SCANNING ELECTRON MICROSCOPICAL STUDIES ON THE SPORES OF PTERIDOPHYTES. VII. THE FAMILY PLAGIOGYRIACEAE[1]

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Abstract: The spores of nine taxa of Formosan *Plagiogyria* are studied by scanning electron microscope. They are found to have trilete spores of medium size (30-36 μ×38-65 μ, in polar×equatorial diameters), mostly with rounded or hemispherical processes, and with raised laesurae having thin or thick margos. Based upon sculptine ornamentations five major types of spores can be discerned. A key to the taxa based on palynological data alone is given. Comparison with other species of *Plagiogyria* found elsewhere are also made. Possible use of spore characteristics in species differentiation and the course of the development of the perispore are discussed. Some outstanding potential of the inherent capacity of scanning electron microscope in palynological studies are pointed out.

INTRODUCTION

Plagiogyriaceae is a small family of relatively primitive ferns having a single genus and about 36 species distributed in tropical and subtropical East Asia and the America (Holttum, 1973). They are found growing on forest floors of mountains with altitude of 1,000 to 2,000 meters. The genus *Plagiogyria* distinguishes itself by the dimorphic fronds (sterile leaves broader and fertile leaves narrow, often longer and acrostichoid), the lack of scales and true hairs (young leaves densely covered with mucilaginous hairs), the enlarged, usually triangular (some tetragonal) stipe bases with or without prominent wings on the ridges, the presence of two rows of pneumatophores on the stipe, the widely V-shaped or U-shaped and winged vascular bundles, and the presence of a complete oblique annulus in the sporangium of the exindusiate sori (Bower, 1926; Copeland, 1960; DeVol, 1972).

The identity of these medium-sized terrestrial ferns can easily be recognized, even by amateurs. In Taiwan, we have eight or more species of *Plagiogyria* (DeVol & Lu, 1975). There are numerous hybrids or intermediate forms, dwarf species, mutants and abnormal fronds. These plants baffled botanists for years, and in many cases, correct species identification even defy the sharp eyes of trained taxonomists or specialists.

We have other problems too. For example, the actual identity of *P. japonica* is not known. Ching (1958) suggested that it is exactly intermediate between *P. euphlebia* and *P. distinctissima* (*P. adnata*) and therefore it might be the hybrid of a cross between the two species. For the group of *P. euphlebia* Copeland (1929) considered *P. euphlebia*, *P. grandis* and *P. christii* as three distinct species. Nakaike (1971) maintained *P. euphlebia* and *P. grandis* as distinct species, but he considered *P. christii* as a synonym of *P. euphlebia*. However, DeVol (1972) suggested that the differences between these species are small and lumped them into one species, *P. euphlebia*,

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with one variety, *P. euphlebia* var. *grandis*. Furthermore, the glaucous *Plagiogyria* with terminal pinna found in Taiwan were considered as *P. formosa* by Nakai (1928). But, according to Nakaike (1971) it is a subspecies of *P. glauca*, and named it as *P. glauca* subsp. *formosana*. DeVol (1972) suggested that it is exactly similar to the Philippine species described earlier as *P. glauca* var. *Philippiensis* by Christ (1898).

Since spores are useful taxonomic characters for species differentiation and for phylogenetic consideration (Erdtman & Sorsa, 1971; Knox, 1951; Kremp & Kawasaki, 1972; Nayar, 1964; Wagner, 1974; Weaver, 1895) and since scanning electron microscope is a superb tool for making palynological observation (Knoblock, Spink & Fulfs, 1970; Martin & Drew, 1969; Woods, 1973), we wish to check the spores of *Plagiogyria* by scanning electron microscope, and try to find out if spore characteristics in these ferns can be employed advantageously as good diagnostic characters for species delimitation and phylogenetic evaluation.

MATERIALS AND METHODS

Spores were collected from fresh plant materials and from dried specimens deposited in the herbarium, Department of Botany, National Taiwan University. After preliminary examinations

Table I. A list of the taxa of *Plagiogyria* used for light and scanning electron microscopical observations. Some measurements of the spores were also given.

Taxon	Collector & Number Locality & Date	Spore size (Polar × equatorial diameter, μ)	Size of Processes (diameter, μ)	Length of laesural arm (μ)	Thickness of laesura (μ)
1. *Plagiogyria adnata* (Blume) Bedd.	*M.T. Kao 5955* Ilan: Mt. Bon-bon Aug. 31, 1964	51-56 × 58-65	2-3	33-40	4-7
2. *P. dunii* Copel.	*C.M. Kuo 1749* Ilan: Tapachienshan Aug. 10, 1972	32-38 × 40-48	2-3	25-30	3-4
3. *P. euphlebia* (Kunze) Mett.	*M.T. Kao 8561* Ilan: Nanhutashan Nov. 6, 1972	45-54 × 52-58	1.5-3	28-35	1-2
4. *P. granisd* Copel.	*M.T. Kao 5911* Ilan: Mt. Bon-bon Aug. 29, 1964	39-46 × 46-54	2-3.0	25-30	1-2
5. *P. glauca* (Blume) Mett. var. *philippiensis* Christ	*M.T. Kao 7571* Chiayi: Mt. Ali Nov. 16, 1969	30-34 × 38-41	raised areas 2-4 μ in dia.	24-28	1-2
6. *P. japonica* Nakai	*K. Ochi 16098* Shikoku: Otoshi, Niihama-shi Sept. 23, 1961	46-50 × 53-59	2-6 small granule less then 1 μ	25-30	2-5
7. *P. koidzumii* Tagawa	*Huang, Kuo & Kao 943* Nantou: Chingshuikou Feb. 18, 1959	32-35 × 39-43	2-3	20-27	1.5-2.0
8. "*P. parva* DeVol"	*T. Nakamura 4487* Hualien: Mukuahshan Aug. 7, 1940	45-50 × 50-56	1-3	27-32	6-8
9. *P. stenoptera* (Hance) Diels	*C.M. Kuo 1309* Pingtung: Tashulinshan Mar. 31, 1972	36-43 × 45-50	2-6	25-30	2-4

of the spores of at least three different specimens of each species under the light microscope, one representative collection of the spores was used for taking light and scanning electron micrographs. The specimen used in our study were listed in Table I. A taxon which Dr. C. E. DeVol intended to name it as a new species, "*P. parva*", in April 15, 1970, but not described later, was also included in our study. Detailed methods and procedures of scanning electron microscopy were as described before (Liew, 1975). Observations were made at magnification from 1,000 to 3,000 times, and for structural details, up to ten thousand times. For light microscopy, direct observations were made on untreated spores dispersed in a drop or two of Hoyer's solution. Light micrographs were uniformly magnified 600 times, and were used as standard for purpose of comparison. Some species from areas other than Taiwan which were here studied or by other authors were also compared and discussed.

RESULTS

Plagiogyrias are found to have anisopolar, tetrahedral trilete spores with triangular to subtriangular amb (See Plates I to III). In size, they range from small to large, and in polar × equatorial diameters, measuring respectively, about 30–46 × 38–54 μ to 45–56 × 50–65 μ. The sculptine pattern on the proximal surface may or may not similar to those on distal surface. Proximal surface may be psilate, finely granulose, with minute, short, acicular protuberances, with or without rounded or hemispherical processes, these processes small to large, 1–6 μ in diameter. Laesural arm about 20–40 μ long, thin or thick, 1–8 μ in thickness, with raised margo and pointed junction tip, extending to or nearly to margins; sides straight or with varying degree of concaveness, contact faces more or less flat, concave or convex. Distal face may be psilate, finely granulose, verrucate, gemmate or tuberculate, processes small to large, few and scattered or numerous and densely distributed, with or without minute, thread-like inter- lining structures.

The nature of the rounded or hemispherical processes is more or less characteristic of each species or taxon. It is assumed that they can be subdivided into several types according to the sizes and structures of the elements or grains. Small spherical grains are termed granules (less than 1 μ in diameter, e. g. in *P. japonica*), larger ones gemmae (about 3 μ in diameter, e. g. in *P. adnata*, *P. dunii*, *P. euphlebia*, *P. grandis*, and "*P. parva*"), and largest ones tubercules (about 6 μ in diameter, e. g. in *P. stenoptera* and *P. japonica*). Hemispherical elements are termed verrucae (e. g. in *P. koidzumii*). Such a definition deem necessary for purpose of clarity and consistency in nomenclature and description.

A short description of the spores of each species of *Plagiogyria* found in Taiwan is given as below. For each type of spores, three different views are shown in both scanning electron micrographs (SEM) and the accompanying light micrographs (LM) arranged beside each SEM: the proximal face, the distal face, and the spore in equatorial view (See Plates I to III). For each micrograph, the scale of magnification is as follow: At 400×, 1 cm is approximately equivalent to 25 μ; 600×, 1 cm = 19 μ; 670×, 1 cm = 17 μ; 1,000×, 1 cm = 10 μ; 2,000×, 1 cm = 5 μ; and 3,300×, 1 cm = 3 μ.

1. *Plagiogyria adnata* (Blume) Bedd. (Plate I, fig. 1; Plate V, figs. 33 & 35)

Spore large in size, 51–56 μ × 58–65 μ (polar × equatorial diameters); amb triangular. Proximal face covered with only a few small rounded processes (gemmae), more towards the equator, gemmae 2–3 μ in diameter; raised laesurae thick, 4–7 μ across, arm about 33–40 μ long, extending to margins; sides straight; contact faces flat to concave. Distal face gemmate, gemmae 2–3 μ in diameter, densely distributed. Both surfaces covered with minute, thread-like interlining structures.

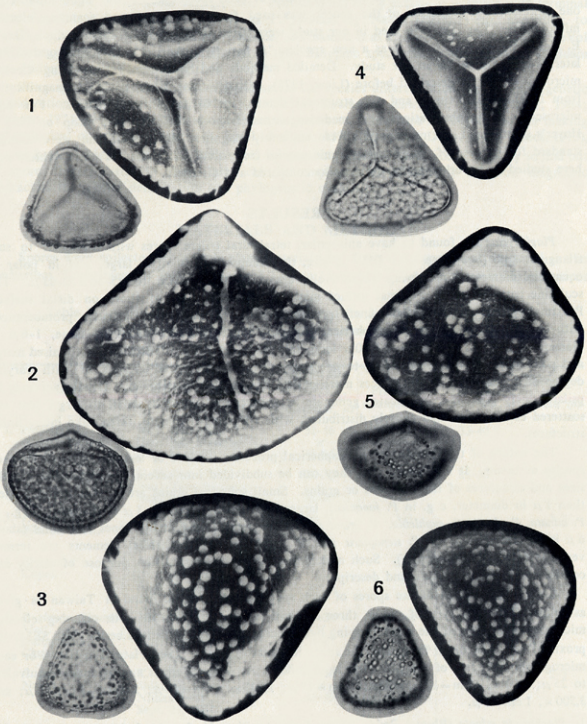

Plate 1. Gemmate spores of *Plagiogyria*.
Most *Plagiogyria* have gemmate spores. It includes *P. adnata* (fig. 1), "*P. parva*" (fig. 2), *P. dunii* (fig. 3), *P. euphlebia* (fig. 4), and *P. grandis* (figs. 5 & 6). Two subtypes of gemmate spores can be discerned: one with thick laesurae (figs. 1-3), the other with thin laesurae (figs. 4-6). For each subtype, three different views of the spores are shown: proximal faces (figs. 1 & 4), equatorial views (figs. 2 & 5), and distal faces (figs. 3 & 6). All SEM are magnified 670×, except figs. 2 & 3 (1,000×). All LM are magnified 400×, except fig. 4 (600×).

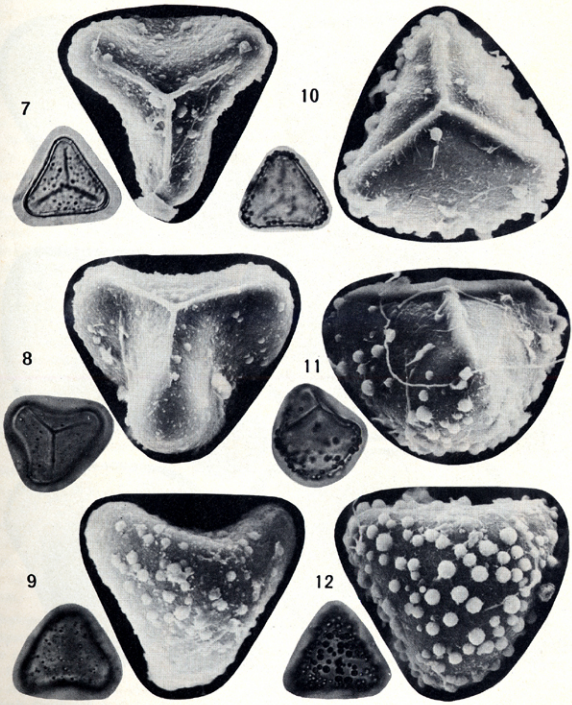

Plate II. Verrucate and tuberculate spores of *Plagiogyria*.
P. koidzumii has verrucate spores (figs. 7–9), and *P. stenoptera* has tuberculate spores (figs 10–12). For each species three views of the spores are shown: proximal faces (figs. 7 & 10), equatorial views (figs. 8 & 11), and distal faces (figs. 9 & 12). All SEM are magnified 1,000× and all LM 400×.

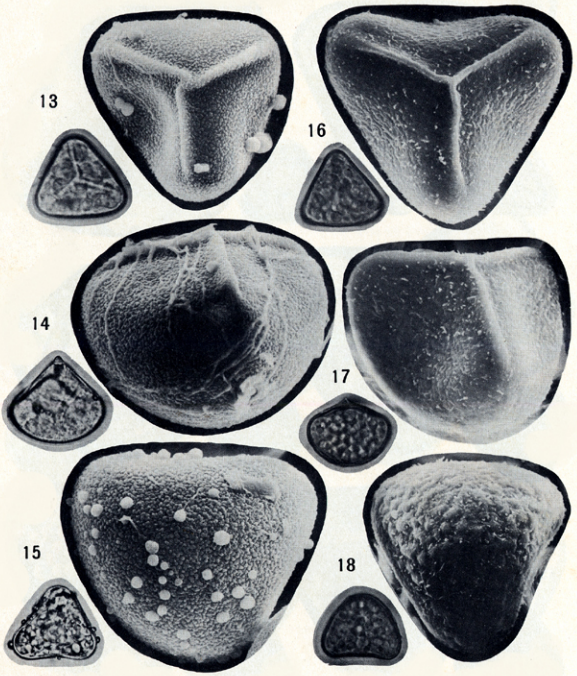

Plate III. Granulose and aciculate spores of *Plagiogyria*.
The spore of *P. japonica* has a granulose surface (figs. 13-15), and *P. glauca* var. *philippiensis* is aciculate (figs. 16-18). Three views of the spores of each species are shown: proximal faces (figs. 13 & 16), equatorial views (figs. 14 & 17), and distal faces (figs. 15 & 18). All SEM are magnified 1,000× and all LM 400×.

2. *Plagiogyria dunii* Copel. (Plate I, fig. 3; Plate V, fig. 32)

Spore medium in size, 32–38 $\mu \times$ 40–48 μ; amb triangular. Proximal face with a few small gemmae, about 2 μ in diameter; raised laesura 3–4 μ thick, arm about 25–30 μ long, almost reaching the margins; sides straight or concave; contact faces flat to slightly concave. Distal face gemmate, gemmae small, 2–3 μ in diameter, densely distributed on the surface.

3. *Plagiogyria euphlebia* (Kunze) Mett. (Plate I, fig. 4; Plate V, figs. 27 & 29)

Spore large in size, 45–54 $\mu \times$ 52–58 μ; amb triangular. Proximal face smooth, with a few small gemmae, 1–3 μ in diameter; raised laesura about 2 μ across, arm about 28–35 μ long, almost reaching the margins, junction with a pointed tip; sides straight or concave; contact faces flat or slightly convex or concave. Distal face gemmate, gemmae small, 1.5–3.0 μ in diameter, randomly and moderately distributed; surfaces with minute thread-like interlining structures.

4. *Plagiogyria grandis* Copel. (Plate I, figs. 5–6; Plate V, figs. 26, 30 & 34)

Spore medium in size, 39–46 $\mu \times$ 46–54 μ; amb triangular to subtriangular. Proximal face with small gemmae, about 2 μ in diameter, moderately distributed; laesura raised, thin, about 2 μ across, arm about 25–30 μ long, almost reaching the margins, junction with a raised tip; sides and contact faces flat, slightly concave to concave. Distal face gemmate, gemmae small, 2–3 μ across, moderately distributed, surface with minute, thread-like interlining structures.

5. *Plagiogyria glauca* (Blume) Mett. var. *philippiensis* Christ. (Plate III, figs. 16–18; Plate IV, fig. 24)

Spore small in size, 30–34 $\mu \times$ 38–41 μ; amb triangular to subtriangular. Proximal face without rounded processes, surface rough, with some short, small, and randomly distributed, acicular protuberances, about 1 μ tall; laesura raised, thin, 1–2 μ across, arm about 24–28 μ long, extending almost to margins, tip of junction pointed; sides and contact faces slightly concave to concave. Distal face rough, with large somewhat amorphous raised blocks or areas, 2–4 μ in diameters, with random grooves, not forming areolate sculpture, surface covered with echinate, short, acicular protuberances.

6. *Plagiogyria japonica* Nakai. (Plate III, figs. 13–15; Plate IV, fig. 19)

Spore large in size, 46–50 $\mu \times$ 53–59 μ; amb triangular. Proximal face finely and densely granulose, mostly without large, rounded processes, but some with a few large tubercules, 2–6 μ in diameter; laesura raised, 2–5 μ thick, arm 25–30 μ long, almost reaching the margins, tip of junction pointed; sides straight to slightly concave; contact faces more or less flat to slightly concave or convex. Distal face finely and densely granulose, with a few large tubercules, 2–5 μ in diameter. Some spores are found to have a few long and thick threads covering both surfaces.

7. *Plagiogyria koidzumii* Tagawa. (Plate II, figs. 7–9; Plate V, fig. 25 & 31)

Spore small in size, 32–35 $\mu \times$ 39–43 μ; amb triangular to subtriangular. Proximal face with a few randomly distributed hemispherical processes (verrucae), 2–3 μ in diameter; raised laesura thin, 1.5–2.0 μ across, arm about 20–27 μ long, extending almost to the margins; sides and contact faces slightly concave to concave. Distal face with a few small verrucae, 2–3 μ in diameter, randomly distributed on the surface. Both faces covered with very minute processes interdispersed with large verrucae.

8. "*Plagiogyria parva* DeVol". (Plate I, fig. 2; Plate IV, fig. 21; Plate V, fig. 28)

Spore large in size, 45–50 $\mu \times$ 50–56 μ; amb triangular to subtriangular. Proximal face gemmate, gemmae small, 1–3 μ in diameter; laesure raised, thick, 6–8 μ across, arm about 27–32 μ long, extending near margins, tip of junction pointed. Distal face gemmate, gemmae small,

1-3 μ in diameter, densely distributed. Both surfaces covered with minute thread-like interlining structures.

9. *Plagiogyria stenoptera* (Hance) Diels. (Plate II, figs. 10-12; Plate IV, fig. 22; Plate V, fig. 36)

Spore small in size, 36-43 $\mu \times$ 45-50 μ; amb triangular. Proximal face with a few large rounded processes (gemmae or tubercules), 2-4 μ in diameter, randomly distributed; laesura raised, 2-4 μ thick, arm about 25-30 μ long, extending almost to the margins, tip of junction pointed. Distal face with numerous large gemmae and tubercules, about 3-6 μ in diameter, moderately distributed. Both surfaces covered with thin, minute, irregular thread-like interlining structures.

DISCUSSION

In the literature, the spores of *Plagiogyria* have been variously described. Thus, Nayar (1964) gave an account of the spores of Plagiogyriaceae as "commonly verrucate, having rather small, hemispherical, often deciduous verrucae scattered irregularly", and "in some species, such as *P. glauca*....., the exine is densely granulose". Erdtman and Sorsa (1971) described *P. glauca* of Java as "irregularly tuberculous (processes irregularly polygonal, c. 0.5-1.5 μm high, 3.0-5.0 μm in diameter)", and for *P. pycnophylla* of India "the exine provided with irregular, coarse, flattened tubercule-like areas". The spores of *P. japonica* (as *P. intermedia*) and *P. stenoptera* (as *P. henryi*) have also been described. But, ornamentations on the surfaces were not mentioned. Kremp and Kawasaki (1972) described the spores of *P. biserrata* of Costa Rica as triquete, about 29 $\times$ 34 μ, trilete and tuberous. DeVol (1972) and DeVol and Lu (1975) noticed that the spores of *Plagiogyria* found in Taiwan have "exine usually with gemmate processes" and "sexine usually granulate".

In our study, it is interesting to observe from the scanning electron micrographs that the spores of *Plagiogyria* found in Taiwan are uniformly covered with rounded or hemispherical processes on the surfaces (except for acicular spores of *P. glauca* var. *philippiensis*). These processes are of various sizes, from 1 to 6 μ in diameter, and may be granules, verrucae, gemmae or tubercules. This character is found to be useful for species delimitation, as evidenced from Plate I to III, and also in the paragraphs on spore description. The thickness and the length of the laesural arm is also of taxonomic significance. A key to the various taxa of *Plagiogyria* found in Taiwan using these and other spore characteristics is given below.

A KEY TO THE SPECIES OF *PLAGIOGYRIA* FOUND IN TAIWAN BASED ON PALYNOLOGICAL CHARACTERISTICS

1. Spore surface finely granulose or rough
   2. Surface finely and densely granulose, covered with a few large rounded processes (tubercules), up to 6 μ in diameter; laesura thick, 2-5 μ across.....*P. japonica*
   2. Surface rough, with grooves and raised areas, covered with short, acicular protubsrances, about 1 μ tall; laesura thin, 1-2 μ across.....*P. glauca* var. *philippiensis*
1. Spore surface more or less psilate, or with minute thread-like interlining structures
   3. Processes large (tubercules), up to 6 μ in diameter; both surfaces covered with conspicuous, minute, thread-like interlining structures .....*P. stenoptera*
   3. Processes small to medium-sized, up to 3 μ in diameter
      4. Laesura with thin margo, about 1-2 μ across
         5. Spore verrucate, surface covered with both very minute and medium-sized processes .....*P. koidzumii*
         5. Spore gemmate, surface covered with minute thread-like interlining structures
            6. Spore large, 45-54 $\mu \times$ 52-58 μ .....*P. euphlebia*
            6. Spore small to medium-sized, 39-46 μ.....*P. grandis*
      4. Laesura with thick margo, up to 8 μ across
         7. Spore small, 32-38 $\mu \times$ 40-48 μ; laesura margo 3-4 μ thick.....*P. dunii*
         7. Spore medium to large, 45-56 $\mu \times$ 45-65 μ; laesura margo thicker, up to 8 μ across

8. Spore large, 51-56 $\mu \times 58$-65 μ; proximal surface covered with only a few rounded processes (gemmae) ..... *P. adnata*
8. Spore medium-sized, 45-50 $\mu \times 50$-56 μ; proximal surface densely covered with rounded processes (gemmae) ..... "*P. parva*"

It is evident from the scanning electron micrographs that five major types of spores can be discerned in Formosan *Plagiogyria*. *P. glauca* var. *philippiensis* is devoid of rounded processes, and has rough proximal and distal surfaces which are covered with short, acicular protuberances (see Plate III, figs. 16-18). *P. japonica* has a densely and finely granulose surface, with only a few large and rounded processes (tubercules, up to 6 μ in diameter; see Plate III, figs. 13-15). *P. stenoptera* has large rounded processes (tubercules), but the surface is almost psilate or subpsilate (see Plate II, figs. 10-12). The fourth and fifth types of spores have small to medium-sized of hemispherical or rounded processes (verrucae or gemmae). *P. koidzumii* is verrucate (see Plate II, figs. 7-9). The rest of the gemmate *Plagiogyria* can be subdivided into two groups. One group has thin laesura (1.5-2 μ thick, in *P. euphlebia* and *P. grandis*; see Plate I, figs. 4-6), while the others has thick laesura (3-8 μ across, in *P. adnata*, *P. dunii*, and "*P. parva*"; see Plate I, figs. 1-3).

From external morphology, *P. japonica* is exactly intermediate between *P. euphlebia* and *P. adnata* (*P. distinctissima*), and this led Ching (1958) to suggest that it might be a hybrid between the two species. We have examined this fern and found that all the spores are completely normal. The surface of the spore of *P. japonica* is finely granulose, with thick laesura, and covered with a few large rounded processes (tubercules). Such a sculptine pattern is totally different from the gemmate spores of both *P. adnata* (with thick laesura) and *P. euphlebia* (with thin laesura). We have not check the chromosome behaviour of this fern, but judging from our observation on spore characteristics alone, we are sure that the chance of *P. japonica* being a hybrid is rare.

The difference in spore characteristics between *P. euphlebia* and *P. grandis* is small, with the former taxon having a larger size of spore. Perhaps, in this respect, it lends support to the proposal forwarded by DeVol (1972), instead of Copeland (1929) or Nakaike (1971). But, when writing such a statement, the author is fully aware of the fact that most of the spores of the genus *Plagiogyria* are gemmate. It is equally true that they are two different species, as suggested by Nakaike (1971).

The difference between *P. glauca* and *P. glauca* var. *philippiensis* is quite very substantial. They have totally different ornamentations on the spore surfaces. *P. glauca* of Malaysia (*A. Samat 375*, Pahang) have been examined and were found to have gemmate spores with medium size of rounded processes (3-4 μ in diameter), while *P. glauca* var. *philippiensis* has spores with rough surfaces covered with acicular protuberances. In this respect, they should better be separated into two distinct species, *P. glauca* and *P. formosana*, as had been suggested by Nakai (1928).

The spore sculptine of *P. koidzumii* was described or diagrammed as psilate or smooth (DeVol, 1972; Ogata, 1940). But, in our study, both LM and SEM indicated that the spore has processes on its surface. Under the SEM, this structures were shown to be hemispherical verrucae, not granules, gemmae or tubercules.

From spore sculptine pattern, "*P. parva* DeVol" belongs to the group of *Plagiogyria* having thick margo on the gemmate spores (*P. adnata*—*P. dunii*). Despite its deminutive size it closely resembles *P. dunii* in external morphology. Although it might "no doubt a dwarf species or mutant" (DeVol, 1972), there is the possibility that it is *P. dunii*.

We have also checked the spores of some other species of *Plagiogyria*. For example, *P. tuberculata* of Malaysia (*B. C. Stone 7192*, Selangor-Pahang) has gemmate spores with rounded processes 2-4 μ in diameter and sparsely distributed on the surface.

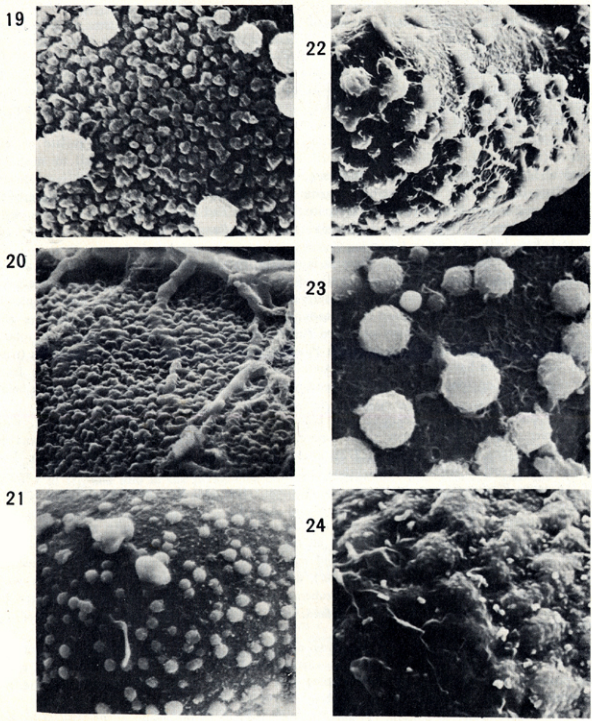

Plate IV. Fine structural details of the spores of *Plagiogyria*.
Fig. 19, granulose surface and large tubercules on the distal face of *P. japonica*; fig. 20, same, proximal face, with some of the long threads also shown; fig. 21, gemmae of "*P. parva*"; fig. 22, large tubercules and thin, minute, irregular thread-like interlining structures on the equator of *P. stenoptera*; fig. 23, same, fine structures on distal face; and fig. 24, acicules on the rough, raised areas and grooves of *P. glauca* var. *philippiensis*. Figs. 19, 20, 23, and 24 are magnified 3,300×, and figs. 21 & 22 2,000×.

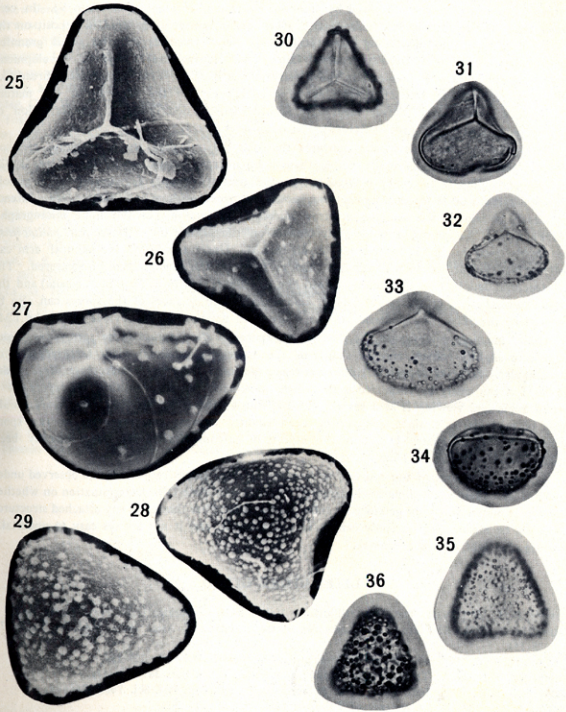

Plate V. The development of the rounded processes of the spores of *Plagiogyria*.
The sequence of development, from young to mature spores, is shown in both scanning electron micrographs (figs. 25-29) and light micrographs (figs. 30-36). Spores are selected from *P. adnata* (figs. 33 & 35), *P. dunii* (fig. 32), *P. euphlebia* (figs. 27 & 29), *P. grandis* (figs. 26, 30 & 34), *P. koidzumii* (figs. 25 & 31), "*P. parva*" (fig. 28), and *P. stenoptera* (fig. 36). For SEM, figs. 25 & 27 are magnified 1,000×, figs. 26, 28, & 29 670×, and all LM 400×.

According to our study, the course of development of the sculptine pattern, from young to mature stage, can clearly be followed by scanning electron micrographs (see Plate V). In very young spore, the surface is psilate or smooth. Rounded processes soon begin to deposit on the surface of the spore and depending upon the species, these structures may be small granules, verrucae, gemmae or even large tubercules. Later, with the increase in age of development, these processes increase in size and in the density of distribution. Finally, minute, thread-like interlining structures of different developmental stages appear on the surfaces of the mature spore. Such a sequence of development is in accord with the description of the formation of the perispore as given by Erdtman (1969), and not Bower (1923).

The preponderance of evidence indicates that for palynological study, scanning electron microscopical observation is much better than light microscopy (Muir, 1970; Wilce, 1972). Several outstanding facts can be pointed out in the present paper. For example, the finely granulose surface of *P. japonica* and the occasional occurrence of long and thick covering threads can clearly be seen in the scanning electron micrographs, but not in the light micrographs. (See Plate IV.) The short, acicular protuberances on the surface of *P. glauca* var. *philippiensis* are clearly seen in the SEM, but not at all in LM. Under the SEM, the laesural arm can easily be distinguished as to whether it is thick or thin, and the exact dimension measured. The fine structural details, e. g. the minute, thread-like interlining structures (e. g. in *P. adnata*) and the minute hemispherical processes (e. g. in *P. koidzumii*) on the surfaces of the spores can also be observed by the SEM. As evidenced in our study, such details are not obvious under the LM.

Under the light microscope, the sides of the spores of *Plagiogyria* can be seen as straight, concave or slightly convex, and the shapes of the spores in proximal view as triangular or subtriangular. Some of these descriptions are just illusions of the light microscope, for, under the SEM it can easily be visualized with a little imagination that by tilting the spore to a certain angle and viewing it at a certain depth of the contact face, the sides of a spores could easily be mistaken as straight, concave or even slightly convex, and the amb of the spore triangular or subtriangular. Details of this aspects of palynological illusions had already been explained and discussed by Hires (1965).

The fine structures of the rounded or hemispherical processes can clearly be observed under the SEM and their exact dimension measured correctly (see Plate IV). Determination on whether they are granules, verrucae, gemmae or tubercules and whether they have any attached structures can easily be made. Such a study cannot be too accurate, and is not always easy to undertake by using the light microscope alone.

LITERATURE CITED

BOWER, F. O., 1923, 1926. The Ferns (Filicales). Vols I & II. Cambridge Univ. Press, Cambridge.

CHING, R. C., 1958. The fern genus *Plagiogyria* on the mainland of Asia. Acta Phytotax. Sinica, 7: 128-154.

CHRIST, H., 1898. Filices Insularum Philippinarum. Bull. Herb. Boiss., 6: 127-154.

COPELAND, E. B., 1929. The fern genus *Plagiogyria*. Philip. J. Sci. Bot., 38: 377-417.

COPELAND, E. B., 1960. Fern flora of the Philippines. Vol. II. Nat. Inst. Sci. Tech., Manila

DEVOL, C. E., 1972. The *Plagiogyria* of Taiwan. Taiwania, 17: 277-292.

DEVOL, C. E. & C. Y. LU., 1975. *Plagiogyria*. In Flora of Taiwan, Vol. I. Pteridophyta and Gymnospermae. p. 141-146. Epoch Pub. Co., Taipei, Taiwan.

ERDTMAN, G., 1975. Pollen and Spore Morphology/Plant Taxonomy. (An Introduction to Palynology. Vol. II) Ronald Press, New York.

ERDTMAN, G., 1969. Hanbook of Palynology. Hafner Pub. Co., New York.

ERDTMAN, G., & P. SORSA., 1971. Pollen and Spore Morphology/Plant Taxonomy: Pteridophyta. Almqvist & Wiksell Pub. Co., Stockholm.

HIRES, C. S., 1965. Spores. Ferns. Microscopic Illusions Analyzed. Vol. I. Mistaire Lab., Millburn, New Jersey.

HOLTTUM, R. E., 1973. *Plagiogyria.* In J. C. Willis (ed.) A Dictionary of the Flowering Plants and Ferns. 8 th ed., revised by H. K. A. Shaw. Cambridge Univ. Press, Cambridge.

KNOBLOCK, I. W., G. C. SPINK, & J. C. FULFS., 1970. Preliminary SEM observations on the relief of the spore wall of some cheilanthoid ferns. Grana, **11**: 23-26.

KNOX, E. M., 1951. Spore morphology in British ferns. Trans. Bot. Soc. Edin., **35**: 437-449.

KREMP, G. O. W., & T. KAWASAKI, 1972. The Spores of the Pteridophytes. Hirokawa Book Co., Tokyo.

LIEW, F. S., 1975. SEM studies on the spores of Pteridophytes. I. The genus *Pyrrosia* Mirbel of Polypodiaceae. Quart. J. Taiwan Mus. (In Press)

MARTIN, P., & C. M. DREW, 1969. SEM of S. W. pollen grains. J. Ariz. Acad. Asc., **5**: 147-176.

MUIR, M. D., 1970. Scanning electron microscopy in palynology. Rev. Palaeobot. Palynol., **10**: 85-97.

NAKAI, T., 1928. Notes on Japanese ferns. VII. (Plagiogyriaceae, Cheiropleuriaceae, Dipteridaceae, Polypodiaceae I.) Bot. Mag. Tokyo, **42**: 203-218.

NAKAIKE, T., 1971. Notes on *Plagiogyria* from Japan and adjacent regions. Bull. Nat. Sci. Mus. Tokyo, **14**: 257-268.

NAYAR, B. K., 1964. Palynology of modern pteridophytes. In P. K. K. Nair (ed) Advances in Palynology, p. 101-141. Nat. Bot. Gard., Lucknow, India.

OGATA, M., 1940. Icones Filicum Japoniae. **8**: 388. Sanshusya Pub. Co., Tokyo.

TAGAWA, M., 1933. Spicilegium Pteridogrophiae Asiae Orientalis 5. Acta Phytotax. Geobot., **2**: 189-201.

WAGNER, W. H., JR., 1974. Structure of spores in relation to fern phylogeny. Ann. Missouri Bot. Gard., **61**: 332-353.

WEAVER, C. B., 1895. A comparative study of the spores of North American ferns. Proc. Iowa Acad. Sci., **3**: 159-161.

WILCE, J. H., 1972. Lycopod spores. I. General spore patterns and the generic segregates of *Lycopodium.* Amer. Fern J., **62**: 65-79.

WOODS, C. C., 1973. Spore variation in the Thelypteridaceae. In A. C. Jermy, J. A. Crabbe & B. A. Thomas (ed.) The Phylogeny and Classification of the Ferns, p. 191-202. Academic Press, London.