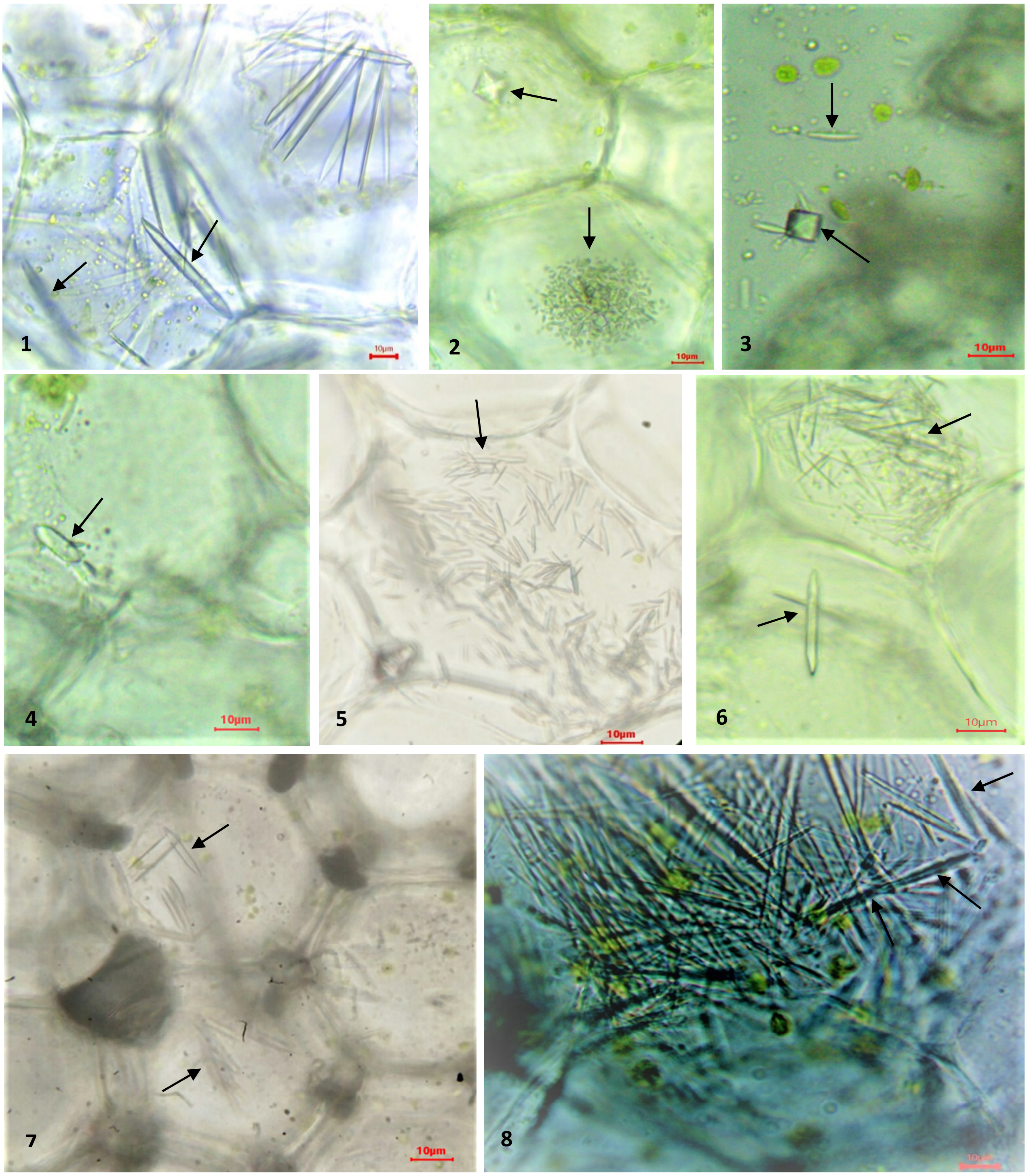

Plate A- ***Anisomeles indica*****, 2.** ***Colebrookea oppositifoia*****, 3.** ***Leonotis nepetifolia*****, 4.** ***Leucas cephalotes*****, 5.** ***Leucas aspera*****, 6.** ***Leucas nutans*****, 7.** ***Leucas decemdentata*****, 8.** ***Pogostemon benghalensis***

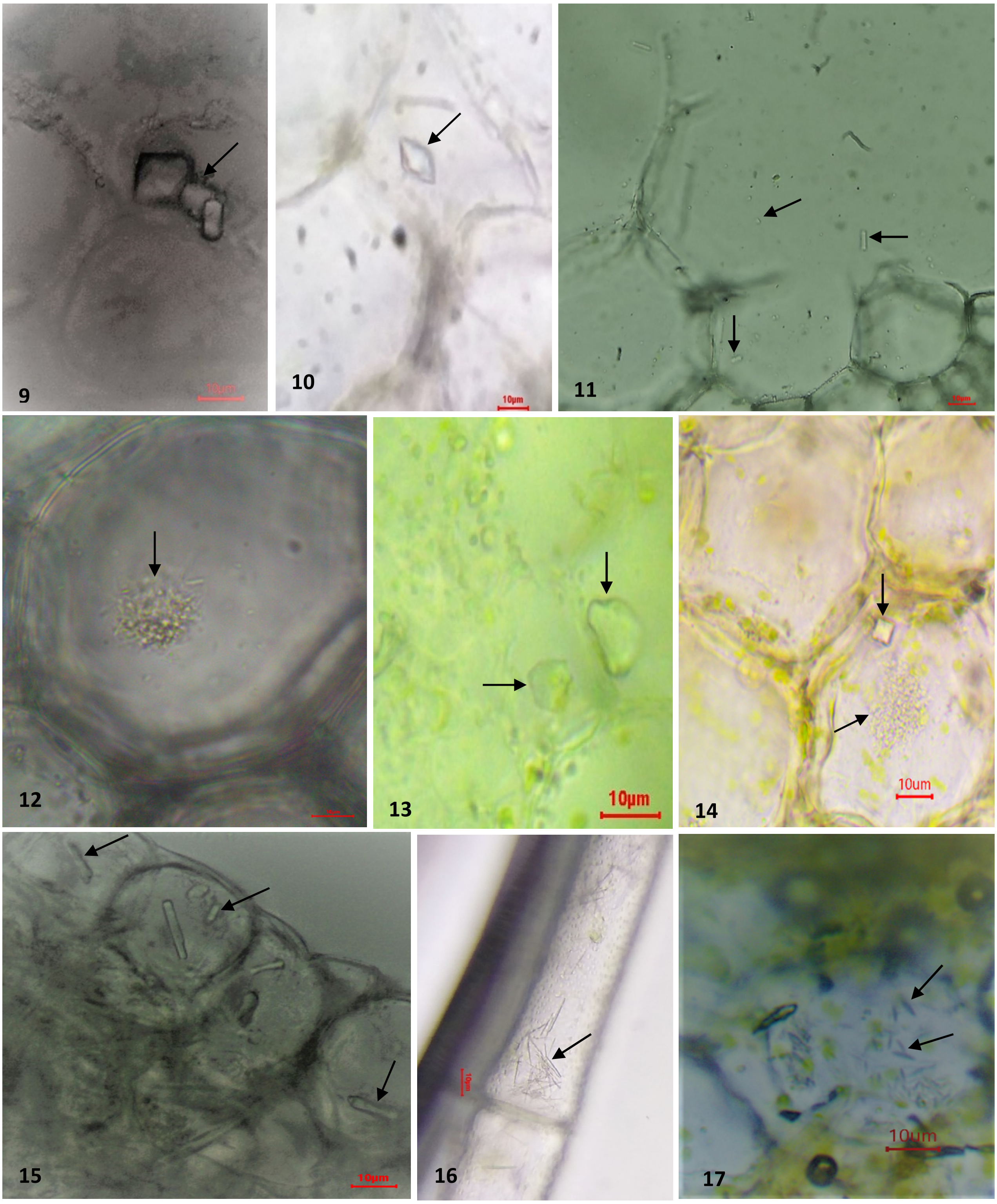

Plate B- 9. *Mesosphaerum suaveolens*, 10. *Isodon rugosus*, 11. *Mosla dianthera*, 12. *Nepeta hindostana*, 13. *Nepeta graciliflora*, 14-15. *Ocimum basilicum*, 16. *Ocimum americanum*, 17. *Ocimum tenuiflorum*

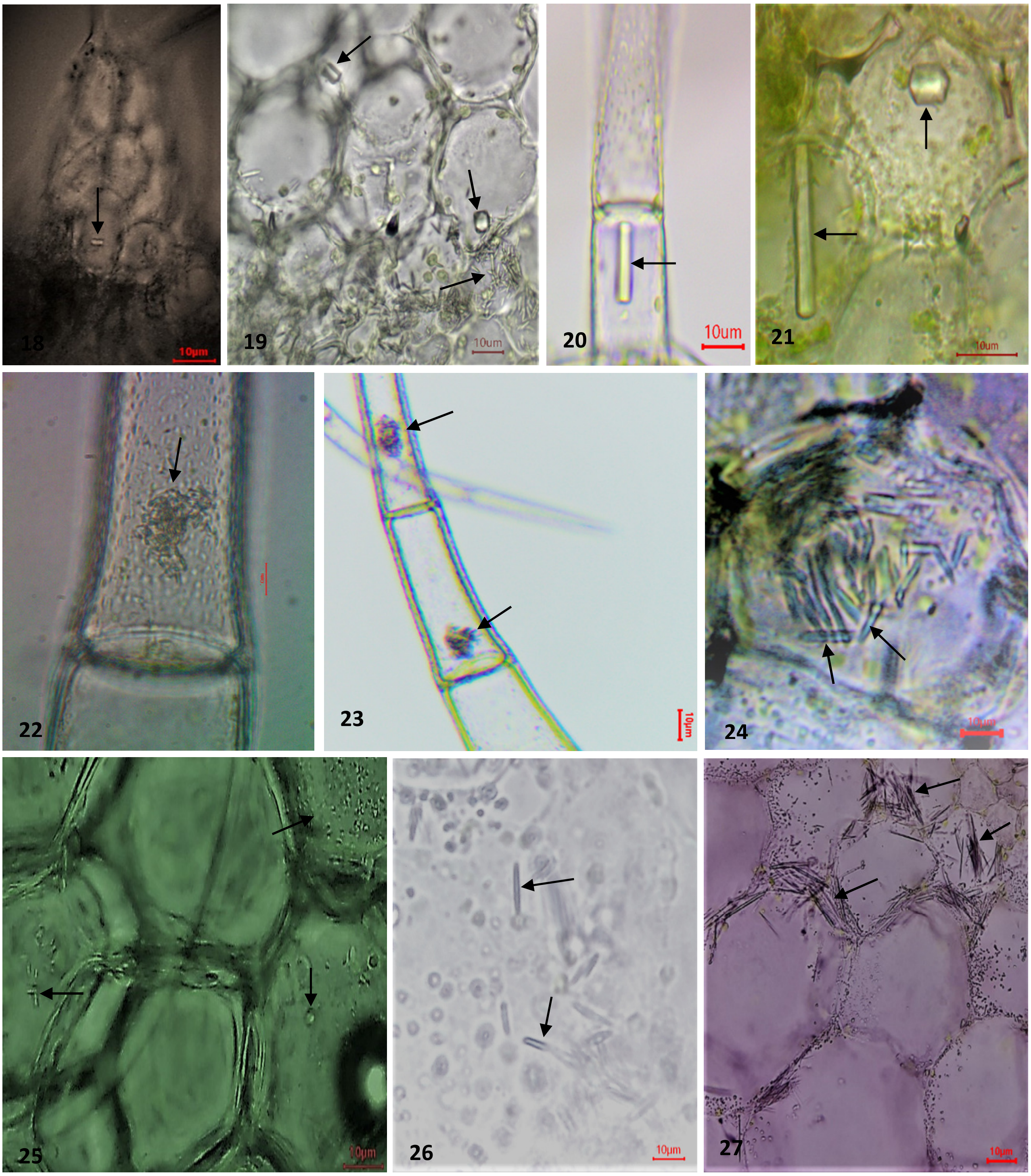

Plate C- 18. *Ocimum tenuiflorum*, 19-20-21. *Ocimum gratissimum*, 22-23. *Ocimum africanum*, 24. *Perilla frutescens*, 25. *Platostoma hispidum*, 26. *Coleus scutellarioides*, 27. *Coleus amboinicus*

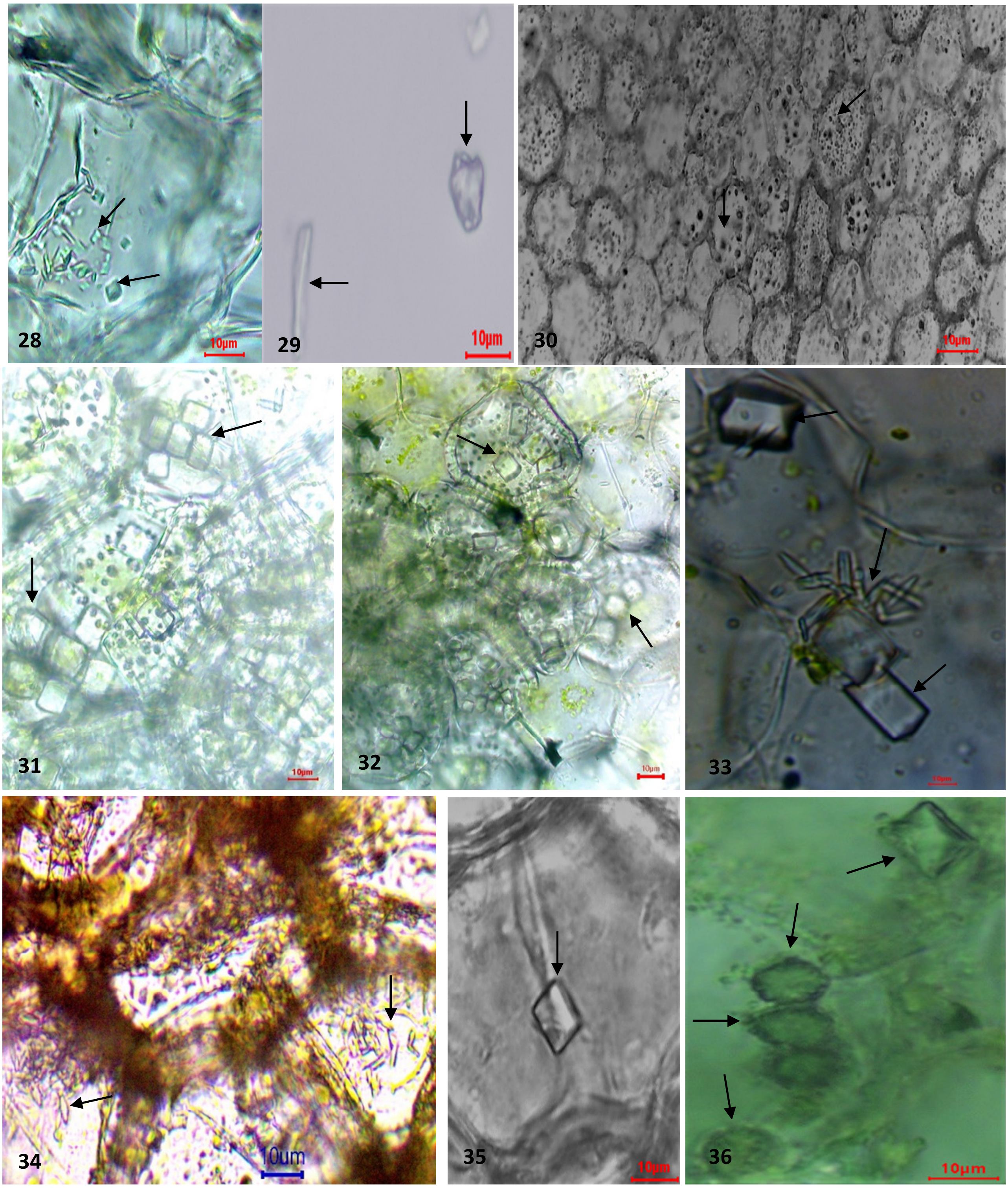

Plate D- 28. *Salvia splendens*, 29. *Salvia plebeia*, 30. *Clerodendrum indicum*, 31. *Clerodendrum infortunatum*, 32. *Clerodendrum splendens*, 33. *Clerodendrum thomsoniae*, 34. *Clerodendrum × speciosum*, 35. *Volkameria inermis*, 36. *Pseudocaryopteris bicolor*

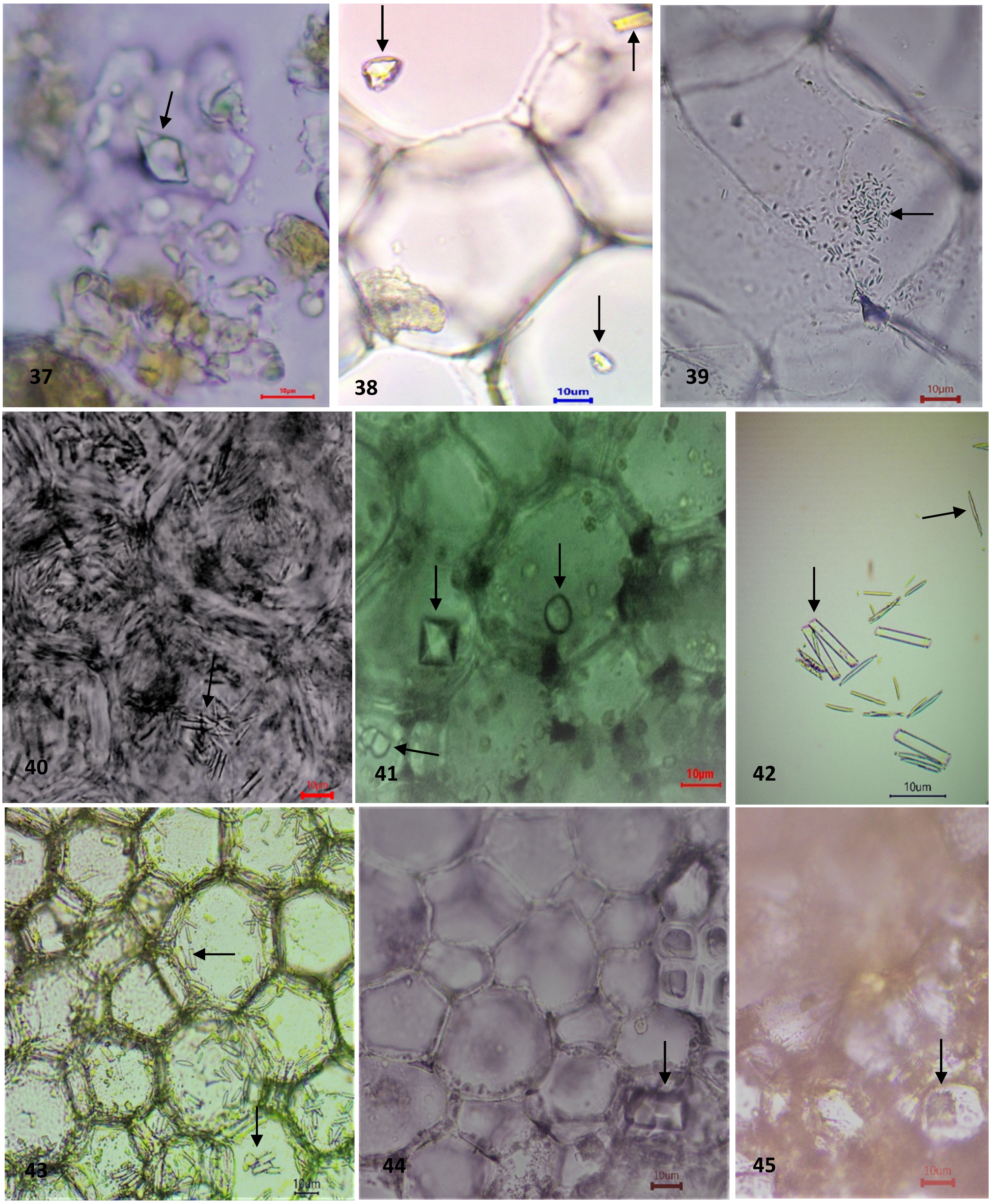

Plate E- 37. ***Holmskioldia sanguinea*, 38.** ***Scutellaria repens*, 39.** ***Vitex negundo*, 40.** ***Premna mollissima*, 41.** ***Gmelina asiatica*, 42-43.** ***Gmelina arborea*, 44-45.** ***Tectona grandis***

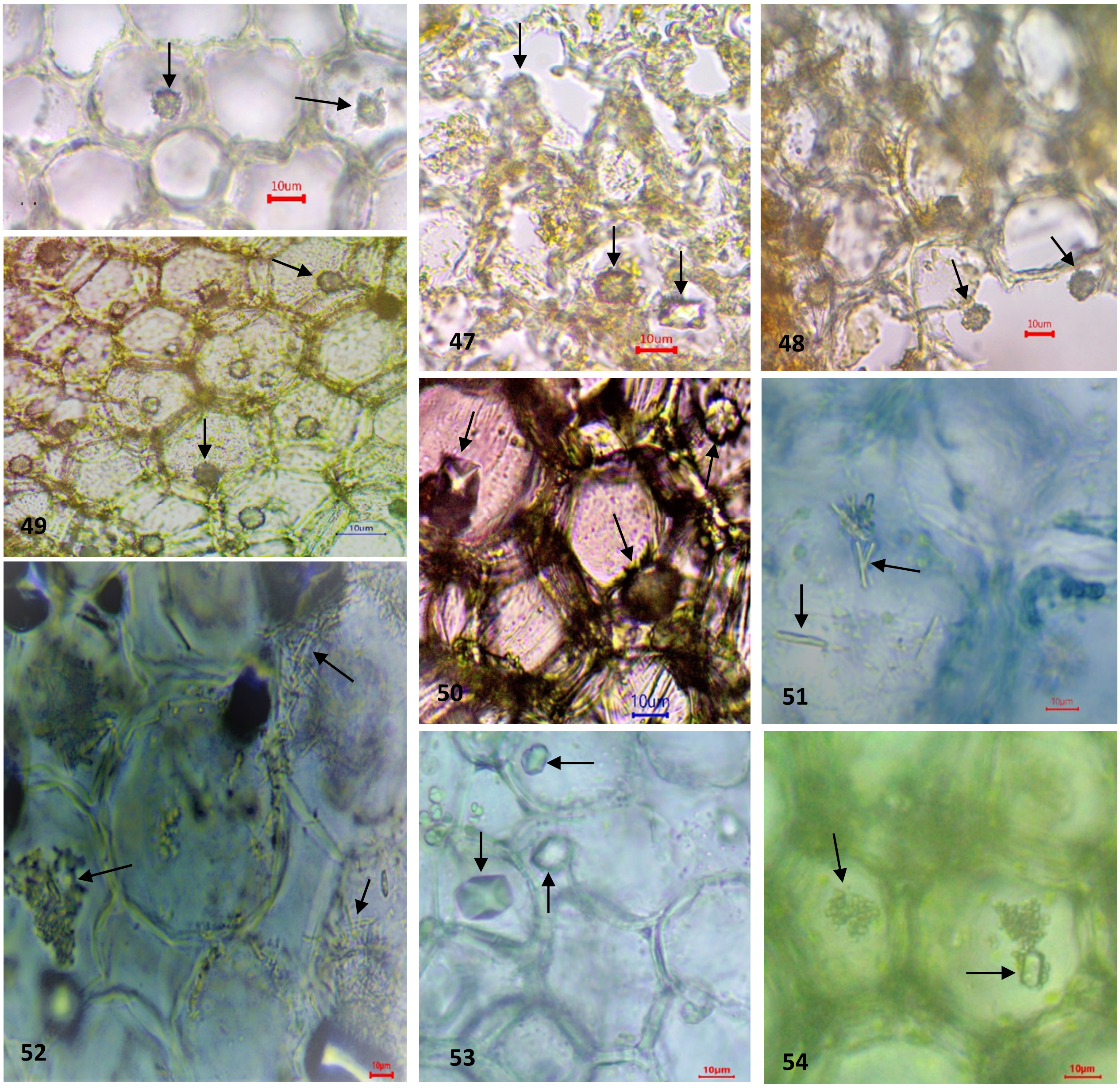

Plate F- 46. *Tectona grandis*, 47-48. *Tectona hamiltoniana*, 49-50. *Callicarpa macrophylla*, 51. *Lantana camara*, 52. *Phyla nodiflora*, 53. *Duranta erecta*, 54. *Petrea volubilis*

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