Structure and distribution of heteromorphic stomata in *Pterygota alata* (Roxb.) R. Br. (Malvaceae, formerly Sterculiaceae)

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ABSTRACT
Thirteen types of stomata along with 18 subtypes and 3 intermediate subtypes between brachyparahexacytic monopolar and dipolar are reported here to be present in the leaves of *Pterygota alata* (Roxb.) R. Br. var. *alata* and *Pterygota alata* (Roxb.) R. Br. var. *irregularis* (W. W. Sm.) Deb & S. K. Basu. The foliar epidermal cells are either polygonal, rectangular, or triangular, having either straight anticlinal walls or sinuous to undulate walls, and isodiametric in surface view. The observed stomata are amphibrachyparacytic, amphicyclocytic, anisocytic, anomocytic, anomotetracytic, brachyparacytic, brachyparahexacytic, brachyparatetracytic, cyclocytic, paracytic, parahexacytic (dipolar), paratetracytic and stephanocytic. Besides these, the presence of giant stomata is a significant finding. Cuticular striations are present on the subsidiary cells, epidermal cells and sometimes even on guard cells.

KEY WORDS
Sterculiaceae,
heteromorphic stomata,
distributional pattern
of stomata,
stomatography.

RÉSUMÉ
Structure et distribution des stomates hétéromorphes chez Pterygota alata *(Roxb.) R. Br. (Malvaceae, anciennenement Sterculiaceae).*
Treize types de stomates, ainsi que 18 sous-types et trois sous-types intermédiaires – entre les variétés monopolaire et dipolaire du stomate brachyparahexacytique – sont ici décrits pour les feuilles de *Pterygota alata* (Roxb.) R.Br. var. *alata* et *P. alata* (Roxb.) R.Br. var. *irregularis* (W.W. Sm.) Deb & S.K. Basu. Les cellules de l'épiderme foliaire sont soit polygonales, rectangulaires ou triangulaires, présentant des parois anticlines rectilignes, ou sinueuses à ondulées, et isodiamétriques en surface. Les stomates observés sont amphibrachyparacytiques, amphicyclocytiques, anisocytiques, anomocytiques, anomotétracytiques, brachyparacytiques, brachyparahexacytiques, brachyparatétracytiques, cyclocytiques, paracytiques, parahexacytiques (dipolaires), paratétracytiques et stéphanocytiques. En outre, la présence de stomates géants est tout à fait remarquable. Des striations cuticulaires recouvrent les cellules compagnes de stomates, les cellules épidermiques et parfois les cellules de garde elles-mêmes.

MOTS CLÉS
Sterculiaceae,
stomates hétéromorphes,
modèle de répartition
des stomates,
stomatographie.

INTRODUCTION

The genus *Pterygota* Schott & Endl. (Sterculiaceae, presently treated under Malvaceae) comprises 17 species, mainly concentrated in the tropics of the old world (Mabberley 2008). *Pterygota alata* (Roxb.) R. Br. is of south-east Asian distribution and very popular as an ornamental tree, planted along streets, commonly known as "Buddha's Coconut". It has one variety, *P. alata* var. *irregularis* (W.W.Sm.) Deb & S.K.Basu which is familiar as 'Mad Tree' due to great variability of the shapes of the leaf blades. So two distinct varieties viz. *Pterygota alata* (Roxb.) R. Br. var. *alata* and *Pterygota alata* (Roxb.) R. Br. var. *irregularis* (W.W.Sm.) Deb & S.K.Basu were studied. The present study reveals that there are 13 different types of stomata along with 18 subtypes and 3 intermediate subtypes between brachyparahexacytic monopolar and dipolar. Observed types include amphibrachyparacytic (2 subtypes), amphicyclocytic (3 subtypes), anisocytic, anomocytic, anomotetracytic (1 subtype), brachyparacytic (2 subtypes), brachyparahexacytic (monopolar with 3 subtypes, dipolar with 4 subtypes and 3 intermediate subtypes in between the two), brachyparatetracytic, cyclocytic (1 subtype), paracytic, parahexacytic (dipolar), paratetracytic, stephanocytic. Significantly, 'Giant Stomata' were frequently observed. The ornamentation as cuticular striations is present on the subsidiary cells, epidermal cells as well as on the guard cells. Comparisons regarding the distribution of different types of stomata, their frequency, sizes of guard cells and aperture are recorded. Moreover, a comparison has also been made in respect to the distribution of stomata in the plants growing in different climatic conditions viz. West Bengal, Tamil Nadu and Andaman and Nicobar Islands. In addition to these stomatal features the nature of epidermal cells and their ornamentation were also studied, and it is felt that the structure of different types of stomata in leaves of *Pterygota alata* would be of interest.

MATERIAL AND METHODS

Mature leaves were collected from different botanical gardens of West Bengal, Tamil Nadu and Andaman and Nicobar islands. Twigs were also preserved in FAA solution [Formaldehyde solution (40%) 5 ml: Glacial Acetic Acid 5 ml: ethanol (70%) 90 ml] for detailed anatomical studies. Leaf clearings were made by excising several sample pieces of about 25 mm^2 from the apex, middle and basal parts of the leaf blades. The samples were then bleached by boiling in 90% alcohol in a water bath for about 30 minutes. The cleared leaves were then washed thoroughly in water. Epidermal peels of abaxial and adaxial surfaces were made. Peels from the laminar portions were stained in 1% aqueous safranin solution for 4-8 minutes, washed in water to remove excess stain before mounting on clean slides in 10% glycerol.

The diagrammatic presentations of the stomata were drawn under mirror type camera lucida. Sometimes stomata were photographed using Olympus Microscope, model no. CH20i. Measurements of guard cells length-width and aperture length-width were made with a calibrated eyepiece micrometer. The stomatal types are described based on Dilcher (1974) and Carpenter (2005). The stomatal types are presented alphabetically under observation along with their respective subtypes.

Stomatal frequency is expressed as stomata per mm^2 leaf area. The microscopic field area (or field of view, ϖr^2) was calculated using a calibrated eyepiece micrometer at (15 × 40) X magnification. The number of a particular stomatal type present in that field was estimated. At least 15 observations from different parts of the lamina were taken into consideration to calculate the mean value of that particular stomatal type. Based on the mean data, frequency of particular stomata (per mm^2) in respect to the total stomatal types observed was calculated.

RESULTS

The epidermal cells as well as stomata of both the varieties of the species have been studied. However, all stomatal types described here were observed either in both cases or only in the typical variety. The epidermal cells are also variable and not restricted to any particular taxon. Therefore, descriptions presented here apply equally to both varieties of *P. alata*. Subsidiary cells are very different from the normal epidermal cells and always with a definite arrangement with the guard cells. These cells stained lightly than the other epidermal cells and sometimes possess different ornamentations.

Mature epidermis

The leaves of *Pterygota alata* are hypostomatic. The epidermal cells of the leaves are variable, either polygonal, rectangular, or triangular with straight anticlinal walls or sinuous to undulate and isodiametric, depending on the specimens, and interestingly not taxon specific (Figs 1B, C; 3A). The cells along the veins on the lower surface of leaf blades are usually rectangular and elongated with almost straight anticlinal walls (Fig. 1A; 3B). The epidermal cells are sometimes with prominent cuticular striations continued to neighboring cells (Fig. 3C).

Structure of mature stomata

Amphibrachyparacytic

Stomata are with four subsidiary cells flanking the lateral sides of the guard cells – two cells to each lateral side. These subsidiary cells do not completely enclose the guard cells and are oriented parallel to the long axis of the guard cells (Figs $1F_1$; 3E).

Apart from this typical type, two subtypes have been observed.

Subtype I. Stomata are with three subsidiary cells, two cells on one lateral side and one on the other lateral side of the guard cells (Fig. $1F_2$).

Subtype II. Stomata are with five subsidiary cells, three cells on one lateral side and two on the other lateral side of the guard cells (Fig. $1F_3$).

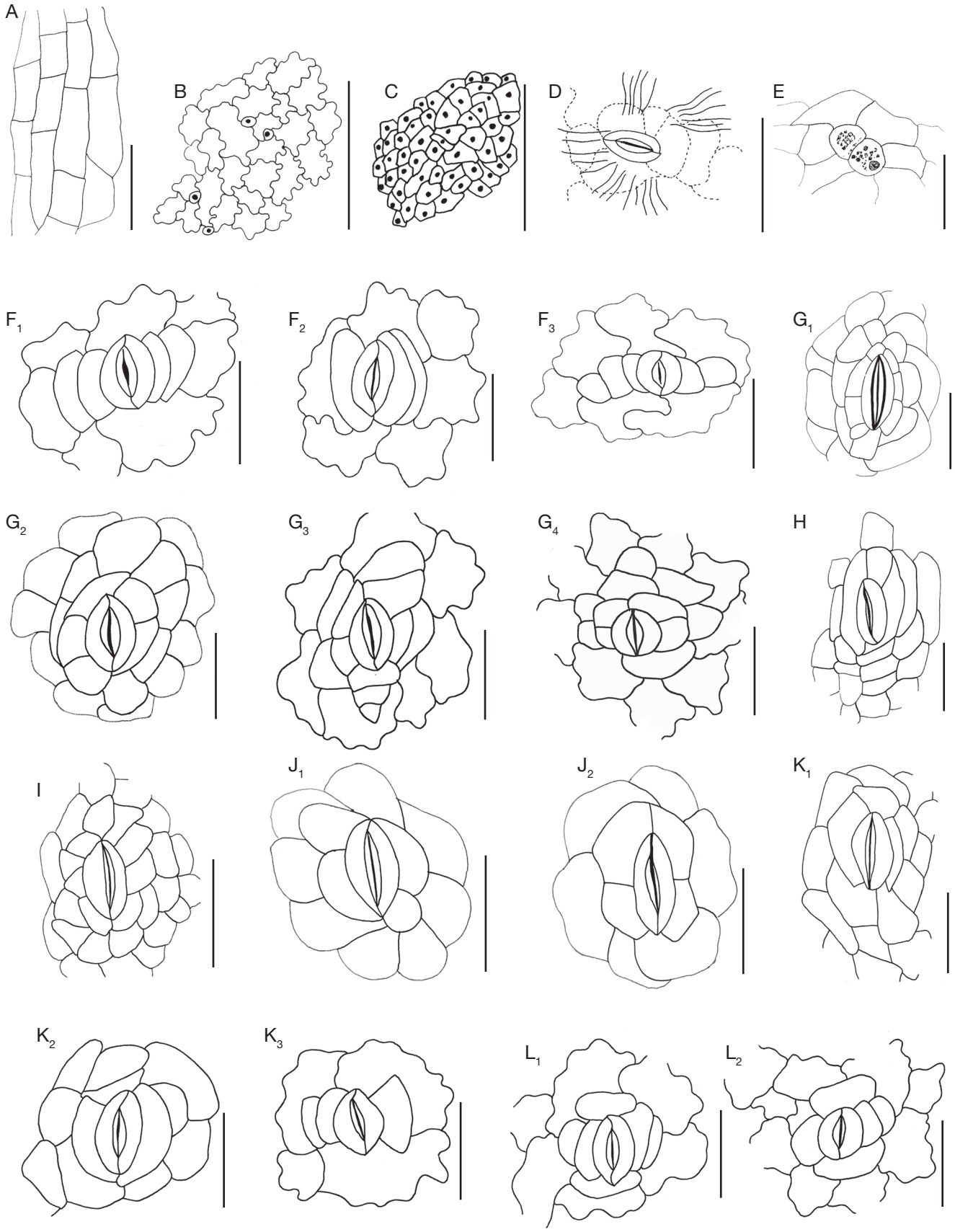

FIG. 1. — **A**, Epidermal cells along veins; **B**, **C**, epidermal cells on leaf surface; **D**, ornamentation on guard cells and subsidiary cells; **E**, persistent stomatal initials; **F**, amphibrachyparacytic: $\mathbf{F_1}$, typical; $\mathbf{F_2}$, subtype-I; $\mathbf{F_3}$, subtype-II; **G**, amphicyclocytic: $\mathbf{G_1}$, typical; $\mathbf{G_2}$, subtype-I; $\mathbf{G_2}$, subtype-II; $\mathbf{G_3}$, subtype-III. **H**, anisocytic; **I**, anomocytic; **J**, anomotetracytic: $\mathbf{J_1}$,typical; $\mathbf{J_2}$, subtype-I; **K**, brachyparacytic: $\mathbf{K_1}$, typical; $\mathbf{K_2}$, subtype-I; $\mathbf{K_3}$, subtype-II; **L**, brachyparahexacytic monopolar: $\mathbf{L_1}$, typical; $\mathbf{L_2}$, subtype-I. Scale bars: 0.1 mm.

Amphicyclocytic
Stomata are with two rings of few to many subsidiary cells, completely ensheathing or encircling the guard cells (Fig. 1G$_1$). Sometimes the anticlinal walls of subsidiary cells are thicker than the normal epidermal cells.

Besides the typical one, three additional subtypes were observed.

Subtype I. Stomata are with two rings of subsidiary cells surrounding the guard cells where the first ring or circle is complete and with five cells but the second ring is incomplete having six cells (Fig. 1G$_2$).

Subtype II. Stomata are with two rings of subsidiary cells enclosing the guard cells with an additional cell in the third row (Fig. 1G$_3$).

Subtype III. Subsidiary cells are in two incomplete rings (Fig. 1G$_4$).

Anisocytic
Stomata are with three subsidiary cells unequal in size of which two being larger and one smaller surrounding the guard cells (Fig. 1H).

Anomocytic
Stomata are with few surrounding cells which are undifferentiated from the normal epidermal cells (Fig. 1I).

Anomotetracytic
Stomata are always with four subsidiary cells arranged in an irregular and variable pattern surrounding the guard cells (Figs 1J$_1$; 3F).

An additional subtype has been recognized.

Subtype. Stomata are always with four unequal subsidiary cells, not completely enclosing at one pole (Fig. 1J$_2$).

Brachyparacytic
Stomata are with two elongated or short lateral subsidiary cells flank the sides of the guard cells without enclosing them completely (Fig. 1K$_1$).

Two subtypes have been found under this category in addition to the typical one.

Subtype I. Stomata are with two elongated lateral subsidiary cells, one on each side of the guard cells enclosing them completely only at one pole. However, the other pole is with a short additional subsidiary cell (Fig. 1K$_2$).

Subtype II. Stomata are with three subsidiary cells, of which two parallel cells are present on one side and single cell on the other side of the guard cells (Fig. 1K$_3$).

Brachyparahexacytic
This type of stomata is again categorized into Monopolar and Dipolar types.

Monopolar
Stomata are with two short parallel subsidiary cells on both sides of the guard cells along with one wide cell at each pole (Figs 1L$_1$; 3G). Therefore, all total six subsidiary cells are present.

Besides the typical one three other subtypes have been recognized.

Subtype I. Stomata are with five subsidiary cells, with two short cells placed on one side, and one on the other side of the guard cells. One subsidiary cell is present at each pole (Figs 1L$_2$; 3I).

Subtype II. Stomata are with seven subsidiary cells. Two short cells are present on either side of the guard cells along with one wide cell at one pole and two short cells at other pole (Fig. 2A$_1$).

Subtype III. Stomata are almost similar to the subtype II, however, two cells are placed side by side at one pole instead of superposed as in the former subtype (Fig. 2A$_2$).

Dipolar
Stomata are with one short parallel subsidiary cell on both sides of the guard cells and two wide cells at each pole.

Four subtypes under this category are recognized though the typical form has not been observed in this studied species.

Subtype I. Stomata are with seven subsidiary cells. Two short cells are present on one side and one cell on the other side of the guard cells, along with two wide cells on each pole (Fig. 2B$_1$).

Subtype II. Stomata are with five subsidiary cells. One short cell is present on each side of the guard cells, along with three wide polar cells, two on one pole and one on the other (Fig. 2B$_2$).

Subtype III. Stomata are with eight subsidiary cells. Two long cells are present on each side of the guard cells, along with two long cells at one pole and two short cells on the other (Figs 2B$_3$; 3H).

Subtype IV. Stomata are with five subsidiary cells. Two long cells are present on one side and one long cell on the other side of the guard cells, with a long cell at one pole and a short cell on the other (Fig. 2B$_4$).

Intermediate type
Besides these subtypes observed under monopolar and dipolar of brachyparahexacytic there are three intermediate types that share the features of both monopolar as well as dipolar.

Intermediate type I. Stomata are with four short lateral subsidiary cells, two cells each are placed on either side of the guard cells along with two wide cells placed side by side one pole and one cell at the other (Fig. 2C$_1$).

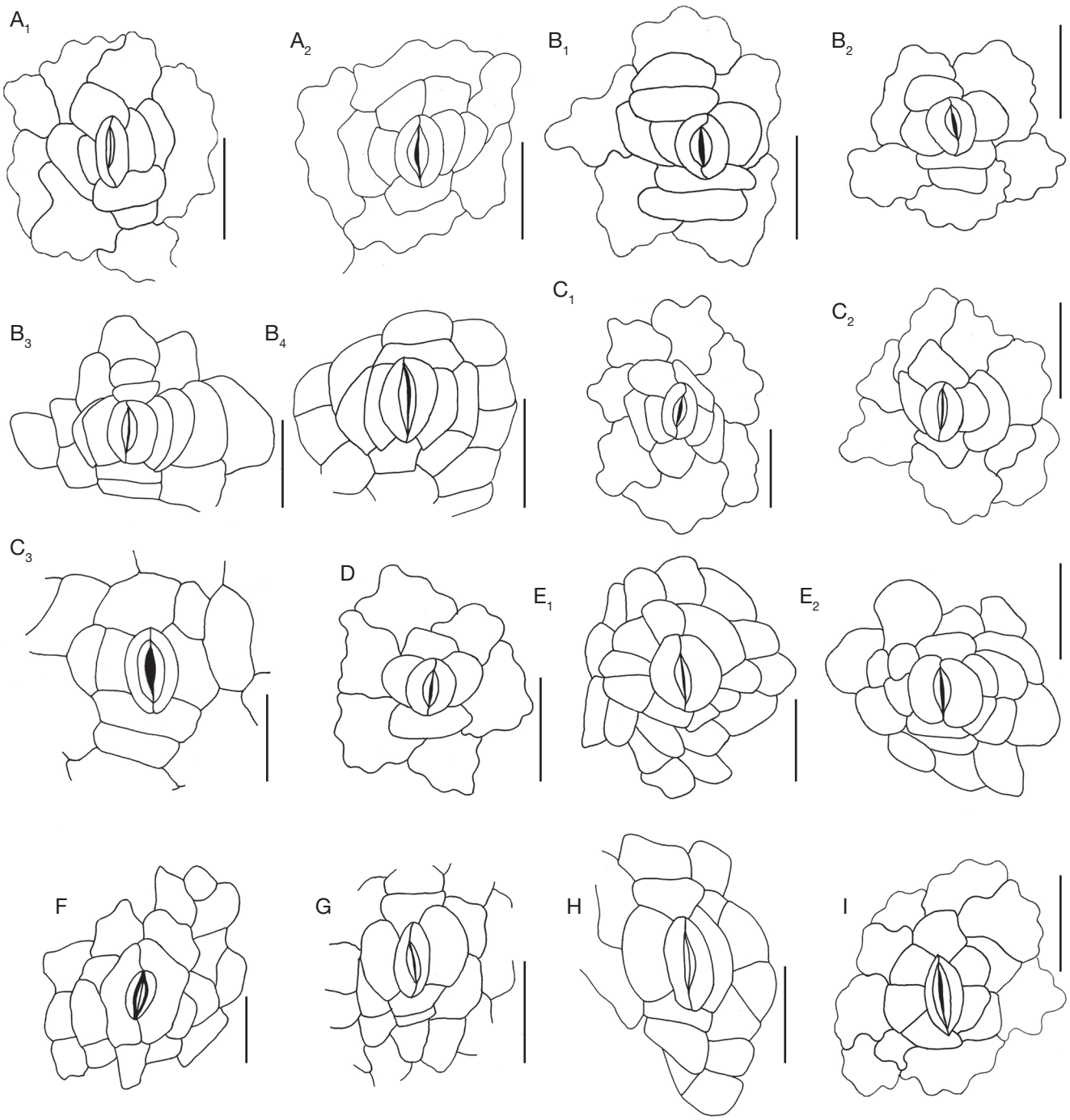

FIG. 2. — **A**, Brachyparahexacytic monopolar contd.: **A_1**, subtype-II; **A_2**, subtype-III; **B**, brachyparahexacytic dipolar: **B_1**, subtype-I; **B_2**, subtype-II; **B_3**, subtype-III; **B_4**, subtype-IV; **C**, brachyparahexacytic intermediate: **C_1**, intermediate-I; **C_2**, intermediate-II; **C_3**, intermediate-III; **D**, brachyparatetracytic; **E**, cyclocytic: **E_1**,typical; **E_2**, subtype-I; **F**, paracytic; **G**, parahexacytic dipolar; **H**, paratetracytic; **I**, stephanocytic. Scale bars: 0.1 mm.

Intermediate type II. Stomata are with three short lateral subsidiary cells, two are placed on one side and one on the other side of the guard cells along with one cell at each pole (Fig. $2C_2$).

Intermediate type III. Stomata are similar to intermediate type I, however, two cells are present at one pole instead of one in the former (Figs $2C_3$; 3J).

Brachyparatetracytic
Stomata are with four subsidiary cells of which one short cell to each side of the guard cells and one wide cell at each pole (Fig. 2D).

Cyclocytic
Stomata are with a single ring of small subsidiary cells surrounding or enclosing the guard cells (Figs $2E_1$; 3K).

TABLE 1. — Frequency (mm²) of different stomatal types in respect to the total stomata observed in *Pterygota alata* (Roxb.) R.Br. var. *alata* in different localities: **ABG**, A.J.C Bose Indian Botanic Garden; **KWB**, Kalyani, West Bengal; **CBE**, Coimbatore; **BK**, Ballygunge Science College Campus, Kolkata; **AND**, Andaman & Nicobar. Abbreviations: **ABP**, amphibrachyparacytic; **AC**, amphicyclocytic; **AN**, anisocytic; ANM, anomocytic; **ATC**, anomotetracytic; **BP**, brachyparacytic; **BPT**, brachyparatetracytic; **BPH**, brachyparahexacytic; **CC**, cyclocytic; **PC**, paracytic; **PHD**, parahexacytic (dipolar); **PTC**, paratetracytic; **SC**, stephanocytic.

Location	ABP	AC	AN	ANM	ATC	BP	BPT	BPH	CC	PC	PHD	PTC	SC
ABG	–	0.205	0.054	0.054	0.054	0.054	0.054	0.315	0.205	–	–	–	–
KWB	–	0.240	0.048	0.048	0.093	–	–	–	0.427	–	–	0.093	0.048
CBE	–	0.024	0.074	0.024	0.201	0.074	–	0.225	0.225	–	–	0.148	–
BK	0.273	–	0.021	–	0.136	0.319	–	0.114	0.090	–	0.021	0.021	–
AND	–	0.2	0.1	0.1	–	–	0.1	0.2	0.2	0.1	–	–	–

TABLE 2. — Frequency (mm²) of different stomatal types in respect to the total stomata observed in *Pterygota alata* var. *irregularis* (W.W.Sm.) Deb & S.K.Basu. Locality and abbreviations: see Table 1.

Location	ABP	AC	AN	ANM	ATC	BP	BPT	BPH	CC	PC	PHD	PTC	SC
ABG	–	0.361	–	0.045	–	0.045	–	0.320	0.225	–	–	–	–

One subtype has been observed in addition to the typical form.

Subtype. Stomata are with the single ring of subsidiary cells surrounding the guard cells, however, a single subsidiary cell is present in the second row (Fig. $2E_2$).

Paracytic
Stomata are with two parallel subsidiary cells along each side completely enclosing the guard cells (Fig. 2F). The subsidiary cells are much larger than other epidermal cells.

Parahexacytic dipolar
Stomata are with one elongated cell situated each side of guard cells and two short cells at each pole (Fig. 2G).

Paratetracytic
Stomata are with one elongate, parallel subsidiary cell on either side of the guard cells, along with one narrow cell at each pole (Figs 2H; 3L).

Stephanocytic
In the typical form the subsidiary cells are arranged radially around the guard cells. The cells are of different shapes and sizes. However, in the present study there are two additional subsidiary cells that have been observed outside the first ring (Fig. 2I). All subsidiary cells are stained lightly than the epidermal cells.

Giant Stomata
These stomata are quite larger than the normal ones and are usually distributed along the veins. In this species stomata are generally 15-24 × 6-8 µm in size with an aperture of 12-18 × 6-9 µm. However, in case of giant stomata these are 27-33 × 6-9 µm having 21-28 × 9-12 µm aperture. Giant stomata are exclusively cyclocytic having 1-3 rows of subsidiary cells (Fig. 3K).

Persistent stomatal initial
These cells are oval to spherical in outline with dense protoplasmic contents. The cells are present as single or in groups of 2-4. Interestingly, the plants collected from Ballygunge Science College Campus, University of Calcutta, Kolkata, West Bengal are with more persistent stomatal initials than the plants from other parts of India (Figs 1E; 3D).

DISCUSSION

The presence of different types of stomata in the leaves of *Pterygota alata* (Roxb.) R.Br. var. *alata* and *Pterygota alata* (Roxb.) R.Br. var. *irregularis* (W.W.Sm.) Deb & S.K.Basu is reported. Stomatal type has long been regarded as one of the persistent and diagnostic features for different taxa and has well been utilized by different workers to establish the groups or to eliminate the controversy about the taxonomic group (Dilcher 1974; Stace 1989; Carpenter 2005). However, occurrence of different types of stomata in the same species is rare. Different types of stomata on the surface of leaves in some members of Araliaceae were reported by Inamdar *et al.* (1969). The polymorphic stomata in *Physalis minima* L. (Solanaceae) were illustrated by Patel & Inamdar (1971) and they had reported 14 different types of both normal and abnormal structures of stomata in this plant. Ghosh & Banerji (1981) had reported the heteromorphic stomata in 19 species of *Ilex* L. (Aquifoliaceae). The polymorphism of stomata in *Solanum nigrum* L. (Solanaceae) had reported by Sharma & Sen (1969). The dimorphism of stomata in more than 200 species of dicotyledonous plants has been discussed by Boldt & Rank (2011).

Metcalfe & Chalk (1950) had stated ranunculaceous (anomocytic) type of stomata as typical to this family. Hussin & Sani (1998) had also observed anomocytic stomata in few species of *Sterculia* L. But, Zebe (1915) was reported rubiaceous (paracytic) stomata in *Reevesia* Lindl. However, the presence of 13 different types of stomata along with 18 subtypes and 3 intermediate subtypes in the two varieties of *Pterygota alata* could be of interest as there is no report of such high stomatal diversity in a single species in the Malvaceae.

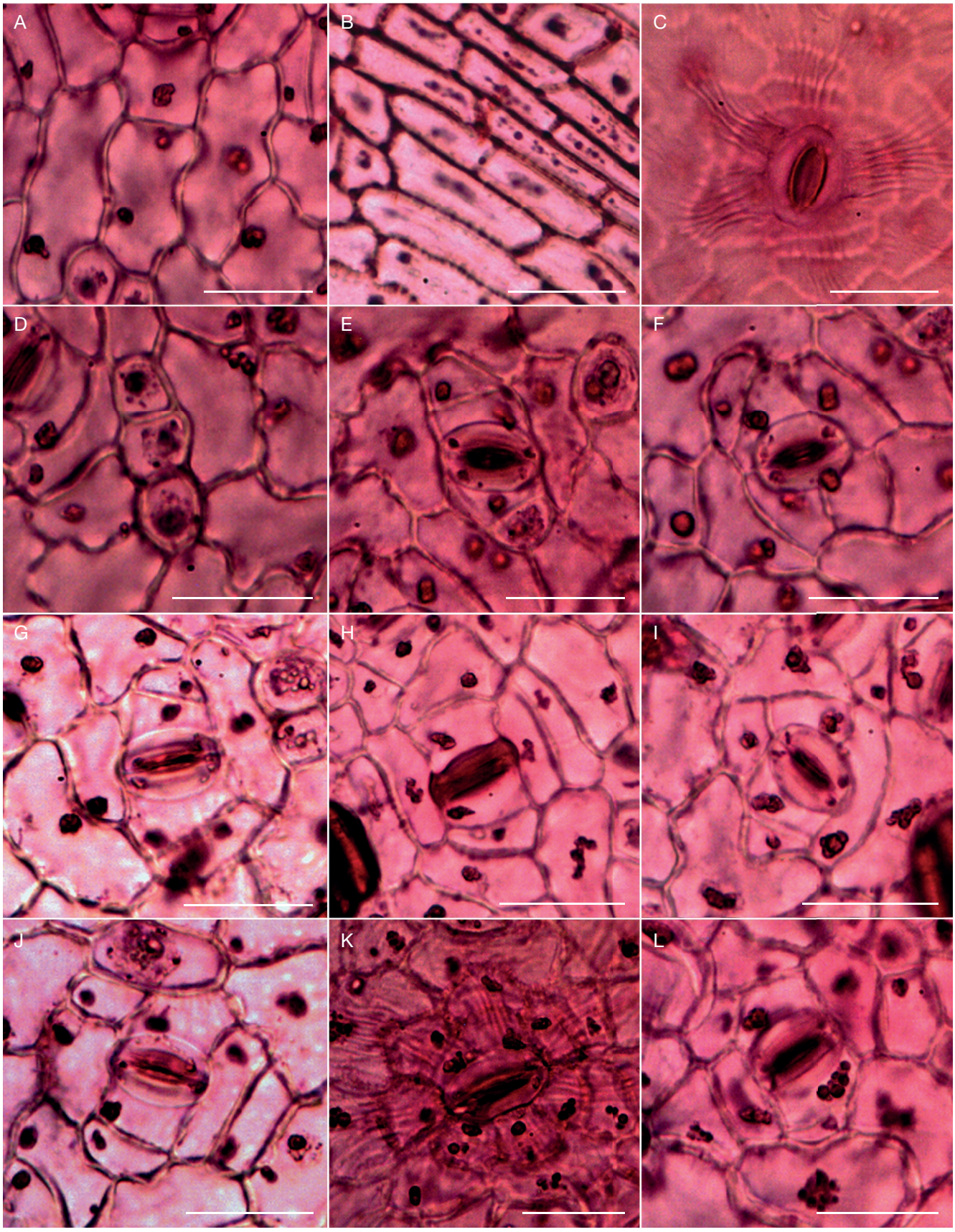

Fig. 3. — **A**, Sinuous epidermal cells; **B**, elongated cells along veins; **C**, cuticular striations; **D**, persistent stomatal initials; **E-L**, stomata: **E**, amphibrachyparacytic; **F**, anomotetracytic; **G**, brachyparahexacytic monopolar typical; **H**, brachyparahexacytic dipolar subtype III; **I**, brachyparahexacytic monopolar subtype I; **J**, brachyparahexacytic intermediate subtype III; **K**, cyclocytic (giant stomata), note striations; **L**, Paratetracytic. Scale bars: 0.05 mm.

An attempt has also been taken to see the correlation between the stomatal diversity and geographical distribution of plants. However, we cannot infer any correlation. Moreover, the stomatal types as well as the nature of epidermal cells may be of individual plant interest. Plant specimens collected from same climatic condition (Kalyani, Kolkata, Howrah of West Bengal) also show individual stomatal diversity. Plants collected from Coimbatore, Tamil Nadu and Andaman & Nicobar Islands also show same result.

The distribution of different types of stomata [frequency (mm^2) in respect to total stomata observed] in the typical variety *alata* exhibits an interesting range (Table 1). Specimens collected from A. J. C. Bose Indian Botanic Garden (ABG), West Bengal are with highest occurrence (0.315) of brachyparahexacytic type, followed by amphicyclocytic and cyclocytic (0.205) and anisocytic, anomocytic anomotetracytic, brachyparacytic and brachyparatetracytic types (0.054). Interestingly amphibrachyparacytic, paracytic, parahexacytic (dipolar), paratetracytic and stephanocytic stomata are totally absent. In case of plants collected from Kalyani, the cyclocytic type is with highest occurrence value (0.427) followed by amphicyclocytic (0.240), paratetracytic and anomotetracytic (0.093), and anisocytic, anomocytic and stephanocytic (0.048). However, amphibrachyparacytic, brachyparacytic, brachyparahexacytic, brachyparatetracytic, paracytic and parahexacytic (dipolar) are not observed in these specimens. Plants collected from south India (Coimbatore, Tamil Nadu) are with both cyclocytic and brachyparahexacytic stomata of highest occurrence (0.225 each), followed by anomotetracytic (0.201), paratetracytic (0.148) and then anisocytic and brachyparacytic (0.074 each). Amphicyclocytic and anomocytic types present at lowest rate (0.024 each). However, amphibrachyparacytic, brachyparatetracytic, paracytic, parahexacytic (dipolar) and stephanocytic are totally absent in these specimens. Significantly amphibrachyparacytic (0.273) is present only in the plants collected from Ballygunge Science College Campus, Kolkata and these plants are also excessively rich in brachyparacytic type of stomata (0.319) followed by anomotetracytic (0.136), brachyparahexacytic (0.114), cyclocytic (0.090) and parahexacytic (dipolar) (0.021). Both anisocytic and paratetracytic are present at low rate (0.021). Here again amphicyclocytic, anomocytic, brachyparatetracytic, paracytic and stephanocytic types of stomata are totally absent. A single specimen was collected from Andaman and Nicobar Islands and it shows major deviation regarding the occurrence of stomata at very low frequency in general. Among the different types of stomata present in this specimen, amphicyclocytic, brachyparahexacytic and cyclocytic are in high value of occurrence (0.2 each). The rest types viz. anisocytic, anomocytic, brachyparatetracytic and paracytic are at low rate (0.1). However, amphibrachyparacytic, anomotetracytic, brachyparacytic, parahexacytic (dipolar), paratetracytic and stephanocytic types are not found.

The variety *irregularis* is quite different from the typical one in respect to the presence as well as distribution [frequency (mm^2) in respect to the total stomata observed] of different types of stomata (Table 2). Here, amphicyclocytic is with highest occurrence (0.361), followed by brachyparahexacytic (0.320) and cyclocytic (0.225), whereas anomocytic and brachyparacytic are of rare occurrence (0.045 each). However, amphibrachyparacytic, anomotetracytic, anisocytic, brachyparatetracytic, paracytic, parahexacytic dipolar, paratetracytic and stephanocytic are totally absent.

Giant stomata are observed in both the taxa. Giant stomata are usually situated along the veins although there is a good number in the intervenal regions of the lamina. The presence of giant stomata is not uncommon in angiospermous families, though it was regarded in the past as rather unusual. Jain & Singh (1975) had reported the occurrence of giant stomata in Celastraceae and Convolvulaceae. Ghosh & Banerji (1981) also reported such type of stomata in seventeen (17) species of *Ilex* L. (Aquifoliaceae). Chandra *et al.* (1969), Kapoor *et al.* (1969), Trivedi & Upadhyay (1974) had revealed the existence of giant stomata in many species of angiosperms. Giant stomata in *Pterygota alata* are usually amphicyclocytic in nature with two to three rings of subsidiary cells. The guard cells as well as subsidiary cell are ornamented with prominent cuticular striations (Figs 1D; 3C, K).

The presence of persistent stomatal initials singly or in group of 2-4 cells together is another interesting finding. The cells are filled with protoplasmic materials. These cells are equally stained as like the normal cells and apparently ⅓rd in size than the normal cells.

In recent classification APG III, Malvaceae, Sterculiaceae, Tiliaceae, Bombacaceae are grouped under one family Malvaceae (*s.l.*) based on molecular data (APG III 2009). The members of these families are also similar in many vegetative as well as reproductive features. Stomata of all taxa exhibit anomocytic type [Metcalfe & Chalk 1950 (Malvaceae, Sterculiaceae, Tiliaceae, Bombacaceae); Rao & Ramayya 1983 (Sterculiaceae); Hussin & Sani 1998 (Sterculiaceae); Baderinwa & Moraviniyo 2002 (Tiliaceae); Parveen *et al.* 2007 (Tiliaceae); Mandal 2010 (Malvaceae); Hossain *et al.* 2013 (Sterculiaceae)]. However, paracytic stomata are reported in *Abelmoschus caillei* (A. Chev.) Stevels (Malvaceae) (Osawaru *et al.* 2011) and in the genus *Reevesia* Lindl. (Zebe 1915). According to Metcalfe & Chalk (1950) and Inamdar & Chohan (1969) the stomatal structure in both Malvaceae and Bombacaceae is similar. Presently about 65 Indian species of the Sterculiaceae, presently treated under Malvaceae, have been studied, where in all members anomocytic stomata are common. In rare cases few paracytic (*Leptonychia moacurroides*) and anisocytic (*Sterculia foetida*) stomata were observed in addition to usual anomocytic type. However, polymorphic stomatal structure in a single species under these families was not reported earlier. Only *Pterygota alata* shows such high degree of polymorphism in stomatal structure (44 types including subtypes and intermediates).

The structural diversity of stomata in a single species is rarely reported in angiosperms as discussed earlier. Very recently, Mandal *et al.* (2014) reported high stomatal polymorphism in *Canella winteriana* (L.) Gaertn. (Canellaceae). In this species 10 types of normal stomata along with 4 subtypes, one intermediate type between stephanocytic and hemiparacytic and some abnormal stomatal structures like contiguous stomata,

different types of twin stomata and cytoplasmic bridge between adjacent stomata, stomata with single guard cell, single guard cell with pore juxtaposed with normal stoma were reported. All these families are unrelated and thus placed very distantly in recent classification systems (Cronquist 1981; Takhtajan 1997; APG III 2009). Therefore, phylogenetic pattern based on polymorphic nature of stomata cannot be drawn. Rather, it is believed that presence of more than one type of stomata in a single species is the reflection of precarious balance between the influences operating at a level of the meristemoid which tends to cause the formation of stomatal mother cells on the one hand and on the other, the influence operating at the level of organ involved in the orientation of cell division (Guyot *et al.* 1968; Humbert & Guyot 1969; Mandal *et al.* 2014).

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