15. THERMAL EFFECT ON SOME EXTANT PALM POLLEN

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Abstract

Pollen grains of twenty species belonging to the family *Arecaceae* were investigated to study the effect of high temperature. Fresh and heated pollen grains at 200 °C were the subject of our investigations with the LM method. The qualitative and quantitative analyses of thermally altered pollen grains with respect to the morphological changes are presented herein. Alterations in general characters of investigated pollen depend on the basic morphology of individual grain. Changes in the size, sculptural elements, thickness and structure of the exine were noticed.

Key words: Palynology, extant palm, high temperature effect.

Introduction

Spores and pollen are the most sensitive indicators to high energy. The colour of microfossil changes during post-burial time due to high temperature and radioactive minerals present in the sediments. The rise of temperature may be attributed to the overburden of sediments and proximity to the igneous sources or the shear zone. At high energy levels organic molecules are subjected to degradation and destruction resulting into change of colour. The original land plant material is often pale yellow to light brown in colour which progressively changes through dark brown to opaque black when it undergoes thermal alteration at increased temperature (GRAY, 1975). The colour of microfossils provides an index for the degree of decomposition and it indicates the level of energy that has affected the rock since its lithification (DORRING, 1986).

The colour of microfossils is of particular interest to the petroleum geologist as it enables to predict the environment conductive to hydrocarbon generation. These studies provide a clue for better understanding about the regional history and source rock evaluation.

The first study dealing with effect of high temperature on the *angiosperm* pollen grains was made by KEDVES and KINCSEK (1989). *Normapolles*-like forms, which are characteristic of the Upper Cretaceous sediments of Europe appeared from recent *Corylus* and *Betula* pollen grains. It was emphasized, that the qualitative alterations of the different taxa of the investigated *brevaxonate Amentiflorae* pollen grains are not the same. Three types can be distinguished: 1. *Corylus, Betula* - important qualitative changes and early morphological characteristic features appeared. 2. *Carpinus* - qualitative changes are not so characteristic. 3. *Juglans* - qualitative changes were not ob-

served after heating. Later, KEDVES, TÓTH and FARKAS (1991) emphasized the following: p. 25: "Detailed methological investigations were carried out on two kinds of recent inaperturate pollen grains (*Juniperus virginiana* L., *Taxus baccata* L.). In consequence of high temperature, secondary changes for *angiosperm* characteristic features appeared on these pollen grains." KEDVES et al. (1993) observed that after heating monocolpate pollen of *Magnolia* (*Magnoliaceae*) and *Chamaedorea elegans* (*Arecaceae*) the shape and P/E ratio changed. In another paper (KEDVES, 1994) pointed out the following: p. 68: "1. The high temperature effect to the recent spores and pollen grains in taxonomical and/or phylogenetical respect has heterogeneous character. Advanced and early characteristic features may appear or in several cases the qualitative effect is neutral. 2. The linear alterations in the temperature and length of time also result in different changes in the qualitative and quantitative characteristic features of the sporomorphs. 3. The high temperature effect change the biopolymer organization of the sporoderm."

The first publication of the LM morphology of the palm pollen grains was of FRITZSCHE (1832, in ERDTMAN, 1952). Later several monographical elaborations, and basic morphological publications were published: ERDTMAN (1944, 1952), THANIKAIMONI (1966, 1970), PUNT and WESSELS BOER (1966), MALLIK and CHAUDHURI (1966-67), SOWUNMI (1968, 1972), KEDVES (1980), FERGUSON (1981, 1986), FERGUSON, DRANSFIELD, PAGE and THANIKAIMONI (1983), FERGUSON, HARVARD and DRANSFIELD (1987), DRANSFIELD, FERGUSON and UBAL (1990), HARLEY (1990), HARLEY and HALL (1991), FERGUSON and HARLEY (1993), and AMBWANI and KUMAR (1993), etc.

The aim of this paper is to investigate the alterations in morphological characteristics in arecaceous pollen after being subjected to high temperature for varying durations. The secondary altered forms are significant for comparative study of fossil palm pollen isolated from pre-Quaternary sediments.

Materials and Methods

The polliniferous material for investigations were collected by S.K.M. TRIPATHI and M. KUMAR from various localities, herbaria, botanical gardens and palynological laboratories. Pollen grains were kept at 200 °C for 1 hour, 25 hours and 100 hours. Slides of these pollen were mounted in glycerin-jelly hydrated at 39.6% and studied under light microscope. In most of the cases morphological alterations in 200 specimens of each species were observed to record changes in dimension, symmetry, exine sculpture and colour. Duration of heating for different species was as under:

1 hour: *Chrysalidocarpus lutescens, Kentia* sp., *Pseudophoenix ekmanii, Hyphaene indica, Nypa fruticans.*

25 hours, and 100 hours: *Chrysalidocarpus lutescens, Cocos nucifera, Roystonea regia, Livistona chinensis, Phoenix sylvestris, P. paludosa, Areca catechu, Elaeis guineensis, Caryota urens, Iriartea ventricosa, Borassus flabellifer, Dictyosperma album, Arenga pinnata, Mauritia flexuosa, Licuala spinosa, Pinanga javanica.*

Results

Chrysalidocarpus lutescens WENDL.
(Plate 15.1., figs. 1-6)

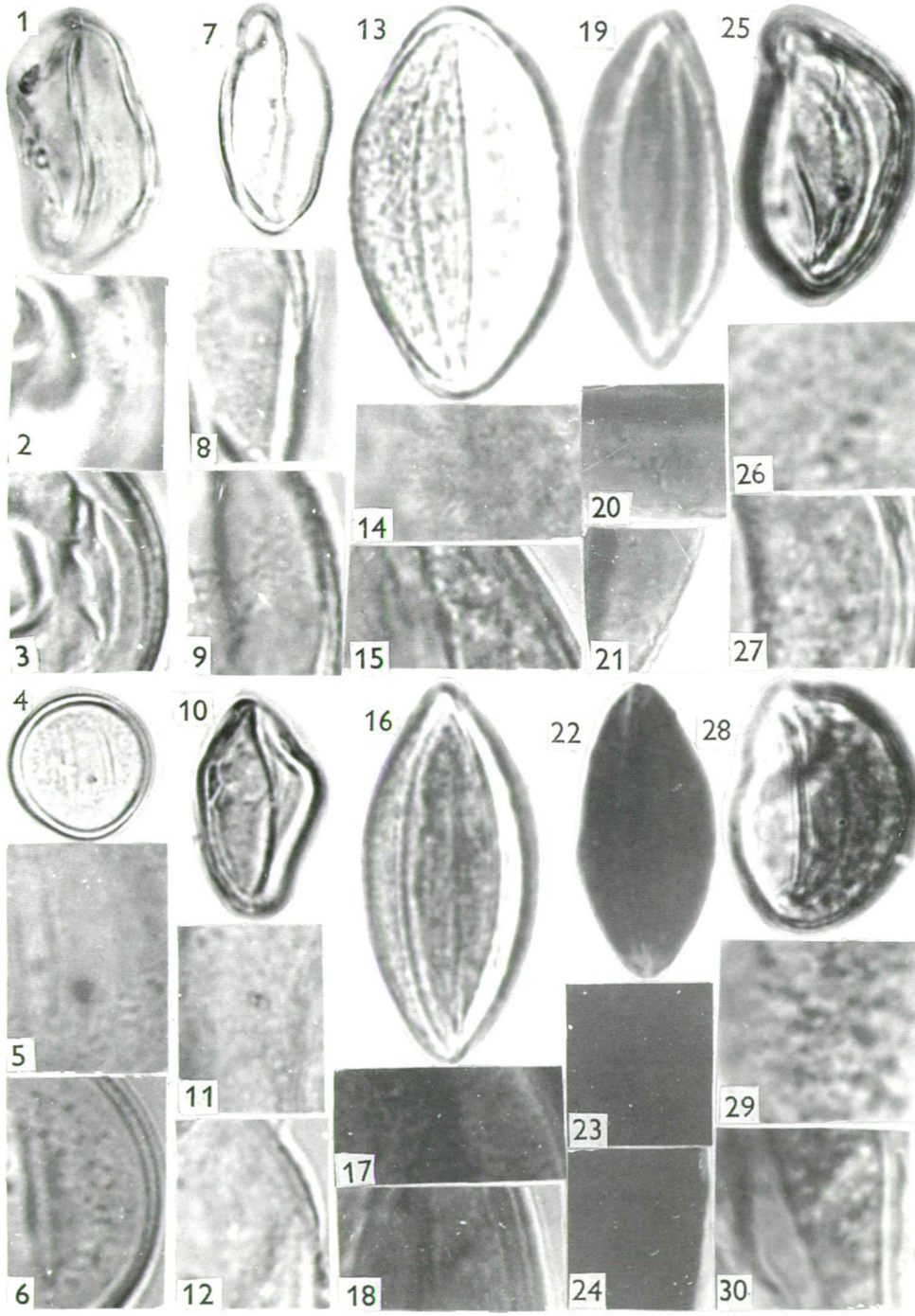
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Plate 15.1.

Pollen grains elliptical in shape. Monosulcate, sulcus extending from end to end. Exine 1.5-2 μm thick, scabrate. After 1 hour of heating marked reduction in size leading to a spheroidal shape was noticed.

Kentia sp.
(Plate 15.1., figs. 7-12)

Pollen grains elliptical in shape. Monosulcate, sulcus extending from end to end. Exine 1-2 μm thick, scabrate. After 1 hour heating size of pollen slightly reduced, exine moderately thickened.

Cocos nucifera LINN.
(Plate 15.1., figs. 13-24, Table 15.1.)

Pollen grains oval to elliptical in shape, lateral ends rounded, rarely pointed. Monosulcate, sulcus long, extending up to lateral ends. Exine 1.5-2.0 μm thick psilate to scabrate. Morphological alterations due to high temperature are clearly discernible. After 1 hour of heating the colour changes to light brown and equatorial diameter starts decreasing with thinning of exine at poles. After 25 hours colour of the pollen changed to light brown. The reduction in polar diameter from 70 x 52 to 51 x 45 μm and in equatorial diameter from 30 to 20 μm was noticed. At 100 hours remarkable reduction in size and exinal sculptures were observed. At this stage the lateral ends became more pointed.

Roystonea regia (H.B.K.) COOK
(Plate 15.1., figs. 25-30, Plate 15.2., figs. 1-6, Table 15.1.)

Pollen grains elliptical to oval in shape. Monosulcate, sulcus extending up to lateral ends. Exine tectate, fossulate. After 1 hour of heating no markable effect on exine sculpture was seen but reduction in size of pollen was noticed. Appearance of thickening of exine around sulcus is characteristic feature at 25 hours whereas, reduction in polar diameter and widening of sulcus was observed after 100 hours. In some pollen a concavity at the apertural side was observed.

Livistona chinensis (JACQ.) R. BR. ex MART.
(Plate 15.2., figs. 7-18, Table 15.2.)

Pollen grains oval to elliptical in shape. Monosulcate, sulcus extending up to lateral ends. Exine microreticulate, reticulations formed by fusion of pilae heads.

Plate 15.1.

1-3. *Chrysalidocarpus lutescens* WENDL., 0 hour, 1. 1000x, 2,3. 2500x.
4-6. *C. lutescens* WENDL., 1 hour, 4. 1000x, 5,6. 2500x.
7-9. *Kentia* sp., 0 hour, 7. 1000x, 8,9. 2500x.
10-12. *K.* sp., 1 hour, 10. 1000x, 11,12. 2500x.
13-15. *Cocos nucifera* LINN., 0 hour, 13. 1000x, 14,15. 2500x.
16-18. *C. nucifera* LINN., 1 hour. 16. 1000x, 17,18. 2500x.
19-21. *C. nucifera* LINN., 25 hours, 19. 1000x, 20,21. 2500x.
22-24. *C. nucifera* LINN., 100 hours, 22. 1000x, 23,24. 2500x.
25-27. *Roystonea regia* (H.B.K.) COOK., 0 hour, 25. 1000x, 26,27. 2500x.
28-30. *R. regia* (H.B.K.) COOK., 1 hour, 28. 1000x, 29,30. 2500x.

Table 15.1.

		POLAR AXIS				L/S RATIO				
Species	Length of time	Smallest (S) size (μm)	Dominant size (μm)	Largest (L) size (μm)	Δ=L-S (μm)	Smallest size (s)	Dominant size	Largest size (l)	Δ= l-s	X
Cocos	0	52.5	65	72.5	20	1.4	1.8	2.5	1.1	200
nucifera	1 hr	52.5	63.79	70	17.5	1.7	2.32	2.8	1.1	200
	25 hrs	47.5	56.94	62.5	15	1.8	2.35	2.8	1	200
	100 hrs	45	51.11	57.5	12.5	1.9	2.37	3.2	1.3	200
Iriartea	0	22.5	28.21	32.5	10	1	1.24	1.7	0.7	200
ventricosa	1 hr	25	28.86	32.5	7.5	1.4	1.60	1.9	0.5	200
	25 hrs	20	24.04	27.5	7.5	1.1	1.41	2	0.9	200
	100 hrs	17.5	21.57	25	7.5	1.1	1.29	1.5	0.4	200
Licuala	0	32.5	37.85	42.5	10	1	1.09	1.2	0.2	200
spinosa	1 hr	30	34.02	40	10	1	1.10	1.3	0.3	200
	25 hrs	25	29.42	32.5	7.5	1	1.09	1.3	0.3	200
	100 hrs	22.5	26.97	32.5	10	1	1.11	1.4	0.4	200
Phoenix	0	12.5	17.20	22.5	10	1	1.21	1.6	0.6	200
sylvestris	1 hr	12.5	16.29	25	12.5	1	1.20	1.7	0.7	200
	25 hrs	12.5	14.52	20	7.5	1	1.18	1.6	0.6	200
	100 hrs	10	12.91	15	5	1	1.16	1.5	0.5	200
Pinanga	0	30	37.50	45	15	1	1.19	1.7	0.7	200
javanica	1 hr	27.5	34.89	40	12.5	1	1.28	1.9	0.9	200
	25 hrs	27.5	31.52	37.5	10	1	1.23	1.6	0.6	200
	100 hrs	25	29.44	35	10	1	1.13	1.3	0.3	200
Roystonea	0	37.5	41.36	47.5	10	1	1.24	1.7	0.7	200
regia	1 hr	32.5	39.71	47.5	15	1	1.25	1.9	0.9	200
	25 hrs	27.5	35.04	40	12.5	1	1.29	1.6	0.6	200
	100 hrs	25	30.66	37.5	12.5	1	1.29	1.7	0.7	200

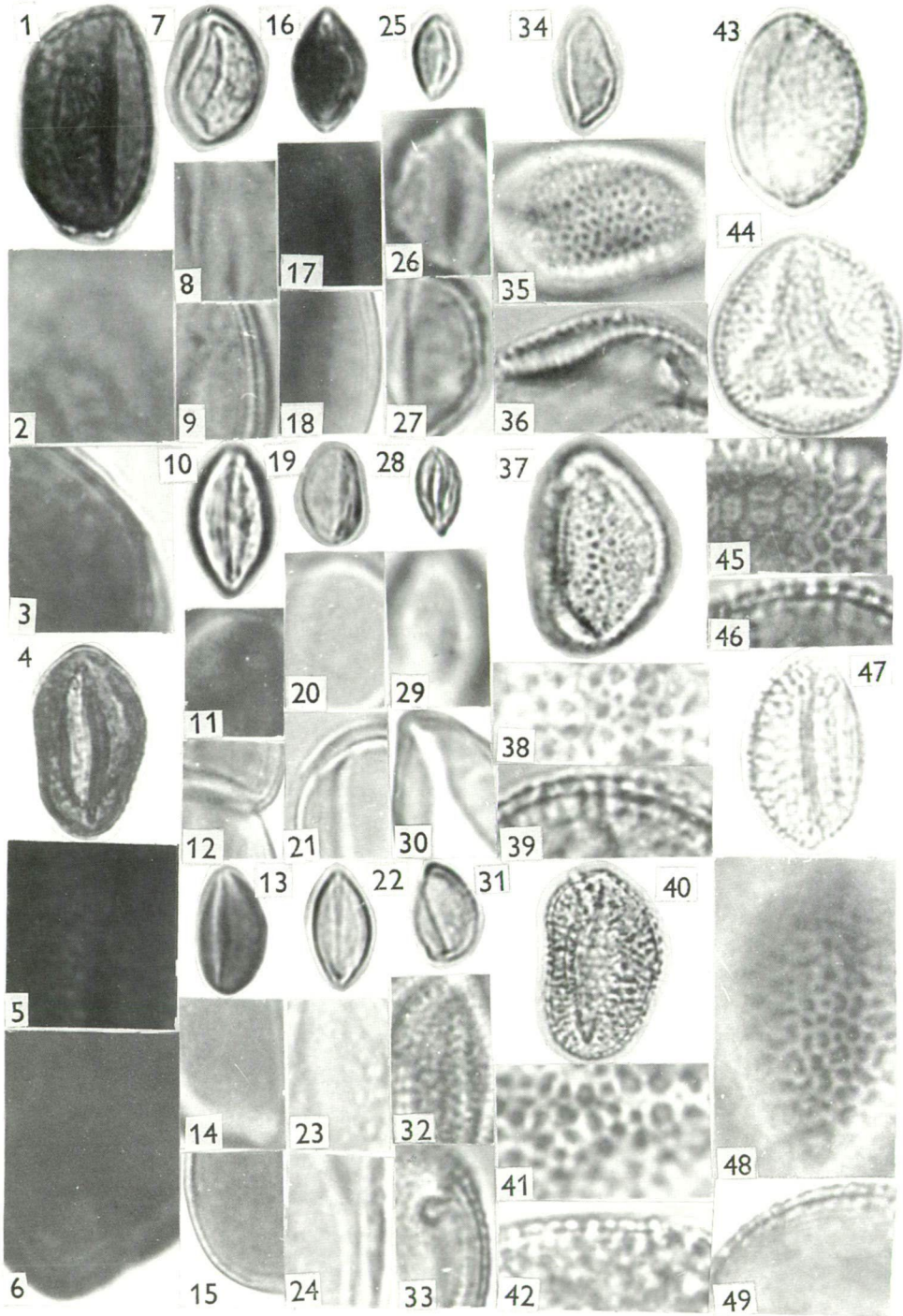
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Plate 15.2.

Pollen grains after 1 hour heating show reduction in P/E diameter. After 25 hours heating reduction in equatorial diameter and thickening of exine around sulcus was observed, reticulations became more clear and pilae heads increased in size. After 100 hours smoothness in sculpture and reduction in size was noticed.

Phoenix sylvestris (LINN.) ROXB.
(Plate 15.2., figs. 19-30, Table 15.1.)

Pollen grains oval-elliptical in shape. Monosulcate, sulcus long, extending up to lateral ends. Exine scabrate to finely reticulate. No appreciable change in morphology after 1 hour and 25 hours was seen. After 100 hours pollen became light brown in colour and reduction in size was noticed.

Phoenix paludosa ROXB.
(Plate 15.2., figs. 31-36)

Pollen elliptical to oval-elliptical in shape. Monosulcate, sulcus long. Exine 1.5-2.0 μm thick, microreticulate, retipilate. No appreciable change was noticed after 1 hour heating.

Pseudophoenix ekmanii BURRET
(Plate 15.2., figs. 37-42)

Pollen grains oval-elliptical in shape. Monosulcate, longisulcate. Exine 1.5-2.0 μm thick, semitectate, microreticulate, retipilate. After 1 hour of heating pollen turned golden in colour. Exine slightly thickens around aperture.

Areca catechu LINN.
(Plate 15.2., figs. 43-49)

Pollen grains oval in shape, showing variation of aperture, viz., monosulcate and trichotomosulcate. Exine 2.0-2.5 μm thick, microreticulate, retipilate. After 1 hour heating reduction in P/E diameter was observed. Thickening of exine around sulcus was noticed. Some pollen exhibit curving at the apertural face.

Plate 15.2.

1-3. *Roystonea regia* (H.B.K.) COOK., 25 hours, 1. 1000x, 2,3. 2500x.
4-6. *R. regia.* (H.B.K.) COOK., 100 hours, 4. 1000x, 5,6. 2500x.
7-9. *Livistona chinensis* (JACQ.) R. BR. ex MART., 0 hour, 7. 1000x, 8,9. 2500x.
10-12. *L. chinensis* (JACQ.) R. BR. ex MART., 1 hour, 10. 1000x, 11,12. 2500x.
13-15. *L. chinensis* (JACQ.) R. BR. ex MART., 25 hours, 13. 1000x, 14,15. 2500x.
16-18. *L. chinensis* (JACQ.) R. BR. ex MART., 100 hours , 16. 1000x, 17,18. 2500x.
19-21. *Phoenix sylvestris* (L.) ROXB., 0 hour, 19. 1000x, 20,21. 2500x.
22-24. *P. sylvestris* (L.) ROXB., 1 hour, 22. 1000x, 23,24. 2500x.
25-27. *P. sylvestris* (L.) ROXB., 25 hours, 25. 1000x, 26,27. 2500x.
28-30. *P. sylvestris* (L.) ROXB., 100 hours, 28. 1000x, 29,30. 2500x.
31-33. *Phoenix paludosa* ROXB., 0 hour, 31. 1000x, 32,33. 2500x.
34-36 *P. paludosa* ROXB., 1 hour, 34. 1000x, 35,36. 2500x.
37-39. *Pseudophoenix ekmanii* BURRET., 0 hour, 37. 1000x, 38,39. 2500x.
40-42. *P. ekmanii* BURRET., 1 hour, 40. 1000x, 41,42. 2500x.
43-46. *Areca catechu* LINN., 0 hour, 43-44. 1000x, 45,46. 2500x.
47-49. *A. catechu* LINN. 1 hour, 47. 1000x, 48,49. 2500x.

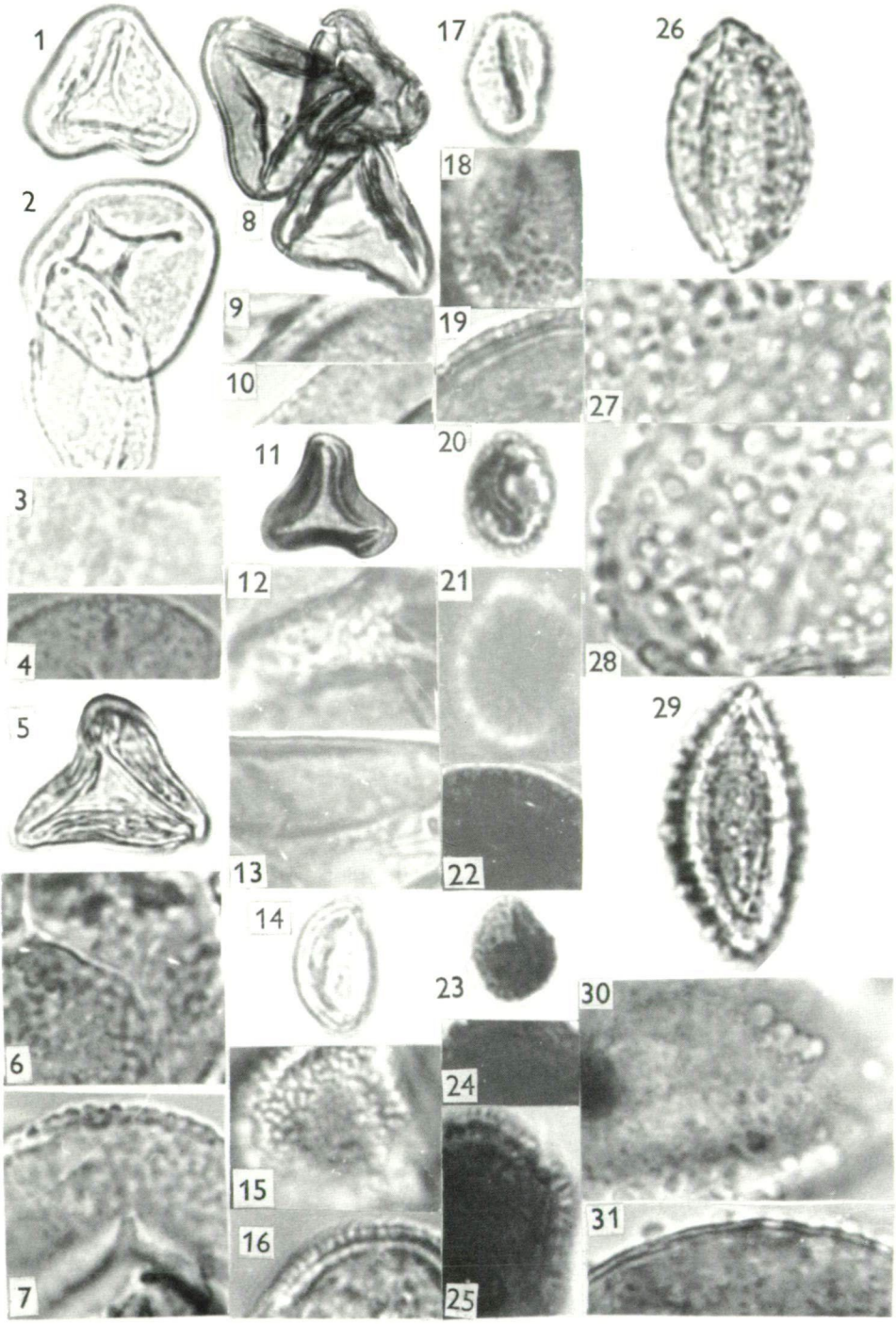
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Plate 15.3.

Elaeis guineensis JACQ.
(Plate 15.3., figs. 1-13)

Pollen grains elliptical or triangular to subcircular in shape, showing apertural variation such as monosulcate, trichotomosulcate and tetratomosulcate. Exine 1.5 μm thick semitectate, finely punctate. After 1 hour heating no considerable change was noticed except concavity in interradial region. After 25 and 100 hours the exine sculpture diminishes in size and concavity between inter-radials region increases.

Caryota urens LINN.
(Plate 15.3., figs. 14-25)

Pollen grains oval in shape. Monosulcate. Exine semitectate, clavate-reticulate, microreticulate. After 1 hour heating slight reduction in equatorial diameter of the grain was observed but after 25 hours decrease in P/E diameter was more pronounced. After 100 hours reduction in the diameter of pilae head, diminishing of reticulations and decrease in the size of the grain were noticed.

Hyphaene indica BECC.
(Plate 15.3., figs. 26-31)

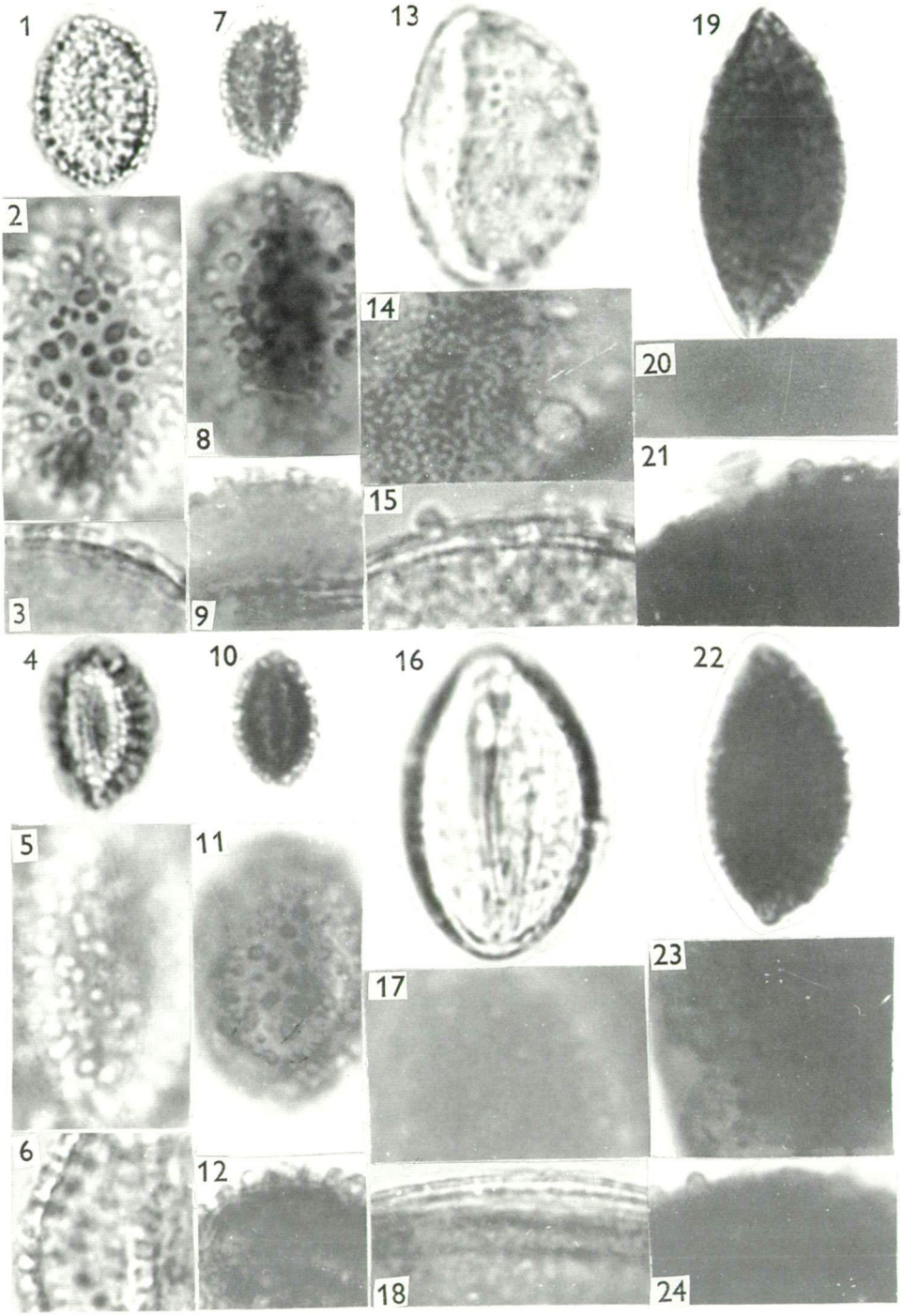
Pollen grains elliptical in shape. Monosulcate, sulcus extending up to lateral ends. Exine semitectate, gemmate, gemmae supratectal, spaces between gemmae microreticulate to scabrate. After 1 hour heating pollen grains show remarkable decrease in equatorial diameter and thinning of exine. The reduction in height and diameter of gemmae and less in their quantity is a characteristic feature at this stage. The intergemmal spaces appear to be faintly reticulate.

Iriartea ventricosa MART.
(Plate 15.4., figs. 1-12, Table 15.1.)

Pollen grains oval in shape. Monosulcate, sulcus long, extending up to lateral ends. Exine 2-4 μm thick, pilate, pilae supratectal. Morphological alterations after 1 hour are clearly observed in this pollen. A gradual decrease in size at 1 h, 25 and 100 hour(s) is a characteristic phenomenon. At 1 hour reduction in diameter of pilae heads and thinning of exine was noticed which because more pronounced after 25 hours. The height of pilae are also reduced after 25 hours and these appears like warts after 100 hours.

Plate 15.3.

1-4. *Elaeis guineensis* JACQ., 0 hour, 1,2. 1000x, 3,4. 2500x.
5-7. *E. guineensis* JACQ., 1 hour, 5. 1000x, 6,7. 2500x.
8-10. *E. guineensis* JACQ., 25 hours, 8. 1000x, 9,10. 2500x.
11-13. *E. guineensis* JACQ., 100 hours, 11. 1000x, 12,13. 2500x.
14-16. *Caryota urens* LINN., 0 hour, 14. 1000x, 15,16. 2500x.
17-19. *C. urens* LINN., 1 hour, 17. 1000x, 18,19. 2500x.
20-22. *C. urens* LINN., 25 hours, 20. 1000x, 21,22. 2500x.
23-25. *C. urens* LINN., 100 hours, 23. 1000x, 24,25. 2500x.
26-28. *Hyphaene indica* BECC., 0 hour, 26. 1000x, 27,28. 2500x.
29-31. *Hyphaene indica* BECC., 1 hour, 29. 1000x, 30,31. 2500x.



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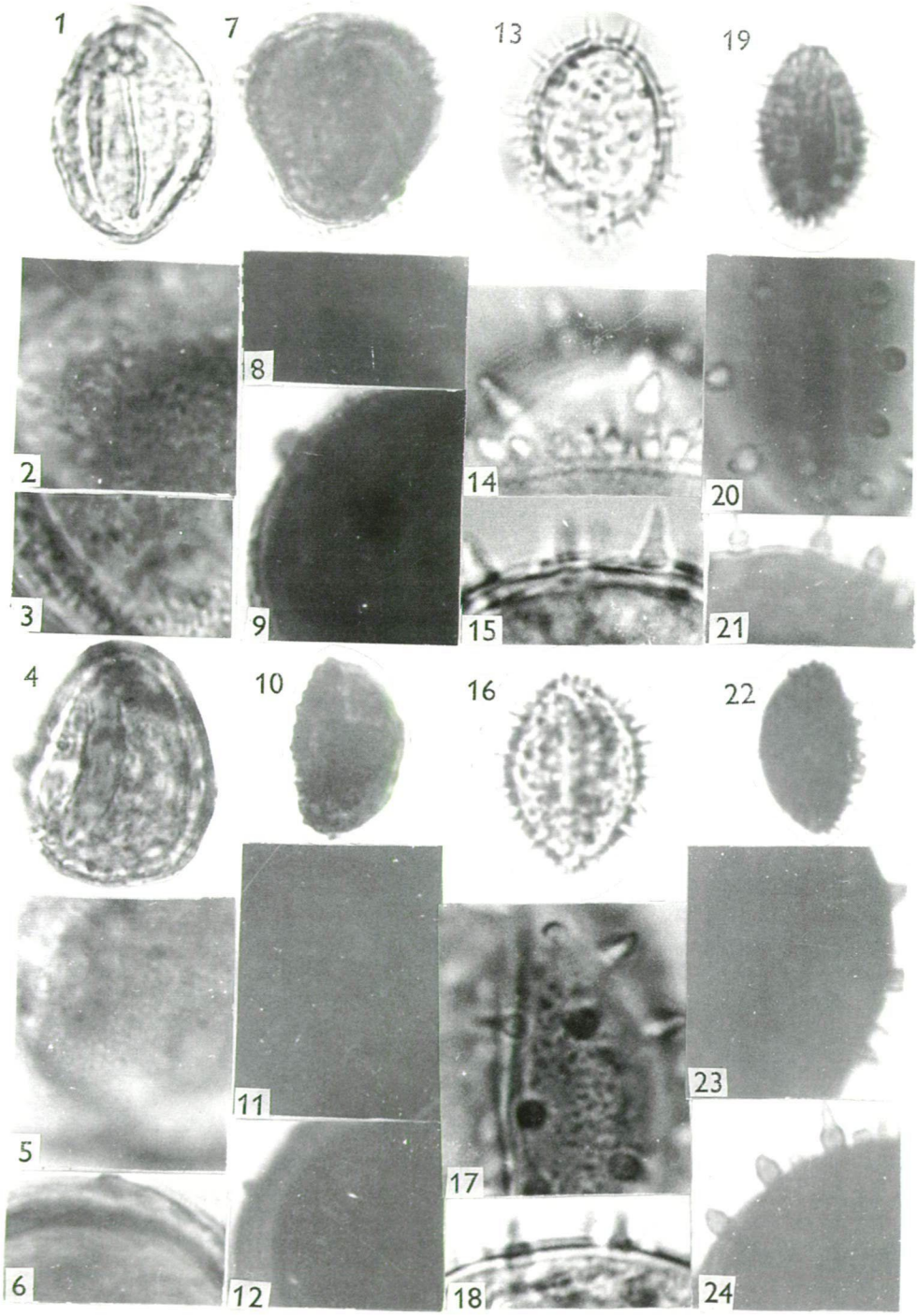

Plate 15.5.

Borassus flabellifer LINN.
(Plate 15.4., figs. 13-24, Table 15.2.)

Pollen grains oval in shape. Monosulcate, sulcus long widely open. Exine 1.5-2.0 μm thick, gemmate, baculate, granulate: exine ornamentation supratectal. Morphological alterations in consequence to the high temperature are clearly visible in this pollen. After 1 and 25 hour(s) a gradual increase in polar diameter and reduction in size and quantity of sculptural elements were observed. The thinning of exine is also observed during 1-100 hours. A remarkable decrease (5-7 μm) in polar diameter and reduction in size of sculptural elements are the result of 100 hours heating.

Dictyosperma album H. WENDL. et DRUDE ex SCHEFF.
(Plate 15.5., figs. 1-12, Table 15.2.)

Pollen grains oval to subcircular in shape. Monosulcate, sulcus long, extending up to lateral ends. Exine 1.5-2.5 μm thick. One hour heating increase in P/E diameter ratio but reduction in polar diameter was observed after 25-100 hours.

Arenga pinnata (WURMB.) MERR.
(Plate 15.5., figs. 13-24, Table 15.2.)

Pollen grain oval in shape. Monosulcate, sulcus medium to large. Sometimes extending up to lateral ends. Exine up to 1.5 μm thick spinose, spines with bulbous base and pointed tips, interspinal spaces laevigate. The important change in morphology after 1 hour is reduction in P/E diameter. After 25 hours further decrease in P/E diameter and thickness of exine were observed. Tips of spines became more slender. The morphological alterations after 100 hours are characteristically different. At this stage markable reduction in size, thinning of exine and disappearance of spine tips in large number of specimens were observed.

Plate 15.4.

1-3. *Iriartea ventricosa* MART., 0 hour, 1. 1000x, 2,3. 2500x.
4-6. *I. ventricosa* MART., 1 hour, 4. 1000x, 5,6. 2500x.
7-9. *I. ventricosa* MART., 25 hours, 7. 1000x, 8,9. 2500x.
10-12. *I. ventricosa* MART., 100 hours, 10. 1000x, 11,12. 2500x.
13-15. *Borassus flabellifer* LINN., 0 hour, 13. 1000x 14,15. 2500x.
16-18. *B. flabellifer* LINN., 1 hour, 16. 1000x, 17,18. 2500x.
19-21. *B. flabellifer* LINN., 25 hours, 19. 1000x, 20,21. 2500x.
22-24. *B. flabellifer* LINN., 100 hours, 22. 1000x, 23,24. 2500x.

Plate 15.5.

1-3. *Dictyosperma album* H. WENDEL. et DRUDE ex SCHEFF., 0 hour, 1. 1000x, 2,3. 2500x.
4-6. *D. album* H. WENDEL et DRUDE ex SCHEFF., 1 hour, 4. 1000x. 5,6. 2500x.
7-9. *D. album* H. WENDEL et DRUDE ex SCHEFF., 25 hours, 7. 1000x, 8,9. 2500x.
10-12. *D. album* H. WENDEL et DRUDE ex SCHEFF., 100 hours, 10. 1000x, 11,12. 2500x.
13-15. *Arenga pinnata* (WURMB.) MERR., 0 hour, 13. 1000x, 14,15. 2500x.
16-18. *A. pinnata* (WURMB.) MERR., 1 hour, 16. 1000x, 17,18. 2500x.
19-21. *A. pinnata* (WURMB.) MERR., 25 hours, 19. 1000x, 20,21. 2500x.
22-24. *A. pinnata* (WURMB.) MERR., 100 hours, 22. 1000x, 23,24. 2500x.

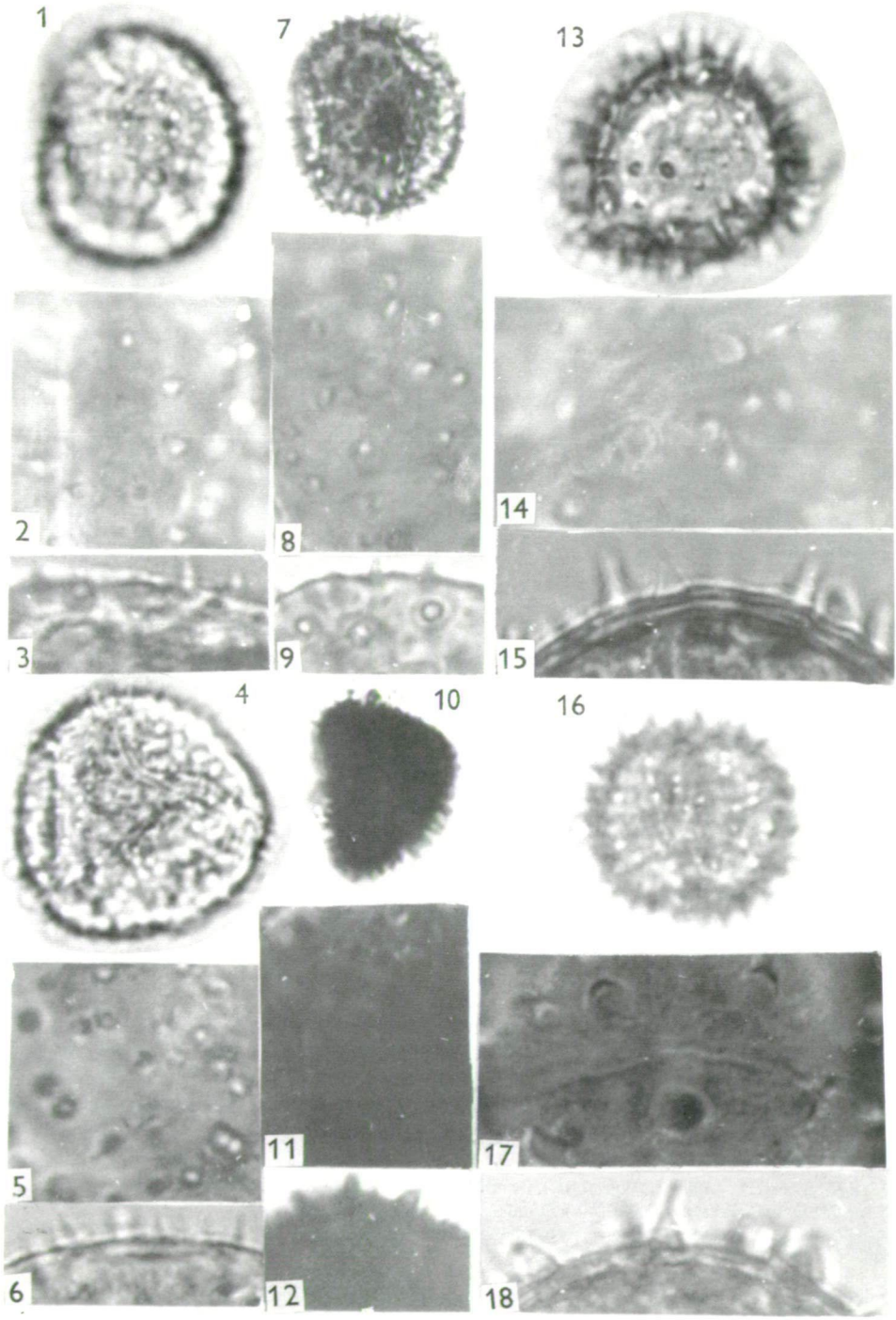

Plate 15.6.

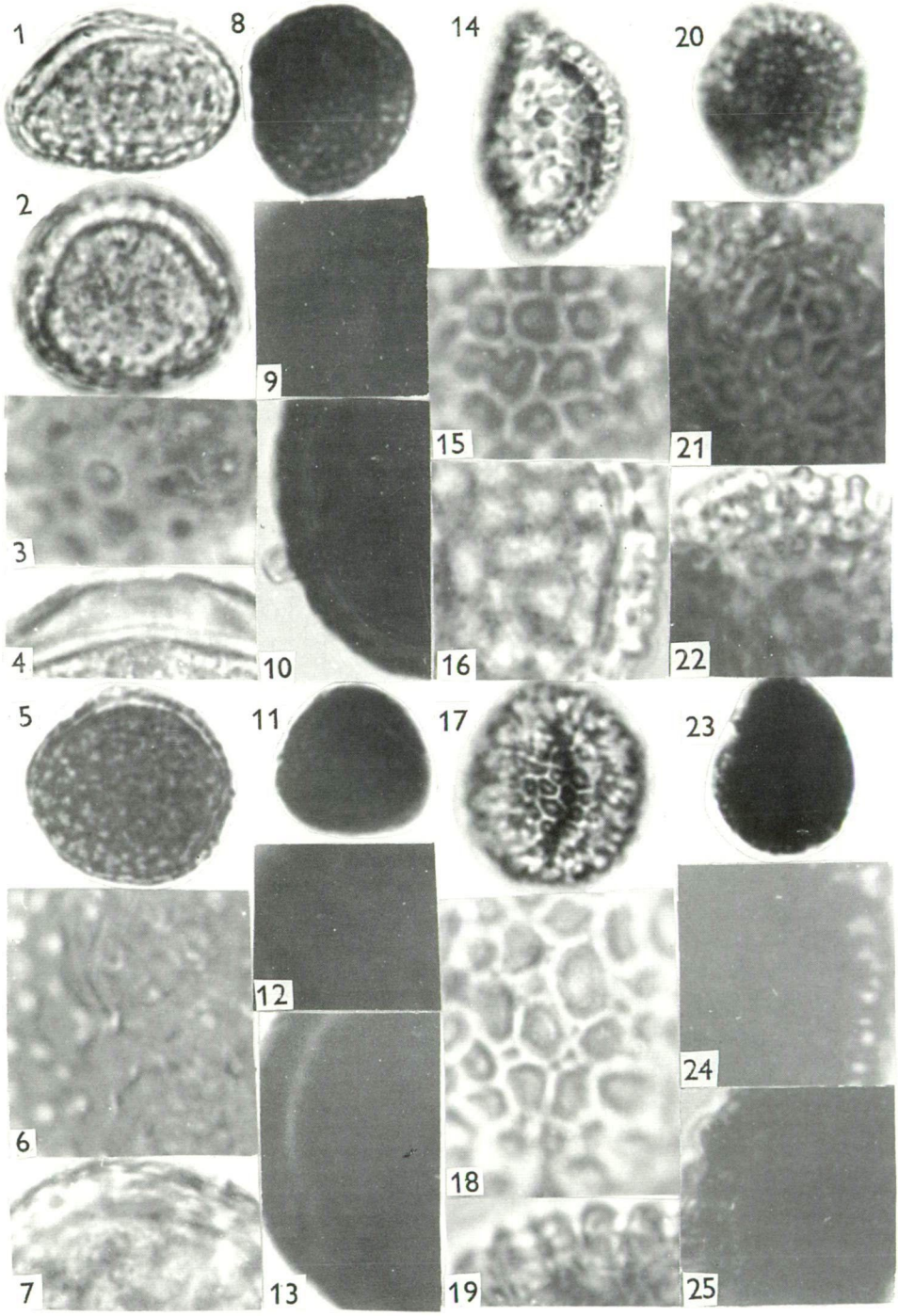

Plate 15.7.

Table 15.2.

Species	Length of time	Smallest (S) size (μm)	Dominant size (μm)	Largest (L) size (μm)	Δ=L-S (μm)	Smallest size (s)	Dominant size	Largest size (l)	Δ= l-s	X
Dictyosperma album	0	37.5	44.66	50	12.5	1	1.12	1.4	0.4	200
	1 hr	35	39.97	47.5	12.5	1	1.15	1.4	0.4	200
	25 hrs	20	26.25	42.5	22.5	1	1.31	2.5	1.5	52
	100 hrs	20	28.93	40	20	1	1.32	1.8	0.8	42
Livistona chinensis	0	20	23.19	27.5	7.5	1	1.32	1.7	0.7	200
	1 hr	20	22.56	27.5	7.5	1	1.35	1.7	0.7	200
	25 hrs	15	18.96	22.5	7.5	1	1.38	1.8	0.8	200
Mauritia flexuosa	0	37.5	46	57.5	20	1	1.15	1.7	0.7	200
	1 hr	37.5	43.87	55	17.5	1	1.13	1.4	0.4	200
	25 hrs	25	39.21	65	30	1	1.29	3.7	2.7	200
	100 hrs	20	35.76	75	55	1	1.31	3.6	2.5	161
Arenga pinnata	0 1/7-687	15	30.12	72.5	57.5	1	1.44	3.4	2.4	124
	0 -838	22.5	31.2	37.5	15	1	1.3	2.1	1.1	62
	1 hr -688	15	32.93	42.5	27.5	1	1.39	2	1	64
	1 hr -839	17.5	31.84	45	27.5	1	1.38	3	2	125
	25 hrs	20	31.28	50	30	1	1.44	2.3	1.3	84
	100 hrs	20	28.16	37.5	17.5	1	1.44	2	1	110
Borassus flabellifer	0 1/7-659	37.5	45.83	57.5	20	1	1.23	1.7	0.7	30
	0 -828	37.5	47.92	60	22.5	1	1.3	1.9	0.9	24
	1 hr -660	30	46.04	60	30	1.1	1.35	1.7	0.6	12
	25 hrs	27.5	47.43	75	47.5	1	1.67	3.4	2.4	71
	100 hrs	35	46.28	75	40	1.1	1.85	3.2	2.1	37

X means number of measured pollen grains.

Mauritia flexuosa LINN.
(Plate 15.6., figs. 1-12, Table 15.2.)

Pollen grains monosulcate, trichotomosulcate or ulcerate, sometimes aperture not clearly discernible. Exine 2-3 μm thick, spinose. Spines 2-3 μm long, slender, 5-6 μm apart. After 1 hour heating slight decrease in length of spines was noticed. After 25 hours pollen changed to brown in colour. Reduction in P/E diameter and slight thickening of exine around the sulcus were observed. After 100 hours colour changed to dark brown, spines reduced by 1.5 μm and decrease in size of pollen was noticed.

Nypa fruticans WURMB.
(Plate 15.6., figs. 13-18)

Pollen grains monosulcate, meridionosulcate. Exine tectate, perforate with supratectal spines. Spine bases broad and tips pointed. After 1 hour pollen became golden yellow in colour and slight reduction in size was noticed.

Licuala spinosa WURMB.
(Plate 15.7., figs. 1-13, Table 15.1.)

Pollen grains monosulcate, oval to elliptical in shape. Sulcus extending up to lateral ends. Exine distinctly reticulate. After 1 hour colour of pollen changed to golden brown, size of pollen got slightly reduced and shape of pollen changed to subtriangular to subcircular. After 25 hours further reduction in size, fainting of reticulation and change of pollen colour to dark brown were noticed. After 100 hours size of pollen reduced remarkably and shape changed to subtriangular. The reticulations disappeared and colour turned dark brown.

Pinanga javanica BLATER
(Plate 15.7., figs. 14-25, Table 15.1.)

Plate 15.6.

1-3. *Mauritia flexuosa* LINN., 0 hour, 1. 1000x, 2,3. 2500x.
4-6. *M. flexuosa* LINN., 1 hour, 4. 1000x, 5,6. 2500x.
7-9. *M. flexuosa* LINN., 25 hours, 7. 1000x, 8,9. 2500x.
10-12. *M. flexuosa* LINN., 100 hours, 10. 1000x, 11,12. 2500x.
13-15. *Nypa fruticans* WURMB., 0 hour, 13. 1000x, 14,15. 2500x.
16-18. *N. fruticans* WURMB., 1 hour, 16. 1000x, 17,18. 2500x.

Plate 15.7.

1-4. *Licuala spinosa* WURMB. 0 hour, 1,2. 1000x, 3,4. 2500x.
5-7. *L. spinosa* WURMB., 1 hour, 5. 1000x, 6,7. 2500x.
8-10. *L. spinosa* WURMB., 25 hours, 8. 1000x, 9,10. 2500x.
11-13. *L. spinosa* WURMB., 100 hours, 11. 1000x, 12,13. 2500x.
14-16. *Pinanga javanica* BLAT., 0 hour, 14. 1000x, 15,16. 2500x.
17-19. *P. javanica* BLAT., 1 hour, 17. 1000x, 18,19. 2500x.
20-22. *P. javanica* BLAT., 25 hours, 20. 1000x, 21,22. 2500x.
23-25. *P. javanica* BLAT., 100 hours, 23. 1000x 24,25. 2500x.

Pollen grains oval to elliptical in shape. Monosulcate, sulcus long, meridionosulcate. Exine 2.5-3.0 μm thick, semitectate, reticulate. After 1 hour heating increase in equatorial diameter and thickness of exine were noticed. Increase in diameter of baculae is also distinctly visible. At 25 hours a distinct reduction in P/E diameter and decrease in length of baculae as well as lumina were observed. After 100 hours the pollen further reduced in size and exine sculpture diminished.

Discussion and Conclusions

Present experiments suggest that most of the alterations appear after 1 hour heating at 200 °C and the modified features get more intensified after 25 and 100 hours. The changes include the qualitative (colour and shape) and quantitative characters. Important changes observed in heated pollen are as follows:

In *Elaeis guineensis* after 25 and 100 hours heating concavity in interradial region appeared (Plate 15.3., figs. 5,11) which results into narrowing of sulcus appearing more or less like a trilete mark.

Most of the investigated pollen exhibit reduction in size after heating for 25 and 100 hours. Reduction in size is pronounceably observed in pollen of *Mauritia flexuosa* (Plate 15.6., figs. 7,10), *Pinanga javanica* (Plate 15.7., figs. 20,23), *Iriartea ventricosa* (Plate 15.4., figs. 7,10) and *Arenga pinnata* (Plate 15.5., figs. 19,22).

The reticulate ornamentation in studied pollen remained unchangent after heating except in *Pinanga javanica* (Plate 15.7., figs. 20,25), *Caryota urens* (Plate 15.3., figs. 20-25) and *Iriartea ventricosa* (Plate 15.4., figs. 7-12) where the meshes diminished in size.

After heating the pollen of *Arenga pinnata* (Plate 15.5., figs. 16-24) and *Mauritia flexuosa* (Plate 15.6., figs. 7-12) for 25 and 100 hours the spines got reduced in size and the bases become more bulbosous. In *Hyphaene indica* (Plate 15.3., figs. 29-31) and *Borassus flabellifer* (Plate 15.4., figs. 16-24) number and size of gemmae got reduced as a response to heating.

In some pollen e.g. *Roystonea regia* (Plate 15.2., figs. 1,4), *Elaeis guineensis* (Plate 15.3., figs. 5,8,11), *Licuala spinosa* (Plate 15.7., figs. 5-8) and *Pinanga javanica* (Plate 15.7., figs. 17, 20) after heating the exine around sulcus thickened.

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