STUDY OF THE LEAF COSTAL CELL DISTRIBUTION PATTERNS AND THEIR TAXONOMIC SIGNIFICANCE IN THE LEGUMINOSAE

P. LEELAVATHI, N. RAMAYYA AND M. PRABHAKAR

Plant Anatomy and Taxonomy Lab., Department of Botany, Osmania University, Hyderabad, India

ABSTRACT

Leaf costal cell distribution in 105 species of Leguminosae embracing its constituent three subfamilies has been investigated. Based on the differences in the degree of their expression on various grades of veins, the costal cell distribution patterns are classified into 'perfect' and 'imperfect' categories. The imperfect category of costal cell pattern is more towards adaxial than on abaxial. Further, in a larger number of species, costal cell distribution patterns are more imperfect towards adaxial surface, than on the abaxial. No correlation has been found between the plant habit and costal cell expression. Based on variation in this feature, six unifacial and 13 bifacial patterns are recognized with limited taxonomic value.

INTRODUCTION

Importance of epidermal characters in the taxonomy of the living as well as fossil angiosperms is too well known to need emphasis (DILCHER, 1974 ; LEELAVATHI, 1976; PRABHAKAR, 1978 ; PRABHAKAR & RAMAYYA, 1975 ; RAJAGOPAL, 1973 ; RAMAYYA & RAJAGOPAL, 1968, 1971, 1974 ; STACE, 1965). Among these, present knowledge of the costal cells is, however, too scanty (ESAU, 1972) to give any idea of its taxonomic potential. Therefore, this investigation was undertaken to gain insight into the distribution of the foliar costal cells in the Leguminosae and to evaluate its taxonomic importance in the family.

MATERIAL AND METHODS

In all, 105 species of Leguminosae have been studied representing its three subfamilies ; 95 collected in and around Hyderabad city, and the remaining ten from different places in India (Table 1). Epidermal peels were removed from mature leaves by hand-peeling or scraping with a scalpel. For difficult materials, the "Double-treatment method" of LEELAVATHI AND RAMAYYA (1975) was employed. In several of the species, the peels of at least ten specimens were studied from base, middle and apex regions, covering from the midvein to the margin. Where leaves are small, the peels represented the entire leaf surface. These were stained with 1 per cent aniline blue in lactophenol and mounted in glycerine (RAMAYYA & RAJAGOPAL, 1968). Herbarium specimens and peel-slides studied are deposited at the Plant Anatomy and Taxonomy Laboratory, Osmania University, Hyderabad, India.

TERMINOLOGY

The following terms as defined below are used in describing the patterns of costal cell distribution :

(1) *Irregularly arranged :* When cells are disorderly distributed with reference to one another (Fig. 1G, H).

Table 1—List of species investigated along with information on the arrangement, orientation and the patterns of costal cell distribution in the leaves of Leguminosae

Sl. no.	Name of the subfamily and species	Source	Costal cell arrangement/Orientation		Unifacial Pattern no.		Bifacial Pattern no.	Total no. of species in each bifacial pattern
			Adaxial	Abaxial	Adaxial	Abaxial		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Mimosoideae							
1.	Desmanthus virgatus Willd.	*Coimbatore	—/—	—/—	I/I		1	
2.	Dichrostachys cinerea (L.) Wt. & Arn.	Hyderabad	—/—	—/—	I/I		1	
3.	Prosopis cineraria (L.) Durce	—do—	—/—	—/—	I/I		1	3
4.	Acacia arabica (Lmk.) Willd.	—do—	—/—	i/v	I/II		2	
5.	A. leucophloea (Roxb.) Willd.	—do—	—/—	i/p	I/II		2	
6.	Leucaena leucocephala (Lamk.) Wit.	—do—	—/—	i/v	I/II		2	
7.	Mimosa hamata Willd.	Aurangabad	—/—	i/p	I/II		2	
8.	M. praniana Gamble	Hyderabad	—/—	i/p	I/II		2	
9.	Neptunia oleracea Lour.	Warangal	—/—	i/p	I/II		2	
10.	Parkia biglandulosa W. & A.	Hyderabad	—/—	i/p	I/II		2	8
11.	Xylia xylocarpa Taub.	Pakhal	—/—	i/p	I/II		2	
12.	Calliandra haematocephala Hassk.	Hyderabad	—/—	i/v	I/V		3	
13.	Mimosa pudica L.	—do—	—/—	i/p	I/V		3	2
14.	Adenanthera pavonina L.	—do—	i/p	i/p	II/II		5	
15.	Albizia amara Boivin	—do—	i/p	i/p	II/II		5	
16.	A. lebbeck (L.) Willd.	—do—	i/p	i/p	II/II		5	
17.	Neptunia triquetra Benth.	Warangal	i/p	i/p	II/II		5	
18.	Prosopis juliflora (Swartz.) DC.	Hyderabad	i/p	i/p	II/II		5	5
19.	Acacia auriculiformis A. cunn. Ex. Benth.	—do—	i/p	i/p	V/V		11	
20.	Pithecellobium dulce (Roxb.) Benth.	—do—	i/p	i/p	V/V		11	2
21.	Samanea saman (Jacq.) Merr.	—do—	i/p	i/p	VI/VI		13	1
	Caesalpinioideae							
22.	Cassia mimosoides L.	—do—	—/—	—/—	I/I		1	
23.	C. obtusa Roxb.	—do—	—/—	—/—	I/I		1	
24.	C. roxburghii DC.	—do—	—/—	—/—	I/I		1	3
25.	Caesalpinia coriaria Willd.	—do—	—/—	i/p	I/II		2	
26.	Cassia auriculata L.	—do—	—/—	i/v	I/II		2	
27.	C. pumila Lamk.	—do—	—/—	i/p	I/II		2	
28.	Delonix elata Gamble	—do—	—/—	i/p	I/II		2	

Table 1—(*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
29.	D. regia (Bojer ex Hook.) Rafin.	—do—	—/—	i/p	I/II		2	
30.	Gleditsia sp.	Lucknow	—/—	i/p	I/II		2	
31.	Parkinsonia aculeata L.	Hyderabad	—/—	i/p	I/II		2	
32.	Peltophorum pterocarpa (DC.) Baker.	—do—	—/—	i/p	I/II		2	
33.	Pterolobium hexapetalum (Roth.) Sant. & Wagh.	Srisailam	—/—	i/p	I/II		2	
34.	Tamarindus indica L.	Hyderabad	—/—	i/p	I/II		2	10
35.	Cassia glauca var. suffruticosa Prain.	—do—	—/—	i/p	I/V		3	
36.	C. grandis L. F.	—do—	—/—	i/p	I/V		3	
37.	C. javanica L.	—do—	—/—	i/p	I/V		3	
38.	C. occidentalis L.	—do—	—/—	i/p	I/V		3	
39.	C. senna L.	—do—	—/—	i/p	I/V		3	
40.	C. sophera L.	—do—	—/—	i/p	I/V		3	6
41.	Brownea grandicaps Jacq.	—do—	i/p	i/p	II/II		5	
42.	Cynometra ramiflora L. var. mimosoides Baker	*Poona	i/p	i/p	II/II		5	2
43.	Saraca asoca (Roxb.) de Wilde.	Hyderabad	i/p	i/p	II/V		6	1
44.	Cassia glauca var. glauca Lamk.	—do—	i/p	i/p	III/V		8	
45.	C. obtusifolia L.	—do—	i/p	i/v	III/V		8	
46.	C. siamea Lamk.	—do—	i/p	i/p	III/V		8	
47.	C. spectabilis DC.	—do	i/v	i/v	III/V		8	
48.	C. tora L.	—do—	i/p	i/v	III/V		8	5
49.	C. alata L.	Rajamundry	i/p	i/p	IV/VI		9	1
50.	C. absus L.	Hyderabad	i/v	i/v	V/V		11	
51.	C. floribunda Cav.	Rajamundry	i/p	i/p	V/V		11	
52.	C. hirsuta L.	Waltair	i/p	i/p	V/V		11	
53.	Wagatea spicata Dalzell	*Poona	i/p	i/p	V/V		11	4
54.	Bauhinia purpurea L. var. purpurea.	Hyderabad	i/p	i/p	VI/VI		13	
55.	B. tomentosa L.	—do—	i/p	i/p	VI/VI		13	
56.	Caesalpinia bonducella L. emend. Dandy & Exell.	—do—	i/p	i/p	VI/VI		13	
57.	C. pulcherrima (L.) Swartz	—do—	i/v	i/v	VI/VI		13	
58.	Cassia fistula L.	—do—	i/p	i/p	VI/VI		13	
59.	Hardwickia binata Roxb.	Pakhal	i/p	i/p	VI/VI		13	
60.	Humboldtia brunonis Wall.	*Poona	i/p	i/p	VI/VI		13	7
	Papilionoideae							
61.	Aeschynomene indica L.	Hyderabad	—/—	i/p	I/II		2	
62.	Alysicarpus hamosus Edgew.	—do—	—/—	i/p	I/II		2	

Table 1—(*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
63.	Crotalaria pusilla L.	—do—	—/—	i/p	I/II		2	
64.	C. ramosissima Roxb.	—do—	—/—	i/p	I/II		2	
65.	Desmodium triflorum (L.) DC.	—do—	—/—	i/p	I/II		2	
66.	Trigonella foenum-graecum L.	—do—	—/—	i/p	I/II		2	
67.	Zornia gibbosa Span.	Waltair	—/—	i/p	I/II		2	7
68.	Alysicarpus rugosus (Willd.) DC.	Hyderabad	—/—	i/v	I/V		3	
69.	Arachis hypogaea L.	—do—	—/—	i/p	I/V		3	
70.	Melilotus alba Desr.	—do—	—/—	i/p	I/V		3	
71.	M. indica All.	—do—	—/—	i/p	I/V		3	
72.	Ormosia travancorica Bedd.	*Poona	—/—	i/p	I/V		3	
73.	Sophora glauca Lesch.	—do—	—/—	i/p	I/V		3	
74.	Stylosanthes fruticosa (Retz.) Alston.	Hyderabad	—/—	i/p	IV		3	7
75.	Dalbergia sissoo Roxb.	—do—	—/—	i/p	I/VI		4	
76.	Derris scandens (Roxb.) Benth.	—do—	—/—	i/p	I/VI		4	2
77.	Heylandia latebrosa DC.	—do—	i/p	i/p	II/II		5	
78.	Zornia diphylla (L.) Pers.	—do—	i/p	i/p	II/II		5	2
79.	Cicer arietinum L.	—do—	i/p	i/p	II/V		6	1
80.	Abrus precatorius L.	—do—	i/p	i/p	III/II		7	1
81.	Alysicarpus monilifer (L.) DC.	—do—	i/p	i/p	III/V		8	
82.	Crotalaria laburnifolia L.	—do—	i/p	i/p	III/V		8	2
83.	Pongamia pinnata (L.) Pierre	—do—	i/v	i/p	V/II		10	1
84.	Crotalaria biflora L.	—do—	i/p	i/p	V/V		11	
85.	C. verrucosa L.	—do—	i/p	i/p	V/V		11	
86.	Medicago sativa L.	—do—	i/v	i/p	V/V		11	
87.	Mucuna pruriens (L.) DC.	—do—	i/p	i/p	V/V		11	
88.	Shuteria vestita Wight. & Arn.	—do—	i/p	i/p	V/V		11	5
89.	Atylosia scarabaeoides (L.) Benth.	—do—	i/p	i/p	V/VI		12	
90.	Clitoria ternatea L.	—do—	i/p	i/p	V/VI		12	
91.	Dalbergia latifolia Roxb.	—do—	i/p	i/p	V/VI		12	
92.	Rhynchosia aurea DC.	—do—	i/p	i/p	V/VI		12	
93.	R. minima Benth.	—do—	i/p	i/p	V/VI		12	
94.	Vigna cylindrica (L.) Skeels.	—do—	i/p	i/p	V/VI		12	6
95.	Butea monosperma (Lam.) Taub.	—do—	i/p	i/p	VI/VI		13	
96.	Cajanus cajan (L.) Millsp.	—do—	i/p	i/p	VI/VI		13	

TABLE 1—(*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
97.	Canavalia ensiformis (L.) DC.	—do—	i/p	i/p	VI/VI		13	
98.	Dolichos lablab L.	—do—	i/p	i/p	VI/VI		13	
99.	Erythrina blakei Hort. ex. Parker	Delhi	i/p	i/p	VI/VI		13	
100.	E. orientalis (L.) Murr.	Hyderabad	i/v	i/p	VI/VI		13	
101.	E. suberosa Roxb.	—do—	i/p	i/p	VI/VI		13	
102.	Phaseolus aconitifolius Jacq.	—do—	i/p	i/p	VI/VI		13	
103.	P. trilobus Ait.	—do—	i/p	i/p	VI/VI		13	
104.	Pterocarpus marsupium Roxb.	Pakhal	i/v	i/p	VI/VI		13	
105.	P. santalinus L.	Hyderabad	i/p	i/p	VI/VI		13	11

*Botanical Survey of India; —/—Costal cells absent; i=irregular; p=parallel; v=variously.

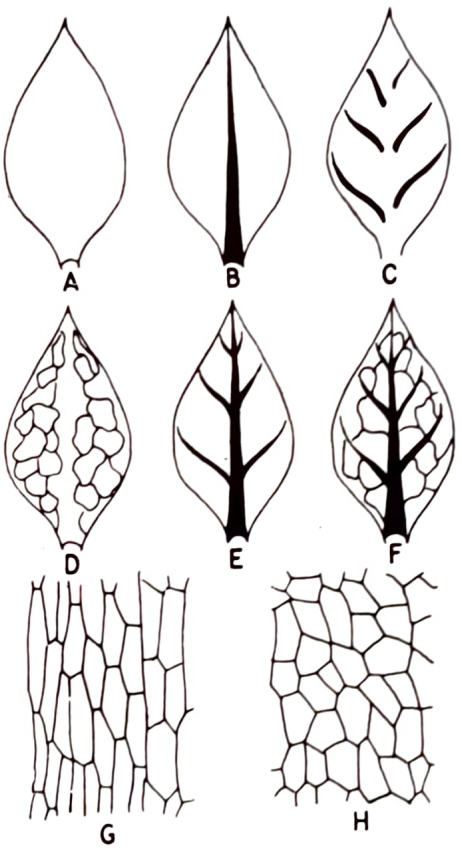

Fig. 1. Diagrammatic representation of costal cell distribution. A. Costal cells absent; B. Present on midvein; C. On primary lateral veins; D. On alveolar veins; E. On midvein and lateral veins; F. On all grades of veins; G. Costal cells irregularly arranged and parallelly oriented; H. Costal cells irregularly arranged and variously oriented.

(2) *Parallelly oriented* : When cells are directed parallel to the long axis of the vein (Fig. 1G).

(3) *Variously oriented :* When cells are oriented in different directions with reference to the long axis of the vein (Fig. 1H).

(4) *Unifacial pattern :* Cell distribution pattern with reference to a single leaf surface.

(5) *Bifacial pattern :* Represents a pair of unifacial patterns occurring on the adaxial and abaxial surfaces of a leaf.

(6) *Costal cells :* Epidermal cells present on veins and distinct from the rest of the laminar cells.

OBSERVATIONS

In all the species the costal cells are irregularly arranged. They are oriented parallel to the veins in 91 species, whereas in the remaining 14 they are oriented variously on both surfaces or on a single surface (Table 1). The costal cell zones are devoid of stomata, except in *Pithecellobium dulce* and *Prosopis juliflora*, wherein the stomata are irregularly arranged and variously oriented over the costal cell zones.

The extent of expression of the costal cells in the leaf is variable depending on the species. On this basis, in all, six patterns of unifacial costal cell distribution were recognised, which are as follows :

Pattern I. Costal cells totally indistinct or absent (Fig. 1A).
Pattern II. Costal cells distinct on the midvein only (Fig. 1B).
Pattern III. Costal cells distinct only on the primary lateral veins (Fig. 1C).
Pattern IV. Costal cells distinct on the primary lateral veins and on those forming alveolar veins (i.e. absent on midvein) (Fig. 1D).
Pattern V. Costal cells distinct only on the midvein and primary lateral veins (Fig. 1E).
Pattern VI. Costal cells distinct on all the veins including those forming alveoli (Fig. 1F).

For convenience, these patterns would be abbreviated as P-I, P-II, etc.

Amongst the species studied, in all 13 bifacial patterns were recognisable which are as below :

Pattern 1. P-I on adaxial and abaxial.
Pattern 2. P-I on adaxial and P-II on abaxial.
Pattern 3. P-I on adaxial and P-V on abaxial.
Pattern 4. P-I on adaxial and P-VI on abaxial.
Pattern 5. P-II on adaxial and abaxial.
Pattern 6. P-II on adaxial and P-V on abaxial.
Pattern 7. P-III on adaxial and P-II on abaxial.
Pattern 8. P-III on adaxial and P-V on abaxial.
Pattern 9. P-IV as adaxial and P-VI on abaxial.
Pattern 10. P-V on adaxial and P-II on abaxial.
Pattern 11. P-V on adaxial and abaxial.
Pattern 12. P-V on adaxial and P-VI on abaxial.
Pattern 13. P-VI on adaxial and abaxial.

The bifacial patterns hereafter will be abbreviaed as P-1, P-2, P-3, etc.

DISCUSSION

The costal cell distribution patterns (Table 1) owe their differences to the degree of their expression in the various grades of the veins (see unifacial costal cell distribution). From this view point, the patterns can be distinguished into two categories, 'perfect'

and 'imperfect'. The former is characterized by costal cell expression over the entire venation system (including those forming the alveoli) as exemplified by P-VI, whereas the second, represented by the patterns characterized by total lack of costal cell expression (P-I), with others displaying costal cells in a limited number of veins in various permutations and combinations as seen in the P-II to P-V. An attempt was made to see if a correlation existed between these two major categories of costal cell distribution and the plant habit. None was however observed. For example, in *Cassia roxburghii* and *C. fistula* which are perennial forms, costal cells are totally absent (P-I) in the former, whereas they are expressed over the entire venation system (P-VI) on both foliar surfaces, in the latter. Similarly in *C. mimosoides* and *C. absus* which are annual herbs, the costal cells are totally absent (P-I) in the former, whereas they occur on the midvein and primary lateral veins (P-V) in the latter (Table 1).

Frequency of the occurrence of the perfect and imperfect categories on leaf surfaces and from species to species is found to be interesting, as seen from data provided in Table 1. From the latter, it is evident that a large number (78%) of the leaf surfaces possess imperfect costal cell patterns. In the species studied, considering the two foliar surfaces, 82 per cent towards the adaxial and 73 per cent towards the abaxial possess imperfect costal cell patterns.

In the six unifacial patterns described, all occur on the leaf adaxial, whereas only P-I, P-II, P-V and P-VI on the leaf abaxial, thus the P-III and P-IV being exclusively confined to the leaf adaxial. Towards leaf adaxial P-I is more frequent, whereas on the abaxial P-II, P-V and P-VI (Table 1). Thus it is evident that costal cell patterns of imperfect category are more common towards adaxial than on the abaxial (Table 1).

Among the 13 bifacial pattern, six (viz., P-1 to P-3, P-5, P-11 and P-13) occur in the Mimosoideae, whereas nine (viz., P-1 to P-3, P-5, P-6, P-8, P-9, P-11 and P-13) in the Caesalpinioideae, while eleven (viz., P-2 to P-8, P-10 to P-13) in the Papilionoideae (Table 1).

Taxonomically the unifacial and bifacial distribution patterns appear significant at the family and infrafamily levels. The unifacial patterns P-III and P-IV are absent in the Mimosoideae and the P-IV in the Papilionoideae, whereas P-I is absent on the abaxial side of the Papilionioideae. Among the 13 bifacial patterns, P-2 is common in the Mimosoideae and Caesalpinioideae, whereas P-2, P-3, P-11, P-12 and P-13 are equally frequent in the Papilionoideae. Further, P-4, P-7, P-10 and P-12 occur exclusively in the Papilionoideae and P-9 in the Caesalpinioideae (Table 1).

In the 105 species studied, only a few seem to be distinguishable directly on the basis of the costal cell distribution patterns. *Cassia alata* is unique, due to its lone possession of the unifacial pattern P-IV on the leaf adaxial. *Abrus precatorious*, *Cassia alata* and *Pongamia pinnata* can be identified due to exclusive occurrence in them, of the bifacial patterns P-7, P-9 and P-10, respectively. Further, the bifacial pattern P-4 occurs only in *Dalbergia sissoo* and *Derris scandens* and pattern P-6 in *Cicer arietinum* and *Saraca asoca* (Table 1). Based on the orientation of the costal cells on both adaxial and abaxial surfaces and their bifacial patterns a few more species can be distinguished viz., *Cassia spectabilis*, *C. absus*, *Caesalpinia pulcherrima* (costal cells variously oriented on both surfaces and possessing bifacial patterns 8, 11 and 13, respectively), *Medicago sativa* and *Erythrina orientalis* (costal cells variously oriented on adaxial and parallelly on abaxial with bifacial patterns 11 and 13, respectively).

It is thus obvious that costal cell distribution patterns alone have limited taxo-

nomic value. In the 105 species, only 12, as shown above, are identified directly on the basis of this character, whereas others can only be grouped into clusters of varied sizes (Table 1).

ACKNOWLEDGEMENT

We express our gratitude to Professor M. Hashim, Head, Department of Botany, Osmania University, Hyderabad, India for facilities and encouragement.

REFERENCES

Dilcher, D. L. (1974). Approaches to the identification of angiosperm leaf remains. *Bot. Rev.* **40** : 1-157.

Esau, K. (1972). *Plant Anatomy*. New York, John Wiley.

Leelavathi, A. (1976). Epidermal studies in the Leguminosae. (*Ph. D. Thesis, Osmania University, Hyderabad, India*).

Leelavathi, A. & Ramayya, N. (1975). Rapid isolation of leaf epidermis by "double-treatment method." *Geobios*, **2** : 117-119.

Prabhakar, M. (1978). Systematics, anatomy and chemotaxonomy of the Indian family Portulacaceae. (*Ph. D. Thesis, Osmania University, Hyderabad, India*).

Prabhakar, M. & Ramayya, N. (1975). Structure and development of trichomes in the family Portulacaceae. *In Form, Structure and Function in plants*, Prof. B. M. Johri Commemoration Volume, (Eds.) H. Y. Mohan Ram *et al.*: 356-386.

Rajagopal, T. (1973). Flora of Hyderabad including a study of the foliar epidermal characters of the species as an aid to taxonomy. (*Ph. D. Thesis, Osmania University, Hyderabad, India*).

Ramayya, N. & Rajagopal, T. (1968). Foliar epidermis as taxonomic aid in the "Flora of Hyderabad". Part I . Portulacaceae and Aizoaceae. *Jour. Osmania Univ.*, (Golden Jubilee Vol.): 147-160.

Ramayya, N. & Rajagopal, T. (1971). Foliar "dermotypes" of the Indian Aizoaceae and their use in identification. *J. Indian bot. Soc.* **50** : 355-362.

Ramayya, N. & Rajgopal, T. (1974). Stomatogenesis in the genus *Portulaca L.* Portulacaceae. *Bot. Jour. Linn. Soc.* **68** : 81-88.

Stace, C. A. (1965). Cuticular studies as an aid to plant taxonomy. *Bull. Brit. Mus. Bot.* **4** : 1-78.