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RESEARCH ARTICLE

Foliar Epidermal Studies of Plants in Euphorbiaceae

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ABSTRACT: This paper describes foliar epidermal structure in 17 species belonging to 17 genera of the family Euphoprbiaceae. Anomocytic stomata is predominant, rarely they are anisocytic, paracytic on the same foliar surface with different combinations. Leaves are hypostomatic and rarely amphistomatic. The foliar surface is smooth, rarely striated. The foliar epidermal cell walls are straight or undulate. Distribution of stomata, stomatal index, stomatal frequency, stomatal size and other cell wall contours are described in detail.

KEY WORDS: Foliar epidermis, stomata, subsidiary cells, Euphorbiaceae.

INTRODUCTION

Epidermal features of the family Euphorbiaceae have been documented by Metcalfe and Chalk (1950); Dehgan (1980); Baruah and Nath (1997); Raju and Rao (1977); Inamdar and Gangadhara (1978); Kakkar and Paliwal (1974); Thakur and Patil (2011). The present authors extended observations on 17 unstudied euphorbiaceous species, results of which are being presented here.

MATERIALS AND METHODS

The plants were collected from places like Nakane Dam, Peint, Harsul Forest, Radhanagari, Dajipur Forest in Maharashtra state. They were also collected from Government Botanical Garden Ootakamund, Tamil Nadu. Healthy herbarium materials from S I N U Botanical Herbarium Singapore, Rancho Santa Ana Botanic Garden, Claremont U. S. A. Preserved plant material obtained from Auckland War Memorial Museum, Auckland (New Zealand).

For the stomatal and epidermal tissues, the fresh, preserved and herbarium materials were used. In case of herbarium materials, the leaves were boiled in water for about 5–10 minutes. The chemical method was followed for the separation of peels. Diluted nitric acid and chromic acid (5–10%) were used in different proportions. In some cases using Three Acid Treatment (TAT) Method (N. Rammayya and V. Vanaja, 1979). Epidermal peels were stained in safranin (1%) and mounted in glycerin and made semi-permanent slides by ringing with nail paints. In case of exceptionally hairy leaves, the hairs were removed prior to separation of epidermal peels by covering the leaf surface with "Stick Fast" (Enelbee Company Jogeshwary, Mumbai) and gently peeling off the gum dried. Similarly Wellcol, a synthetic gum, and rubber solution were used for getting the peels. In some cases Favicol (Pidillite Industries, Mumbai) was gently applied on the leaf surface and allowed to dry for 2–3 minutes and gently peeled off the Favicol film (Nayeem and Dalvi, 1989).

The stomatal index (S.I.) was calculated as defined by Salisbury (1927, 1932).

$$Viz\ S.I. = \frac{S}{E+S} \times 100$$

Where,

"S" is the number of the stomata per unit and

"E" is the number of epidermal cells in the same area (including guard cell).

Stomatal frequency was calculated as defined by Ghosh and Davis (1973).

Stomatal frequency = Number of stomata per unit area.

Stomatal frequency and stomatal index have been calculated out of 10 readings. The cellular sketches were drawn using camera lucida and were inked with Camligraph or Rotring isographs technical pens.

The terms used for describing stomata are that of Metcalfe and Chalk (1950), Van Cotthem (1970) and Stace (1965). The typification of subsidiary cells followed is that of Ramayya and Rajgopal (1980).

Stomata and trichome relationships are decided as per Rajgopal and Pochaiah (1983).

Category 1: Often more than one cell covers the free zone between a trichome and stomata.

Category 2: Mostly one cell covers the free zone between trichome and stomata.

Category 3: No free zone present as the stomata itself abuts the trichome.

Terminology related to epidermis is followed that of Shanmukha Rao (1987). The trichomes are mainly after Ramayya (1962, 1972).

Observations:

1. *Agrostistachys indica* Dalz.

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cells chlorophyllous, sides 4–7, mostly 5–6, rarely 7, mostly curved, rarely straight, unevenly shaped, rarely tetragonal, thick, sinuses U-shaped, rarely V-shaped, tetragonal to pentagonal, rarely heptagonal (Fig. 3).

Leaf-Abaxial:

Stomata mostly paracytic, and rarely anisocytic; orientation random, distribution mostly on lamina, around the veinlet and, rarely on veinlet S.I.=18.04. Subsidiaries mostly 4, rarely 3, wavy, F as well as C-type. Walls mostly wavy, sides mostly 4–6. Guard cells wide, chlorophyllous, inner wall thick. Epidermal cells chlorophyllous, sides mostly 5–6, rarely 4, walls mostly wavy (Fig. 4).

2. *Balliospermum axillare* (Wight) Baillon

Leaves amphistomatic.

Leaf-Adaxial:

Epidermal cells chlorophyllous. Stomata mostly anomocytic; orientation random, distribution mostly on around the midvein and veinlet. S.I.=8.4. Subsidiaries mostly 4–5, mostly F-type. Walls straight, sides 4–6. Guard cells elliptical, pore narrow. Epidermal cells chlorophyllous, sides mostly 4–6, rarely 5. Few foot cells of trichomes present (Fig. 5).

Leaf-Abaxial:

Stomata mostly anomocytic, rarely paracytic, contiguous, orientation random, distribution mostly laminar. S.I.=12.64. Subsidiaries 4–5, rarely 2, predominantly F-type, rarely C-type. Guard cells elliptical, pore narrow. Epidermal cells chlorophyllous, sides 4–6, rarely 5 (Fig. 6).

3. *Blachia denudata* Benth.

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cells chlorophyllous, sides mostly 4–6, rarely 8, wavy, mostly isodiametric, undulate, few star-shaped, sinuses mostly U-shaped. (Fig. 7).

Leaf-Abaxial:

Stomata mostly anomocytic; rarely anisocytic; orientation random, distribution mostly on laminar region and along midvein and veinlets. S.I.=16.35. Guard cells elliptical, pore wide, outer wall of guard cell thick. Subsidiaries mostly 4–5, rarely 3, mostly F-type, rarely C-type. Walls undulate. Epidermal cells sides mostly 5–6, rarely 4,undulate, sinuses mostly U-shaped (Fig. 8).

4. *Bridelia retusa* Spreng.

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cells chlorophyllous, sides mostly 5–6, rarely 4 straight, penta to hexagonal, some isodiametric (Fig. 9).

Leaf-Abaxial:

Stomata mostly anomocytic; orientation random, distribution mostly on intercostals region. S.I.=13.75. Subsidiaries mostly 4–6, rarely 5, mostly F-type, rarely C-type, Guard cells elliptical, pore narrow. Epidermal cells chlorophyllous, sides 5–7 rarely 6, straight, slightly curved, sinuses mostly V-shaped, elongated papillae present (Fig. 10).

5. *Cicca acida* (L.) Merr.

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cells chlorophyllous, sides mostly 4–5, rarely 6, mostly straight, tetra to pentagonal, rarely hexagonal (Fig. 11).

Leaf-Abaxial:

Stomata mostly anomocytic, orientation random, distribution intercostal region. S.I.=11.85. Subsidiaries mostly 4–6, rarely 5, walls undulate, sinuses mostly U-shaped. Guard cells elliptical, pore narrow. Epidermal cells undulate, sides 5–7, rarely 6 (Fig. 12).

6. *Euphorbia helioscopia* Linn.

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cells chlorophyllous. Sides mostly 4–5, rarely 6, straight, tetra to hexagonal (Fig. 13).

Leaf-Abaxial:

Stomata mostly anomocytic, orientation random, distribution mostly on laminar region. S.I.=10.93. Subsidiaries mostly 5, rarely 4, sides mostly 5, rarely 4. Guard cells elliptical, pore wide. Epidermal cells straight, sides mostly 4–5, rarely 6 (Fig. 14).

7. *Excaecaria bicolor* Hassk.

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cells chlorophyllous, cells undulate, sinuses mostly U-shaped, sides mostly 4–5, rarely 6 (Fig. 15).

Leaf-Abaxial:

Stomata mostly anomocytic, rarely paracytic, orientation random, distribution on laminar region. S.I.=15.17. Subsidiaries 4–5, rarely 3, sinuses mostly U-shaped, sides mostly 6, rarely 4. Epidermal cells undulate, sides 6–7, rarely 5 (Fig. 16).

8. *Glochidion hohenckeri* Bedd.

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cells chlorophyllous, sides 5–6, rarely 4, mostly penta to hexagonal, few isodiametric (Fig. 17).

Leaf-Abaxial:

Stomata mostly anomocytic, orientation random, distribution diffuse. S.I.=17.98. Subsidiaries 5–7, rarely 6, mostly F-type, walls straight to slightly curved, sides mostly 6–7, rarely 4 (Fig. 18).

9. *Homalanthus polyandrus* Cheesem

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cell chlorophyllous, sides 4–6, undulate, sinuses mostly U-shaped (Fig. 19).

Leaf-Abaxial:

Stomata mostly anomocytic, rarely paracytic, rarely giant stomata, orientation random, distribution mostly on lamina, midvein and veinlet. S.I.=14.73. Subsidiaries mostly 4–5, rarely 2,mostly F-type, undulate, sides mostly 5–6, rarely 3. Guard cells elliptical, pore narrow. Epidermal cells undulate, sinuses U-shaped, sides mostly 5–6, rarely 4 (Fig. 20).

10. *Homonoia riparia* Lour.

Leaves amphistomatic.

Leaf-Adaxial:

Stomata mostly anomocytic orientation random, distribution intercostal region. S.I.=4.68. Subsidiaries mostly 4–6, rarely 5, mostly F-type rarely C-type, Guard cells elliptical, pore narrow. Epidermal cells chlorophyllous, sides 5–7, rarely 6, undulate, sinuses mostly U-shaped, dense elongated papillae present (Fig. 21).

Leaf-Abaxial:

Stomata mostly anomocytic, orientation random, distribution intercostal region. S.I.=13.25. Subsidiaries mostly 4–6, rarely 5, mostly F-type, rarely C-type, Guard cells elliptical, pore narrow. Epidermal cells chlorophyllous, sides 5–7, rarely 6, undulate, sinuses mostly U-shaped, numbers of elongated papillae present (Fig. 22).

11. *Jatropha panduraefolia* Andr.

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cells chlorophylllous, sides mostly 5–6, mostly penta to hexagonal (Fig. 23).

Leaf-Abaxial:

Stomata mostly paracytic, rarely contiguous, abutting, orientation random, distribution mostly on lamina. S.I.=13.25. Subsidiaries 4–5, rarely 2, mostly F-type, rarely C-type, sides 4–6, rarely 5 straight, slightly undulate. Guard cells elliptical, pore wide, outer wall thick. Epidermal cells chlorophyllous, sides 4–6, rarely 5. Cells striated (Fig. 24).

12. *Jonnesia principes* Vella.

Leaves amphistomatic.

Leaf-Adaxial:

Stomata mostly anomocytic, few contiguous, orientation random, distribution mostly on and around the midvein. S.I.=9.13. Subsidiaries mostly 4–5, mostly F-type, rarely C-type, walls mostly straight, sides mostly 4–5. Guard cells elliptical, pore elongated. Epidermal cells straight, few slightly curved, while few tapered at one end, sides mostly 4–6, rarely 5. Few foot cells of trichome present on and around the midvein, mostly on laminar region (Fig. 25).

Leaf-Abaxial:

Stomata mostly anomocytic, orientation random, distribution diffuse. S.I.=18.28. Subsidiaries mostly 4–5, mostly F-type, rarely C-type, walls straight, sides 5–6, rarely 4. Guard cells elliptical, pore narrow. Epidermal cells mostly straight, sides 5–6, rarely 4. Foot cells of trichomes mostly seen on laminar region. Cells surrounding the foot cells striated (Fig. 26).

13. *Kirganelia reticulata* (Poir) Baill.

Leaves are hypostomatic.

Leaf-Adaxial:

Epidermal cells are chlorophyllous, sides mostly 4–6 rarely 5, straight, tetra to hexagonal. (Fig. 27)

Leaf-Abaxial:

Stomata mostly anomocytic, orientation random, distribution along midvein and veinlet. S.I.=12.35. Subsidiaries mostly 5, rarely 4, walls straight, slightly undulate, sides mostly 5–6, rarely 4. Guard cells elliptical, pore narrow. Epidermal cells sides mostly 6, rarely 4. (Fig. 28)

14. *Mallotus stenanthes* Muell-Arg.

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cells chlorophyllous, undulate, sides mostly 5–7, unevenly shaped, sinuses mostly U-shaped. (Fig. 27)

Leaf-Abaxial:

Stomata mostly anomocytic, rarely anisocytic, orientation random, distribution mostly laminar, rarely around the midvein and veinlet. S.I.=15.72. Subsidiaries 5–6, rarely 4, mostly F-type, walls undulate, sinuses

mostly U-shaped, sides 6–8, rarely 4–5. Guard cells elliptical, pore wide. Epidermal cells undulate, sinuses U-shaped, sides 6–8, rarely 4. Glands with wavy outline on laminar region present (Fig. 28).

15. *Manihot esculenta* Crantz.

Leaves amphistomatic.

Leaf-Adaxial:

Stomata mostly anomocytic, rarely lateral contiguous, orientation random, distribution along the midvein and veinlet. S.I.=5.85. Subsidiaries mostly 5, rarely 4, sides mostly 5. Guard cells elliptical, pore narrow, walls mostly 5, rarely 4, slightly undulate. Epidermal cells slightly undulate. Sides mostly 5, rarely 4 (Fig. 29).

Leaf-Abaxial:

Stomata mostly anomocytic, orientation random, distribution intercostal region. S.I.=13.02. Guard cells elliptical, pore narrow. Subsidiaries mostly 5–6, rarely 4, slightly undulate, sinuses mostly V-shaped, rarely U-shaped. Epidermal cells straight to slightly undulate, sides mostly 4, rarely 6 (Fig. 30).

16. *Neoscortechinia kingii* Hook. *f*

Leaves hypostomatic.

Leaf-Adaxial:

Epidermal cells chlorophyllous, cell walls thick, sides mostly 4–6, undulate, penta to hexagonal, sinuses mostly U-shaped. Many foot cells radiating trichomes present (Fig. 31).

Leaf-Abaxial:

Stomata mostly paracytic, rarely contiguous abutting, orientation random, distribution mostly on laminar region. S.I.=17.38. Subsidiaries mostly 2, walls slightly curved, sides mostly 3, rarely 4–5. Guard cells elliptical, pore wide, outer wall thick. Epidermal cells straight, slightly curved long uneven shaped, sides mostly 5–6, rarely 4. Few cells surrounding subsidiary cells longer. Few cells of foot cells of trichomes present on laminar region (Fig. 32).

17. *Securinega virosa* (Roxb. ex Willd.) Baillon

Leaves hypostomatic.

Leaf-adaxial:

Epidermal cells chlorophyllous, sides 4–6, straight, and mostly tetra to hexagonal (Fig. 33).

Leaf-Abaxial:

Stomata mostly anomocytic, rarely paracytic, orientation random, distribution diffuse. S.I.=12. Subsidiaries mostly 4–5, rarely 3, mostly F-type, walls straight, slightly curved, sides mostly 5–6, rarely 4. Guard cells elliptical, pore narrow. Epidermal cells straight, slightly curved, sides mostly 4–5, rarely 6 (Fig. 34).

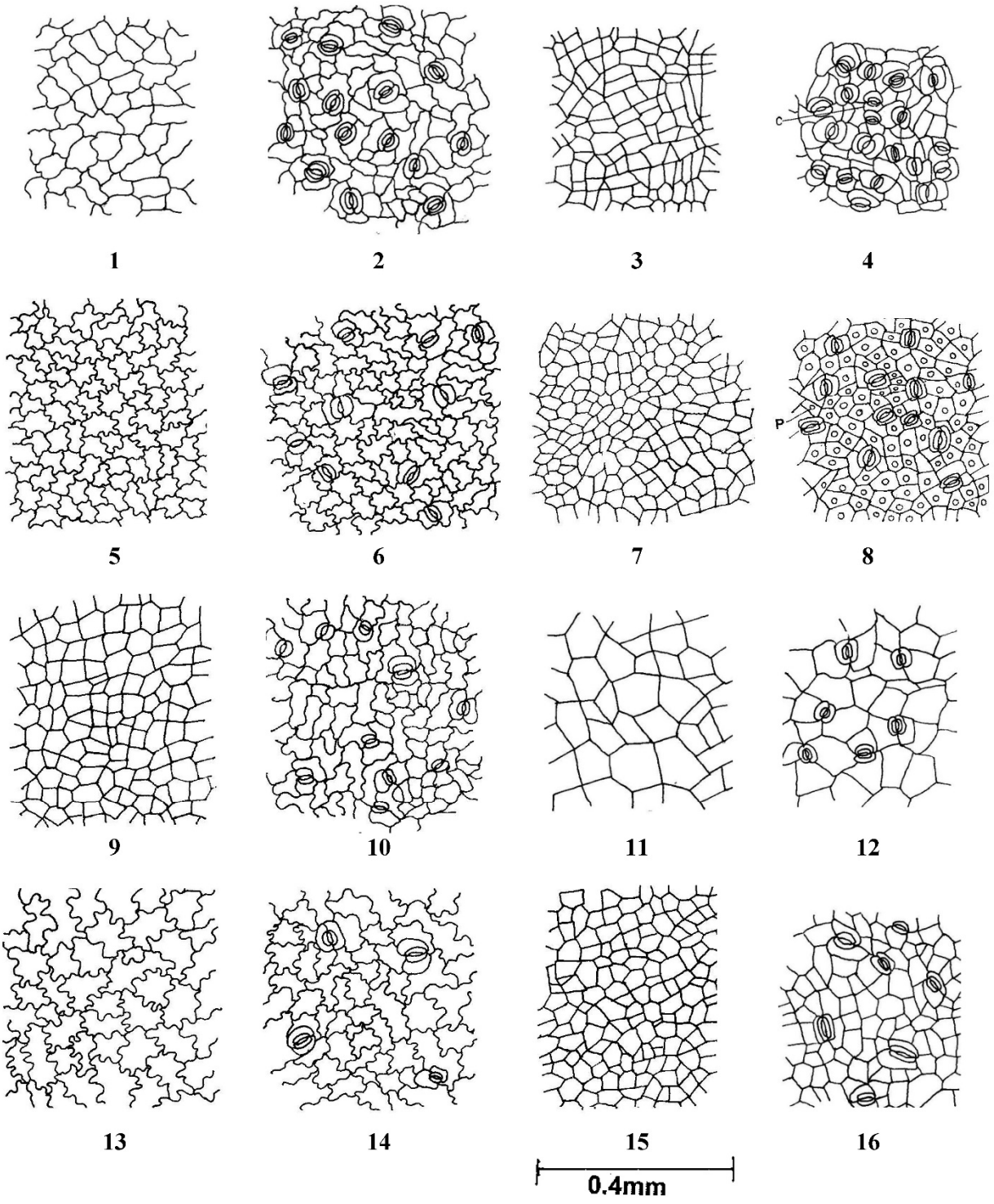
DISCUSSION

Metcalfe and Chalk (1950) recorded stomata usually paracytic in the tribe Acalypheae, Dalechampieae, Euphorbieae, Hippomaneae and Phyllantheae, with some exceptions. Similar type is also noted in genera *Glochidion* and *Stillingia*. They also recorded anisocytic type in the genera such as *Andrachne, Aporosa, Baccaurea* and *Richeria.* Anomocytic stomata are also noted in some species of *Euphorbia*. Dehgan (1980) studied epidermal morphology of the genus *Jatropha* and examined all species having paracytic stomata, except *Jatropha fremontioides* wherein anisocytic type is reported. Inamdar and Gangadhara (1978) while studying 53 species of the family noted anomocytic, paracytic, diacytic, anisocytic, and parallelocytic types. Baruah and Nath (1997) investigated four species of *Croton* and *Codiaeum variegatum*. They noticed paracytic type.

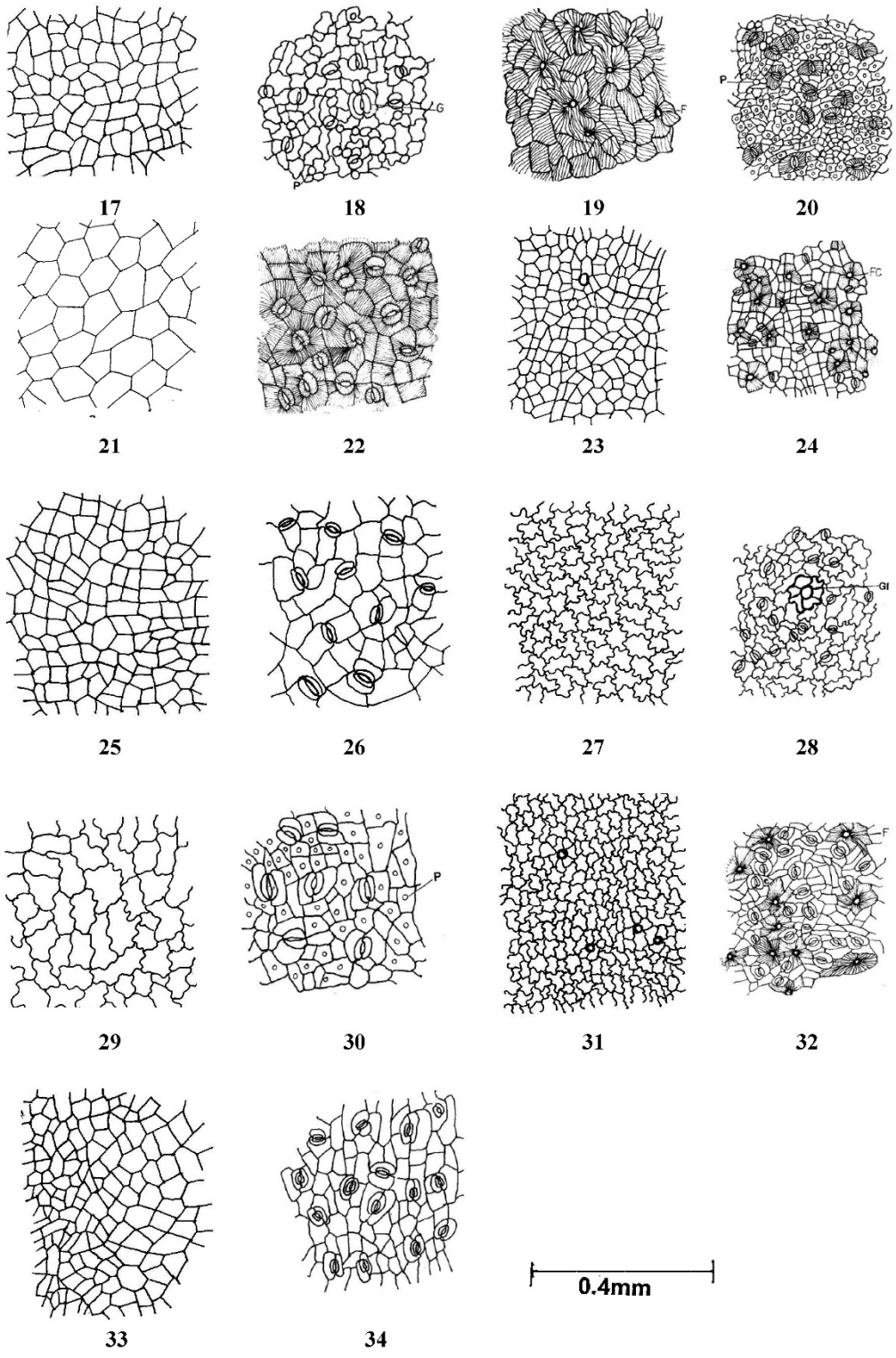
Raju and Rao (1977) reported paracytic, anisocytic, anomocytic and diacytic type in 50 species of the family. They also recorded tetracytic and cyclocytic types. Rao and Raju (1975) observed paracytic, anomocytic, anisocytic and diacytic type in case of *Micrococca mercurialis*, however paracytic type is predominant.

Generally, the stomates are anomocytic. However, other types such as paracytic, hexacytic and anisocytic are also noted in some taxa. They are paracytic on leaf abaxial in case of *Jatropha panduraefolia, Neoscortechinia kingii.* They are anomocytic on leaf adaxial viz., *Baliospermum axillare*, *Jonnesia principes*, *Manihot esculenta* and *Homonoia riparia*. Similar type is also noted on abaxial surface in *Bridelia retusa*, *Cicca acida*, *Euphorbia helioscopia*, *Glochidion hohenckeri*, *Homonoia riparia*, *Jonnesia principes*, *Kirganelia reticulata*, *and Manihot esculenta*. Different stomatal types are also found in different combinations on the same foliar surface in some taxa. They are mostly anomocytic, rarely anisocytic on leaf abaxial in *Actephila excelsa*, *Blachia denudata* and *Mallotus stenanthes*. They are usually paracytic, rarely anomocytic on leaf abaxial in *Agrostistachys indica*. They are mostly hexacytic, rarely anomocytic on leaf abaxial in *Aporosa lindleyana*. They are generally anomocytic, rarely paracytic on leaf abaxial in case of *Baliospermum axillare, Excaecaria bicolor*, *Homalanthus polyandrus* and *Securinega virosa*. Giant stomata is found only one species viz., *Homalanthus polyandrous.*

Different stomatal types as documented above have been on record for the family Euphorbiaceae. It appears that paracytic type is mostly common in majority of the tribes of the family. Other stomatal types are compara-



1 & 2: *Agrostistachys indica.* 3 & 4: *Baliospermum axillare.* 5 & 6: *Blachia denudata.* 7 & 8: *Bridelia retusa.* 9 & 10: *Cicca acida.* 11 & 12: *Euphorbia helioscopia.* 13 & 14: *Excaecaria bicolor.* 15 & 16: *Glochidion hohenckeri.*
Abbreviations used:C-Type (common subsidiary):Collalo-subsidiary which abutes on one or more adjacent stomata, but not any other cells. F-Type (free subsidiary): subsidiary neither abutes on another stomata for allo-subsidiaries. Fc: Foot cell of trichome. G: Giant stomata. Gl: Gland. P: Papillae. S. I.: Stomatal Index. Str: Striations.



17 & 18: *Homalanthus polyandrous.* 19 & 20: *Homonoia riparia.* 21 & 22: *Jatropha panduraefolia.* 23 & 24: *Jonnesia principes.* 25 & 26: *Kirganelia reticulate.* 27 & 28: *Mallotus stenanthus.*29 & 30: *Manihot esculenta.* 31 & 32: *Neoscortechinia kingii.* 33 & 34: *Securinega virosa.* Abbreviations used:C-Type (common subsidiary): Collalo-subsidiary which abutes on one or more adjacent stomata, but not any other cells. F-Type (free subsidiary): subsidiary neither abutes on another stomata for allo-subsidiaries. Fc: Foot cell of trichome. G: Giant stomata. Gl: Gland. P: Papillae. S. I.: Stomatal Index. Str: Striations.

tively less frequent. The present author is, therefore, inclined to regard the paracytic as the primitive in the family, while the rest other types appear derived from it. However, Cronquist (1968) and Paton (1957), in general, conceived the anomocytic type as a least specialised and other types are as later attainment from it. It therefore appears rather problematic to regard the paracytic type of stomata as basic especially in a fairly advanced family like the Euphorbiaceae. More number of genera and species need to be investigated to reach to such a conclusion.

Generally, the guard cells are elliptical in outline, rarely they are circular e.g. *Agrostistachys indica*, *Homalanthus polyandrous*. The guard cells are chlorophyllous. The walls of guard cells are unevenly thick. The inner walls are usually thick. In few cases, the inner walls of guard cells are considerably thick e.g. *Agrostistachys indica*. In some cases, the outer walls of guard cells are very thick viz., *Actephila excelsa*, *Blachia denudata*, *Jatropha panduraefolia*, *Neoscortechinia kingii*.

The stomates generally exhibit random orientation and are distributed diffusely. They are observed usually in the intercostal region and also occasionally around the veins and veinlets. Rarely, they occur on the veins and veinlets, apart from the intercostal region e.g. *Actephila excelsa*, *Agrostistachys indica*, *Baliospermum axillare*, *Glochidion hoenckeri*, Homalanthus *polyandrous*, *Homonoia riparia*, *Jatropha panduraefolia*, *Kirganelia reticulata*, *Manihot esculenta*, *Neoscortechinia kingii*. Out of 17 species investigated by the present author's majority of the species (13 species) have the leaves hypostomatic. The rest others have leaves amphistomatic e. g. *Baliospermum axillare, Homonoia riparia, Jonnesia principes, Manihot esculenta*. Solereder (1908) and Metcalfe and Chalk (1950) recorded their occurrence usually confined to the abaxial surface and rarely on both surfaces, the latter condition is noted in case of *Euphorbia corollata, E. radians* and *Stillingia sylvatica*. Raju and Rao (1977) documented generally amphistomatic condition in the tribe Crotoneae, Phyllantheae, Bischofieae, Chrozophoreae, Acalypheae, Plukenetieae, Dalechampieae, Micrandreae, Manihoteae, Jonnesieae, Hippomaneae, Hureae and Euphorbieae. Raju and Rao (*loc. cit.*) reported the leaves amphistomatic in case of *Euphorbia buxifolia*, which were ones, described epistomatic by Warming (1896). They are also reported amphistomatic in the species of *Euphorbia* (Reiche, 1923; Vindt, 1960; Kakkar and Paliwal, 1974). Similar condition is also noted for *Stillingia sylvatica* (Holm, 1911). Nair and Maitreyi (1962) and Rao (1963) described the leaves hypostomatic in *Sebastinia chamaelea* and *Hevea brasiliensis* respectively. Raju and Rao (*loc. cit.*) pointed out discrepancies in the earlier observations of these species. They revealed amphistomatic condition for either of the taxa. Olowokudejo (1993) reported paracytic and brachyparacytic stomata in some species of *Jatropha*. Raju and Rao (1987) reported high percentage of anomocytic stomata in *Chamaesyce*. Levin (1986) noticed anomocytic type in *Podocalyx* and paracytic in *Paradrypetes.* Levin (1980) pointed out also overwhelmingly hypostomatic condition of although both hypo - and amphistomatic conditions occur in the species of *Petalostigma and Tetracoccus.* Rao and Raju (1975) later also noted hypostomatic condition in *Sebastinia chamaelea*. Levin (1986) pointed out also overwhelmingly hypostomatic condition, although both hypostomatic and amphistomatic conditions occur in the species of *Petalostigma and Tetracoccus*. Raju and Rao (1987) reported high percentage of anomocytic stomata in *Chamaesyce*. Levin (1986) noticed anomocytic type in *Podocalyx* and paracytic type in *Paradrypetes*. Rao and Raju (1975) found the leaves amphistomatic in *Micrococca mercurialis*. Dehgan (1980) found stomata restricted to the abaxial surface in the genus *Jatropha*, with a few exceptions. Inamdar and Gangadhara (1978) in their ontogenetic study of stomata in 53 species belonging to three different tribes observed the foliar lamina either hypostomatic or amphistomatic. Baruah and Nath (1997) reported stomata present on both epidermises in three species of the genus *Croton*, except *Codiaeum variegatum* wherein hypostomatic condition is reported. Kakkar and Paliwal (1974) recorded anomocytic, anisocytic, paracytic and cyclocytic type of stomata in different species of the genus *Euphorbia*. The euphorbiaceous taxa show both hypostomatic and amphistomatic conditions of leaves. The euphorbiaceous taxa are herbs, shrubs and trees. They are subjected to variable period of favorable or unfavorable conditions in their life-time. Generally, the plants with amphistomatic leaves are correlated with habitat without water stress (*cf.*) Shanmukha Rao and Rammaya, (1981). Therefore, it appears that plants with hypostomatic leaves have to face habitats with water stress.

The subsidiaries are generally 4 to 5. These numbers are, however, encountered especially in case of anomocytic type of stomata. Rarely, they are more than six e.g. *Cicca acida*, *Glochidion hohenckeri*. Ramayya and Rajagopal (1980) recognised seven different types of subsidiary cells. They belong to exclusively F-type in the taxa investigated. Rarely and exclusively C-type are also noted e.g. *Actephila excelsa*, *Baliospermum axillare*, *Blachia denudata*, *Jatropha panduraefolia*, *Jonnesia principes.*. However, in some cases, both types occur on the same surface viz., *Agrostistachys indica*. The walls of subsidiaries are straight, rarely otherwise

e.g. *Actephila excelsa*, *Glochidion hohenckeri*, *Hura crepitans*, *Jatropha panduraefolia*, *Jonnesia principes*, *Kirganelia reticulata*, *Securinega viros*a.

The highest stomatal index 18.04 is found on abaxial foliar surface of *Agrostistachys indica*, whereas it is the lowest 10.93 in case of *Euphorbia helioscopia*. On adaxial side the highest stomatal index is 8.4 in case of *Baliospermum axillare*, whereas it is the lowest 4.68 in case of *Homonoia riparia.* Species-wise details of stomatal index are tabulated in Table 1. The highest stomatal frequency (per sq. cm.) is 3.4 on abaxial surface in case of *Actephila excelsa*, whereas it is the lowest 0.7 in case of *Euphorbia helioscopia*. The highest stomatal frequency is 1.2 observed in *Manihot esculenta* on adaxial surface, whereas the lowest stomatal frequency is 1.1 in case of *Baliospermum axillare* and *Homonoia riparia* on adaxial surface. The stomatal frequency for each species is given in Table 3. The biggest stomata 12.5 (M) is observed on adaxial surface in *Homonoia riparia*, whereas the smallest stoma on the same adaxial surface is 5.9 (M) in *Manihot esculenta*. The biggest stomata 17.5 (M) is observed on abaxial surface in *Jatropha panduraefolia*, whereas the smallest on the same abaxial surface is 9.8 (M) in *Bridelia retusa.* The stomatal sizes are given in Table 2. Stace (1965) considers the distribution and frequency of stomata as of considerable taxonomic significance, though sometimes may be connected with the ecology of the species. The literature survey also indicates that these have been employed widely especially in pharmacognostic studies. These can be conveniently employed to distinguish species of a genus.

Stomatal abnormalities are also observed in few taxa studied. They belong to the category of contiguous stomata. Two to three adjacent stomata abute each other laterally e.g. *Baliospermum axillare, Jatropha panduraefolia* or polarolaterally in *Neoscortechinia kingii*. Stomatal abnormalities are frequent in angiosperms and conceived to be freaks during stomatogenesis. The epidermal cells on either side of leaves are generally polygonal in the intercostals zone. They are usually tetra to hexagonal and isodiametric or rarely septa to octagonal. They are similarly observed in the members of this family (Metcalfe and Chalk, 1950; Dehgan, 1980; Baruah and Nath, 1997; Raju and Rao, 1977; Inamdar and Gangadhara, 1978). The cell walls are generally straight; sometimes they are arcuate or undulate, sinuses being U-shaped or V-shaped.

The U-shaped sinuses are observed on adaxial side in case of *Blachia denudata*, *Excaecaria bicolor, Homalanthus polyandrous*, *Homonoia riparia*, *Mallotus stenanthes*, *and Neoscortechinia kingii.* The sinuses are also U-shaped on abaxial side viz., in *Blachia denudata,Cicca acida, Excaecaria bicolor, Homonoia riparia, Mallotus stenanthus.* The sinuses are V-shaped on adaxial side e.g. *Bridelia retusa*. In some cases, sinuses are mostly U-shaped rarely V-shaped on abaxial surface in case of *Agrostistacys indica*. Sinuses are mostly V-shaped, rarely

U-shaped on abaxial surface in case of *Manihot esculenta*. Sinuous anticlinal walls are also recorded by Metcalfe and Chalk (1950), Dehgan (1980), Baruah and Nath (1997) and Raju and Rao (1977). Cell walls straight to arched or undulate are also described in the species of *Euphorbia* by Kakkar and Paliwal (1974). The intercostal epidermises are usually similar in size on either foliar sides in majority of species. They are small adaxially and larger abaxially in *Securinega virosa*. They are larger abaxially and smaller adaxially in *Homonoia riparia*, *Manihot esculenta*, *and Neoscortechinia kingii.*

The midvein cells are generally elongated, tetra- to pentagonal in shape on both surfaces in majority of the species. The side-walls are mostly straight. The cross-walls are generally straight and rarely oblique. In few cases especially on the abaxial sides, cells of veins and veinlets are akin to the adjacent foliar cells e.g. Jatropha *panduraefolia*, *Manihot esculenta*. The midvein cells are larger than those of the veinlet cells in case of *Actephila excelsa*, *Glochidion hohenckeri*, *Jatropha panduraefolia.* The cells of veinlet are larger than those of the midvein e.g. *Agrostistachys indica*, *Blachia denudata*, Bridelia *retusa*, *Cicca acida*, Excaecaria *bicolor*, *Homonoia riparia*, *Jonnesia principes*, Neoscortechinia *kingii*, *Securinega virosa*. Few cells are tapering at one end in case of midvein and veinlets in *Agrostistachys indica*, *Blachia denudata*, Cicca *acida*, *Glochidion hohenckeri*, *Homalanthus polyandrus*, *Manihot esculenta*, *Neoscortechinia kingii*.

The adaxial and abaxial epidermises are overlaid by a thick to moderately thick cuticle. The epidermal cells are mostly compact without intercellular spaces. However, intercellular spaces noted by Inamdar and Gangadhara (1978) in case of *Euphorbia heterophylla* (*op. cit.*). The topography of the cuticle is generally smooth or rarely ornamented. Cutin folds occur as striations in *Homonoia riparia* and *Jatropha panduraefolia*. They are present throughout the adaxial foliar surface in *Homonoia riparia*. They are present throughout the abaxial foliar surface in *Jatropha panduraefolia.* Striations are observed only on guard cells and associated subsidiary cells in *Jatropha panduraefolia*. The striae are restricted only to the guard cells e.g. *Homonoia riparia*. The striations are also noted on the cells surrounding the bases of trichomes e.g. *Jonnesia principes*, *Neoscortechinia kingii*. They usually radiate from the base of trichomes. Metcalfe and Chalk (1950) recorded cuticular striations radiating from the two sides of the stomata on abaxial surface of *Excaecaria agallocha*. Raju and Rao (1977)

Table 1. Stomatal index

Sr . No.	Name of Plants	Upper Epidermis		Lower Epidermis	
		On / Around Vein	Intercoastal	On / Around Vein	Intercoastal
1	*Agrostistachys indica*	A	A	8.98	18.04
2	*Baliospermum axillare*	3.4	8.4	8.32	12.64
3	*Blachia denudata*	A	A	11.67	16.35
4	*Bridelia retusa*	A	A	8.86	13.75
5	*Cicca acida*	A	A	A	11.85
6	*Euphorbia helioscopia*	A	A	A	10.93
7	*Excaecaria bicolor*	A	A	A	15.17
8	*Glochidion hohenckeri*	A	A	11.73	17.98
9	*Homalanthus polyandrous*	A	A	8.15	14.73
10	*Homonoia riparia*	4.68	A	8.98	13.25
11	*Jatropha panduraefolia*	A	A	8.98	13.25
12	*Jonnesia principes*	6.38	9.13	10.25	18.28
13	*Kirganelia reticulata*	A	A	8.9	12.35
14	*Mallotus stenanthus*	A	A	9.85	15.72
15	*Manihot esculenta*	5.85	A	7.35	13.02
16	*Neoscortechinia kingii*	A	A	8.27	17.38
17	*Securinega virosa*	A	A	6.85	12

***The figures relate to a mean of ten counts. A = Absent.**

observed striations in the species of *Antidesma*, *Bischofia*, *Croton*, *Dalechampia*, *Excaecaria*, *Homonoia*, *Hura*, *Jatropha*, *Ricinus*, *Sebastinia*, *Tragia* and *Trewia*. Rao (1963) also noted them in case of the genus *Hevea*. These authors critically observed the distribution of striations. Inamdar and Gangadhara (1978) noted striations in case of *Croton bonplandianum*, *Tragia cannabina*, *T. mollurina*, *Trewia polycarpa*, *Jatropha panduraefolia* and *Dalechampia scadens*. These are shown in their illustrations, however, made no reference about their occurrence. They are likewise noted by Dehgan (1980) and Rao and Raju (1975). The epidermis is papillate on either sides e.g. *Homalanthus polyandrous*, *H. populifolius*, *Homonoia riparia*, and *Manihot esculenta* It is observed that they are more frequent on the abaxial foliar surfaces than the adaxial ones. Out of the 17 species presently studied, only one species viz., *Mallotus stenanthes* show presence of glands on abaxial foliar surface.

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Table 2. Stomatal frequency (per sq. cm.)

Sr. No.	Name of Plants	Upper Epidermis		Lower Epidermis	
		On / Around Vein	Intercoastal	On / Around Vein	Intercoastal
1	*Agrostistachys indica*	A	A	0.8	1.7
2	*Baliospermum axillare*	1.1	A	A	2.2
3	*Blachia denudata*	A	A	0.7	1.5
4	*Bridelia retusa*	A	A	A	1.4
5	*Cicca acida*	A	A	A	1.4
6	*Euphorbia helioscopia*	A	A	A	0.7
7	*Excaecaria bicolor*	A	A	A	1.3
8	*Glochidion hohenckeri*	A	A	A	2.7
9	*Homalanthus polyandrous*	A	A	0.7	2.4
10	*Homonoia riparia*	1.1	A	1.3	2
11	*Jatropha panduraefolia*	A	A	A	1.2
12	*Jonnesia principes*	0.9	1.1	1.6	3.6
13	*Kirganelia reticulata*	A	A	A	1.3
14	*Mallotus stenanthus*	A	A	0.7	1.6
15	*Manihot esculenta*	0.6	1.2	1	1.4
16	*Neoscortechinia kingii*	A	A	A	2.4
17	*Securinega virosa*	A	A	0.6	1.3

***The figures relate to a mean of ten counts . A = Absent.**

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Table 3: Size of stomata (μ)

Serial Number	Name of Plants	Upper Epidermis								Lower Epidermis							
		Length In Range (Stomata)	Mean	Breadth in Range (Stomata)	Mean	Length in Range (Pore)	Mean	Breadth in Range (Stomata)	Mean	Length In Range (Stomata)	Mean	Breadth in Range (Stomata	Mean	Length in Range (Pore)	Mean	Breadth in Range (Stomata)	Mean
1	*Agrostistachys indica*	A	A	A	A	A	A	A	A	9–11	10.5	7–10	7.8	3–5	4	1–2	1.4
2	*Baliospermum axillare*	16–17	16.5	11–13	11.5	4–6	5.2	1–2	1.2	16–18	16.8	11–14	12.1	5–6	5.3	1–2	1.5
3	*Blachia denudata*	A	A	A	A	A	A	A	A	15–18	16.7	10–13	12.3	5–6	6.2	1–4	2.8
4	*Bridelia retusa*	A	A	A	A	A	A	A	A	9–10	9.8	6–7	6.3	4–6	4.8	1–2	1.4
5	*Cicca acida*	A	A	A	A	A	A	A	A	12–14	13.3	9–11	10.3	7–9	7.8	1–2	1.6
6	*Euphorbia helioscopia*	A	A	A	A	A	A	A	A	10–13	11.6	8–10	8.7	6–9	7.8	1–3	2.1
7	*Excaecaria bicolor*	A	A	A	A	A	A	A	A	13–17	15.8	11–14	12.6	10–13	11.2	2–3	2.6
8	*Glochidion hohenckeri*	A	A	A	A	A	A	A	A	14–17	15.4	12–15	13.3	6–8	6.8	2–3	2.7
9	*Homalanthus polyandrous*	A	A	A	A	A	A	A	A	13–19	13.6	10–16	11.9	8–11	9.2	1–3	1.4
10	*Homonoia riparia*	12–13	12.5	9–11	10.4	9–12	10.3	1–2	1.5	13–15	14.7	9–12	11.3	8–12	9.9	1–2	1.5
11	*Jatropha panduraefolia*	A	A	A	A	A	A	A	A	12–14	12.7	10–12	11.5	5–7	6.3	2–3	2.5
12	*Jonnesia principes*	11–13	12.2	10–11	10.4	8–10	8.7	1–2	1.2	11–14	12	9–12	10.3	9–10	9.4	1–2	1.1
13	*Kirganelia reticulata*	A	A	A	A	A	A	A	A	13–15	13.6	11–13	11.9	10–12	10.9	2–3	2.6
14	*Mallotus stenanthus*	A	A	A	A	A	A	A	A	16–19	17.5	12–14	13	4–7	5.9	1–2	1.6
15	*Manihot esculenta*	15–17	15.9	12–14	13.4	7–9	7.9	1–2	1.8	15–18	16.9	12–14	13.5	7–10	8.1	1–2	1.9
16	*Neoscortechinia kingii*	A	A	A	A	A	A	A	A	12–15	14	7–10	9.2	5–8	6.9	1–2	1.7
17	*Securinega virosa*	A	A	A	A	A	A	A	A	15–17	16.1	11–13	12.2	10–12	11.4	1–2	1.1

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大戟科植物葉面表皮之研究

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摘要：本文針對大戟科下的17個屬，於每屬中挑出一物種作葉面表皮構造之描述。在所有的氣孔類型中，不規則狀氣孔佔了多數，但仍有少數的例子是由不等型氣孔及平行型氣孔構成之組合排列在同一葉表皮上；本文研究之物種葉片大都屬於氣孔下生型，只有少數屬於上下葉表面皆有氣孔的類型；葉表面多屬光滑，少數呈現細紋狀；葉表皮細胞壁則呈現線性排列或具波浪狀。氣孔之分布、氣孔指數、氣孔頻率、氣孔大小及細胞壁輪廓等詳細資訊一併於文中討論。

關鍵詞：葉表皮、氣孔、副衛細胞、大戟科。