KARYOTYPE ANALYSIS OF SOME FORMOSAN GYMNOSPERMS[1]

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Abstract: Karyotypes of 13 species of 9 genera and 3 families of gymnosperms have been studied. The chromosome number and/or karyotype analysis of 6 species had been reported by previous workers. The karyotypes of the remaining species are reported here by the present authors for the first time. The diploid chromosome number in Pinaceae is 24, while it is 22 in both the Taxodiaceae and Cupressaceae. For all Formosan species, the karyotypes of *Pinus* are similar. The secondary constriction of a chromosome may be a useful character for identification of species. SAT-chromosome have been found in the genus *Cunninghamia*. The karyotypes of *Pinus* are symmetrical while they are asymmetrical for the other genera of Pinacene. *Pinus* is considered to be the most primitive taxon among genera of Pinaceae. A key for identification of these genera based on their karyotypes has been prepared.

INTRODUCTION

The karyotype has been used as a distinctive character for species differentiation in many groups of plants. Up to this date, there have been only a few cytological investigations on the Formosan gymnosperms, so the gymnosperms have remained almost untouched cytogenetically.

For a better understanding of the phylogeny and taxonomy of Formosan gymnosperms, a karyotypic study of these plants seems essential. The present paper reports the results of the cytological investigation of 13 important taxa of Formosan gymnosperms.

MATERIALS AND METHODS

Seeds of all 13 taxa were collected from the North-central part of Formosa as shown in Table 1.

The seeds were germinated on moistened filter paper in petri dishes for 7–12 days. It was necessary to remove the seed coats of the seeds of *Pinus morrisonicola* and *P. armandi* var. *mastersiana*, in order to shorten the time of germination.

After germination, the root tips were pretreated with a 0.1% colchicine solution for 4–5 hrs. in order to disrupt the formation of spindle apparatures and to shorten the length of the chromosomes. Root tips were than cut off and fixed with Carnoy's solution for 12–24 hours (Darlington et al, 1962; 158). If the dispersion of the cells were difficult, as is the case in most species of Cuppressaceae, pretreatment with 1 N HCl for 7–10 min. at 60°C was found necessary for the softening of the tissues. The materials were then transferred into 45% acetic-orcein for 12–24 hours.

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Table 1. Data of seed collection of Formosan gymnosperms

Species	Number	Date	Locality and Habitat	Collector
Keteleeria davidiana var. *formosana*	1	Dec. 23 1970	Taipei city, alt. 10m., growing in the Botanical Garden.	S. R. Kuo
	2	Dec. 23 1970	Taipei city, alt. 10m., growing in the Botanical Garden.	S. R. Kuo
Picea morrisonicola	1	Nov. 15 1970	Pi-lu Chi, Taichung Co., alt. 2650m., natural forest mixed with broad-leaf trees.	S. R. Kuo
Pinus armandi var. *mastersiana*	1	Oct. 1970	Alishan, Chiayi Co.	H. Y. Lee
P. morrisonicola	1	Oct. 17 1970	Chi-tou, Nantou Co., alt. 1050 m., growing in Garden.	S. R. Kuo
	2	Nov. 13 1970	Ku-kuan, Taichung Co., alt. 920 m., natural forest mixed with *Pinus taiwanensis*.	S. R. Kuo
P. taiwanensis	1	Oct. 18 1970	Chi-tou, Nantou Co., alt. 950 m., planted tree in garden as speciment.	S. R. Kuo
	2	Oct. 18 1970	Chi-tou, Nantou Co., alt. 950 m., growing in garden.	S. R. Kuo
	3	Nov. 13 1970	Ku-kuan, Taichung Co., alt. 920 m., in natural forest mixed with *Pinus morrisonicola*.	S. R. Kuo
Pseudotsuga wilsoniana	1	Nov. 14 1970	Li-shan, Taichung Co., alt. 2050m., in natural forest mixed with broad leaf trees.	S. R Kuo
	2	Nov. 14 1970	Li-shan, Taichung Co., alt. 250 m., in natural forest mixed with broad leaf trees.	S. R. Kuo
	3	Nov. 15 1970	Ching-shan, Taichung Co., alt. 1400 m., in natural forest mixed with broad leaf trees.	S. R. Kuo
Tsuga chinensis var. *formosana*	1	Nov. 17 1970	Lin-tien-shan, Hualien Co., alt. 2400 m., in natural forest.	T. W. Hu
Cunninghamia konishii	1	Oct. 17 1970	Chi-tou, alt. 1050 m., mother tree.	S. R. Kuo
	2	Oct. 31 1970	Ta-yuan-shan, Ilan, Co., alt. 1950 m., reserve seeding tree.	S. R. Kuo
	3	Oct. 31 1970	Ta-yuan-shan, Ilan Co., alt. 1950m., reserve seeding tree.	S. R. Kuo
C. lanceolata	1	Oct. 17 1970	Chi-tou, alt. 1050 m., planted in garden.	S. R. Kuo
Taiwania cryptomeriodes	1	Oct. 26 1970	Ssu-chi, Ilan Co., alt. 1500 m., reserve seeding tree.	S. R. Kuo
Chamaecypairs formosensis	1	Nov. 15 1970	Pi-lu-chi. Taichung Co., alt, 2400m., natural forest mixed with other species.	S. R. Kuo
	2	Nov. 15 1970	Pi-lu-chi. alt. 2400 m., natural forest mixed with other species.	S. R. Kuo
C. obtusa var. *formosana*	1	Nov. 3 1970	Ta-yuan-shan, Ilan Co., alt. 1850m., reserve seeding tree.	S. R. Kuo
	2	Nov. 3 1970	Ta-yuan-shan Ilan Co., alt. 1850m., reserve seeding tree.	S. R. Kuo
Thuja orientalis	1	Nov. 14 1970	Li-shan, Taichung Co., alt. 1950m., planted in garden.	S. R. Kuo
	2	Nov. 14 1970	Li-shan, Taichung Co., alt. 1950m., planted in garden.	S. R. Kuo

Reserve seeding tree: tree selected for the collection of seeds. Mother tree: tree selected for maternal part during artificial pollination in the breeding system.

After rinsing in 45% acetic acid about 1 min., the root tips were cut off and placed on a slide in a drop of acetic-orcein and tapped thoroughly with the end of a needle. Extraneous tissues were discarded. After adding a coverglass, the material was gently passed through a flame 2 or 3 times.

Pressure was then applied to the cover slip and the slide was checked under h. p. with a compound Olympus microscope. If the chromosome preparation was found to be satisfactory, it was sealed with paraffin wax.

The length of each chromosome was measured from end to end with the exclusion of the region of the centromere and segments of secondary constrictions. The arm of a curved chromosome was measured along the curve. The longer arm of a given chromosome was labeled the "l" arm; the shorter, the "s" arm. Comparisions were made between the length of arms and chromosomes, satellites, position of centromeres and secondary constrictions, etc. The length of arm and chromosome were shown by mean values of total length of arm and chromosome pairs.

The index of centromere position (I. C. P.) is the ratio of the length of the shorter arm to the longer one. When I. C. P. is equal to 0.00 the chromosome is called telocentric (t); acrocentic (ac.) when I. C. P. is less than 0.50; submetacentric (sm.) when I. C. P. is between 0.50 to 0.75; and metacentric (mc.) when I. C. P. is between 0.76 to 1.00.

The index of relative length (I. R. L.) of each chromosome is the ratio of its length to the mean value of the length of total chromosome. If I. R. L. is smaller than 0.76, the chromosome is called a small chromosome (S); medium small (M1) when the I. R. L. is between 0.76 to 1.00; medium large (M2) when the I. R. L. is between 1.01 to 1.25; and large when I. R. L. is equal to 1.26 or greater.

RESULTS

The following results represent the findings of our investigations on the 13 taxa of gymnosperms which were distributed as follows: Pinaceae (7 species), Taxodiaceae (3 species), and Cupressaceae (3 species).

I. PINACAE

1. **Keteleeria davidiana** Beissn var. **formosana** Hay.

Six chromosome counts were made from root tips of seedlings belonging to 2 trees. The diploid chromosome number in this species is found to be 24. Sugihara (1942: 505) reported that the haploid chromosome number of this species is 12.

The size of chromosomes 1 and 2 are large; 3 to 7 are medium large; 8 to 11 are medium small; and 12 is small (2L+5M2+4M1+1S). Chromosomes 1 to 7 have metacentric centromeres; 8 to 12 have acrocentric centromeres (7mc+5ac.). There are four chromosomes with secondary constrictions. Chromosome 4 has 2 secondary constrictions. Secondary constrictions in the short arm are found in chromosomes 2 and 4. While those in the long arm are found in chromosomes 6 and 7. (pl. I: 1-2, Fig. I: 1, Table 2)

In the pro-metaphase, there are many secondary constrictions found on the chromosomes (pl. I: 2). These were not observed in the metaphase or anaphase.

2. **Picea morrisonicola** Hay.

Eight chromosome counts were made from seeds of one tree. The number of diploid chromosomes is 24.

The size of chromosome 12 is small; 9 to 11 are medium small; and 1 to 8 are medium large (1S+3M1+8M2). The position of the centromere in chromosomes 4 and 12 are acrocentric; submetacentric in chromosomes 7, 10, and 11; and metacentric in the rest (2ac.+3sm.+7mc.). 4 chromosomes possess secondary constrictions: chromosome 4 has one in its long arm, 5 and 10 in their short arms. There are 2 secondary constrictions in chromosome 9, one in the short arm, the other in the long arm. (Pl. I: 3, Fig. I: 2, Table 2)

3. **Pinus armandi** Fr. var. **mastersiana** Hay.

Chromosomes from 6 cells of one tree were examined. The number of diploid chromosomes is 24.

The size of the chromosomes are medium large in chromosomes 1 to 5; medium small in 6 to 11; and small in 12 (5M2+6M1+1S). The centromere in chromosome 12 is submetacentric, the rest being metacentric (11mc.+1sm.). Four chromosomes possess 1 to 2 secondary constrictions. Chromosomes 5 and 6 are found to have two secondary constrictions in their short arms, while chromosomes 7 and 11 have one secondary constriction in the short arms. (Pl. I: 4. Fig. I: 3, Table 2)

4. **Pinus morrisonicola** Hay.

12 cells of 3 trees were investigated. The diploid chromosome number in this species is 24.

Chromosomes 1 to 6 are medium large; 7 to 11 are medium small; 12 is small (6M2+5M1+1S). The position of the centromere in chromosome 12 is submetacentric, and metacentric in all others (11sm.+1mc.). Secondary constrictions are found in chromosomes 2, 3, 4, 6, 8, 11, and 12. There are two secondary constrictions in each arm of chromosome 3 and 4; one in the short arm of chromosome 2, 6, 11 and 12; and one in the long arm of chromosome 8. (Pl. I: 5, Fig. I: 4, Table 2). Negative heterochromatin and breakage segments were observed in some cells. The breaking point is on the segment with heterochromatin (Pl. I: 6).

5. **Pinus taiwanensis** Hay.

Karyotype analysis was made on 10 cells from 3 trees. The diploid chromosome number in this species is 24.

The size of the chromosomes are medium large in chromosome 1 to 7; medium small in 8 to 11; and small in 12 (7M2+4M1+1S). The centromere is submetacentric in chromosome 12; and metacentric in the rest (11sm.+1mc.). Four chromosomes were found to have secondary constrictions. They are found in the long arm of chromosome 4 and in the short arm of chromosomes 7, 8, and 9. (Pl. I: 7, Fig. 1: 5, Table 2)

6. **Pseudotsuga wilsoniana** Hay.

Thomas and Ching reported on the karyotype of this species (1968: 140). In our study 16 cells from 3 trees were observed. The diploid chromosome number is 24.

The size of chromosomes 1 to 3 are large; 4 to 6 are medium large; 7 and 8 are medium small; 9 to 12 are small (3L+3M2+2M1+4S). The centromeres of chromosomes 1 to 6 are metacentric, and acrocentric in 7 to 12 (6mc.+6ac.).

We observed that a secondary constriction occurred in the short arm of all cells examined on chromosomes 4 and 5. A secondary constriction in the long arm of chromosome 11 was found only in 4 cells (Pl. II: 1, Fig. I: 6, Table 2). The authors also found a secondary constriction in the median position of the long arm of one pair of chromosomes but were not able to determine to which chromosome it belonged (Pl. II: 2).

7. **Tsuga chinensis** Pritz. var. **formosana** (Hay.) Li & Keng

The karyotype was investigated in 4 cells from 1 tree. The diploid chromosome number is 24.

The size of chromosomes 1 to 6 are medium large; medium small in 7 to 11; and small in 12 (6M2+5M1+1S). The centromeres are metacentric in chromosomes 1 to 7; submetacentric in chromosomes 8 to 11; acrocentric in chromosome 12 (7mc.+4sm.+1ac.). Secondary constrictions were found in the short arm of chromosomes 2 and 5; and also in the long arm of chromosome 9 (Pl. I: 8, Fig. I: 7, Table 2).

II. TAXODIACEAE

1. **Cunninghamia konishii** Hay.

14 cells from 3 trees were investigated. The diploid chromosome number in this species is 22. Hirayoshi et al and Stiff reported that the haploid chromosome number of this species is 12 and the diploid is 24 (Khoshoo 1961: 4).

Chromosomes 1 and 2 are large, 3 and 4 are medium large, 5 to 9 are medium small, and the rest are small (2L+2M2+5M1+2S). The position of centromeres are metacentric in chromosomes 1, 2, 3, 5 and 6; and submetacentric in the rest (5mc.+6sm.). Only one chromosome possessed a secondary constriction in this species. It was found in the short arm of chromosome 1, but its occurence was not constant.

A satellite found in the short arm of chromosome 4 is an important character of this species (Pl. II: 3, Fig. I: 8, Table 2).

2. **Cunninghamia lanceolata** (Lamb.) Hook.

The haploid chromosome number and the morphology of its chromosomes have been reported by Sugihara (1941: 191) and Mohra et al (1956: 172). We observed the karyotypes of 8 cells from 1 tree. The diploid chromosome number is 22.

The size of chromosomes 1, 2, and 3 are large; medium large in 4 and 5; medium small in 6, 7, 8 and 9; and small in the rest (3L+2M2+4M1+2S). Chromosomes 1, 2, 3, 5 and 6 have metacentric centromeres and all others have submetacentric (5mc.+6sm.). A secondary constriction was found in the short arm of chromosome 1, but its occurence was not constant.

A satellite was found in chromosome 4 of this species. It appears that this is an important generic character (Pl. II: 4, Fig. I: 9, Table 2).

3. **Taiwania cryptomerioides** Hay.

Sax and Sax (1933: 360) found the haploid chromosome number of this species to be 11. Chromosomes from 7 cells belonging to 1 tree observed by the present authors. The diploid chromosome number is 22.

The chromosomes are large in chromosomes 1 and 2; medium large in 3 to 5; medium in 6 to 9; and small in 10 and 11 (2L+3M2+4M1+2S). The position of centromeres are acrocentric in chromosomes 3 and 8; submetacentric in 9, 10 and 11; the rest being metacentric (2ac.+3sm.+6mc.). Both chromosomes 4 and 6 possess secondary constrictions in their short arms (Pl. II: 5, Fig. I: 10, Table 2).

III. CUPRESSACEAE

1. **Chamaecyparis formosensis** Mat.

Karyotype analysis was done on 11 cells from 2 trees. The diploid chromosome number is 22.

The size of the chromosomes are large in chromosomes 1 and 2; medium large in 3 to 5; medium small in chromosomes 6 to 9; small in 10 and 11 (2L+3M2+4M1+2S). The position of the centromere in chromosome 10 is acrocentric; submetacentric in chromosomes 4, 7, 9 and 11; and metacentric in the rest (1ac.+4sm.+6mc.). Both chromosomes 4 and 6 possess secondary constrictions in a subterminal position on their long arms (Pl. II: 6, Fig. I: 11, Table 2).

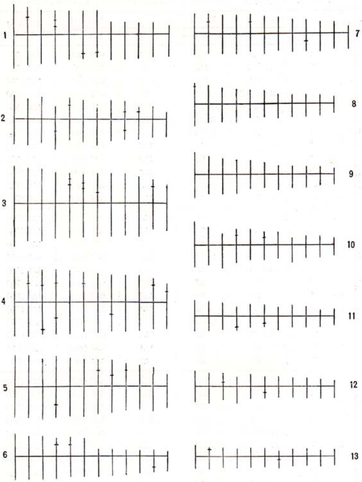

Fig. 1. The karyotypes of: 1. *Keteleeria davidiana* var. *formosana*, 2. *Picea morrisonicola*, 3. *Pinus armandi* var. *mastersiana*, 4. *Pinus morrisonicola*, 5. *Pinus taiwanensis*, 6. *Pseudotsuga wilsoniana*, 7. *Tsuga chinensis* var. *formosana*, 8. *Cuninghamia konishii*, 9. *Cunninghamia lanceolata*, 10. *Taiwania cryptomerioides*, 11. *Chamaecyparis formosensis*, 12. *Chamaecyparis obtusa* var. *formosana*, 13. *Thuja orientalis*.

Table 2. Karyotype analysis of important Formosan Gymnosperms

Species	Chromosome	Length			Index of centeromere position	Index of relative length
		Short arm	Long arm	Total		
Keteleeria davidiana var. *formosana*	1	10.9	12.2	23.1	0.89 (m)	1.40 (L)
	2	3.8+6.0	11.2	21.0	0.88 (m)	1.28 (L)
	3	8.6	10.7	19.3	0.80 (m)	1.17 (M_2)
	4	3.2+2.5+2.5	10.7	18.9	0.77 (m)	1.15 (M_2)
	5	8.3	9.2	17.5	0.90 (m)	1.06 (M_2)
	6	8.2	7.0+2.0	17.2	0.91 (m)	1.04 (M_2)
	7	8.5	6.5+2.0	17.0	1.00 (m)	1.03 (M_2)
	8	4.3	9.3	13.6	0.46 (ac)	0.83 (M_1)
	9	4.2	9.2	13.4	0.46 (ac)	0.81 (M_1)
	10	4.0	9.0	13.0	0.44 (ac)	0.79 (M_1)
	11	4.1	8.3	12.4	0.49 (ac)	0.76 (M_1)
	12	3.0	8.2	11.2	0.37 (ac)	0.68 (S)
Picea morrisonicola	1	8.4	8.8	17.2	0.95 (m)	1.21 (M_2)
	2	7.2	9.4	16.6	0.76 (m)	1.17 (M_2)
	3	7.8	8.5	16.3	0.92 (m)	1.15 (M_2)
	4	4.5	4.5+6.5	15.5	0.41 (ac)	1.09 (M_2)
	5	2.7+4.8	7.8	15.3	0.96 (m)	1.08 (M_2)
	6	6.7	8.5	15.2	0.79 (m)	1.07 (M_2)
	7	5.0	9.6	14.6	0.52 (sm)	1.03 (M_2)
	8	6.5	7.9	14.4	0.82 (m)	1.02 (M_2)
	9	3.8+2.5	4.5+2.9	13.7	0.85 (m)	0.97 (M_1)
	10	1.6+2.6	7.2	11.4	0.58 (sm)	0.81 (M_1)
	11	4.5	6.6	11.1	0.68 (sm)	0.78 (M_1)
	12	2.8	6.4	9.2	0.44 (ac)	0.65 (S)
Pinus armandi var. *mastersiana*	1	13.2	15.1	28.3	0.87 (m)	1.24 (M_2)
	2	12.7	13.9	26.6	0.91 (m)	1.17 (M_2)
	3	12.3	13.5	25.8	0.91 (m)	1.13 (M_2)
	4	11.0	12.5	23.5	0.88 (m)	1.03 (M_2)
	5	2.4+2.0+6.5	12.4	23.3	0.88 (m)	1.02 (M_2)
	6	3.7+2.0+5.1	12.1	22.9	0.89 (m)	1.00 (M_1)
	7	7.1+3.8	12.0	22.9	0.91 (m)	1.00 (M_1)
	8	10.8	12.0	22.8	0.90 (m)	1.00 (M_1)
	9	10.5	11.5	22.0	0.91 (m)	0.96 (M_1)
	10	9.5	12.0	21.5	0.79 (m)	0.94 (M_1)
	11	2.5+5.7	9.5	17.7	0.86 (m)	0.78 (M_1)
	12	6.5	10.0	16.5	0.65 (sm)	0.72 (S)

Table 2. (Continued)

Species	Chromosome	Length			Index of centeromere position	Index of relative length
		Short arm	Long arm	Total		
Pinus morrisonicola	1	12.0	12.2	24.2	0.98 (m)	1.14 (M_2)
	2	4.5+6.5	12.5	23.5	0.88 (m)	1.11 (M_2)
	3	5.6+5.8	6.8+2.0	23.2	0.97 (m)	1.10 (M_2)
	4	4.6+6.8	5.8+5.9	23.1	0.97 (m)	1.09 (M_2)
	5	11.1	11.5	22.6	0.97 (m)	1.07 (M_2)
	6	4.2+6.5	10.9	21.6	0.98 (m)	1.02 (M_2)
	7	10.0	11.0	21.0	0.91 (m)	0.99 (M_1)
	8	9.9	4.6+6.0	20.5	0.93 (m)	0.97 (M_1)
	9	9.4	10.7	20.1	0.88 (m)	0.94 (M_1)
	10	9.4	10.3	19.7	0.91 (m)	0.93 (M_1)
	11	2.5+5.8	9.8	18.1	0.84 (m)	0.86 (M_1)
	12	2.8+3.5	9.7	16.0	0.65 (sm)	0.75 (S)
Pinus taiwanensis	1	11.2	11.5	22.7	0.97 (m)	1.18 (M_2)
	2	11.0	11.3	22.3	0.97 (m)	1.16 (M_2)
	3	9.5	12.5	22.0	0.76 (m)	1.14 (M_2)
	4	10.6	6.6+4.5	21.7	0.95 (m)	1.13 (M_2)
	5	10.2	10.9	21.2	0.94 (m)	1.10 (M_2)
	6	9.8	10.8	20.6	0.91 (m)	1.08 (M_2)
	7	4.0+5.5	10.0	19.5	0.95 (m)	1.01 (M_2)
	8	5.8+3.8	9.6	19.2	1.00 (m)	0.99 (M_1)
	9	3.0+5.5	8.8	17.5	0.97 (m)	0.91 (M_1)
	10	7.6	8.6	16.2	0.88 (m)	0.84 (M_1)
	11	6.8	9.0	15.8	0.76 (m)	0.82 (M_1)
	12	4.5	7.6	12.1	0.59 (sm)	0.63 (S)
Pseudotsuga wilsoniana	1	8.1	8.7	16.8	0.93 (m)	1.40 (L)
	2	7.6	8.1	15.7	0.94 (m)	1.30 (L)
	3	7.4	8.1	15.5	0.91 (m)	1.28 (L)
	4	2.6+4.2	8.1	14.9	0.81 (m)	1.21 (M_2)
	5	3.0+4.0	7.4	14.4	0.95 (m)	1.19 (M_2)
	6	6.7	7.5	14.2	0.89 (m)	1.18 (M_2)
	7	2.8	7.6	10.4	0.37 (ac)	0.86 (M_1)
	8	2.8	7.2	10.0	0.39 (ac)	0.83 (M_1)
	9	2.3	6.8	9.1	0.34 (ac)	0.75 (S)
	10	2.2	6.3	8.5	0.35 (ac)	0.70 (S)
	11	2.2	4.0+1.9	8.1	0.36 (ac)	0.69 (S)
	12	2.0	5.4	7.4	0.37 (ac)	0.61 (S)

Table 2. (Continued)

Species	Chromosome	Length			Index of centromere position	Index of relative length
		Short arm	Long arm	Total		
Tsuga chinensis var. *formosana*	1	7.0	7.9	14.9	0.89 (m)	1.20 (M_2)
	2	2.7+4.0	7.5	14.4	0.92 (m)	1.16 (M_2)
	3	6.7	7.2	13.9	0.93 (m)	1.12 (M_2)
	4	6.4	7.5	13.9	9.84 (m)	1.12 (M_2)
	5	3.0+3.8	6.8	13.6	1.00 (m)	1.10 (M_2)
	6	6.0	7.5	13.5	0.84 (m)	1.09 (M_2)
	7	5.6	6.5	12.1	0.86 (m)	0.98 (M_1)
	8	5.0	7.0	12.0	0.71 (sm)	0.97 (M_1)
	9	4.8	2.8+4.0	11.6	0.71 (sm)	0.94 (M_1)
	10	4.0	6.9	10.9	0.58 (sm)	0.88 (M_1)
	11	4.0	5.8	9.8	0.69 (sm)	0.79 (M_1)
	12	2.4	5.8	8.2	0.41 (ac)	0.66 (S)
Cunninghamia konishii	1	1.5+6.0	8.1	15.6	0.93 (m)	1.55 (L)
	2	6.4	6.9	13.3	0.93 (m)	1.32 (L)
	3	5.7	6.8	12.5	0.84 (m)	1.24 (M_2)
	4	0.5+4.5	7.0	12.0	0.71 (sm)	1.19 (M_2)
	5	4.8	5.2	10.0	0.92 (m)	0.99 (M_1)
	6	4.5	5.0	9.5	0.90 (m)	0.94 (M_1)
	7	3.1	5.3	8.4	0.58 (sm)	0.84 (M_1)
	8	3.0	5.0	8.0	0.60 (sm)	0.80 (M_1)
	9	3.0	4.8	7.8	0.63 (sm)	0.78 (M_1)
	10	3.0	4.5	7.5	0.67 (sm)	0.75 (S)
	11	2.5	3.5	6.0	0.71 (sm)	0.60 (S)
Cunninghamia lanceolota	1	1.6+6.2	8.2	16.0	0.95 (m)	1.60 (L)
	2	6.5	6.9	13.4	0.94 (m)	1.33 (L)
	3	5.7	7.0	12.7	0.81 (m)	1.26 (L)
	4	0.5+4.5	7.0	12.0	0.71 (sm)	1.20 (M_2)
	5	5.0	5.1	10.1	0.98 (m)	1.20 (M_2)
	6	4.3	4.8	9.1	0.90 (m)	0.91 (M_1)
	7	3.2	5.6	8.8	0.57 (sm)	0.88 (M_1)
	8	2.9	4.9	7.8	0.59 (sm)	0.78 (M_1)
	9	2.9	4.7	7.6	0.62 (sm)	0.76 (M_1)
	10	2.8	4.2	7.0	0.67 (sm)	0.70 (S)
	11	2.3	3.6	5.9	0.64 (sm)	0.59 (S)

Table 2. (Continued)

Species	Chromosome	Length			Index of centromere position	Index of relative length
		Short arm	Long arm	Total		
Taiwania cryptomerioides	1	8.5	9.0	17.5	0.94 (m)	1.65 (L)
	2	6.3	7.1	13.4	0.87 (m)	1.26 (L)
	3	4.0	8.5	12.5	0.47 (ac)	1.18 (M_2)
	4	2.2+3.4	6.5	12.1	0.86 (m)	1.14 (M_2)
	5	5.3	5.5	10.8	0.96 (m)	1.02 (M_2)
	6	2.0+2.4	5.5	9.9	0.80 (m)	0.93 (M_1)
	7	4.6	4.9	9.5	0.94 (m)	0.89 (M_1)
	8	2.6	6.4	9.0	0.41 (ac)	0.85 (M_1)
	9	3.3	4.8	8.1	0.69 (sm)	0.76 (M_1)
	10	3.1	4.6	7.7	0.67 (sm)	0.72 (S)
	11	2.5	4.0	6.5	0.63 (sm)	0.61 (S)
Chamaecyparis formosensis	1	5.4	5.5	10.9	0.98 (m)	1.31 (L)
	2	5.2	5.5	10.7	0.95 (m)	1.29 (L)
	3	4.8	5.0	9.8	0.96 (m)	1.18 (M_2)
	4	3.3	4.1+1.0	8.4	0.65 (sm)	1.01 (M_2)
	5	4.1	4.3	8.4	0.95 (m)	1.01 (M_2)
	6	4.0	2.9+1.2	8.1	0.98 (m)	0.98 (M_1)
	7	3.0	5.1	8.1	0.59 (sm)	0.98 (M_1)
	8	3.7	4.1	7.8	0.90 (m)	0.94 (M_1)
	9	3.1	4.1	7.2	0.75 (sm)	0.87 (M_1)
	10	2.0	4.2	6.2	0.48 (ac)	0.75 (S)
	11	2.3	3.5	5.8	0.66 (sm)	0.70 (S)
Chamaecyparis obtusa var. *formosana*	1	5.6	5.7	11.3	0.98 (m)	1.33 (L)
	2	4.9	6.2	11.1	0.79 (m)	1.32 (L)
	3	3.4+1.4	4.9	9.7	0.98 (m)	1.15 (M_2)
	4	3.2	6.1	9.3	0.52 (sm)	1.11 (M_2)
	5	4.1	4.4	8.5	0.93 (m)	1.01 (M_2)
	6	3.6	2.1+2.1	7.8	0.86 (m)	0.93 (M_1)
	7	3.4	4.0	7.4	0.85 (m)	0.88 (M_1)
	8	3.2	4.1	7.3	0.78 (m)	0.87 (M_1)
	9	3.1	4.2	7.3	0.74 (sm)	0.87 (M_1)
	10	2.4	4.3	6.7	0.56 (sm)	0.80 (M_1)
	11	2.1	4.1	6.4	0.51 (sm)	0.74 (S)
Thuja orientalis	1	4.2	4.5	8.7	0.93 (m)	1.25 (M_2)
	2	1.0+2.5	4.7	8.2	0.77 (m)	1.18 (M_2)
	3	3.5	4.0	7.5	0.88 (m)	1.08 (M_2)
	4	3.0	4.2	7.2	0.71 (sm)	1.03 (M_2)
	5	3.1	4.0	7.1	0.78 (m)	1.02 (M_2)
	6	3.3	3.7	7.0	0.89 (m)	1.00 (M_2)
	7	2.0	1.2+3.1	6.3	0.47 (ac)	0.90 (M_1)
	8	2.8	3.5	6.3	0.80 (m)	0.90 (M_1)
	9	3.0	3.2	6.2	0.94 (m)	0.89 (M_1)
	10	2.5	3.6	6.1	0.69 (sm)	0.87 (M_1)
	11	2.9	3.2	6.1	0.91 (m)	0.87 (M_1)

2. **Chamaecyparis obtusa** Sieb. et Zucc. var. **formosana** (Hay.) Rehd.

7 cells from 2 trees were analysed. The diploid chromosome number is 22.

The size of the chromosomes are large in chromosomes 1 and 2; medium large in 3 to 5; medium small in 6 to 10; and small in 11 (2L+3M2+5M1+1S). The position of the centromere in chromosomes 4, 9, 10, and 11 are submetacentric and in all others are metacentric (4sm.+7mc.). A secondary constriction is found on the short arm of chromosome 3, and on the long arm of chromosome 6 (Pl. II: 7, Fig. I: 12, Table 2).

3. **Thuja orientalis** Linn.

The karyotype of this species has been reported by Mohra et al (1956: 173). In our study 9 cells from 2 trees were analysed. The diploid chromosome number is 22.

The size of the chromosomes are medium large in chromosomes 1 to 6; and medium small in all others (6M2+5M1). The position of the centromere is acrocentric in chromosome 7; submetacentric in chromosomes 4 and 10; and metacentric in the rest (1ac.+2sm.+8ac.). Secondary constrictions are found in the short and long arms of chromosome 2 and 7 respectively (Pl. II: 8, Fig. I: 13, Table 2).

DISCUSSION AND CONCLUSION

Karyotypes of 13 species of Formosan gymnosperms have been studied by the present authors. The chromosome number and/or karyotype analysis have been previously reported for *Keteleeria davidiana* var. *formosana*, *Pseudotsuga wilsoniana*, *Cunninghamia lanceolata*, *Cunninghamia Konishii*, *Taiwania cryptomerioides* and *Thuja orientalis* (7, 11, 13, 14, 15). The present paper report the karyotypes for the first time of the following 7 species of gymnosperms. *Picea morrisonicola*, *Pinus armandi* var. *mastersiana*, *Pinus morrisonicola*, *Pinus taiwanensis*, *Tsuga chinensis* var. *formosana*, *Chamaecyparis formosensis*, *Chamaecyparis obtusa* var. *formosana*.

The somatic chromosome number is 24 for the Pinaceae, while it is 22 in both the Taxodiaceae and Cupressaceae.

The karyotype is similar for the Formosan species of *Pinus*. There are 12 long chromosomes in this genus, 11 of which are metacentric. Thus it is very difficult to distinguish these taxa by their chromosome morphology. Secondary constrictions can not be always observed, neverthless, they are always found in the same position on definite chromosome if they appear. The secondary constriction in the chromosome has been suggested by Pederick (1970: 171–180) as a useful character for the indentification of taxa in *Pinus*.

In some cells of *Pinus morrisonicola*, the negative heterochromatin and the breakage segments were observed. The breaking point is on the segment with heterochromatin.

In *Keteleeria davidiana* var. *formosana*, there are many secondary constrictions found on the chromosomes in prometaphase but not in metaphase and anaphase.

In *Pseudotsuga wilsoniana*, Thomas and Ching (1968: 140) reported that the secondary constrictions were found on chromosomes 4, 6 and 11. We found secondary constrictions on chromosomes 4 and 11, but did not find any on 6, however, we did find one on chromosome 5 and also one on a long arm of a small chromosome, the number of which has not been identified.

The fourth pair of chromosomes in *Cunninghamia lanceolata* and *C. konishii* are SAT-chromosomes and these were not observed on any of the other 11 species.

Neverthless, SAT-chromosome was also observed by Chuang and Hu (1963) in *Amentotaxus argotaenia.*

In *Thuja orientalis*, there is only one chromosome with a acrocentric centromere, the rest being metacentric or submetacentric. Secondary constrictions were found in the long arm of the J-shape chromosome and short arm of chromosome 3 respectively. These results are not the same as reported by Mohra et al (1956: 173).

Since the chromosome morphology of *Picea morrisonicola, Pseudotsuga wilsoniana, Keteleeris davidiana* var. *formosana* and *Tsuga chinensis* var. *formosana* is asymmetrical, they be considered more advanced taxa than *Pinus.*

A key based on the karyotypic characters of some genera of gymnosperms found on Formosa is as follows:

A_1. Diploid chromosome number 24
- B_1. Metacentric chromosome with 11 bivalents............................*Pinus*
- B_2. Metacentric chromosome with less than 7 bivalents
  - C_1. Acrocentric chromosome with 5 or 6 bivalents
    - D_1. Small chromosome with 1 bivalent.........................*Keteleeria*
    - D_2. Small chromosome with 4 bivalents......................*Pseudotsuga*
  - C_2. Acrocentric chromosome with 1 or 2 bivalents (s)
    - D_1. Chromosome 4 acrocentric......................................*Picea*
    - D_2. Chromosome 4 metacentric.....................................*Tsuga*

A_2. Diploid chromosome number 22 or 14
- B_1. SAT-chromosome present
  - C_1. SAT on the short arm of 4th chromosome; 2n=22........*Cunninghamia*
  - C_2. SAT on the long arm of 3rd chromosome; 2n=14...........*Amentotaxus*
- B_2. SAT-chromosome absent
  - C_2. Acrocentric chromosome with 2 bivalents........................*Taiwania*
  - C_2. Acrocentric chromosome with 1 bivalent
    - D_1. Chromosome 11 metacentric....................................*Thuja*
    - D_2. Chromosome 11 submetacentric.........................*Chamaecyparis*

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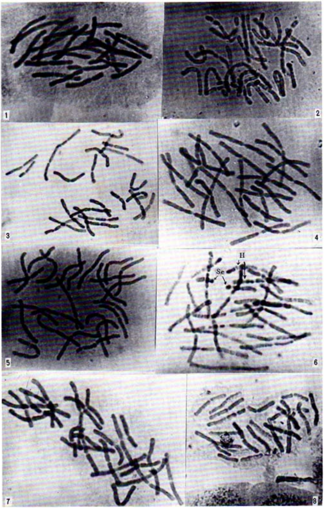

Plate 1. Chromosomes in metaphase. 1-2. *Keteleeria davidiana* var. *formosana* (×1250). 3, *Picea morrisonicola* (×1000). 4. *Pinus armandi* var. *mastersiana* (×1000). 5-6, *Pinus morrisonicola* (×1000). 7. *Pinus taiwanensis* (×1150). 8. *Tsuga chinensis* var. *formosana* (×1500). H, Heterochromatin. Se, Segment. Sc, Secondary constriction. S, Satellite.

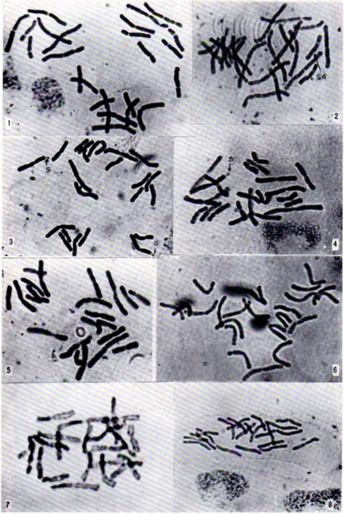

Plate 2. Chromosomes in metaphase. 1-2, *Pseudotsuga wilsoniana* (× 1150, × 1250). 3, *Cunninghamia konishii* (× 1000). 4, *Cunninghamia lanceolata* (× 1250). 5, *Taiwania cryptomerioides* (× 1150). 6, *Chamaecyparis formosensis* (× 1500). 7, *Chamaecyparis obtusa* var. *formosana* (× 2000). 8, *Thuja orientalis* (× 1250).