EPIDERMAL STRUCTURE AND DEVELOPMENT OF STOMATA IN SOME CAMPANULACEAE WITH A NOTE ON THEIR BEARING ON TAXONOMY IN THE FAMILY

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ABSTRACT

In the investigated species Campanulaceae, stomata are anomocytic, transitional, anisocytic, and tetracytic, rarely paracytic or bipolar. The most frequent type or only type is anomocytic. Stomta with subsidiary cells are mesogenous, except amesoperigenous tetracytic ones. Anomocytic are perigenous. Trichomes are glandular, unicellular or uniseriate, tubercled. Taxonomic significance of epidermal structures are also discussed.

INTRODUCTION

As far as the authors are aware, there is no literature on the stomata and trichomes in Campanulaceae beyond what is mentioned by METCALFE AND CHALK (1950). These observations are based on the study of the mature leaves and lack the data on their ontogeny. Therefore, the epidermal structures are studied in some Campanulaceae to supplement the existing information and to assess their taxonomic significance if any.

MATERIAL AND METHODS

The present study is based on the Formalin-Acetic acid-Ethanol fixed leaves of *Campanula colorata* Wall. and *Lobelia alsinoides* Lam. collected from the forests of Gujarat, *L. nicotianaefolia* Roth. from Mahableshwar and dry ones of *Wahlenbergia marginata* A.DC. available in the herbarium of this department. The dry leaves are rehydrated by putting in boiling water for about 10 minutes before they are investigated.

The epidermal peels are stained with Safranin (aqueous) or Delafield's hematoxylin and mounted in glycerine jelly. The stomatal index, density, relative frequency (%) of different types of stomata are calculated from camera lucida drawings of five different peels on each of the surface at an uniform magnification. For the size of the epidermal cells and stomata, ten readings at random on each surface are taken and their mean values are tabulated. The epidermal cell sizes are length $\times$ breadth and stomatal sizes length-breadth of guard-cells $\times$ length-breadth of pore. The stomatal and trichome indices are worked out after the method of SALISBURY (1927).

For stomata encountered in the present study, we have followed the circumscription and terminology of METCALFE AND CHALK (1950), METCALFE (1961), PANT AND BANERJI (1965a) and SHAH AND KOTHARI (1975). A stoma with a subsidiary cell at each pole is considered here as bipolar, not described by earlier workers.

OBSERVATIONS

Aspects of mature epidermis—The leaves of *Campanula* and *Wahlenbergia* are amphistomatic (cf. Figs. 1A-D and F) with slightly sunken stomata in the latter (Fig. 1L), whereas those of *Lobelia* are hypostomatic (cf. Figs. 1 E, K, and M). The epidermal cells have anti-

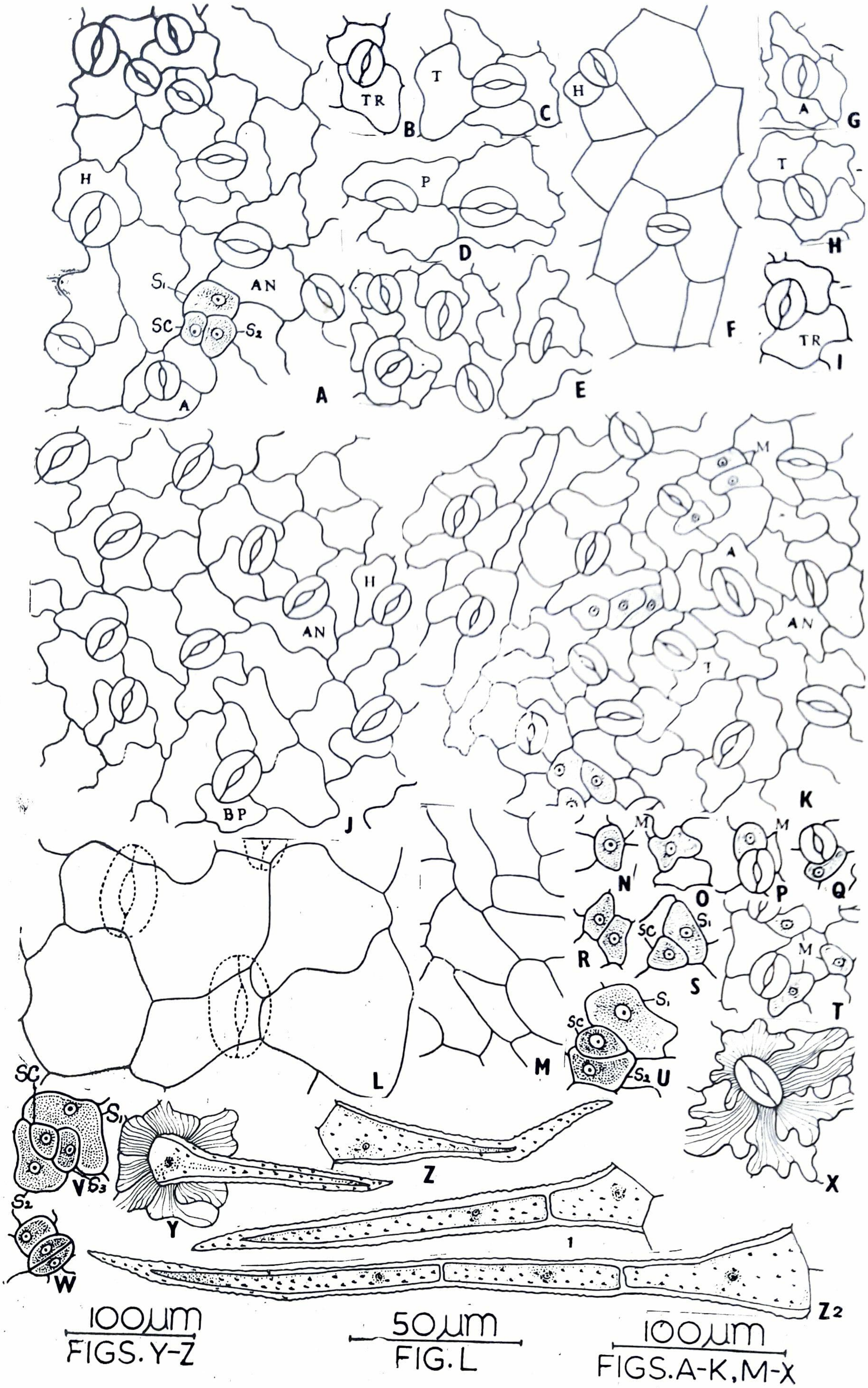

Fig. 1. *Campanula colorata* A-D, N, O, F, Z ; *Lobelia alsinoides* G—J, P and Q ; *L. nicotianaefolia* E, K, M, R—X, Y, Z_1 and Z_2. *Wahlenbergia marginata* L.

A—M stomata as observed in epidermal peels. N—W stages in stomatal ontogeny. Y-Z_2 Trichomes. (All figures from the abaxial surface except F & M which are of the adaxial surface of the leaf).

AN—anomocytic, H—haplocytic, TR—transitional, A—anisocytic, T—tetracytic, P—paracytic and BP—bipolar stomata ; M—meristemoid ; S1—S3 subsidiary cell segments ; SC—small segment.

clinal walls straight or slightly sinuous (Fig. 1 M) on adaxial surface of *Campanula* and *Lobelia* respectively, and much sinuous on the abaxial surface of the last two taxa (Fig. 1 A-D, E, G-K) and on both surfaces of *Wahlenbergia* (Fig. 1 L).

From Table 1 it will be seen that the epidermal cells are largest on both surfaces of *Campanula.* In other taxa the size differences are not much but they are smallest on both surfaces in *L. nicotianaefolia.* The densities are higher on the abaxial surface than on the adaxial one except in *Wahlenbergia* where the converse is true.

In amphistomatic leaves, the stomatal number and density are also more on the abaxial surface than on the adaxial one. The shortest and longest guard cells are observed on the abaxial surface of *Campanula* and *Wahlenbergia* accompanied by almost longest pore on the abaxial and adaxial surfaces in these taxa respectively.

The trichomes are more on the adaxial surface than on the abaxial one in *Campanula* and *L. nicotianaefolia* but the converse is true for their densities.

Mature stomata—They are anomocytic, haplocytic, transitional forms between paracytic and diacytic, anisocytic, tetracytic, and very rare paracytic and bipolar, mostly evenly distributed throughout the epidermis without definite pattern of orientation. Only the first type occurs on both surfaces of *Wahlenbergia* (Fig. 1 L), first two types on the adaxial surface of *Campanula* (Fig. 1 F) and all types on the abaxial surface of *L. nicotianaefolia* (Fig. 1 E, K), together with paraytic and bipolar in *Campanula* (Fig. 1 A-D) and *L. alsinoides* (Fig. 1 G-J) respectively.

In spite of the diversity, the most frequent type is anomocytic in all the taxa. Other types are rare (less than 10%) except the haplocytic ones which have a somewhat higher proportion (12-20%, Table 1).

The unusual stomatal forms are (i) a wall formation in a subsidiary cell in *L. alsinoides* (2%) (Fig. 1 J), (ii) a stoma with one guard cell in *Campanula* (2%) and *L. nicotianaefolia* (3%) (Fig. 1 D, E) and (iii) cuticular striation on epidermal cells spreading from guard cells (Fig. 1 K) or from the trichome bases (Fig. 1 Y).

Ontogeny—The stomata follow a mixed sequence of ontogeny since the developmental stages and mature stomata are found together in *Campanula* (10%), *L. alsinoides* (13%) and *L. nicotianaefolia* (34%) (Fig. 1 A, K, T).

Meristemoids (M) are variously shaped, distinguished by their smaller sizes, denser cytoplasm and relatively larger nuclei (Fig. 1 K, N, O, T). They are evenly scattered in the epidermis, at times contiguous obliquely (Fig. 1 Q, F, L), laterally (Fig. 1 T) or polar (Fig. 1 K) to mature stoma in *Campanula* and *L. alsinoides* (2%) and *L. nicotianaefolia* (18%). Seldom the two meristemoids are contiguously placed in *L. alsinoides* (3.6%) and *L. nicotianaefolia* (5%) (Fig. 1 K, R).

More commonly a meristemoid transforms into a guard cell mother cell without cutting off any subsidiary cell (Fig. 1 W). Sometimes it divides by 1-3 curved walls, to produce larger segments S_1—S_3 and the smaller segment (SC) (Fig. 1 S, U, A, V). The S_1—S_3 transform into subsidiary cells and SC into a guard cell mother cell. These organize into a stoma with one subsidiary cell (haplocytic), two subsidiary cells (paracytic, transitional) and three subsidiary cells (anisocytic). Seldom the S_1, S_2 and SC are almost of the same size arranged in a linear triad (Fig. 1 K). The SC organizes into a guard cell mother cell and S_1 and S_2 into subsidiary cell but their orientation with reference to guard cells is such that a *bipolar stoma* is formed (cf. Fig. 1 J).

A stoma has in addition to lateral subsidiary cells, the polar perigenes organised into subsidiary cells so that a stoma is tetracytic (cf. Fig. 1H). Following PANT (1965) the ontogeny of the stomata with subsidiary cells is mesogenous since the subsidiary cells

Table-1—showing relative frequency (%) of different stomatal types, their index (SI), density (SD), size (SC) and trichome index (TI) and density (TD) and epidermal cell size (ECS) and density (ECD).

Name	Organe	Surface	Types of Stomata							SI	SD	TI	TD	ECD	ECS	SC
			H	T	AN	A	Tr	BP	P							
Campanula colorata Wall.	L	ad	18		82					6.66	32.76	17.64	98.28	458.64	73.67×50.04	30.58—8.34% 15.29—4.17
		ab	6	3	80	6	2		3	19.64	180.18	12.5	131.04	737.1	66.72×48.65	38.92—13.9× 18.07—5.56
Lobelia alsinoides Lam.	L	ad												819.0	52.82×37.53	
		ab	20	1	64	12	2	1		18.18	196.56			884.52	61.16×31.97	31.97—9.73× 15.29—4.17
Lobelia nicotianaefolia Roth	L	ad										7.27	65.52	835.38	51.43×29.19	
		ab	12	6	62	14	6			15.12	212.94	6.41	81.9	1195.74	59.77×27.8	30.58—8.34× 16.68—4.17
Wahlenbergia marginata A. DC	L	ad			100					16.66	132.07			792.45	56.0×37.8	30.8—20.3× 18.2—7.0
		ab			100					25	264.15			660.38	60.2 —42.0	25.2—5.6 15.4—3.5

and guard cells are the products of the same meristemoid, except the the tetracytic ones in which it is mesoperigenous, where laterals are mesogenous and polars are perigenes. Anomocytic stomata are perigenous.

Trichomes—They are eglandular, conical and unicellular (Fig. 1 Y, Z) or uniseriate two-three celled (Fig. 1 Z_1—Z_2) ; lumen broad or narrow ; contents evanscent ; walls thick, surface tubercled.

SUMMARY AND DISCUSSION

According to METCALFE AND CHALK (1950) Campanulaceae and Lobeliaceae which may be amphistomatic or hypostomatic, are with anomocytic stomata. These observations are confirmed for the genus *Wahlenbergia,* where only anomocytic stomata are present on both surfaces, but not for *Campanula* and *Lobelia* as there are more than one type of stoma on abaxial surface. The most frequent type, of course, is anomocytic (62—82%) in these taxa.

The diversity in the stomatal types even on the same surface has been well established in dicotyledons and many monocotyledons (PANT & KIDWAI 1964, 1966, 1967 ; PANT & BANERJI, 1965a, 1965b ; SHAH & GOPAL, 1970, 1971, 1972 ; SHAH & KOTHARI, 1973 ; KOTHARI & SHAH 1975, etc.). The present report is an addition to the list.

The formation of stomata with one guard cell can be attributed to an irregularity in the cell division where the guard cell mother cell fails to divide to produce two guard cells, and it transforms itself into a bean shaped guard cell developing a normal pore on one side.

The differential behaviour of the meristemoids to cut off subsidiary cell segments is responsible for the production of different types of stomata but what causes the differential behaviour is not known. Very likely it has something to do with some inherent factors (PANT & KIDWAI, 1964).

The mixed ontogeny is due to a continuous process of differentiation and repeated divisions of meristemoids from young to mature leaves.

There are reports (SHAH & KOTHARI 1976 ; FAROOQUI 1979) that the contiguous stomata are the products of two adjacently placed meristemoids simultaneously developing into stomata or a meristemoid contiguously cut off to a mature stoma also developing into a stoma becoming contiguous to the existing one. In the present study, though contiguous meristemoids or a meristemoid cut off contiguous to a mature stoma are observed but the contiguous stomata are not encountered and, therefore, further activities of such meristemoids are not traced.

The trichomes are unicellular with silicified or calcified thickening in *Campanula,* and mostly thick walled unicellular or occasionally uniseriate in *Lobelia* (METCALFE & CHALK, 1950). The occurrence of unicellular trichomes in *Campanula* and unicellular or uniseriate ones in *L. nicotianaefolia* confirm the observations of these authors but the trichomes in the present study are distinctly tubercled in the taxa in which they occur, a point not referred to in earlier works.

From the data presented, it is evident that considerable new information is supplemented which is taxonomically important. *Wahlenbergia* and *L. alsinoides* can be distinguished by the absence of trichomes. *Campanula* with unicellular trichomes can be separated from *L. nicotianaefolia* in which uniseriate trichomes are also present. The anomocytic sunken stomata in *Wahlenbergia* again is a distinctive feature to separate it from *Campanula* and *Lobelia* where more than one type of stoma are present. The hypostomatic leaves in the last genus separate it from *Campanula.*

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