STRUCTURE AND ONTOGENY OF STOMATA IN SEEDLINGS OF SOME GAMOPETALAE

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ABSTRACT

Four types of aberrant and five types of normal stomata have been observed in the seedlings of 23 species belonging to gamopetalous families, viz. Acanthaceae, Labiatae and Plantaginaceae. The normal stomata are anomocytic, anisocytic, paracytic, diacytic and with a single subsidiary cell. The ontogeny of anomocytic types is haplocheilic or perigenous while that of the other types is syndetocheilic or mesogenous. Aberrant developments noticed are persistent stomatal cell, arrested development, degeneration of guard cell(s), and contiguous stomata.

INTRODUCTION

Although considerable literature is now available on the structure and ontogeny of foliar stomata, cotyledonary stomata are neglected by botanists, except the work of INAMDAR AND PATEL (1976) on Solanaceae and NAIDU AND SHAH (1981) on Labiatae. Therefore, the present work has been undertaken to give a comprehensive and comparative account of structure and ontogeny of foliar cotyledonary and hypocotyledonary stomata.

MATERIAL AND METHODS

The seeds of 23 species investigated were obtained from local sources as well as from the Botanical Garden, Stockholm, Sweden, Berlin and West Germany through the courtesy of their Directors. The seeds of the following 23 species were grown at an atmospheric temperature (April 41.8°C, May 44.2°C) in the Botanical Garden of Sir P. P. Institute of Science, Bhavnagar. *Andrographis echioides* Nees ; A. *paniculata* Nees, *Barleria cristata* L., *B. montana* Nees, *B. prionitis* L, *Barleria* spp., *Blepharis maderaspatensis* (L.) Roth., *B. molluginifolia* Pers., *Anisomelis indica* Br., *Hyptis suaveolens* Poit., *Leonotis nepetifolia* Br., *Ocimum basilicum* L., *Salvia coccinea* Juss., *Plantago alpina* L., *P. camtschatica* Link., *P. coronopos* L., *P. indica* L., *P. lanceolata* L., *P. major* L., *P. major* var. *atropurpurea* Hort., *P. media* L., *P. sempervirens* Crenf. and *P. psyllium* L.

Epidermal peels were taken by direct peel method from fresh as well as fixed materials ; (1 : 3 acetic ethanol) of cotyledons, hypocotyle and first leaves, stained with Delafield's haematoxylin and mounted in glycerin jelly by usual method. Ringing was done with DPX mountant. Camera Lucida drawings were made with the help of Carl-Zeiss trinocular research microscope at table level.

Mean value of 15 observations showing the percentage of different types of stomata, stomatal frequency and index per mm^2, size of guard and epidermal cells in μm, nature of an anticlinal epidermal walls and surface are given in tables 1 and 2.

OBSERVATIONS

ASPECT OF MATURE EPIDERMIS

The cotyledons and leaves of the species examined here, except *Plantago camtschatica* are amphistomatic. *P. camtschatica* cotyledons and leaves are hypostomatic. The epi-

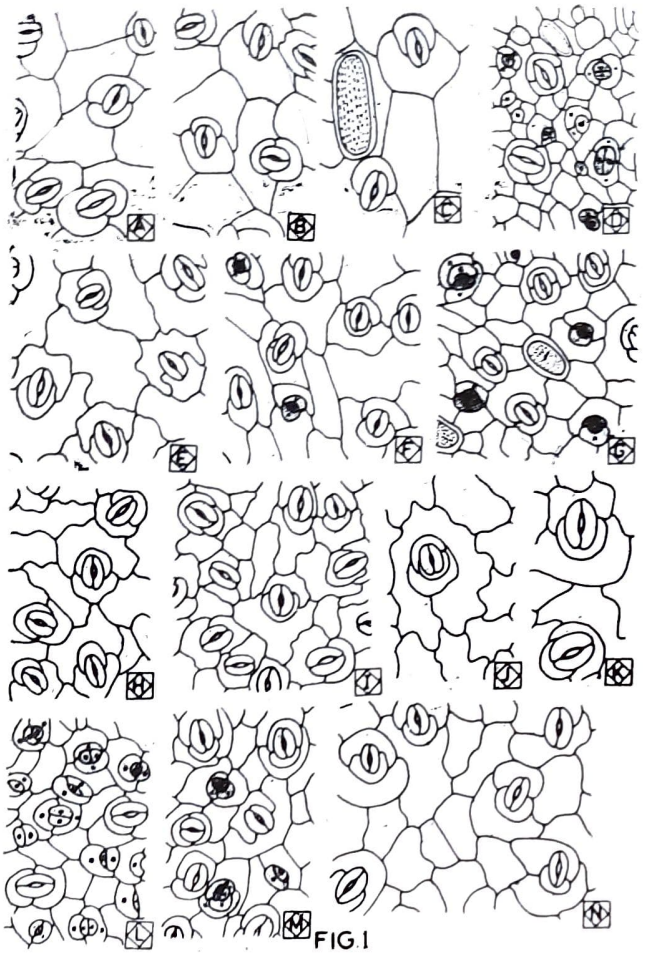

FIG. 1

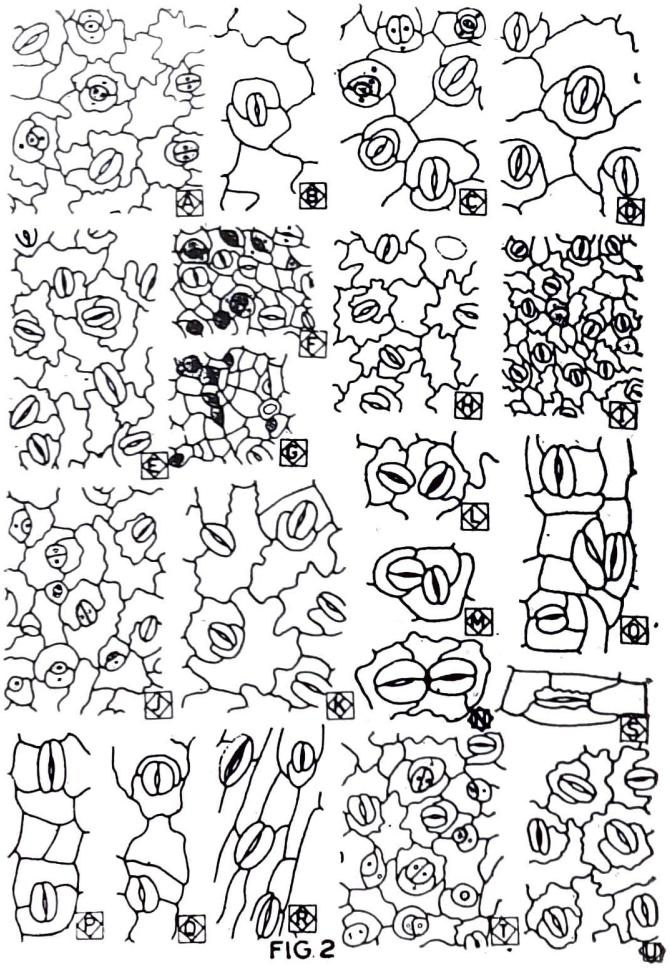

FIG. 2

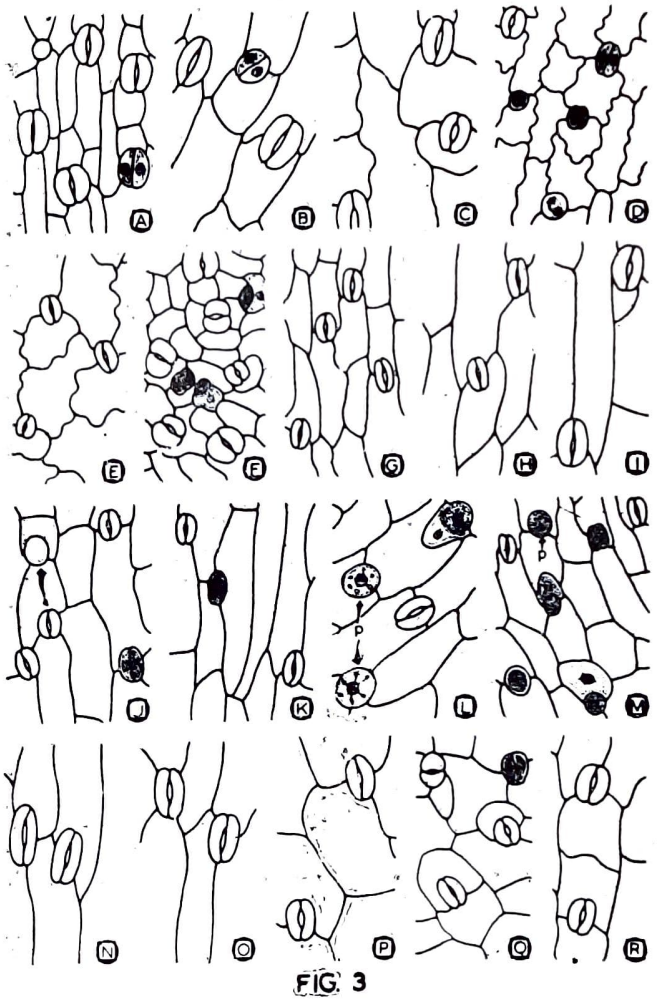

FIG. 3

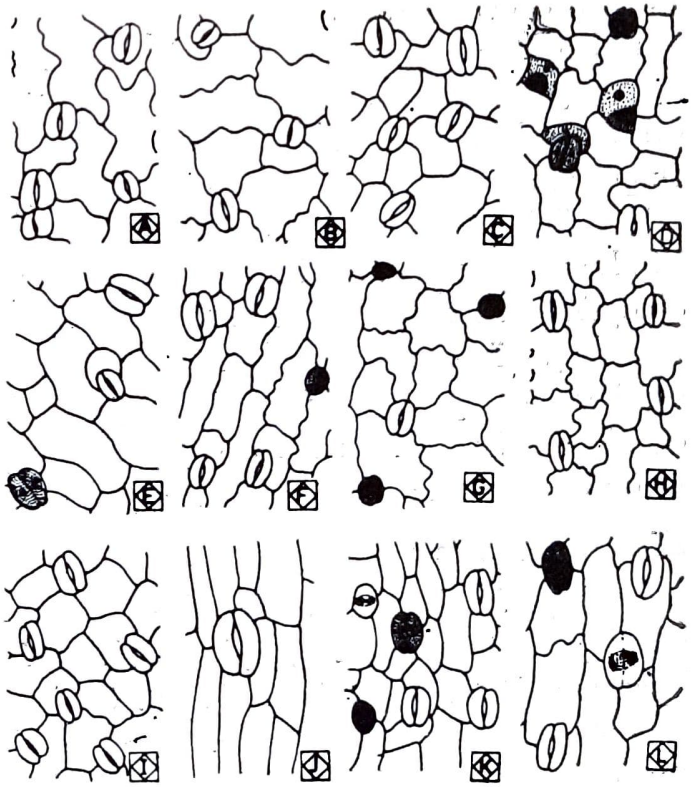

FIG. 4

dermal cells are irregularly arranged in cotyledons and leaves and parallel to the long axes or transversely or obliquely oriented on the hypocotyl. Both normal and abnormal stomata may occur on the same surface of an organ. The normal stomata on the cotyledons, hypocotyl and leaves of investigated species are either anomocytic, anisocytic, paracytic, diacytic and with a single subsidiary cell (Figs. 1-4). The mature stomatal apparatus consist of lenticular pore surrounded by two kidney-shaped guard cells with or without subsidiary cells. The guard cells may be equal or unequal (Figs. 2, N, O, S, R, U ; 3, C, F, M, Q ; 4, A, C). This may be due to unequal division of the guard mother cell. Anomalous stomatal developments have been noticed on hypocotyl, cotyledons and leaves. In the species investigated the more common abnormalities are occurrence of contiguous stomata (Figs. 2, L ; O ; 3, F ; 4, A) and degeneration of guard cell (Figs. 2, R-S). The other abnormalities are persistent cells (Figs. L-M) and arrested development (Fig. 3, J).

DEVELOPMENT

In young cotyledons, hypocotyl and leaves, the protodermal cells are uninucleate, polygonal, isodiametric or elongated with uniform staining. The stomatal meristemoids are cut off either in corners or on one side of the protoderm cells. Stomatal meristemoids occur either solitary or in pairs and can be distinguished from other protoderm cells by their smaller size, prominent nuclei and denser cytoplasm. The ontogeny of normal and abnormal stomata is as under:

Normal stomata

(i) Anomocytic stomata develop directly from the meristemoid by a straight division of the guard mother cell and without cutting off any subsidiary cells, the stomata are formed as Anomocytic.

(ii) Paracytic stomata are formed by cutting off two parallel subsidiary cells, one on each side of the meristemoid, and straight division of the guard mother cell parallel to the subsidiary cells. The intervening pore is developed in anticlinal direction of the guard cell and parallel to the main axis. This way the paracytic stomta is formed.

(iii) Stoma with a single subsidiary cell arises after cutting off one subsidiary cell from the meristemoid, parallel to the guard mother cell and formed the stoma with a single subsidiary cell in any direction.

(iv) Diacytic stomata develop up to triad stage like that of the paracytic type but here the guard mother cell divides by a wall at right angles to the subsidiaries and diacytic stomata are formed.

(v) In anisocytic stomata the meristemoid behaves like an apical cell with three cutting faces producing three unequal subsidiaries and two guard cells by a straight division of the guard mother cell parallel to the last subsidiary cell. Here the subsidiary cells are unequal and one subsidiary cell is smaller the other two.

Abnormal stomata

(i) *Persistent stomatal cell*—The stomatal initial normally is devoid of chloroplast, develops uniform thickening, but lacks differential wall thickening. Chloroplasts appear later and become persistent (Figs. 3, L, M). The persistent stomatal cell normally occupies the position of a stoma and has the same staining effect. It is either spherical or ovoid in outline (Figs. 3, L, M). The persistent stomatal cell may also divide in any

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Figs. 1—4. Structure of stomata in seedlings. 1,2×260; 3,4×290.

Table 1—Percentage of different types of stomata, stomatal frequency and index per mm², size of guard and epidermal cells in μ, nature of epidermal walls and surface. Figs. ca ×260.

Serial No.	Name of the plant/organ	Stomata								Epidermis			
		Percentage					Frequency per mm²	Index per mm²	Size of guard cells in μ		Size of cells in μ		Nature of wall	Surface
		P.	An.	A.	D.	S.S.			L	B	L	B		
Fig. 1 A-F	*Andrographis echioides*				100		400	22	23.6	5.4	43.1	30.8	Arch-Sinuous	Amphistomatic
G-H	*A. paniculata*				100		240	23	21.4	5.9	33.9	26.5	Sinuous	,,
I-J	*Barleria cristata*				100		96	25	21.0	6.1	*31.5*	21.7	,,	,,
K	*B. montana*				100		128	27	30.3	7.7	45.5	**38.8**	,,	,,
L	*B. prionitis*				100		208	35	30.1	8.1	50.5	31.6	Arch-Sin.	,,
M-N	*Barleria* spp.				100		96	24	32.1	8.9	46.5	36.1	,,	,,
Fig. 2 A-B	*Blepharis maderaspatensis*				100		288	40	26.5	6.6	51.5	37.5	Sinuous	,,
C-D	*B. molluginifolia*				100		800	47	26.2	7.8	45.9	29.9	Arch-Sin.	,,
E-F	*Anisomelis ovata*			38	62		768	**60**	23.9	5.1	32.4	11.9	Arched	,,
G-H	*Hyptis suaveolens*			27	73		560	42	18.2	5.1	48.6	23.2	Sinuous	,,
I	*Leonotis nepatifolia*			19	81		**864**	56	17.1	6.9	32.4	14.1	,,	,,
J-N	*Ocimun basilicum*			41	59		354	53	23.8	8.5	92.1	32.3	Arch-Sin.	,,
O-V	*Salvia coccinia*				100		240	19	22.3	8.5	58.1	18.2	,,	,,

Sin=Sinuous ; P—Paracytic ; A—Anomocytic ; An—Anisocytic ; D—Diacytic S.S.—Single subsidiary cell : Bold numbers—Maximum. Italics numbers—Minimum.

Table 2—Percentage of different types of stomata, stomatal frequency and index per mm², size of guard and epidermal cells in μ, nature of epidermal walls and surface. Figs. ca ×290.

Serial No.	Name of the plant/organ	Stomata								Epidermis			
		Percentage					Frequency per mm²	Index per mm²	Size of guard cells in μ		Size of cells in μ		Nature of wall	Surface
		P	An.	A.	D.	S.S.			L	B	L	B		
Fig. 3 A-B ..	*Plantago alpina* ..	..	..	100	..	..	144	21	25.7	10.0	61.9	18.4	Arched ..	Amphistomatic & stomatic.
C-E ..	*P. camtschatica* ..	..		93	07	..	160	19	23.8	8.8	68.1	40.0	Sinuous ..	Amphistomatic.
F-G ..	*P. coronopus* ..	..	..	70	30	..	256	41	19.9	9.6	46.7	19.7	Arched ..	,,
H-M ..	*P. indica*	..	..	80	20	..	240	18	**33.4**	**10.6**	**99.5**	33.5	Straight & arch.	,,
N-R ..	*P. lanceolata* ..	..	..	94	06	..	176	22	21.8	8.3	48.5	36.5	Arched ..	,,
Fig. 4 A-C ..	*P. major*	..	..	97	03	..	96	16	22.8	8.6	77.3	37.6	Sinuous ..	,,
D-E ..	*P. major* var. *atropurpurea* ..	..	..	92	..	08	*80*	13	25.0	9.1	42.6	21.0	Arch. & Sin.	,,
F-G ..	*P. media*	..	..	100	..	..	112	*11*	21.8	7.4	65.8	22.6	Sinuous ..	
H-I ..	*P. sempervirens* ..	..	..	99	..	02	96	12	25.1	9.1	51.7	20.5	Straight & arch.	,,
J-L ..	*P. psyllium*	..	..	75	..	25	*80*	*11*	24.8	7.7	42.4	18.9	,, ..	,,

Sin—Sinuous ; P—Paracytic ; A—Anomocytic ; An—Anisocytic ; D—Diacytic ; S.S.—Single subsidiary Cell : Bold numbers—Maximum. Italics numbers—Minimum.

plane, but an intervening pore does not develop. It occurs solitary and remain in same stage.

(ii) *Arrested development*—During ontogeny the nucleus and the cytoplasm of the stomatal meristemoids degenerate at any stage of development and become arrested (Fig. 3 J). Sometimes the arrested stomatal cells resemble epidermal cell. Arrested developments can be easily distinguished from the persistent stomatal cell by lack of chloroplast, a prominent nucleus and dense staining properties.

(iii) *Degeneration of guard cell*—Sometimes both the guard cells degenerate and a central pore becomes smaller in size (Figs. 2, H, S). Degeneration of the guard cells is commonly seen in mature scenscent leaves which are about to fall but here it has been observed in cotyledons and first foliage leaves which are yet to mature.

(iv) *Contiguous stomata*—Contiguous stomata are common (Figs. 2, L, M, N, O ; 3, F ; 4, A). They develop from the meristemoids placed adjacently or as a result of readjustment during maturation of the epidermis. Such contiguous stomata should not be regarded as abnormal. The contiguous stomata have variable orientations; they may be juxtaposed, superimposed, obliquely oriented or at right angles to each other.

The ontogeny of the anomocytic stomata confirms the haplocheilic (FLORIN, 1931, 1933) or perigenous (PANT, 1965)—while that of the other types in syndetocheilic (FLORIN, 1931, 1933) or mesogenous (PANT, 1965) type.

DISCUSSION

According to METCALFE AND CHALK (1950) stomata in the leaves of Acanthaceae are diacytic and paracytic, of Labiatae are diacytic and anomocytic, and of Plantaginaceae are only diacytic. The cotyledonary stomata are not referred to by these authors. The stomata in the present investigated seedling organs of the Acanthaceae are diacytic and anomocytic, of Labiatae are diacytic and anomocytic and of Plantaginaceae are diacytic, anomocytic and with a single subsidiary cell. The ontogeny of anomocytic is perigenous while that of the other type is mesogenous.

INAMDAR AND PATEL (1976), and NAIDU AND SHAH (1981) studied the structure and development of normal and abnormal stomata in the seedlings and development of normal and abnormal stomata in the seedlings of some Solanaceae and Lamiaceae, respectively. INAMDAR AND PATEL (1976) are of the opinion that contiguous types of stomata in different orientation and structure which are observed in their investigation are under one type, i.e. contiguous. Overlapping and superimposed stomata are not of different types but in fact there is no difference. NAIDU AND SHAH (1981) have listed about fourteen types of unusual stomatal structures under natural condition in the cotyledons of some Lamiaceae, some of which are really not abnormal.

The present investigation have similar observation to that of INAMDAR AND PATEL (1976). During the course of present investigation normal and abnormal stomatal structure observed are : anomocytic, anisocytic, paracytic, diacytic and with a single subsidiary cell, persistent stomatal cell, arrested development, degeneration of guard cell and contiguous stomata.

NAIDU AND SHAH (1981) have also mentioned that contiguous, overlapping and superimposed stomata are distinct from one another but in fact there is not much difference among these three types. Contiguous, overlapping and superimposed stomata should have been considered under one heading. NAIDU AND SHAH (1981) also regard the stoma with common subsidiary cell as unusual but the occurrence of a common subsidiary cell is observed in many taxa and has not been considered as abnormal by any of the

earlier workers (see also RAMAYYA & RAJGOPAL, 1970). Therefore, most of the unusual stomatal forms described by NAIDU AND SHAH (1981) are normal, or it has oriented from the one meristemoid.

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