Keisuke KANAMORI*: **Studies on the sterility and size variation of spores in some apogamous ferns**

金森啓祐*: アポガミーをするシダ類における胞子の不稔性と大きさの変異について

(Plates VI–VII)

In the previous paper[1], the author reported that in the genus *Dryopteris* the spores of the apogamous species show remarkable variation in their size than those of the sexual ones, and also there is a tendency that those showing less variation in spore size form the apogamous embryos more frequently, among the apogamous species. In addition to them he described three types of abortive or sterile spores in the apogamous species. In this paper, he would like to deal with similar spore characters of some species in other genera. The author would like to express his sincere thanks to Prof. H. Ito for his valuable advices during this study.

Materials and Methods Twenty-two species belonging to six genera were used in the present study. The methods for preparation and observation of spores were the same as described in the previous paper. Usual aceto-carmine squash technique was used for observation of young and abortive or sterile spores. Two hundred sporangia were observed in each frond.

Results and Discussion Figs. 1–11 are the histograms showing the variation of spore sizes in *Pteris* species. It is obvious from these figures that the apogamous species have wider ranges of size variation than the sexual ones. There is a clear difference between the apogamous species and the sexual ones in relation to the difference between the maximum and the minimum size of spores (DMM). The DMM is more than 18.8 μ in the apogamous species, while that of the sexual ones is less than 15.0 μ (Table 1).

Figs. 14–17 are the histograms showing the size variation of spores in *Cyrtomium* species. It is also obvious that the apogamous species have

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Table 1. Size and ploidy of spores in some ferns.

Name of species	Ploidy of species	Ploidy of spores	Average of spore size (μ)	DMM (μ)
PTERIDACEAE				
Pteris				
*wallichiana**	dipl.	monopl.	29.6	7.5
*multifida**	di-, (tetrapl.)	mono-, (dipl.)	32.4	11.2
*dispar**	dipl.	monopl.	32.7	11.2
*semipinnata**	tetrapl.	dipl.	37.7	15.0
natiensis	dipl.	dipl.	40.3	18.8
nipponica	tripl.	tripl.	41.4	22.5
cretica	tripl.	tripl.	42.7	30.0
kiuschiuensis	tripl.	tripl.	42.9	22.5
oshimensis	tripl.	tripl.	44.4	26.3
setuloso-costulata	tripl.	tripl.	44.8	26.3
fauriei	tripl.	tripl.	45.3	22.5
Aspidiaceae				
Polystichum				
rigens	unknown	unknown	46.1	22.5
tsus-simense	tripl.	tripl.	42.6	30.0
Cyrtomium				
*balansae**	dipl.	monopl.	36.4	15.0
falcatum	tripl.	tripl.	40.0	26.3
fortunei var. *fortunei*	tripl.	tripl.	41.7	33.8
fortunei var. *clivicola*	tripl.	tripl.	40.4	22.5
Phegopteris				
polypodioides	tripl.	tripl.	50.0	41.2
Athyrium				
okuboanum	tripl.	tripl.	45.3	33.8
unifurcatum	tripl.	tripl.	44.1	33.8
Diplazium				
hachijoense	tripl.	tripl.	49.5	41.2
virescens	tripl.	tripl.	46.8	33.8

* sexual species

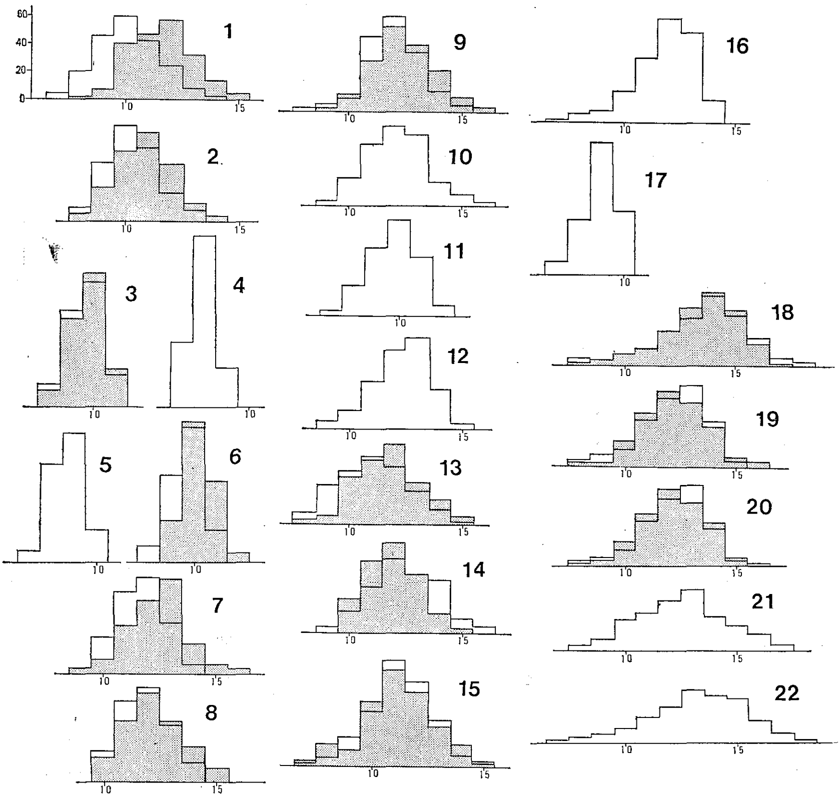

Fig. 1–22. Histograms of spore size variation. Vertical axis: numbers of spores. Horizontal axis: Numbers of graduations of micrometer (1 division=3.75). 1. *Pteris cretica*. 2. *P. nipponica*. 3. *P. multifida*. 4. *P. wallichiana*. 5. *P. dispar*. 6. *P. semipinnata*. 7. *P. fauriei*. 8. *P. kiuschiuensis*. 9. *P. setuloso-costulata*. 10. *P. oshimensis*. 11. *P. natiensis*. 12. *Polystichum rigens*. 13. *P. tsus-simense*. 14. *Cyrtomium falcatum*. 15. *P. fortunei* var. *fortunei*. 16. *C. f.* var. *clivicola*. 17. *C. balansae*. 18. *Phegopteris polypodioides*. 19. *Athyrium okuboanum*. 20. *A. unifurcatum*. 21. *Diplazium virescens*. 22. *D. hachijoense*.

wider variation than the sexual one. The DMM is more than 22.5 μ in the apogamous species and that of the sexual one is 15.0 μ. The same results are also obtained in other genera namely *Polystichum, Phegopteris, Athyrium* and *Diplazium* (Figs. 12–13 and 18–22; and Table 1).

Two hundred mature spores were measured in each species and a tendency was observed in the average values that the spore size increases with the ploidal level of spores (Table 1). For example, in the genus *Pteris*, sexual species (monoploid spores) show about 30 μ as the average; a sexual tetraploid species (diploid spores) shows about 38 μ; and apogamous triploid species (triploid spores) show more than 41 μ.

The author described three types of abortive or sterile spores in the apogamous species of *Dryopteris*[1]. They are: (1) Dwarf and shrunken type; (2) Irregularly dividing type; and (3) Imperfectly dividing type. These three types were observed in all the apogamous species in this study, above all the first type was most frequent.

An interesting fact was often observed during the meiosis especially in such species as *Phegopteris polypodioides*, *Athyrium okuboanum* and *A. unifurcatum* which have a wide range of spore size. The large spore mother cells had obviously large number of chromosomes at the metaphase of reduction division, though the exact chromosome numbers were not counted (Figs. 23–24). Furthermore, it was observed immediately after the meiosis that the larger spore cells had larger nuclei than the smaller ones (Figs. 25–26). It seems that these four photographs might explain the unbalanced genetical condition in the spores similar to that discussed by Manton[2]. It may be supposed that the extremely large or small spores are abortive and may not germinate. It has, however, not been understood as to under what condition such irregular meiosis might be taken place in such apogamous species.

Two hundreds of young sporangia of the apogamous species were squashed and observed in order to understand the interrelation between the numbers of abortive or sterile spores and the size variation of spores (Table 2). I observed 6400 spores contained in 200 sporangia, each having usually 32 spores. When there were small spore particles in a sporangium as in the case of type (2) of abortive spores, they were omitted from counting. It may be said that the numbers of sporangia which have even numbers of abortive spores (especially the multiples of "four") predominates other sporangia having odd numbers of abortive spores; for example, in *Pteris* and *Diplazium*. It may be supposed that such four abortive spores might have derived from a single spore mother cell in which a certain abnormality had taken place at the meiosis as previously reported for *Dryopteris* species. On the other hand, odd numbers of abortive spores appeared more frequently in *Cyrtomium* species. This may be because in these species abortive spores of

Table 2. Abortion of spores in some apogamous species.

No. of abortive spores per sporangium / Name of species	Number of sporangia having abortive spores																				Percentage of abortive spore against total spores
	0	1	2	3	4	5	6	7	8	10	12	16	18	20	22	24	25	26	28	32	
Pteris																					
cretica	142	8	23	3	16		3		6		3	4				2					5.3%
nipponica	119	11	21	6	24		4		8		2	2			3						5.9
Cyrtomium																					
falcatum	90	11	17	6	38	4	6		4		3				2				5	14	13.4
fortunei var. *fortunei*	78	5	20	5	37	4	12	2	21	5	6	1				3	1				11.2
fortunei var. *clivicola*	67	10	26	13	30	5	10	5	18	4	5	6	1				1				11.3
Diplazium																					
hachijoense	84	8	22	4	32	2	8		14	4		10		4		6		2			13.0

types (2) and (3) predominate those of type (1). It seems that there is a correlation to some extent between the range of the size variation in mature spores and the ratio of the abortion observed in young spores in the apogamous species.

The author pointed out previously that the frequency of formation of the apogamous embryo in the apogamous species may have a correlation with the range of spore size variation for *Dryopteris*. Similar results were obtained in *Pteris*. Five species (*P. fauriei* and related species) having narrower range of spore size variation may show high frequency of apogamy than *P. cretica* having wider range of spore size variation.

References

1) Kanamori, K. (1969). Journ. Jap. Bot. **44**: 207–217. 2) Manton, I. (1950). Problems of cytology and evolution in the Pteridophyta.

Explanation of Plates VI–VII

Pl. VI. Spore mother cells with unbalanced chromosomes.

Fig. 23. *Athyrium okuboanum*. c. ×330.

Fig. 24. *Phegopteris polypodioides*. c. ×660.

Pl. VII. Very young spore cells with various sized nuclei of *Athyrium unifurcatum*. c. ×660.

Solid arrow: Smaller spore mother cells with smaller number of chromosomes or smaller spore cells with smaller nucleus.

Dotted arrow: Larger spore mother cells with larger number of chromosomes or larger spore cells with larger nucleus.

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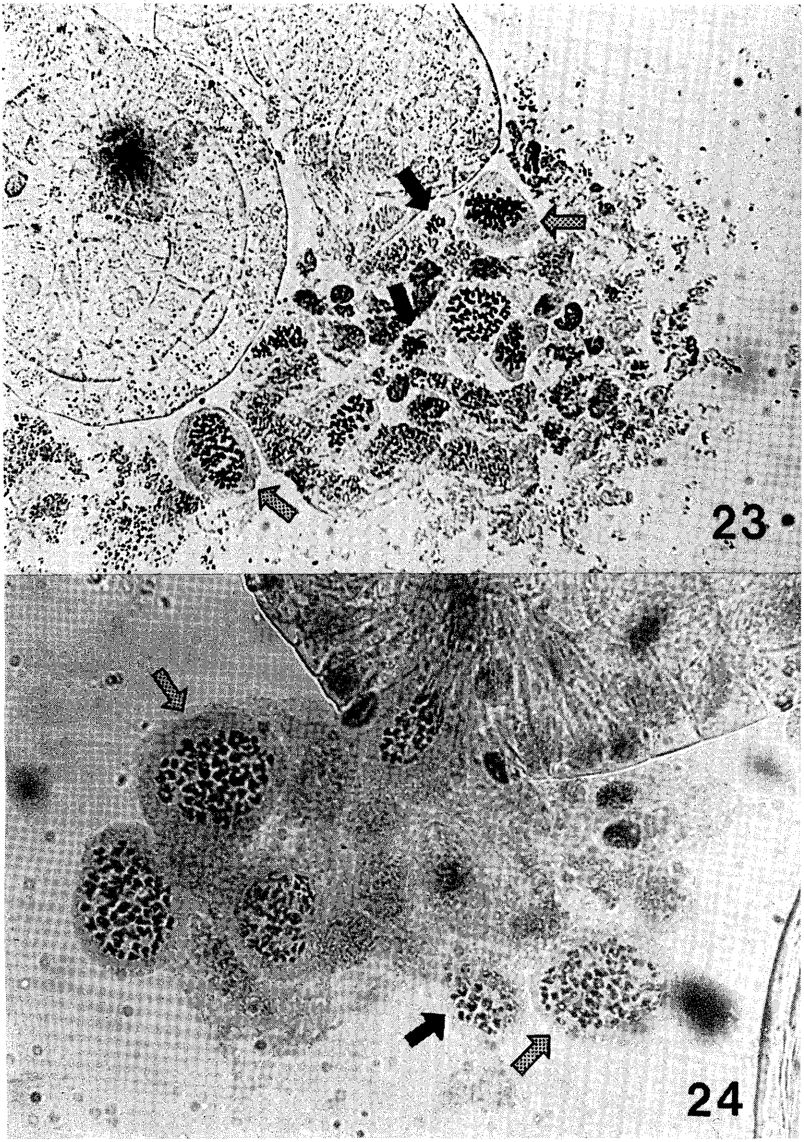
日本産の2科6属のシダ類について胞子の大きさを測定し，その変異の幅は普通の種とアポガミーをする種とでは明らかに差があることが知られた。また胞子の大きさは，胞子の倍数性が増すにつれて増加する傾向が認められた。一胞子のう中に含まれる発育不全または不稔と思われる胞子の生じる過程を観察した結果，胞子母細胞の減数第一分裂中期に観察される染色体数の多少とそれから生じる若い胞子細胞の核の大きさとがある程度相関を示す傾向が見られた。

胞子の大きさの変異の幅の狭い種の方が変異の幅の広い種よりもアポガミーをする頻度が高くなることがイノモトソウ属で認められた。これは著者が以前にオシダ属で報告したことと同じである。



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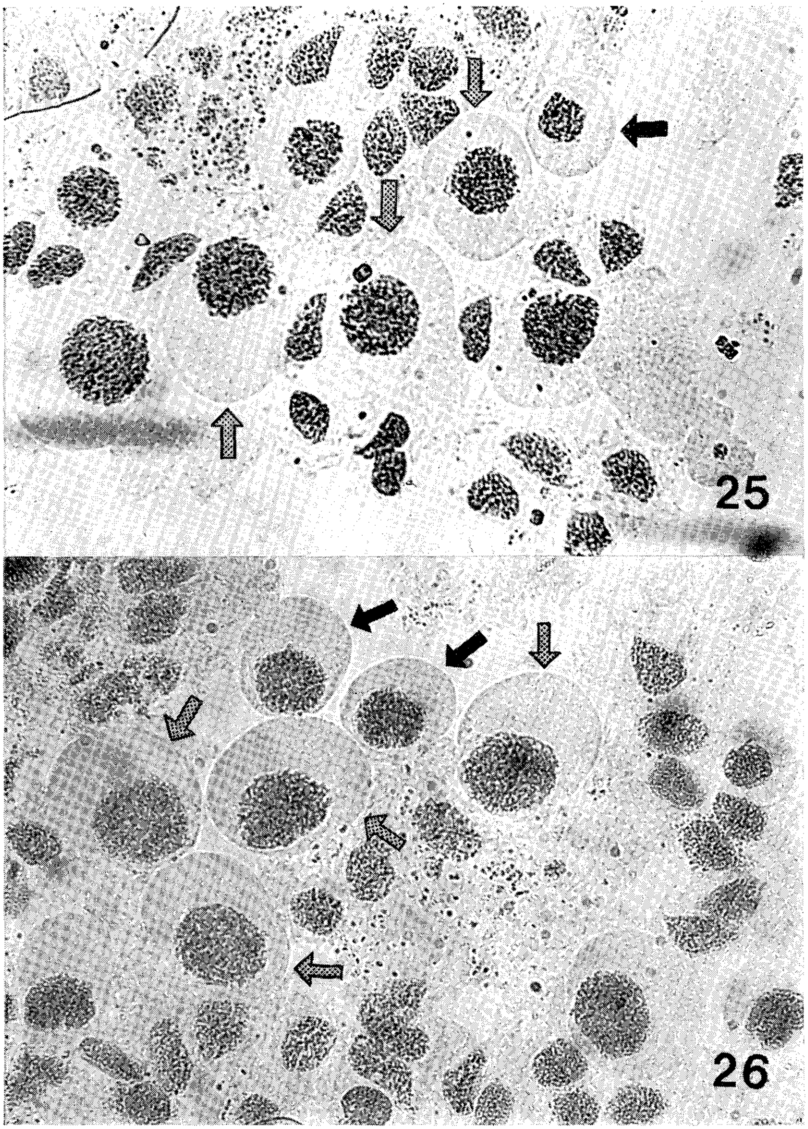

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