Geographical distribution of polyploids in Japanese fern flora(1)

その他（別言語等）のタイトル	日本のシダフロラにおける倍数体の地理的分布(1)
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Geographical Distribution of Polyploids in Japanese Fern Flora (1)

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The chromosomal studies on Japanese pteridophytes have been rapidly developed since Kurita (1960) reported chromosome numbers of 24 taxa. The chromosome numbers of Japanese species based principally on the data from 1960 till 1979 were summarized in this Bulletin, No. 4, p. 221–271 in 1975 and No. 9, p. 217–229 in 1980, and subsequently more chromosome numbers of some species have been reported untill the present time. Table 1 is a list of the chromosome numbers reported by several authors from 1980 till 1985 and my unpublished data which are shown in plate 1. Up to the present time, approximately the chromosome numbers of 460 species (including variety and hybrid) are calculated in Japanese fern flora. The numbers of the species authenticated cytologically are about a half of Japanese fern taxa, 940 (species, varieties and hybrids).

In the case of angiosperms, the frequency of the polyploids within a given areas clearly increases from low to high latitudes and altitudes (Löve & Löve, 1971), and this tendency has been confirmed in Japanese angiosperm flora by Funabiki in 1967, that is, the coefficient of correlation between the polyploid frequency and the geographical latitude is about $r = 0.784$. However in various fern floras, the lack of correlation between the frequency of polyploid ferns at different latitude has been shown by many authors. According to Manton (1958), the proportion of polyploids is 53% out of the 45 species studied in British Islands (50°–61° N) and it is 42% in 38 species in Madeira (32° N), while it is 60% in 132 species in Sri Lanka (5.5°–9.5°N). Furthermore the grade of polyploidy is higher in the fern flora of Sri Lanka than those of other two localities. In addition, in the fern flora of Sri Lanka the numbers of hybrids and apogamous species are more than in the fern

Table 1 Chromosome numbers of Japanese Pteridophytes reported from 1980 till 1985.

Taxa	Chromosome number	Ploidy	Locality	Reference
Lycopodium L.				
L. annotium L.	n=34	2X	Kirigamine, Kurohime, Nagano Pref.	Takamiya and Kurita 1983
L. annotinum var. *acrifolium* Fernald	n=34	2X	Kurohime, Nagano Pref.	ibid.
L. carolinanum L.	n=68	4X	Tengan, Shiga Pref.	ibid.
L. cernuum L.	n=108	6X	Chichijima, Tokyo Pref., Uji, Kyoto Pref., Yakushima, Kagoshima Pref., Katagami, Nagasaki Pref.	ibid.
L. chinense Christ	n=68	4X	Kurohime, Nagano Pref.	ibid.
L. clavatum var. *niponicum* Nakai	n=34	2X	Kurohime, Kirigamine, Nagano Pref.	ibid.
L. complanatum L.	n=23	2X	Kurohime, Nagano Pref.	ibid.
L. cryptomerinum Maxim.	n=136	6X	Sasari, Kyoto Pref.	ibid.
L. fordii Bak.	n=136	6X	Yakushima, Kagoshima Pref.	ibid.
L. obscurum L.	n=34	2X	Nigorikawa, Hokkaido Pref., Kirigamine and Kurohime, Nagano Pref.	ibid.
L. phlegmaria L.	n=ca. 275	12X	Yakushima, Kagoshima Pref.	ibid.
L. selago var. *acuminatum* Sugimoto	n=136	6X	Tanigawa, Gunma Pref.	ibid.
L. serratum var. *serratum* f. *serratum*	n=68	4X	Kurohime, Nagano Pref., Tanigawa, Gunma Pref., Ishizuchi, Ehime Pref.	ibid.
	n=136	6X	Uchiura, Sekison, Chiba Pref., Ogasa, Shizuoka Pref., Makihara, Aichi Pref.	ibid.
	2n=204	3X	Mt. Shiratori, Miyazaki Pref.	Takamiya 1984
L. serratum var. *serratum* f. *intermedium* Nakai	n=68	4X	Uchiura, Chiba Pref.	Takamiya and Kurita 1983
	n=136	6X	Uchiura, Chiba Pref., Ogasa, Shizuoka Pref., Ito, Wakayama Pref., Yakushima Kagoshima Pref.	ibid.
L. sieboldii Miq.	n=136	6X	Yakushima, Kagoshima Pref.	ibid.
L. sithense var. *nikoense* Takeda	n=23	2X	Kurohime, Nagano Pref.	ibid.
L. casuarinoides Spring	2n=68	2X	Isl. Yakushima, Kagoshima Pref.	Takamiya & Tanaka 1983

Sceptridium Lyon				
S. nipponicum Holub	n=45	2X	Miyatojima, Naruse-cho Miyagi Pref.	Sahashi 1981-a
S. microphyllum Sahashi	n=45	2X	Mizumoto-cho, Muroran, Hokkaido	ibid.
S. nipponicum var. *minus* Sahashi	n=45	2X	Karuizawa, Nagano Pref.	ibid.
S. triangularifolium	n=45	2X	Isl. Ohshima, Tokyo Pref.	Sahashi 1983
S x *pulchrum*	meiosis irreg. (90I, 45II)	4X	Isl. Ohshima, Tokyo Pref.	ibid.
S. x *longistipitatum* Sahashi	2n=180	4X	Isl. Tokyo Pref.	ibid.
S. formosanum	n=90	4X	Isl. Yakushima, Kagoshima Pref., Tokunoshima and Okinoerabujima, Okinawa Pref.	Sahashi 1981-b
S. japonicum var. *japonicum*	n=135	6X	Juniko, Aomori Pref., Shiogama, Miyagi Pref., Kitakata, Fukushima Pref., Namekawa, Toyama Pref., Isl. Ohshima, Tokyo Pref., Ise, Mie Pref., Ashizurimisaki, Kohchi Pref., Yadake, Miyazaki Pref., Sendai, Kagoshima Pref., Isl. Yakushima, Kagoshima Pref.	Sahashi 1984
Plagiogyria (Kunze) Mett.				
P. matsumureana Makino	2n=130	2X	Tateyama, Toyama Pref.	Nakato & Mitui 1983
	n=65	2X	Hinoemata, Fukushima Pref.	ibid.
P. euphlebia Mett.	2n=260	4X	Gifu-shi, Gifu Pref., Kyoto-shi Kyoto Pref.	ibid.
	n=130	4X	Murasugi, Niigata Pref.	ibid.
P. japonica Nakai	2n=260	4X	Kyoto-shi, Kyoto Pref.	ibid.
Mecodium Presl ex Copel.				
M. wrightii Copel.	n=28 2n=ca. 56	2X	Hinoemata, Fukushima Pref.	Mitui
Vandenboschia Copel.				
V. amabilis K. Iwats.	n=36	2X	Oirase, Aomori Pref.	Mitui
Pteris L.				
P. excelsa Gaud	2n=58	2X	Muramatsu, Niigata Pref.	Mitui
Arachniodes Blume				
A. amabilis (Bl.) Tindale	n=41	2X	Isl. Yakushima, Kagoshima Pref.	Shimura et al 1982

A. dimorphophyllum Ching	n=41	2X	Nago City, Okinawa Pref.	Shimura et al. 1982
A. japonica (Kurata) Nakaike	n=41	2X	Nago City, Okinawa Pref.	ibid.
A. hekiana Kurata	n=41 2n=82	2X	Ooguchi City, Kagoshima Pref.	ibid.
A. simplicior var. *major* (Tagawa) Ohwi	n=41 n=82	2X 4X	Shizuoka City, Shizuoka Pref.	ibid.
A. cantilenae Kurata	n=41	2X	Izumimura, Kumamoto Pref.	ibid.
A. hasseltii (Bl.) Ching	n=41	2X	Mt. Yonaha, Okinawa Pref.	ibid.
A. yasu-inouei Kurata	n=82	4X	Ooguchi City, Kagoshima Pref.	ibid.
A. sp.	n=41	2X	Fukuoka City, Fukuoka Pref.	ibid.
A. x *clivorum* Kurata	meiosis irreg. (2n=82)	2X hybr.	Kurume City, Fukuoka Pref.	ibid.
A. x *kurosawae* Shimura et Kurata	meiosis irreg. (2n=123)	3X hybr.	Shizuoka City, Shizuoka Pref.	ibid.
A. x *masakii* Kurata	meiosis irreg. (2n=82)	2X hybr.?	Shinnanyo City, Yamaguchi Pref.	ibid.
	n=41	2X hybr.	Mikawacho, Yamaguchi Pref.	ibid.
	n=41	2X hybr.?	Yamaemura, Kumamoto Pref.	ibid.
A. x *minamitanii* Kurata	meiosis irreg. (2n=82)	2X hybr.	Ebino City, Miyazaki Pref.	ibid.
A. x *pseudo-hekiana* Kurata	meiosis irreg. (2n=123)	3X hybr.	Mt. Shibi, Kagoshima Pref.	ibid.
A. x *respicies* Kurata	meiosis irreg. (2n=123)	3X hybr.	Higashi Izumimachi, Shizuoka Pref.	ibid.
A. x *sasamotoi* Kurata	meiosis irreg. (2n=123)	3X hybr.	Shimoda City, Shizuoka Pref.	ibid.
A. x *subamabilis* Kurata	meiosis irreg. (2n=123)	3X hybr.	Yamaguchi City. Yamaguchi Pref.	ibid.
A. x *sp.*	meiosis irreg. (2n=82)	2X hybr.	Toyookamura, Shizuoka Pref.	ibid.
A. x *kenzo-satakei* (Kurata) Kurata	meiosis irreg. (2n=82)	2X hybr.	Owase City, Mie Pref.	ibid.

Cyrtomium Presl

C. falcatum (L.f.) Pr.	n=41	2X	Joogasaki-kaigan, Itoo-shi, Shizuoka Pref.	Matsumoto & Shimura 1985
	n=123	3X apog.	Kisami, Shimoda-shi, Shizuoka Pref.	ibid.
C. atropunctatum Kurata	n=123	3X apog.	Numanokawa, Kawazu-cho, Komo-gun, Shizuoka Pref.	ibid.
C. fortunei var. *clivicola* (Makino) Tagawa	n=123	3X apog.	Ubume, Shizuoka-shi, Shizuoka Pref.	ibid.
C. macrophyllum var. *tukusicola* (Tagawa) Tagawa	n=123	3X apog.	Ubume, Shizuoka-shi, Shizuoka Pref.	ibid.

Polystichum Roth				
P. pseudo-makinoi Tagawa	n=82	4X	Shizuoka City, Shizuoka Pref.	Shimura & Ohishi 1980
P. formosanum Ros.	n=41	2X	Iriomote Island, Okinawa Pref.	ibid.
P. fibrilloso-paleaceum var. *marginale* Serizawa	n=41	2X	Susono City, Shizuoka Pref.	ibid.
P. deltodon (Bak.) Diels	n=82	4X	Kumamura, Kumamoto Pref.	ibid.
P. yaeyamense Makino	n=41	2X	Isl. Iriomote, Okinawa Pref.	ibid.
P. ohmurae var. *fujipedis* Namegata et Kurata	n=41	2X	Misakubo-cho, Shizuoka Pref.	ibid.
P. tagawanum var. *atrosquamatum* Kurata	n=82	4X	Gotenba City, Shizuoka Pref.	ibid.
P. sp.	2n=82 meiosis irreg.	2X hybr.	Gotenba City, Shizuoka Pref.	ibid.
P. x *suyamanum* Kurata ex Serizawa	2n=ca. 123 meiosis irreg.	3X hybr.	Susono City, Shizuoka Pref.	ibid.
P. gemiferum Tagawa	n=41	2X	Yakushima, Kagoshima Pref.	Mitui
Athyrium Roth				
A. okuboanum Makino	2n=120	3X apog.	Ohsawa, Tagami, Niigata Pref.	Mitui
Diplazium Sw.				
D. sibiricum var. *blabrum* (Tagawa) Kurata	n=82	4X	Togakushi, Nagano Pref.	Mitui
D. squamigerum Ohwi	2n=164	4X	Tagami, Niigata Pref.	ibid.
Struthiopteris Weiss				
S. niponica Nakai	n=31	2X	Isl. Yakushima, Kagoshima Pref.	Mitui
Polypodium L.				
P. amamianum Tagawa	n=36 2n=72	2X	Amamiohshima, Kagoshima Pref.	Shimura et al. 1980
P. someyae Yatabe	n=37	2X	Haruno-cho, Shizuoka Pref.	ibid.
P. sp.	meiosis irreg. (2n=111)	3X hybr.	Oki Isls. Shimane Pref.	ibid.
P. vulgare L.	n=74	4X	Oki Isls. Shimane Pref.	ibid.
	2n=74	2X	Mt. Daisetsuzan, Kamikawa-cho, Kamikawa-gun, Hokkaido District	Takei 1981

P. fauriei Christ	2n=74	2X	Yahatakogen, Geihoku-cho, Yamagata-gun, Hiroshima Pref.	Takei 1981
P. formosanum Bak.	2n=72	2X	Formosa, collected by N. Kamimura	ibid.
P. niponicum Mett.	2n=72	2X	Ugakyo, Hiroshima City, Hiroshima Pref.	ibid.
Lepisorus (J. Sm) Ching				
L. annuifrons (Makino) Ching	2n=70	2X	Hosomidani, Yoshiwa-mura, Seki-gun Hiroshima Pref.	Takei 1981
L. ussuriensis (Reg.) Ching var. *distans* (Makino) Tagawa	2n=74	2X	Omogo-mura, Kamiukena-gun Ehime Pref.	ibid.
L. onoei Ching	2n=50	2X	Gokurakujisan, Hatsukaichi-cho Seki-gun, Hiroshima Pref.	ibid.
L. thunbergianus Ching	2n=50	2X	Kiyosumiyama, Amatsukominatomachi, Awa-gun, Chiba Pref. Hiroshima City, Hiroshima Pref. Matsuyama City, Ehime Pref. Dannoharu, Oita City. Oita Pref. Takeda City, Oita Pref.	ibid.
	2n=100	4X	Ashiyasu-mura, Nakakoma-gun, Yamanashi Pref. Yasufuruichi, Hiroshima City, Hiroshima Pref. Yabakei, Yabakei-cho, Shimogegun Oita Pref.	ibid.
	2n=102	4X	Hoosenji, Kokonoemachi, Kusugun, Oita Pref.	ibid.
L. thunbergianus var. *angustus* (Ching) Kurata	2n=52	2X	Mt. Tateyama, Nakaniikawa-gun, Toyama Pref.	ibid.
Lemmaphyllum Pr.				
L. microphyllum Pr.	2n=72	2X	Miyajima-cho, Seki-gun, Hiroshima Pref.	Takei 1981
L. microphyllum var. *obovata* C. Chr.	2n=72	2X	Isl. Yoronto, Ooshima-gun, Kagoshima Pref.	ibid.
Neocheiropteris Christ				
N. ensata Ching	2n=142	4X	Usa City, Oita Pref.	Takei 1981
N. subhastata Tagawa	2n=144	4X	Kamifukawa, Hiroshima City, Hiroshima Pref.	ibid.
Pyrrosia Mirbel				
P. linearifolia Ching	2n=72	2X	Miyajima-cho, Saeki-gun, Hiroshima Pref.	Takei 1981
P. lingua Farwell	2n=72	2X	Ujina, Hiroshima City, Hiroshima Pref.	ibid.
P. tricuspis Tagawa	2n=74	2X	Taishakukyo, Tojo-cho, Hibagun, Hiroshima Pref.	ibid.

Microsorium Link				
M. buergenianum Ching	2n=144	4X	Isl. Amamiooshima, Ooshima-gun, Kagoshima Pref.	Takei 1981
M. hancockii Ching	2n=72	2X	Isl. Amamiooshima, Ooshima-gun Kagoshima Pref.	ibid.
Colysis Pr.				
C. wrightii Ching	2n=72	2X	Isl. Amamiooshima, Ooshima-gun, Kagoshima Pref.	Takei 1981
C. pothifolia Pr.	2n=72	2X	Isl. Amamiooshima, Ooshima-gun, Kagoshima Pref.	ibid.
C. elliptica (Thunb) Ching	2n=72	2X	Hiwasa-cho, Kaifu-gun, Tokushima Pref.	ibid.
C. shintenenshis (Hayata) H. Ito	2n=108	3X	Isl. Iriomote, Taketomi-cho, Okinawa Pref.	ibid.
Crypsinus Pr.				
C. engleri (luerss) Copel.	2n=70	2X	Isl. Yakushima, Kagoshima Pref.	Takei 1981
C. yakushimensis (Makino) Tagawa	2n=70	2X	Murotomisaki, Muroto City, Koochi Pref.	ibid.
C. hastatus (Thunb.) Copel.	2n=70	2X	Dannoharu, Oita City, Oita Pref.	ibid.

flora of the other two. From these results, she concluded that the evolution was proceeding faster in the tropics than in temperate latitudes, and mentioned three favourable factors for the fern flora in the tropics. First, there is a more rapid growth and large period of vegetation available in tropics compared with the highly seasonal climates, second, there is greater wealth of habitats in a more closely populated and stratified vegetation, and lastly, there is the greater erosion by frequent landslides which provide more frequent opportunities for recolonization of ecological sites. Walker (1966) reported that out of 256 Jamaican fern species, approximately 60% were polyploids and that the grade of polyploidy was strikingly similar to that of Sri Lanka. On the other hand, Sorsa (1958, 1961) reported that out of 17 species, only 8 species were polyploids in Finland and that usually only one low numbered cytotype could be found in most species which had two or three cytotypes in other parts of Europe.

In Japanese fern flora, the proportion of polyploids is approximately 56% (diploid 250 taxa, polyploid 311 taxa) as far as the present study. The frequencies of polyploids in three areas have been calculated in Japan, that is, in the Ryukyu Islands (25–30 N°, 31%), in the Bonin Islands (25–30 N°, 30%) and in the higher mountain flora (40%), and their proportions of polyploids are lower than that of

all the Japanese fern flora. These results seem to indicate that the correlation of the proportion of polyploids and the environmental factors in a given areas is very complicated.

More detailed studies are necessary to elucidate the relationship between vegetation zone and the frequency of the polyploids, so I am going to clarify the chromosomal features in 41 areas along the Japanese Islands using the chromosome numbers authenticated in Japanese species until the present time.

Method

The proportion of polyloids and the degree of polyploidy within a given area were expressed by the following formulae by Funabiki (1967).

$$\text{Percentage of polylopids} = \frac{p+p'}{(d+d')+(p+p')} \times 100$$

p = number of polyploid species and varieties and hybrids.

p′ = number of species (and varieties and hybrids) which give both polyploids and diploid numbers.

d = number of diploid species and varieties and hybrids.

d′ = numbers of species (and varieties and hybrids) which give both polyploids and diploid numbers.

$$\text{Dgree of polyploidy} = \frac{\text{Mean (2n) of the chromosome list}}{\text{Mean (X) of the chromosome list}}$$

Results

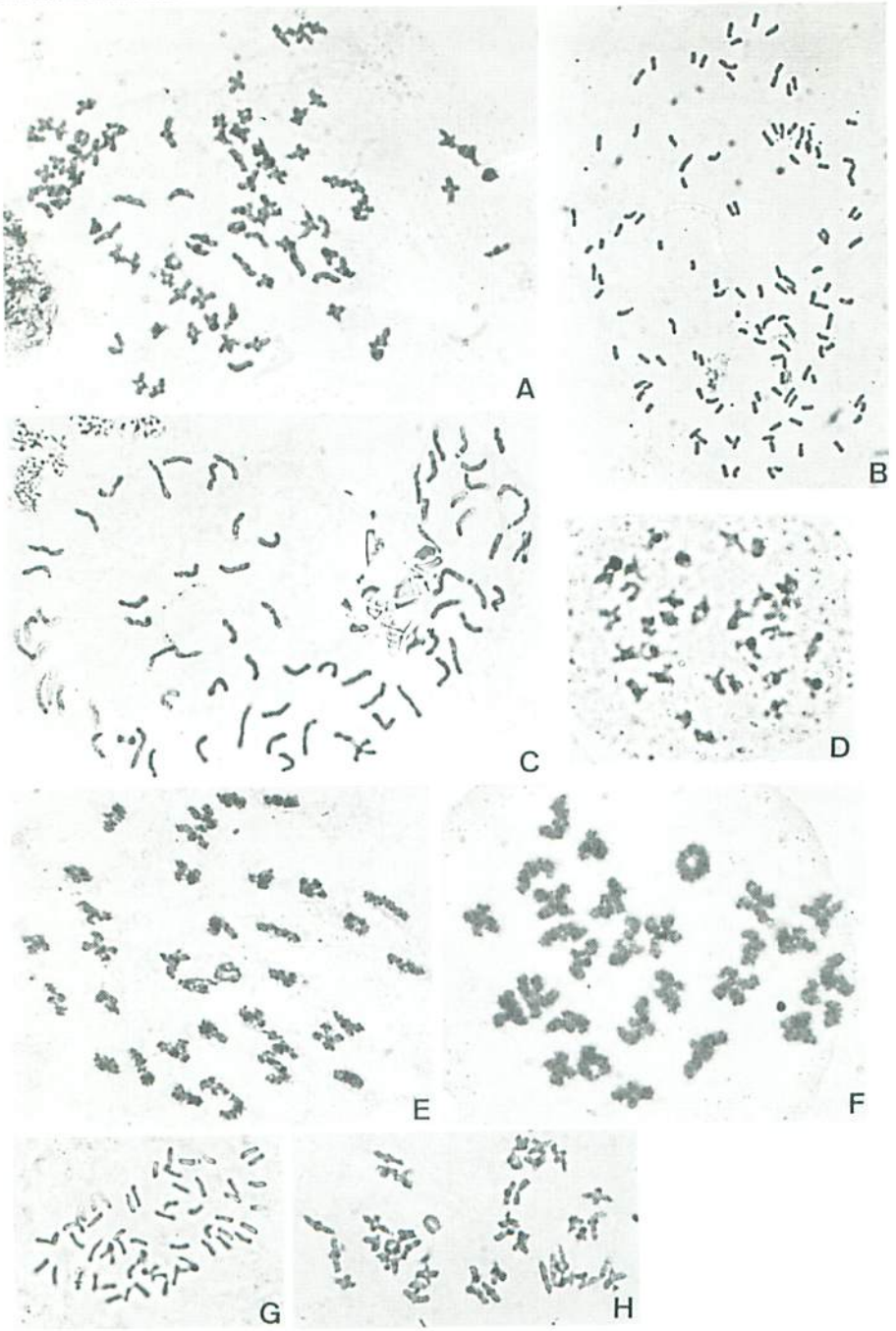
1. Chromosomal features of 41 fern floras in Japanese Islands.

The chromosomal features (proportion of polyploid, mean n-number, and degree of polyploid) in 41 fern floras are shown in table 2.

(to be continued)

Table 2 Chromosomal features of 41 fern floras in Japanese Islands

Area	Number of Spp.	Spp. Cytol. known (%)	Approxim-ate latitude	Proportion of polyploid (%)	Mean n-number	Degree of polyploid	Warmth Index
Hokkaido	139	79	43.0	28.0	59.9	2.67	54.3
Aomori	121	79	40.5	25.7	55.8	2.54	76.9
Yamagata	144	83	38.5	38.8	59.7	2.76	91.1
Niigata	206	81	37.5	49.8	68.5	2.94	102.7
Fukushima	157	79	37.5	36.5	57.4	2.75	98.3
Toyama	169	83	37.0	46.5	67.0	2.97	105.5
Ishikawa	133	85	37.0	48.8	70.0	2.93	104.3
Gunma	175	86	36.5	38.1	55.8	2.73	107.6
Tochigi	198	86	36.5	45.6	64.7	2.91	100.4
Ibaragi	163	87	36.5	49.3	71.8	2.89	101.6
Fukui	192	85	36.0	53.0	70.7	3.04	112.8
Saitama	209	84	36.0	45.2	63.3	2.82	109.2
Chiba	198	86	35.5	57.6	99.5	3.05	120.3
Tokyo	205	86	35.5	51.6	68.7	2.93	120.4
Kanagawa	237	85	35.5	50.4	67.1	2.91	117.8
Yamanashi	201	84	35.5	41.0	62.0	2.78	109.9
Kisodani	147	85	35.5	39.8	59.8	2.73	93.3
Shimoina	212	79	35.5	43.4	62.1	2.83	96.9
Gifu	227	81	35.5	47.4	66.3	2.89	119.7
Tottori	187	83	35.5	50.6	64.2	2.93	113.6
Shizuoka	344	74	35.0	50.5	67.9	2.92	128.7
Aichi	231	86	35.0	54.2	71.0	3.03	118.7
Hyogo	217	85	35.0	53.4	67.3	3.01	125.7
Okayama	156	89	34.5	52.5	69.1	2.97	117.1
Hiroshima	185	83	34.5	48.3	64.9	2.88	119.2
Izu	155	84	34.5	54.2	67.4	3.02	130.0
Izu-Shoto	157	78	34.0	50.0	71.3	3.05	143.5
Mie	282	78	34.0	51.3	69.9	2.99	122.7
Yamaguchi	226	80	34.0	56.5	69.6	3.03	125.3
Tokushima	252	77	34.0	50.0	68.1	2.95	126.7
Wakayama	253	80	33.5	54.2	69.6	3.05	129.7
Ehime	259	81	33.5	53.3	68.3	2.98	124.9
Fukuoka	263	76	33.5	54.4	70.9	3.00	128.6
Saga	231	81	33.0	55.5	71.3	3.04	129.4
Ohita	226	80	33.5	52.4	65.6	3.16	123.7
Kumamoto	296	76	33.0	52.4	65.6	3.16	130.6
Miyazaki	243	76	32.0	54.0	70.2	3.08	141.3
Nagasaki	242	81	33.0	53.3	67.1	2.97	138.9
Yakushima	310	59	30.5	50.1	99.7	2.96	140.0
Ogasawara	77	54	26.0	39.2	69.7	2.95	210.0
Okinawa	120	46	25.5	46.1	70.5	2.97	212.3



A. Meiosis in *Diplazium sibiricum* var. *glabrum* (n=82) **B.** Somatic chromosomes in *Athyrium okuboanum* (2n=120) **C.** Somatic chromosomes in *Vandenboschia amabilis* (2n=72) **D.** Meiosis in *Struthiopteris niponica* (n=31) **E.** Meiosis in *V. amabilis* (n=36) **F.** Meiosis in *Mecodium wrightii* (n=28) **G.** Somatic chromosomes in *Pteris excelsa* (2n=58) **H.** Meiosis in *Polystichum gemiferum* (n=41)