

**Observations on the Structure and Ontogeny of Stomata
and Trichomes on Developing and Mature Pericarps
of *Cassia occidentalis* L.**

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Abstract. Paracytic, anisocytic, anomocytic, transitional forms, tetracytic, cyclocytic stomata and partly and completely amphicyclic forms are found, often on the same surface, in nine combinations. The most frequent type is paracytic. A few morphological variations in the basic types and eight types of abnormalities in stomata are recorded. The stomatal ontogeny may be mesogenous, mesoperigenous or perigenous. Trichomes are multicellular glandular club-shaped and unicellular eglandular. The taxonomic significance of stomata is indicated.

The structure and ontogeny of stomata are studied on the stem, leaflets, rachises, stipules and sepals in 19 species of *Caesalpiniaceae* belonging to the genera *Bauhinia*, *Caesalpinia*, *Cassia*, *Delonix*, *Peltophorum*, *Saraca* and *Tamarindus* (SHAH and GOPAL 1971) but such studies on the pericarp are very meagre. In *Cassia occidentalis* stomata on pericarps are paracytic (OKPON 1969) or paracytic and anomocytic together with contiguous stomata and stomata with one guard cell as abnormalities and multicellular glandular and unicellular, tubercled, eglandular trichomes (PATEL *et al.* 1976). These studies lack much of the desired information on the range of diversity and detailed ontogeny of stomatal types and their taxonomic significance. In the present paper, therefore, the observations on the structure and ontogeny of stomata and trichomes on the developing and mature pericarps of *C. occidentalis* are recorded as supplementary, new data.

MATERIAL AND METHODS

Pods of various sizes of *Cassia occidentalis* were collected from plants growing locally as weeds. The ovaries and pods cut in pieces of suitable size were fixed in formalin-acetic acid-ethanol. They were microtomed (10 μ m thickness) and the sections stained with safranin-fast green combination were made permanent in the usual way. The epidermal peels from the apical, basal, middle and marginal regions of the fresh pericarps of the developing and mature pods were stained with Delafield's hematoxylin and mounted in glycerine.

The stomatal and trichome indices, stomatal, trichome and epidermal densities/mm², average length $\times$ breadth of guard cells, pores and epidermal

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cells and relative frequency [%] of different types of stomata are tabulated for ready reference. They are calculated from camera lucida drawings of five peels of different pods in each group at a uniform magnification, whereas the stomatal and trichome indices are calculated by SALISBURY's (1927) method. For the purpose of counting the relative frequency of different stomatal types, the basic types fitting with the terminology and description of mature stomata by METCALFE and CHALK (1950), METCALFE (1961), PANT and BANERJI (1965), STACE (1965) and SHAH and KOTHARI (1975) are considered. The ontogenetic terms—perigenous, mesogenous and mesoperigenous (PANT 1965) are used in the text as they are easy to follow. The different stomatal types are labelled in figures for the perusal of readers.

The pods are divided into three categories, 1–2 cm long, 3–6 cm long and 7–12.5 cm long including dehiscent pods. They are designated in the table as young, maturing and mature pods, respectively.

RESULTS AND DISCUSSION

Epidermal cells may be rectangular, polygonal and isodiametric or variously elongated with straight, anticlinal walls. Stomata are oriented throughout the surface irregularly (Figs. 1, 3, 11, 15) or in the same direction (Fig. 5). As can be judged from the data on stomatal indices, stomata are few on margins, the largest number in the middle region and almost an equal number in basal and apical regions or more in the former than in the latter region. The stomatal and epidermal cell densities are highest in all regions of the young pods. On the other hand the number and density of trichomes and the mean epidermal cell sizes are highest in different regions of the maturing pods. But the average guard cell and pore sizes are higher in the apical regions than those in the margins of maturing pods where the pores are longest (Table 1).

From Table 1 it will also be seen that stomata are paracytic (PA), anisocytic (A), anomocytic (An), haplocytic (H), transitional forms between paracytic and diacytic (Tr), tetracytic (T) and cyclocytic (C), different types often occurring side by side in different combinations (*cf.* Figs. 1, 3, 5, 10, 11, 15). There are nine combinations, two with six types (Figs. 1–2, 3–4), one with five types (Figs. 5–10), three with four types (Figs. 11–13 and 14–16, 27–29, 30–32), two with three types (Figs. 33–35, 36–38) and one with two types (Figs. 39–40). The most frequent type is PA (*cf.* Figs. 1, 3, 5, 11, 32, 36) except on the margin of maturing pericarps where An, H and T are in equal proportions (see Figs. 33, 35). Other types are less frequent, though A, An and Tr constitute a higher percentage in some cases.

A few morphological variations affecting the basic types are produced as follows: (i) A wall formation takes place in one or all subsidiary cells of PA, Tr, A or H (Figs. 7, 10, 33, 41, 43, 48), some of such forms resembling an A (Figs. 42, 44, 47) or An type (Figs. 15, 51). The wall formation is observed even during the ontogenetic stages (Fig. 26). (ii) The neighbouring perigenes assume the form of subsidiary cells. Such stomata may be (a) partly amphicyclic PA (Figs. 52, 60) or A (Figs. 12, 49) or H and PA with an outer incomplete C ring (Figs. 33, 54) or (b) completely amphicyclic, the inner ring of subsidiary cells surrounded by an outer ring of subsidiary cells. The different forms of such stomata are (1) inner Tr with an outer A (Fig. 14),

PA (Fig. 45) or C (Fig. 46), (2) inner PA and outer PA (Fig. 32) or C (Fig. 38), (3) inner A and outer PA (*cf.* Fig. 15), (4) inner T and outer C (Fig. 56) rings and (5) both rings are C (Figs. 13, 55). (iii) At times both the processes operate simultaneously in the same stoma (Figs. 50, 53; also *cf.* Fig. 33).

Abnormalities are (i) stomata with unequal guard cells (Figs. 1, 8, 17, 44, 60), (ii) subsidiary cell-like guard cells (Fig. 9), (iii) obliquely oriented guard cells (Fig. 10), (iv) one guard cell (Fig. 7, 50, 57, 58, 61), (v) without



Figs. 1-2, 3-4, 5-10, 11-13, 14-16 — epidermal peels from different regions of young (middle, apical), mature (apical), young (marginal) and mature (marginal) pericarps, respectively. Figs. 17-26 — ontogenetic stages from mature (middle) pericarp. (M — meristemoid; SM — small cell; S₁ and S₂ — subsidiary cells; SC — small central cell; GC — guard cells; P — perigenes).

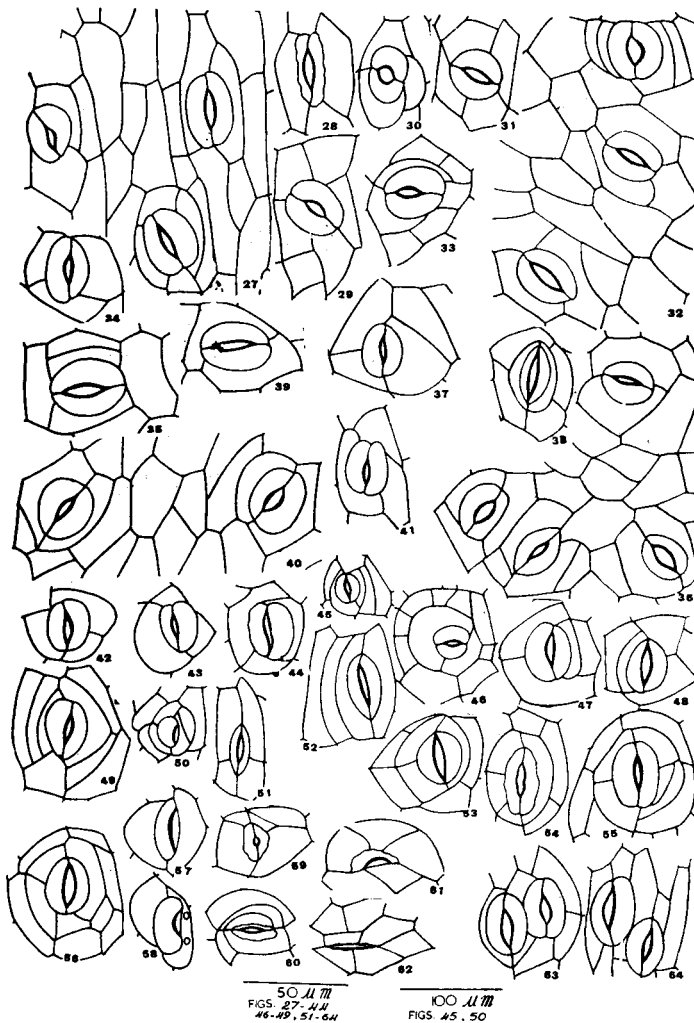
TABLE 1

Stomatal index (SI), stomatal density (SD/mm²), epidermal cell density (ECD/mm²), trichome index (TI), trichome density (TD/mm²), size of guard cells, pore and epidermal cells and types of stomata. PA — Paracytic; A — Anisocytic; An — Anomocytic; H — Haploclastic; T — Tetraclastic; Tr — Transitional and C — Cycloclastic; SGC — Size of guard cells; SP — Size of pore; SEC — Size of epidermal cells

No. Fruit	Region	SI	SD	ECD	TI	TD	SGC [μm]	SP [μm]	SEC [μm]	PA	A	Types of stomata			Tr	C
												An	H	T		
1 Young	Basal	6.3	249.6	3609	0.7	2.4	18.1 × 9.0	11.8 × 2.2	29.3 × 12.5	71.0	5.0	11.0	5.0	—	8.0	—
	Middle	10.6	300.7	2606	0.9	28.8	24.6 × 6.6	16.5 × 2.3	35.9 × 17.8	75.0	2.5	10.0	7.5	2.5	2.5	—
	Apical	5.6	191.0	3466	0.8	33.6	24.9 × 8.1	16.8 × 4.4	32.8 × 20.9	62.2	8.4	8.4	—	8.4	8.4	4.2
	Marginal	2.2	178.8	3851.5	1.0	33.6	26.8 × 4.9	17.2 × 2.5	31.5 × 17.2	45.0	11.0	—	—	—	33.0	11.0
2 Maturing	Basal	4.1	119.2	2769	1.4	28.8	26.2 × 9.7	17.1 × 5.6	35.7 × 17.2	83.4	—	—	—	—	16.6	—
	Middle	8.8	278.1	2880.6	2.3	48	26.7 × 7.8	4.6 × 3.7	42.4 × 16.2	72.0	7.0	21.0	—	—	—	—
	Apical	4.1	120.0	2721	2.2	48	26.8 × 9.0	15.9 × 3.4	40.2 × 18.7	62.2	8.4	16.8	8.4	—	4.2	—
	Marginal	1.9	59.6	3019.7	2.2	48	26.5 × 6.2	23.1 × 3.4	35.9 × 18.1	—	33.3	—	33.3	33.3	—	—
3 Mature	Basal	6.9	198.6	2682	0.6	9.6	31.1 × 9.4	18.8 × 4.8	30.0 × 15.5	56.0	22.0	—	—	11.0	11.0	—
	Middle	9.4	258.0	2503.2	0.7	14.4	24.5 × 7.7	14.0 × 4.9	34.5 × 13.6	38.4	7.7	30.8	—	7.7	15.4	—
	Apical	6.2	182.4	2716.8	0.9	19.2	31.8 × 10.6	19.3 × 3.4	37.1 × 16.8	86.0	5.2	2.6	2.6	—	2.6	—
	Marginal	2.2	65.4	2838.7	1.8	43.2	29.3 × 8.6	16.9 × 5.9	26.2 × 13.1	45.6	16.8	—	—	—	8.4	16.8

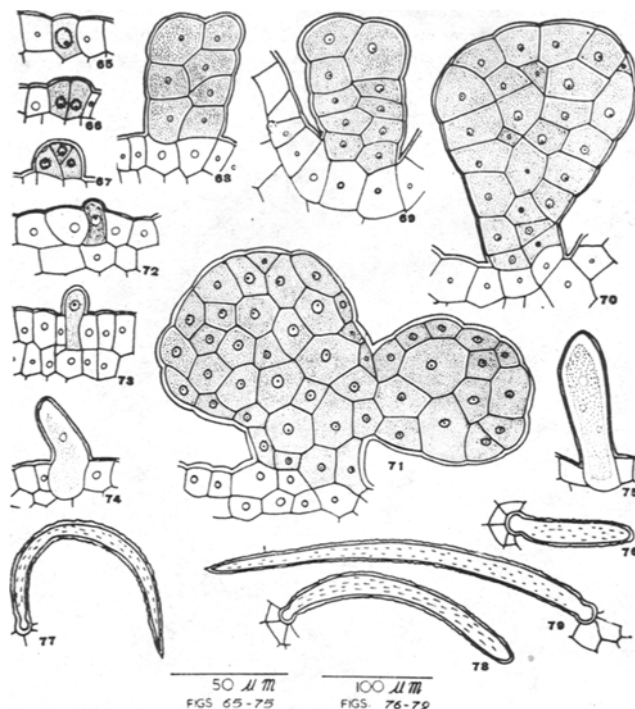
guard cells (Fig. 62), (vi) degenerating guard cells, (vii) variously oriented contiguous stomata of equal or unequal sizes (Figs. 63, 64) and (viii) wavy outer walls of one or both guard cells (Figs. 28, 54, 59, 60, 61).

A detailed ontogeny (Figs. 17–26) of different types of stomata confirms the descriptions given by SHAH and GOPAL (1971). An, C and T are perigenous. Most of the PA and Tr are mesogenous but a few are mesoperigenous. Rarely a few T are tetramesoperigenous since two polar subsidiary cells are perigenous and lateral mesogenous (*cf.* Fig. 35). Since most of the A and a few An or T are secondarily derived from mesogenous or mesoperigenous P or



Figs. 27–29, 30–32, 33–35, 36–38, 39–40 — epidermal peels from different regions of mature (middle, basal) and maturing (margin, middle, basal) pericarps, respectively. — Figs. 41–64 — stomata as seen in epidermal peels of mature pericarps. — Figs. 41–56 — an increase in the number of subsidiary cells (for details see text). — Figs. 57, 58, 61 — stomata with one guard cell. — Figs. 59, 60 — stomata with wavy guard cells. — Fig. 62 — a stomatic pore. — Figs. 63, 64 — juxtaposed and obliquely oriented contiguous stomata, respectively.

Tr by wall formation, their ontogeny is also considered similar to the types from which they are derived. Contiguous stomata may be the result of two meristemoids simultaneously developing into stomata (Fig. 19) or a meristemoid, cut off contiguously to a mature stoma, develops into a stoma (*cf.* Fig. 3).



Figs. 65—70 — ontogenetical stages leading to a fully organised glandular trichome. — Fig. 71 — a branched glandular trichome. — Figs. 72—75 — ontogenetical stages of an eglandular trichome. — Figs. 76—79 — shapes of eglandular trichomes.

Trichomes are glandular and eglandular on ovaries but only the latter type is observed on pericarp. A glandular trichome initial with a large nucleus and dense cytoplasm (Fig. 65) undergoes several periclinal and anticlinal divisions to form a club-shaped multicellular hair (Figs. 67—70). At times two adjacent initials (Fig. 66) simultaneously develop into such glandular trichomes which ultimately are branched (Fig. 71). The cells of the glandular trichomes retain their cytoplasm and nuclei. Eglandular trichome initial is similar to the glandular trichome initial (Fig. 72) but as it increases in size, it loses the contents gradually and finally is enucleate (Figs. 73—75). A fully developed eglandular trichome is unicellular, conical (Figs. 77, 79) or cylindric (Figs. 76, 78) in shape, being straight (Fig. 79), curved (Fig. 78) or hooked (Fig. 77), with distinct cuticular striation.

The supplementary data to that already published on the stomata in *C. occidentalis* are (i) Tr, T and C stomata, (ii) various types of partly and completely amphicyclic stomata, (iii) the different ways in which variations

in the basic morphology of a stoma are brought about and (iv) several abnormalities. The uniform patterns of ontogeny for different types of stomata on different organs (SHAH and GOPAL 1971) and pericarps also support the view of STEBBINS and KHUSH (1961). In spite of diversity, the prevalence of paracytic stomata on different organs adds a point of taxonomical significance. The diversity in stomatal types is due to the capacity of the stomatal initials to retain their meristematic activity but the exact cause of their differential activity is not known. INAMDAR *et al.* (1974) and GANGADHARA and INAMDAR (1975) attribute stomatal abnormalities to the action of growth regulators but in pericarps they are found under natural conditions. They are due to irregularity or omission of certain ontogenetic stages. The exact cause of such omission or irregularity is not known. The data, therefore, have to be carefully considered when taxonomic significance of stomata is assessed. The occurrence of superposed contiguous stomata in *C. occidentalis* (PATEL *et al.* 1976) is not confirmed by this study. In fact, the figures 24 and 29 of these authors, beyond doubt, depict juxtaposed contiguous stomata.

Our observations on trichomes are at variance with those of PATEL *et al.* (1976) on three counts: (i) Glandular trichomes are found in ovaries only. (ii) Branched glandular trichome and its ontogeny are not described by these authors. (iii) Various types of eglandular trichomes are also not reported by them.

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