STOMATA AND TRICHOMES IN LEAVES OF YOUNG AND ADULT PALMS[1]

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Abstract

Results of a study on the leaf epidermis of young and adult plants of *Areca catechu*, *Borassus flabellifer*, *Cocos nucifera*, *Elaeis guineensis*, *Hyphaene thebaica*, *Livistona chinensis*, *Phoenix sylvestris* and *Rhapis excelsa* are reported. The distribution of stomata and trichomes per unit area on the abaxial and adaxial epidermes was estimated. Measurements were also made of guard cells, trichomes, and ordinary epidermal cells. The stomatal index was calculated for seven species.

The stomata are totally absent on adaxial epidermis of *Cocos nucifera* and *Rhapis excelsa*, while in *Areca catechu*, *Elaeis guineensis* and *Livistona chinensis* they are sparsely distributed. In the rest (*Borassus flabellifer*, *Hyphaene thebaica* and *Phoenix sylvestris*) stomata are equally common on the adaxial and abaxial surfaces. The frequency of the distribution of stomata is higher in adult palms. The lengths of guard cells on abaxial and adaxial surfaces (where present) do not differ significantly between young and adult palms. The number of rows of interstomatal cells is maximum in *Elaeis guineensis* which also shows the lowest stomatal index. The maximum width of such epidermal cells among young palms is in *Areca catechu* and, among adults, in *A. catechu* and *Elaeis guineensis*. *Phoenix sylvestris* (young as well as adult) bears the narrowest inter-stomatal cells. Trichomes are totally absent in *Phoenix* and *Livistona*, and absent on the adaxial epidermis in *Cocos* and *Rhapis*. Longest trichomes are in *Hyphaene*, and shortest in *Elaeis*.

The family Arecaceae (Palmae) comprising over 2,600 species is divided into nine sub-families. The habitat of these distinctive members of flowering plants is restricted to tropical and sub-tropical regions. Although some aspects of the anatomy of palms have been studied by various investigators (Arber, 1922; Ball, 1941; Bavappa, 1966, Beccari, 1913; Branner, 1884; Drabble, 1904; Gage, 1901; Glassman, 1972; Parthasarathy, 1968; Periasamy, 1966; Swamy & Govindarajalu, 1961; Tomlinson, 1957, 1960, 1961, 1964, 1965, 1966, 1969; Tomlinson & Zimmermann, 1966a, b, 1968a, b; Uhl, 1966, 1969; Uhl, Morrow & Moore, 1969; Yampolsky, 1924; Zimmermann & Tomlinson, 1965), no critical investigation on a quantitative basis was made on the epidermal structure of palms. The present investigation is primarily conducted to find out whether there exists any difference between leaves of young and adult plants of some palm species with regard to frequency, form, and arrangement of epidermal cells, number of interstomatal cell-rows, size of guard-cells, and stomata. The morpho-

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logy and frequency of the epidermal trichomes were also studied in each species.

Materials and Methods

Seedlings up to the age of three years (54-month-old seedlings in *Hyphaene thebaica*), and adult plants of *Areca catechu* L., *Borassus flabellifer* L., *Cocos nucifera* L., *Elaeis guineensis* Jacq., *Hyphaene thebaica* Mart., *Livistona chinensis* R. Br., *Phoenix sylvestris* Roxb. and *Rhapis excelsa* Henry, representing five sub-families, were included for the study of their leaf epidermal structure. The seedlings of the above species were raised at the crop garden of the Indian Statistical Institute, during 1968-1970. Leaf samples from adult specimens of some species were collected from the Indian Botanic Garden, Calcutta, and the remaining from the premises of the Indian Statistical Institute.

In the case of adult palms, samples for obtaining the epidermal peelings were drawn from mature leaves. A portion of the lamina was cut from the mid-portion of one of the middle leaflets excluding the mid-rib. In seedlings, however, samples were drawn from the last but one oldest green leaf. Here, as far as possible, a mid-region was selected.

Epidermal peelings of palm leaves are obtained undamaged by a simple method of Artschwager (1930). Small bits of lamina, say 5 mm square, cut with a sharp knife or blade are treated with 30% nitric acid and boiled together with a pinch of Potassium chlorate in a test tube. Within a couple of minutes, the acid digests the inner tissues including the vascular fibres, and two cuticular layers separate out from each bit. Then the layers are poured in a petri-dish containing water, washed thoroughly, and mounted for observation.

In a palm species whose upper (adaxial) and lower (abaxial) leaf epidermal peels exhibit contrasting differences in their patterns, more than one bit of lamina can be treated with the acid simultaneously, and the adaxial and abaxial peels identified without any difficulty. *Cocos nucifera* is a good example for this since its upper epidermis is totally devoid of stomata. But in species where the two epidermal surfaces possess stomata, and so becomes difficult to distinguish one from the other, the following procedure was adopted to avoid a possible error. To get the peel of abaxial epidermis, the selected leaflet is scarped off of its adaxial surface and one or more bits of this region cut and treated with the acid. Now each bit gives only a single cuticular layer. Similarly, to obtain an adaxial layer, the abaxial surface of the lamina is scrapped off. This method guarantees uniform epidermal peels compared to the conventional method, being followed by some workers, of peeling the epidermis with a blade.

Transectional views of trichomes were also prepared to study their orientation with regard to the adjoining tissues. Camera lucida drawings of trichomes have been provided for from six species.

The frequencies of stomata and trichomes per unit area of the lamina were worked out. Measurements were also made of the lengths of guard cells and trichomes, and width of ordinary epidermal cells. In this regard, the methods described by Salisbury (1928) were useful. For some species, the stomatal index was also calculated separately for the abaxial and adaxial surfaces.

Observations

STOMATAL FREQUENCIES IN 8 SPECIES — Of the 5×5 mm epidermal peel, the total number of stomata visible in a field obtained by using a lens-combination of 7×40 was counted. The area of each field was calculated to be 0.17 sq. mm. Ten different fields per sample were examined, aggregating to an area of 1·7 sq. mm. The figures presented in Table 1 are the means for one field covering 0·17 sq. mm. For each species, figures relating to young as well as adult palms are given.

Stomata are totally absent on the adaxial epidermis of young as well as adult *Cocos nucifera* (Fig. 1), and *Rhapis excelsa* (Fig. 2). Among other palms, stomatal distribution on both the surfaces is almost similar for *Borassus flabellifer*,

TABLE 1 — STOMATAL FREQUENCY IN PALM LEAVES (PER UNIT AREA OF 0.17 SQ. MM)

SPECIES	AGE (MONTHS)	YOUNG PLANTS		ADULT PLANTS	
		ABAXIAL EPIDERMIS	ADAXIAL EPIDERMIS	ABAXIAL EPIDERMIS	ADAXIAL EPIDERMIS
Areca catechu	14	22.0	0.1	27.9	1.1
Borassus flabellifer	36	20.4	19.9	28.5	24.4
Cocos nucifera	12	15.5	—	25.7	—
Elaeis guineensis	12	27.0	0.2	42.0	2.1
Hyphaene thebaica	54	22.3	23.2	23.3	23.2
Livistona chinensis	36	36.2	1.9	74.6	27.8
Phoenix sylvestris	16	35.5	33.8	74.7	69.8
Rhapis excelsa	12	21.2	—	24.7	—

N.B. Each measurement is the average for ten observations.

Hyphaene thebaica, and *Phoenix sylvestris*, but the remaining three species (*Areca*, *Elaeis*, and *Livistona*) come very close to *Cocos* and *Rhapis* by having only stray stomata on the adaxial surface. Between young and adult palms, the frequency of stomata generally shows an increasing trend as the palms grow, with the exception of *Hyphaene*. *Phoenix* registers over one hundred per cent increase. Most striking is the situation with *Livistona* which shows a 2-fold increase in the number of stomata on abaxial surface, and over 14-fold increase on the adaxial epidermis.

Examinations of the structure of epidermis in all the above eight species of palms have shown that the guard cells possess 2-cutinized ledges. But no transverse cuticular band was observed as has been reported in caryotoid palms by Tomlinson (1961) and Mahabale & Shirke (1967).

LENGTH OF GUARD CELLS — The length of guard cells for the various species are shown in Table 2. Among young plants, guard cells are longest in the adaxial epidermis of *Hyphaene thebaica*, and shortest in *Livistona chinensis*. Among adult plants, the length of guard cells is maximum for *Cocos nucifera*, and minimum for *Phoenix sylvestris*. The length of guard cells on abaxial and adaxial surfaces (where present) does not differ significantly between young and adult palms, except in *Cocos nucifera* (Figs. 3, 4).

NUMBER OF ROWS OF INTER-STOMATAL CELLS AND THEIR WIDTH — Data on the number of longitudinal, inter-somatal rows of epidermal cells and the width of these cells are presented in Table 3. The number of such rows is greater in *Elaeis guineensis*, though the inter-stomatal rows are not as distinct as in *Phoenix sylvestris* or *Borassus flabellifer*. The number of rows is the lowest in the abaxial epidermis of young *Areca catechu*. In the case of abaxial epidermis of adults, *Elaeis guineensis* shows the maximum number of rows, and minimum in *Cocos nucifera*. The maximum width of epidermal cells/interstomatal cells of young palms occur in the adaxial epidermis of *Areca catechu* (Fig. 5) and minimum in *Phoenix sylvestris* (Fig. 6). In adults it is maximum

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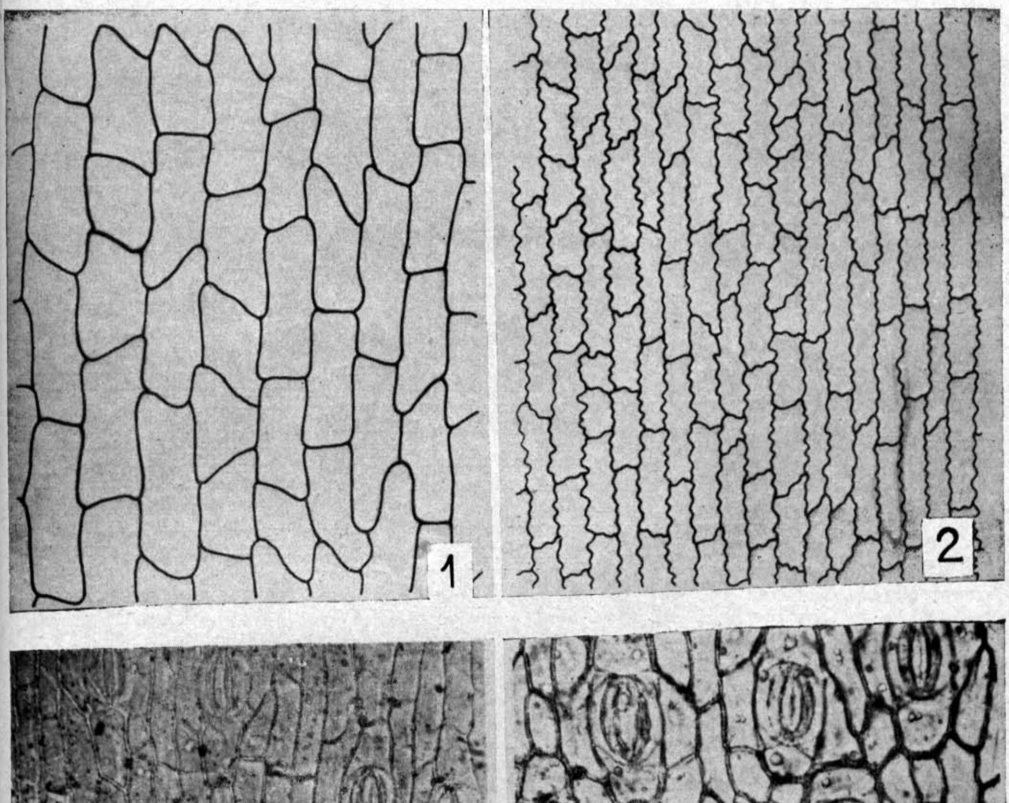
Figs. 1-4 — Fig. 1. Adaxial epidermis of lamina of young *Cocos nucifera*; note the absence of stomata and tendency of epidermal cells to become hexagonal. × 380. **Fig. 2.** Adaxial epidermis of adult *Rhapis excelsa* showing sinuous cell walls; note the absence of stomata and trichomes. × 320. **Fig. 3.** Abaxial epidermis of young *C. nucifera* with shorter guard cells. × 300. **Fig. 4.** Abaxial epidermis of adult *C. nucifera* with longer guard cells. × 300.



Figs. 1-4

TABLE 2 — LENGTH OF GUARD-CELLS (IN MICRON) IN PALM LAMINA

Species	Age (Months)	Young plants		Adult plants	
		Abaxial epidermis	Adaxial epidermis	Abaxial epidermis	Adaxial epidermis
Areca catechu	14	28.76	30.58	34.42	32.60
Borassus flabellifer	36	33.41	33.82	32.85	34.02
Cocos nucifera	12	32.72	—	40.91	—
Elaeis guineensis	12	29.57	28.55	33.01	32.81
Hyphaene thebaica	54	34.83	36.45	35.64	36.05
Livistona chinensis	36	20.09	20.33	21.47	24.50
Phoenix sylvestris	16	21.06	22.60	19.85	20.09
Rhapis excelsa	12	24.01	—	24.10	—

N.B. Each measurement is the average for ten observations.

TABLE 3 — NUMBER OF INTERSTOMATAL ROWS OF CELLS AND THEIR WIDTH (IN MICRON)

Species	Young plants				Adult plants			
	No. of rows		Width of cell		No. of rows		Width of cell	
	Ab-axial epi-dermis	Ad-axial epi-dermis	Ab-axial epi-dermis	Ad-axial epi-dermis	Ab-axial epi-derims	Ad-axial epi-dermis	Ab-axial epi-dermis	Ad-axial epi-dermis
Areca catechu	5.7	—	14.42	18.02	6.7	—	13.78	18.27
Borassus flabellifer	6.8	8.8	10.01	9.29	8.7	7.8	8.66	8.52
Cocos nucifera	7.4	—	12.42	17.74	5.8	—	12.71	17.86
Elaeis guineensis	11.1	—	12.19	15.88	10.4	—	13.67	19.32
Hyphaene thebaica	7.4	8.3	9.08	9.98	6.7	6.6	10.22	9.57
Livistona chinensis	7.7	—	7.52	7.82	6.7	9.1	5.92	7.52
Phoenix sylvestris	6.3	8.1	7.36	7.10	6.2	7.1	5.52	5.30
Rhapis excelsa	7.6	—	9.97	10.00	6.3	—	9.06	11.42

N.B. Each figure is the average for ten observations.

in *Elaeis*, and minimum in *Phoenix*. The width of cells becomes smaller in adult *Phoenix*, *Areca*, *Livistona*, and *Borassus*.

FREQUENCY AND LENGTH OF TRICHOMES — Data on the frequency of trichomes per unit area are presesented in Table 4. The maximum number of trichomes on the abaxial epidermis is found in the adult plants of *Areca* and *Elaeis*. Trichomes are totally absent in *Livistona*, and *Phoenix*. They are also absent on the adaxial epidermis of *Cocos* and *Rhapis*.

Table 5 contains data on the length of trichomes from surface vew. Trichomes of *Hyphaene thebaica* show the maximum length of 363·29 μ in the young, and 323·10 μ in the adult. The shortest is in *Elaeis guineensis*.

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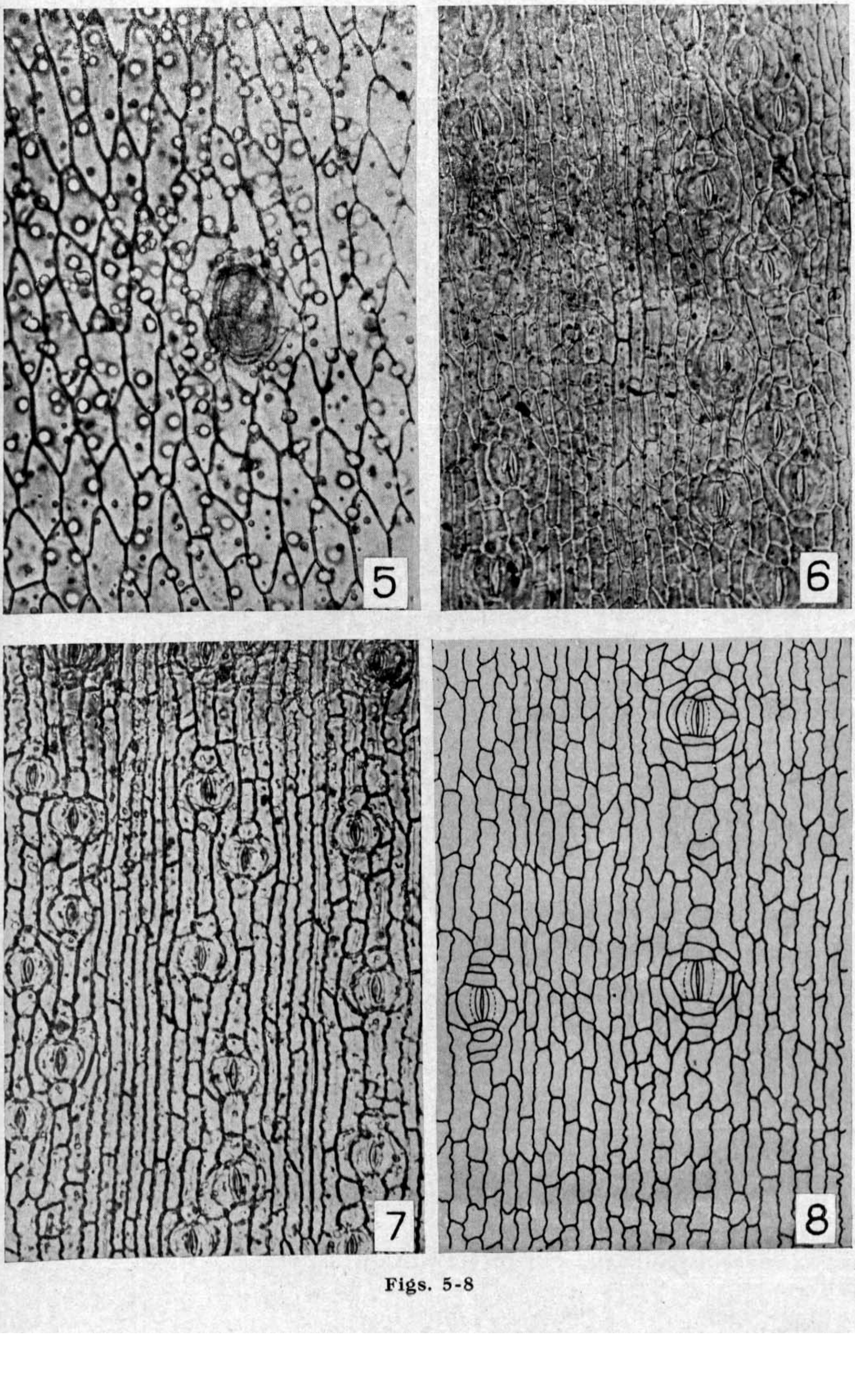
Figs. 5-8 — Fig. 5. Adaxial epidermis of lamina of young *Areca catechu* showing a trichome in the centre. Epidermal cells are hexagonal. × 300. **Fig. 6.** Adaxial epidermis of young *Phoenix sylvestris* with narrow epidermal cells. × 300. **Fig. 7.** Abaxial epidermis of *P. sylvestris* showing semi-sinuous cell walls. × 300. **Fig. 8.** Adaxial epidermis of young *Livistona chinensis*. × 300.



Figs. 5-8

TABLE 4 — NUMBER OF TRICHOMES PER UNIT AREA (0.17 SQ. MM)

SPECIES	AGE (MONTHS)	YOUNG PLANTS		ADULT PLANTS	
		ABAXIAL EPIDERMIS	ADAXIAL EPIDERMIS	ABAXIAL EPIDERMIS	ADAXIAL EPIDERMIS
Areca catechu	14	0.8	0.7	1.4	0.4
Borassus flabellifer	36	1.0	0.8	0.8	0.6
Cocos nucifera	12	0.4	nil	0.4	nil
Elaeis guineensis	12	0.8	0.8	1.7	0.7
Hyphaene thebaica	54	0.3	0.3	0.2	0.2
Livistona chinensis	36	nil	nil	nil	nil
Phoenix sylvestris	16	nil	nil	nil	nil
Rhapis excelsa	12	0.3	nil	0.4	nil

TABLE 5 — LENGTH OF TRICHOMES IN PALM LAMINA (IN MICRON)

SPECIES	AGE (MONTHS)	YOUNG PLANTS		ADULT PLANTS	
		ABAXIAL EPIDERMIS	ADAXIAL EPIDERMIS	ABAXIAL EPIDERMIS	ADAXIAL EPIDERMIS
Areca catechu	14	78.16	67.23	66.42	54.27
Borassus flabellifer	36	87.08	90.32	90.32	106.11
Cocos nucifera	12	91.53	absent	112.19	absent
Elaeis guineensis	12	33.21	29.57	76.95	55.49
Hyphaene thebaica	54	303.75	363.29	323.19	322.38
Livistona chinensis	36	absent	absent	absent	absent
Phoenix sylvestris	16	absent	absent	absent	absent
Rhapis excelsa	12	180.71	absent	160.38	absent

N.B. Each measurement is the average for ten observations.

STOMATAL INDEX — In order to find out the relative frequencies of stomata and ordinary epidermal cells, stomatal index was calculated for the following seven species: *Areca catechu, Borassus flabellifer, Cocos nucifera, Elaeis guineensis, Hyphaene thebaica, Phoenix sylvestris,* and *Rhapis excelsa.* The data are presented in Table 6.

Practically for all the species, the stomatal index is higher in adult plants. It would also be noticed from the data that, in all the species, the index for the abaxial epidermis is greater than that for adaxial epidermis.

Discussion

Although the climatic factors can bring about variation in the frequency distribution of stomata on leaf surfaces as reported by Salisbury (1928), relating to the woodland flora of England, and by Hirano (1931) in *Citrus* species, for many species of palms the stomatal index can be regarded as a dependable character for identification. Bavappa (1966) identified the various varieties of *Areca catechu* on the basis of the number of stomata per unit area. Among the palms studied, *Cocos* and *Rhapis* can be

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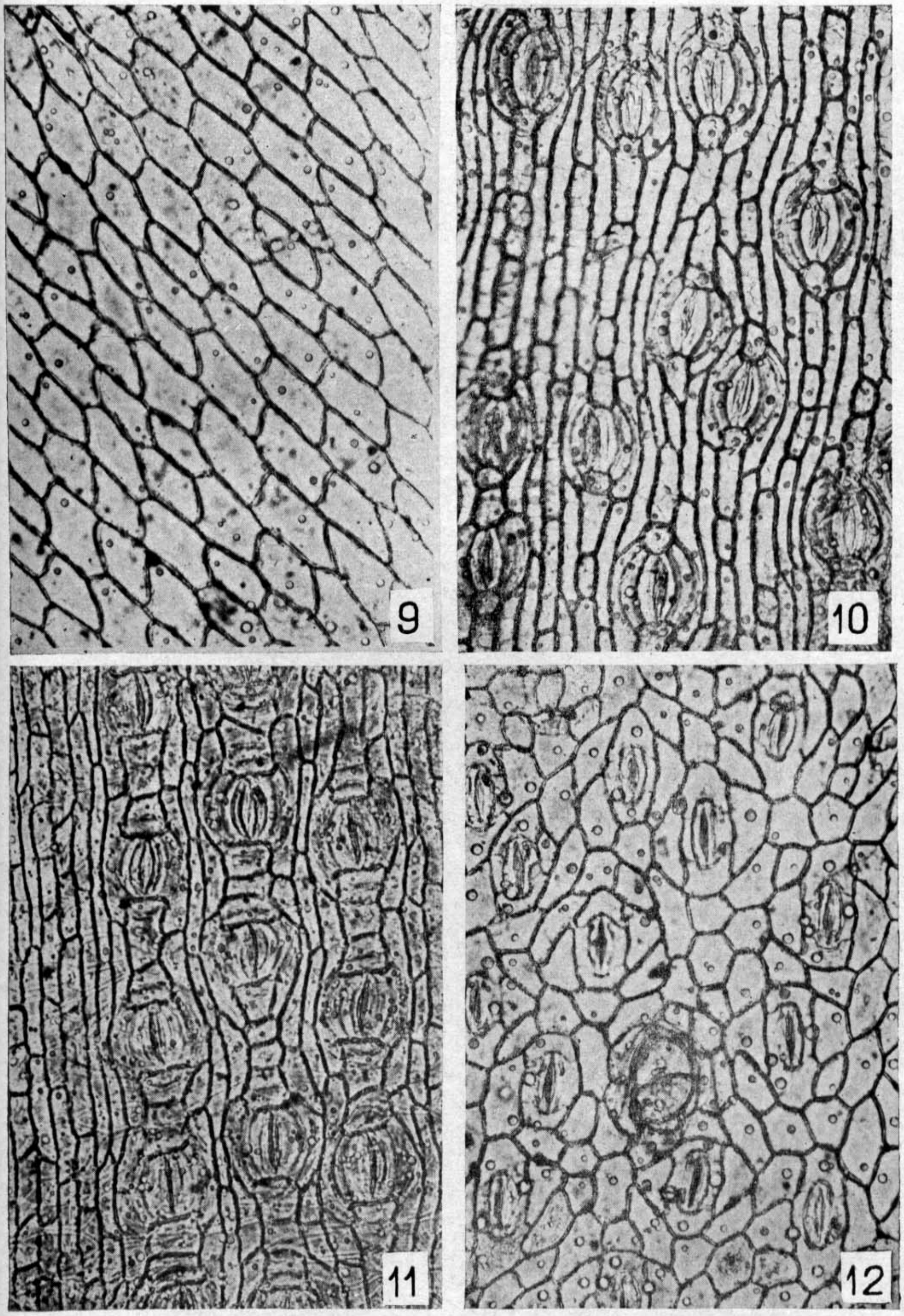
Figs. 9-12 — **Fig. 9.** Adaxial epidermis of lamina of adult *Elaeis guineensis* showing hexagonal cells. × 300. **Fig. 10.** Adaxial epidermis of adult *Borassus flablelifer* showing thick-walled epidermal cells. × 300. **Fig. 11.** Adaxial epidermis of adult *Hyphaene thebaica* showing long, thick-walled epidermal cells. × 300. **Fig. 12.** Abaxial epidermis of adult *E. guineensis* showing a trichome. × 300.



Figs. 9-12

TABLE 6 — STOMATAL INDICES OF YOUNG AND ADULT PALMS

SPECIES	YOUNG PLANTS		ADULT PLANTS	
	ABAXIAL EPIDERMIS	ADAXIAL EPIDERMIS	ABAXIAL EPIDERMIS	ADAXIAL EPIDERMIS
Areca catechu	5.79	—	9.43	—
Borassus flabellifer	7.23	6.85	8.66	8.26
Cocos nucifera	6.51	—	9.36	—
Elaeis guineensis	4.66	—	10.60	—
Hyphaene thebaica	6.97	4.92	6.04	5.98
Phoenix sylvestris	8.11	6.25	7.27	6.89
Rhapis excelsa	6.33	—	—	—

N.B. Stomatal index for *Livistona chinensis*, and adult *Rhapis excelsa* (abaxial epidermis) could not be calculated due to technical difficulties.

easily distinguished by the total absence of stomata on the adaxial epidermis. *Borassus*, *Hyphaene*, and *Phoenix* differ from the rest by having almost equal number of stomata on the adaxial and abaxial epidermes.

Stomatal frequency in all but one species (*Hyphaene thebaica*) is higher in adult palms. In *Livistona chinensis* the increase, especially on adaxial epidermis, is phenomenal. The size of stomata either increases (*Cocos nucifera*) or remains more or less the same in young and adult palms. Similarly, the number of rows of interstomatal cells and their width either increases or decreases slightly in adults. The increased frequency of stomata per unit area in most species has been brought about by a decrease in the number of rows and/or thickness of interstomatal cells, and/or by a conspicuous reduction in such cells along the stomatal rows (Figs. 3, 4; 6, 7; 10, 15). In *Livistona chinensis*, mass transformation of ordinary epidermal cells into guard cells seems to take place at a latter stage (after three years).

The guard cells always lie parallel to the long axis of the lamina, and they are always in pair with two longitudinal ledges (Tomlinson, 1961). According to Rudolph (1911), however, in some plants there is a tendency for the development of two additional ledges within the guard cells. In the present investigation too, the type of additional ledges reported by Rudolph was observed in *Borassus flabellifer*.

Tomlinson (1961) reported that the adaxial epidermal cells of palm leaves are often irregular in shape and, accordingly, he classified palms into three groups. We found in our study, though on a limited number of species, two more additional types in *Cocos* and *Rhapis*. Thus, the five groups are enumerated below with examples from the species under investigation: (*a*) Long cells with slightly thickened sinuous walls — *Rhapis excelsa* (Fig. 2); (*b*) Long cells with semi-sinuous thin walls, especially in the young — *Phoenix sylvestris* (Fig. 7), *Livistona chinensis* (Fig. 8); (*c*) Hexagonal cells with thick walls — *Elaeis guineensis* (Fig. 9) — *Areca catechu* (Fig. 5); (*d*) Long, rectangular, non-sinuous, thick-walled cells tending to be hexagonal — *Cocos nucifera* (Fig. 1); and (*e*) Long,

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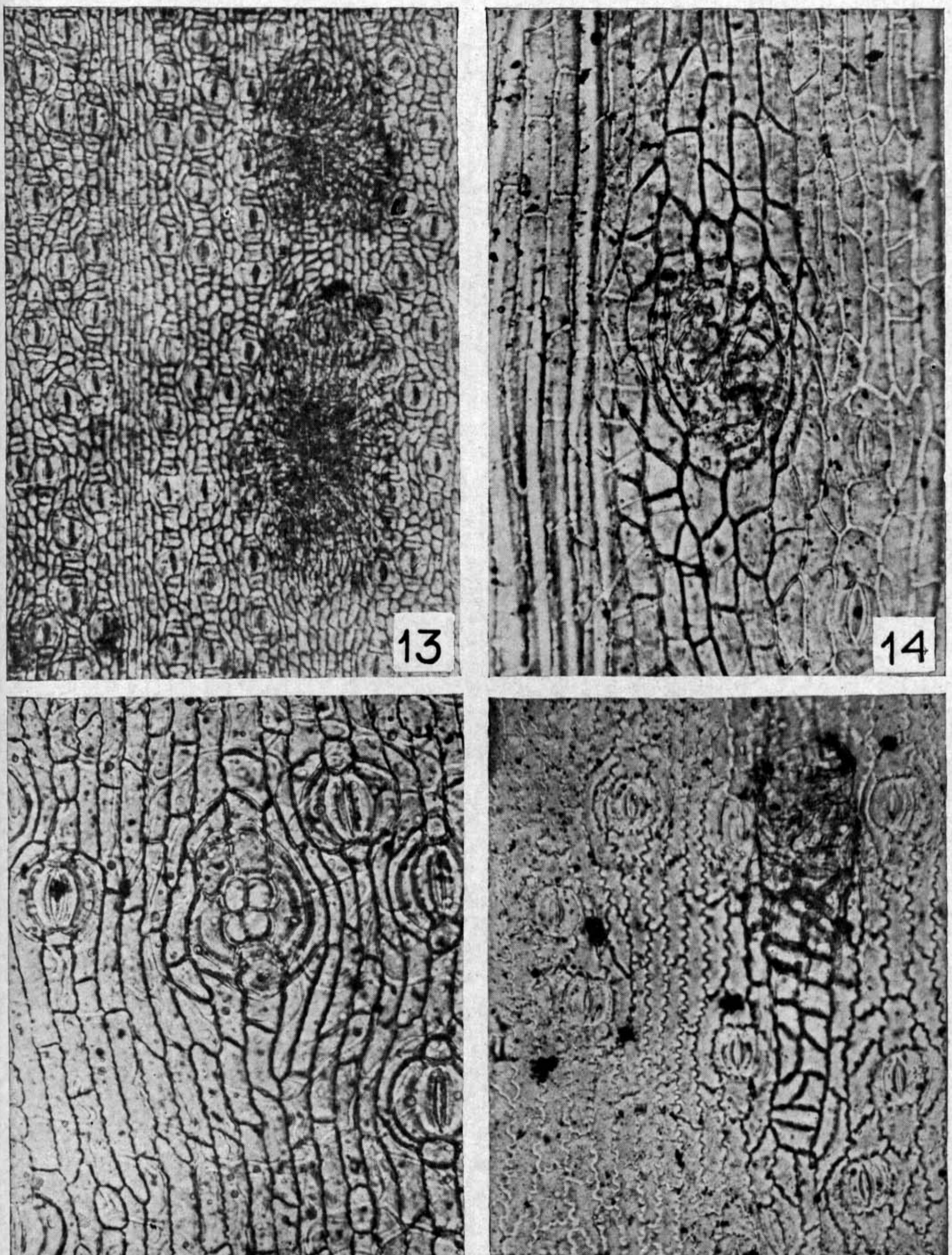
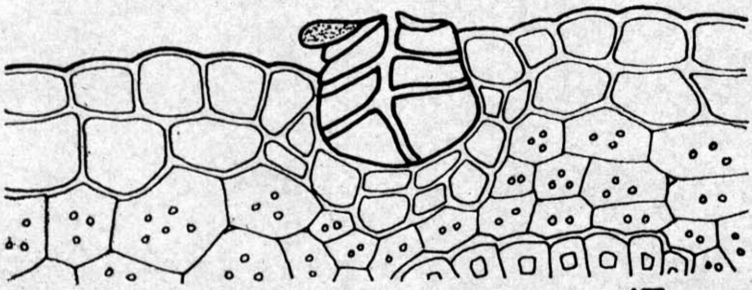
Figs. 13-16 — **Fig. 13.** Adaxial epidermis of lamina of adult *Hyphaene thebaica* showing two large trichome. × 110. **Fig. 14.** Abaxial epidermis of young *Cocos nucifera* showing a trichome. × 300. **Fig. 15.** Abaxial epidermis of young *Borassus flabellifer* showing a 4-chambered trichome. × 300. **Fig. 16.** Abaxial epidermis of young *Rhapis excelsa* showing a long filament-like trichome. × 305.



Figs. 13-16



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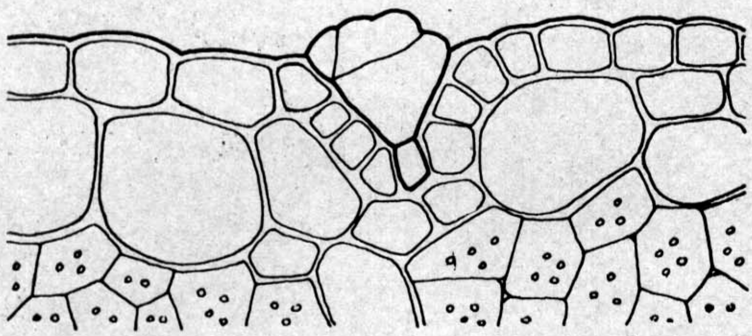

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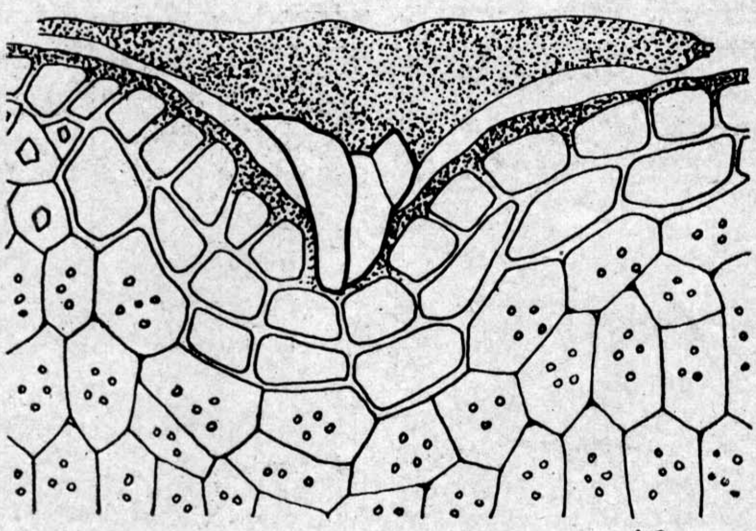

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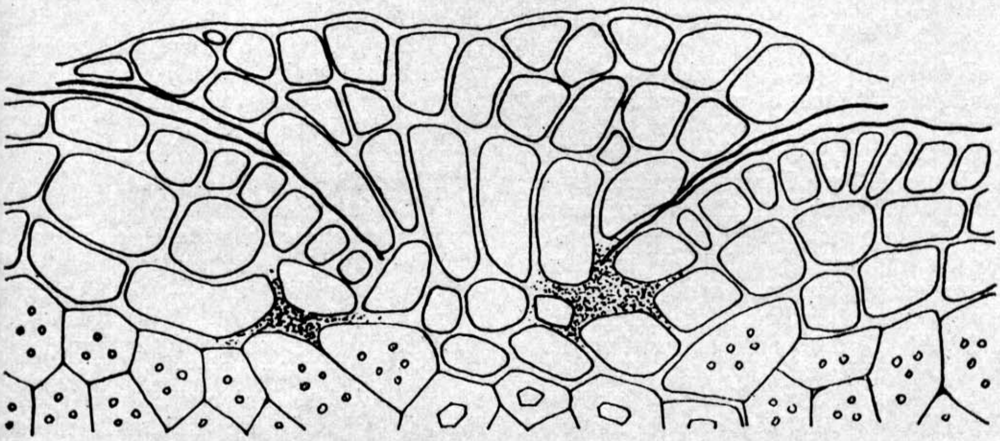
Figs. 17-19. T.s. trichomes of young palms. **Fig. 17.** *Areca catechu*, abaxial epidermis. × 550. **Fig. 18.** *Elaeis guineensis*, adaxial epidermis. × 650. **Fig. 19.** *Cocos nucifera*, abaxial epidermis. × 600.

thick-walled, non-sinuous cells — *Borassus flabellifer* (Fig. 10) — *Hyphaene thebaica* (Fig. 11).

Trichomes are of diverse form, structure, and function, and may show wide variation within families and smaller plant groups, and even in the same plant (Esau, 1958). On the other hand, Metcalfe & Chalk (1950) reported considerable uniformity in trichomes within a plant group. The types of trichomes have been used in the classification of genera



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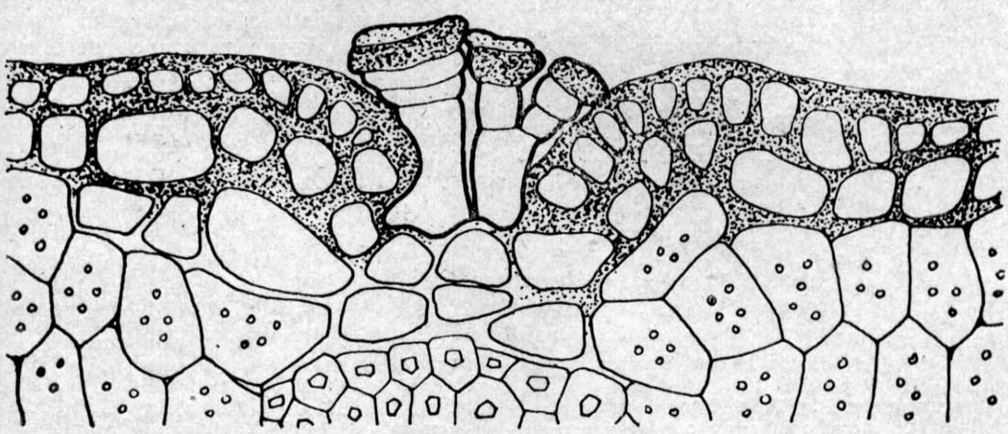

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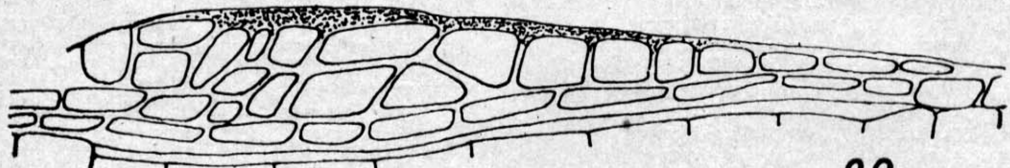

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Figs. 20-22. Trichomes of young palms. **Fig. 20.** T.s. trichome from adaxial epidermis of *Hyphaene thebaica*. The trichome is sunken with a massive base. × 530. **Fig. 21.** T.s. trichome of young *Borassus flabellifer*, abaxial epidermis. × 600. **Fig. 22.** L.s. trichome of *Rhapis excelsa* (abaxial epidermis) showing a filament-like structure. × 750.

and even species in certain families, and in the recognition of interspecific hybrids (Heintzelmann & Howard, 1948; Metcalfe & Chalk, 1950; Rollins, 1944). By their study on *Pinus radiata*, Rook, Hellmers & Hesketh (1971) also concluded that the presence or absence of trichomes and their shape serve as diagnostic features.

Tomlinson (1961) made a detailed study of trichomes of palms and classified them into seven types. Five of them are more or less recognisable in the limited number of species studied by us. Tomlinson combined the borassoid and sabaloid groups into one type according to the morphology of their trichomes. Moreover, in *Borassus flabellifer*, we could come across abundant trichomes (Fig. 15) although Tomlinson mentions that it is probably absent.

(*a*) Sunken, broad-base with usually 3-4 tiers of cutinized or sclerotic cells, round to oval in surface view, distal thin-walled cells not persistent — *Areca catechu* (Figs.5,17

(*b*) Sunken, narrow-base of 1-3 inflated cutinized cells, distal thin-walled cells form a shield as in *Cocos*, not persistent (persistent in *Elaeis guineensis*), round to oval in surface view — *Elaeis guineensis* (Figs. 12, 18), *Cocos nucifera* (Figs. 14, 19).

(*c*) Multicellular, slightly sunken, massive base, sclerotic, distal margin produces an ephemeral shield-like expanse of thin-walled delicate cells, wart-like in surface view — *Hyphaene thebaica* (Figs. 13, 20).

(*d*) Sunken base of usually 2 cylinder of cutinized cells, distally divided into a few tiers of thin-walled cells, marginal cells are delicate and ephemeral, clearly 4-chambered in surface view — *Borassus flabellifer* (Figs. 15, 21).

(*e*) Slightly sunken base of a small group of sclerotic cells, flattened filament of thin-walled cells in surface view, and also in longitudinal view — *Rhapis excelsa* (Figs. 16, 22).

Of the species studied, the cuticle of *Borassus flabellifer*, *Cocos nucifera*, *Hyphaene thebaica*, *Livistona chinensis*, and *Phoenix sylvestris* is considerably thicker than that of the rest. Priestly (1943) reported that a hard layer of cuticle is effective against the infestation by parasites. The relative resistance of *Areca triandra* against mites, a serious pest of *A. catechu*, has been attributed to the presence of a thicker cuticle in the former (Bavappa, 1966).

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