

Karyomorphological Studies in Twelve Species in the Taxodiaceae with Special Reference to Cytotaxonomical Position of *Sciadopitys verticillata*

Masahiro HIZUME

Biological Institute, Faculty of Education,
Ehime University, Matsuyama 790, Japan

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Abstract

Eleven species of nine genera and their alliance *Sciadopitys verticillata* in the Taxodiaceae were karyomorphologically investigated. The chromosome number in the species was $2n=22$ except for $2n=20$ for *Sc. verticillata* and $2n=66$ for *Sequoia sempervirens*. The chromosome number of *Taxodium ascendens* was recorded here for the first time. The chromosomes at interphase in the species were of the diffuse type, but those in *Sc. verticillata* were of the chromocenter type. The condensation pattern in the chromosome segments at mitotic prophase was of the continuous type. The chromosomes of each metaphase complement in each species showed gradual decrease in length from the longest to the shortest chromosomes, especially those in *Cunninghamia lanceolata*, *Taiwania cryptomerioides* and *T. flousiana* showed more gradual decrease. Centromeres were located at median to submedian regions of the metaphase chromosomes in all of the species, thus the chromosome complements were of the symmetric type. However, the chromosome complements of *C. lanceolata*, *T. cryptomerioides* and *T. flousiana* were less symmetric than those of the other species. The secondary constrictions were located at the proximal regions of certain chromosomes in *Cryptomeria japonica*, *Cr. fortunei*, *T. cryptomerioides*, *T. flousiana*, *Glyptostobus pensilis*, *Sequoiadendron gigantea*, *Metasequoia glyptostroboides*, *Taxodium distichum* and *Ta. ascendens*, at the interstitial regions of certain chromosomes in *Sc. verticillata* and certain clones containing 3 or 4 nucleoli in *Cryptomeria* species, and at the terminal regions of certain chromosomes in *Se. sempervirens* and *C. lanceolata*. Six nucleolar chromosomes were observed in *M. glyptostroboides* and *S. sempervirens* while two were observed in the other species. Based on these karyomorphological characteristics the species excluding for *Sc. verticillata* were divided into five groups.

Introduction

The family Taxodiaceae is composed of 15 species in seven monotypic genera and three genera containing a few species each. The species of the Taxodiaceae were distributed all over the Northern Hemisphere as important members of the forest during Tertiary era. Furthermore, the extinct species grew at the restricted regions of Eastern Asia and North America and Tasmania (Frolin, 1963).

The chromosome number of $2n=22$ was reported in certain species in the Taxodiaceae (Khoshoo, 1961), excepting *Sequoia sempervirens* ($2n=66$) was a hexaploid species (Hirayoshi and Nakamura, 1943). Some individual plants of *Cryptomeria japonica* showed exclusively the chromosome numbers of $2n=33$ or 44 (e.g., Chiba, 1951; Zinnai and Chiba, 1951) and those of *Glyptostrobus pensilis* (= *G. heterophylla*) showed $2n=33$ (Price *et al.*, 1973). Thus, the basic chromosome number of $x=11$ is accepted for the genus of Taxodiaceae (Khoshoo, 1961).

Detailed karyomorphological observation on chromosomes at interphase and mitotic phases may supply us some important roles in phylogenetic relationships among the species of the Taxodiaceae containing basically the same chromosome number of $2n=22$. This study is dealt with karyomorphology in the mitotic division cycle in eleven species of nine genera and their alliance *Sciadopitys verticillata* in the Taxodiaceae distributed in Northern Hemisphere.

Materials and Methods

The localities or sources, and numbers of plants of the species investigated were tabulated in Table 1. The seedlings and the scion cuttings were cultivated in pots and their root tips were used for chromosome observations. The living voucher specimens have been reserved in the Experimental Botanical Garden, Biological Institute, Faculty of Education, Ehime University.

The root tips 5 mm long were treated with 2mM 8-hydroxyquinoline at 10°C for about 20 hours and then fixed in the mixture of ethanol, glacial acetic acid and chloroform (2:1:1) at 4°C overnight. After the fixed root tips were macerated in the mixture of 1N hydrochloric acid and 45% acetic acid (2:1) at 60°C for 15–25 seconds, their meristematic cells were isolated on glass slides and, were stained and squashed with 2% aceto-orcein.

An observation was made on the chromosomes at interphase, mitotic prophase and metaphase. Chromosome morphology at interphase, prophase and metaphase were classified and described according to Tanaka's nomenclature system (1977). Each metaphase chromosome was measured in length of long arm, short arm and satellite. Arm ratio was estimated by long arm length / short arm length. Nomenclature system of Levan *et al.* (1964) modified for species of the Taxodiaceae by Schlarbaum and Tsuchiya (1984b) was used for designation of individual chromosomes. Relative length was

estimated by chromosome length / total length of all chromosomes of complement \times 100. Quantity of chromosomes, symmetry index and homogeneity index were estimated tentatively by total length of all chromosomes in a complement, total length of all long arms / total length of all short arms, and length of the longest chromosome / length of the shortest chromosome, respectively.

Table 1. Locality or source, and number of plants studied of twelve species in the Taxodiaceae

| Species | Chromosome number (2n) | No. of plants | Locality or source |
|--|------------------------|---------------|---|
| <i>Cunninghamia lanceolata</i> (Lamb.) Hook. | 22 | 10 | Kobe Municipal Arbor., Kobe C., Hyogo Pref., Japan |
| | 22 | 5 | Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan |
| <i>Taiwania cryptomerioides</i> Hayata | 22 | 5 | Kobe Municipal Arbor., Kobe C., Hyogo Pref., Japan |
| | 33 | 1 | Pref., Japan |
| | 22 | 2 | Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan |
| <i>Taiwania flousiana</i> Gaussen | 22 | 25 | Nanjing Forestry University, Nanjing, China |
| <i>Cryptomeria japonica</i> D. Don. | 22 | 3 | Hiroshima Pref. Exp. For. Stn., Miyoshi C., Hiroshima Pref. |
| | 22 | 5 | Yuki T., Hiroshima Pref. |
| | 22 | 6 | Omogo V., Ehime Pref. |
| | 22 | 20 | Yanase, Umaji V., Kochi Pref. |
| | 22 | 32 | Anhui, China |
| <i>Cryptomeria fortunei</i> Hooibrenk ex Otto et Dietr. | 22 | 4 | Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan |
| <i>Glyptostrobus pensilis</i> (Staunt.) Koch | 22 | 34 | Hiroshima University, Hiroshima C., Hiroshima Pref., Japan |
| <i>Taxodium distichum</i> (Linn.) Rich. | 22 | 1 | Kansai For. Tree Breed. Inst., Syoou T., Okayama Pref. |
| <i>Taxodium ascendens</i> Brongn. | 22 | 2 | Clyde Robin Seed Co., Calif., USA |
| | 22 | 1 | Hiroshima Botanical Garden, Hiroshima C., Hiroshima Pref. |
| <i>Sequoiadendron gigantea</i> (Lindl.) Buchholz | 66 | 2 | Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan |
| | 66 | 3 | Kansai For. Tree Breed. Inst., Syoou T., Okayama Pref., Japan |
| <i>Metasequoia glyptostroboides</i> Hu et Cheng | 22 | 5 | Hiroshima University, Hiroshima C., Hiroshima Pref., Japan |
| | 22 | 10 | Ehime Pref. Exp. For. Stn., Kawauchi T., Ehime Pref., Japan |
| <i>Sciadopitys verticillata</i> (Thunb.) S. et Z. | 20 | 20 | Owase, Wakayama Pref. |
| | 20 | 2 | Kanmuri, Yosiwa V., Hiroshima Pref. |
| | 20 | 28 | Omogo V., Ehime Pref. |

Results

1. *Cunninghamia lanceolata* (Lamb.) Hook., 2n=22, Table 2 and Fig. 1

The chromosome number in the 15 plants was 2n=22, which verified Sugihara (1941a;

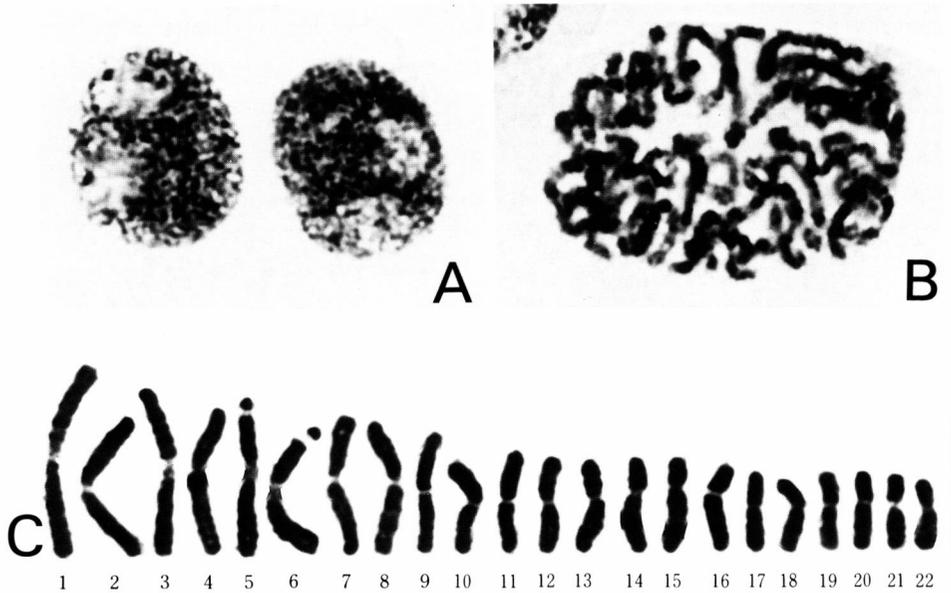


Fig. 1. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Cunninghamia lanceolata* ($2n=22$). Bar represents $10\ \mu\text{m}$.

$n=11$) and Mehra and Khoshoo (1956; $2n=22$).

The chromosomes at interphase formed many small chromomeres and fibrous chromatin distributed homogeneously throughout the nucleus. Several plants showed frequently one or two spherical heteropycnotic bodies about $1\ \mu\text{m}$ diameter at the surface of the nucleolus (Fig. 1A). One or two nucleoli were observed in each nucleus. The chromosomes at mitotic prophase appeared as homogeneous threads with a constant width (Fig. 1B) and not differentially condensed among chromosome segments. The somatic chromosomes in the metaphase complement showed a gradual decrease in length from the longest ($14.3\ \mu\text{m}$) to the shortest ($5.3\ \mu\text{m}$) chromosomes (Table 2, Fig. 1C). Their centromeres were located at the median regions in most cases. However, the chromosome pair 8 had a centromere at the submedian region and the pairs 7 and 9–11 had at the median–submedian regions. The chromosome pair 3 with the median centromere possessed a secondary constriction at the terminally interstitial region of the short arm and a satellite $1.0\text{--}1.2\ \mu\text{m}$ long. The satellites varied in shape among the cells on the same slide depending on degree of chromosome condensation, while they varied in size among the plants studied. These morphological variation of satellites supported the previous document by Han *et al.* (1984). Morphology of the chromosomes at interphase was categorized to be the diffuse type and that at prophase was the continuous type (Tanaka, 1977). Morphology of the chromosome set at metaphase was gradual and somewhat symmetric. The metaphase karyotype was very similar to that reported by Han *et al.* (1978), Schlarbaum and Tsuchiya (1984b), Toda (1985), Fang and Hsu (1986) and Li (1987e).

2. *Taiwania cryptomerioides* Hayata, $2n=22$ and 33, Table 3 and Fig. 2

The somatic chromosome number in the plants was $2n=22$, excepting a plant distinct with gigas leaves showed $2n=33$, and verified the documents of $n=11$ by Sax and Sax (1933) and Sugihara (1941b) and $2n=22$ by Matsumoto (1933) and Kuo *et al.* (1972).

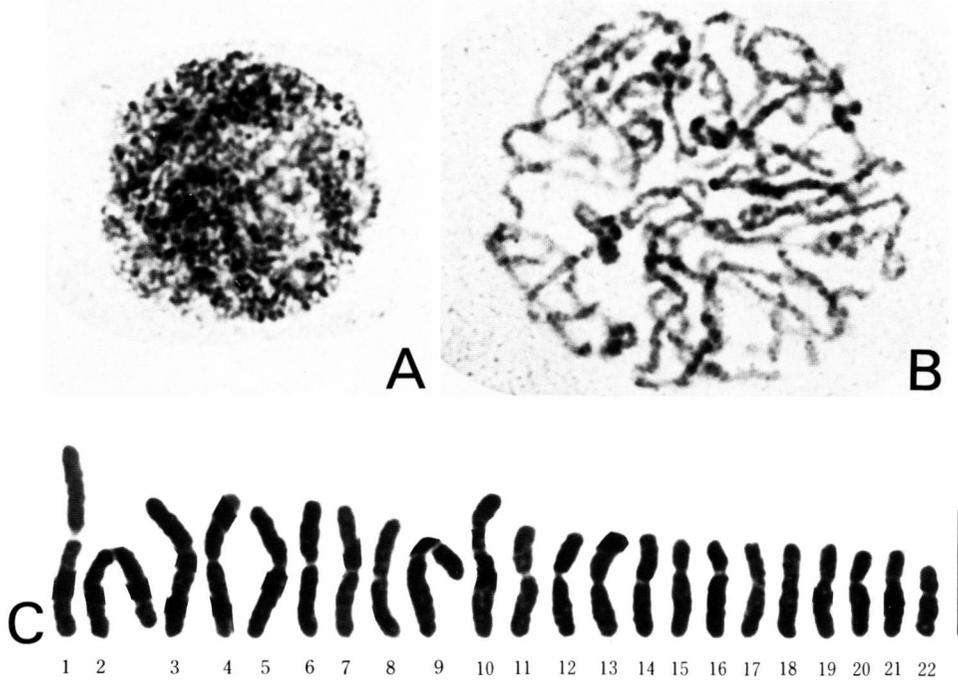


Fig. 2. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Taiwania cryptomerioides* ($2n=22$). Bar represents $10 \mu\text{m}$.

The chromosomes at interphase were observed as numerous small chromomeres and fibrous chromatins without any heteropycnotic body (Fig. 2A). Maximum two nucleoli were counted in each nucleus, but three in the triploid plant. The chromosomes at mitotic prophase condensed homogeneously (Fig. 2B). In the metaphase chromosome complement a gradual decrease in length was observed from the longest ($15.0 \mu\text{m}$) to the shortest ($6.2 \mu\text{m}$) chromosomes (Table 3, Fig. 2C). Centromeres were observed at the median regions of six pairs of chromosomes, the median-submedian regions of three pairs (6, 10, 11) of chromosomes and the submedian regions of two pairs (5, 8) of chromosomes. The secondary constriction was presented at the proximal region of the short arm of the chromosome pair 5. The constricted region was elongated and was weakly stained. The chromosomes at interphase and mitotic prophase were morphologically categorized to be the diffuse and continuous types. The chromosome complement at metaphase showed the gradual and less symmetric karyotype as observed in *C. lanceolata*. The metaphase karyotype was similar to that reported by Kuo *et al.* (1972), Schlarbaum and Tsuchiya (1984b), Toda *et al.* (1986), except for location and number of the secondary constrictions.

3. *Taiwania flousiana* Gaussen, $2n=22$, Table 4 and Fig. 3

The chromosome number of $2n=22$ was counted in the 20 plants and confirmed the previous documents (Fang, 1986; Li, 1986c).

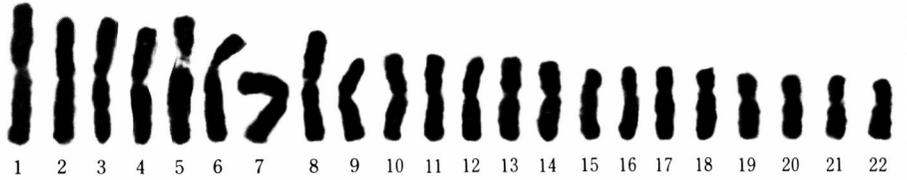


Fig. 3. Photomicrograph of chromosomes at mitotic metaphase in the root tip cells of *Taiwania flousiana* ($2n=22$). Bar represents $10\ \mu\text{m}$.

The chromosomes at interphase and mitotic prophase were morphologically very similar to those observed in *T. cryptomerioides*. One or two nucleoli were formed in each nucleus. The chromosome complement at metaphase displayed a gradual decrease in length from the longest ($11.7\ \mu\text{m}$) to the shortest ($5.1\ \mu\text{m}$) chromosomes (Table 4, Fig. 3). Three pairs of chromosomes (pairs 3, 9, 10) had centromeres at the submedian regions and the other chromosomes had centromeres at median or median-submedian regions. A secondary constriction appeared at the proximal region of the chromosome pair 3. Gross morphology of the chromosome complement at metaphase was similar to that reported by Fang (1986) and Li (1986c), except for location and number of the secondary constrictions.

4. *Cryptomeria japonica* D. Don, $2n=22$, Table 5 and Figs. 4, 5.

The thirty clones investigated showed the chromosome number of $2n=22$, which

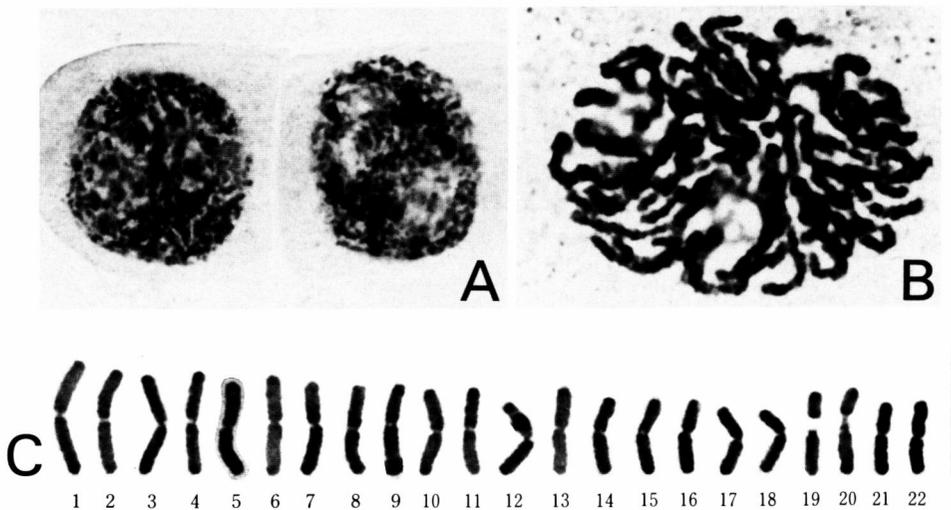


Fig. 4. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Cryptomeria japonica* ($2n=22$). Bar represents $10\ \mu\text{m}$.

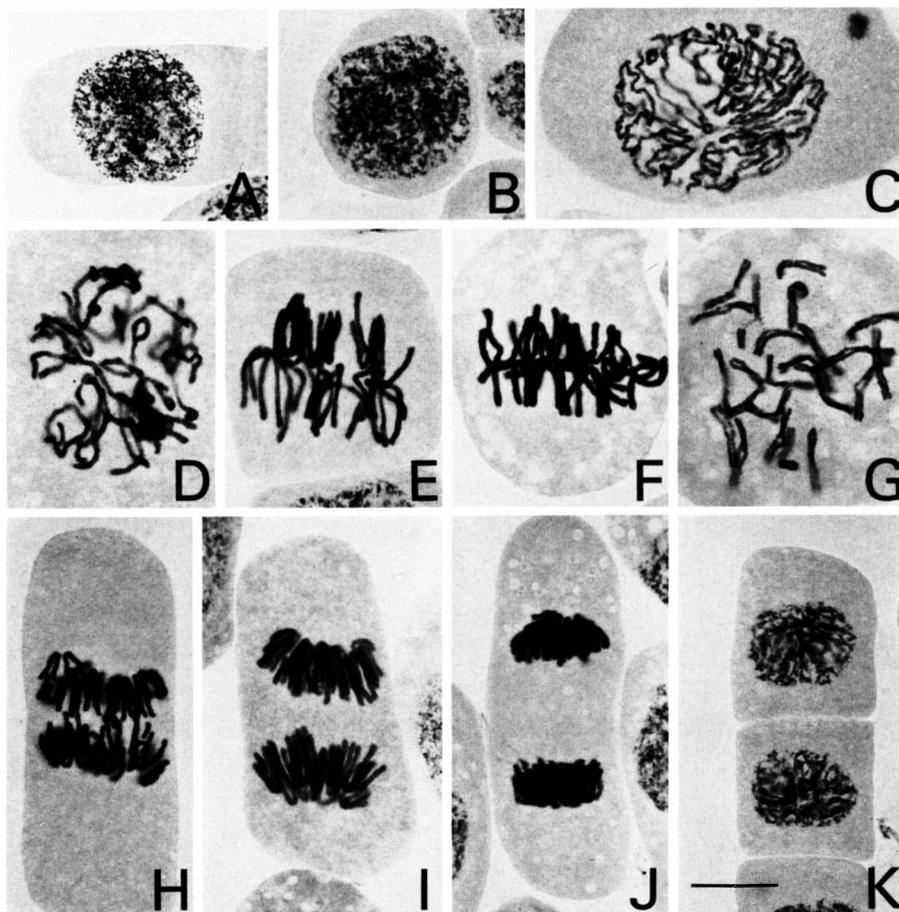


Fig. 5. Photomicrographs of chromosomes during mitotic division in the root tip cells of *Cryptomeria japonica* ($2n=22$) without pretreatment. A and K: interphase, B,C and D: prophase, E,F and G: metaphase, H and I: anaphase, J: telophase. Bar represents $10\ \mu\text{m}$.

verified the previous counts (*e.g.*, Sax and Sax, 1933; Matsumoto, 1933; Mehra and Khoshoo, 1956).

Chromosome morphology at each mitotic phase without pretreatment were presented in Fig. 5. The chromosomes at interphase formed many small chromomeres and fibrous chromatins dispersed homogeneously over the nucleus and formed no heteropycnotic body (Fig. 4A). Maximum number of nucleoli per nucleus was constant for each clone but varied between two and four for the cultivated population studied. The clones with two nucleoli were most frequently observed. The chromosomes at mitotic prophase were of folding threads with a constant width and their segments were similar in degree of condensation to each other (Fig. 4B). The chromosomes of the metaphase complement showed a gradual decrease in length from the longest ($9.4\ \mu\text{m}$) to the shortest ($5.9\ \mu\text{m}$) chromosomes (Table 5, Fig. 4C). The chromosomes showed their centromeres at median or median-submedian regions. The chromosome pair 10 possessed the secondary constriction at the

proximal region of the short arm and the large satellite $2.8 \mu\text{m}$ long. Since the small chromosome arm was observed at proximal region of the satellited chromosome, the position of the secondary constriction was precisely at the proximally interstitial region. The elongated constricted regions were frequently lightly-stained. In the clones containing three or four nucleoli per nucleus, the secondary constriction was present at the interstitial region of the short arm of the chromosome pair 6 in addition to the chromosome pair 10. This karyotype of this species at mitotic metaphase recorded here was similar to that reported previously by Sax and Sax (1933), Mehra and Khoshoo (1956), Kuroki (1969) and Schlarbaum *et al.* (1984b). Moreover, the present observation supported Toda (1979a,b,c), Somego (1980) and Kondo *et al.* (1985) reported three karyotypes with differences of the secondary constrictions in this species.

The chromosomes at interphase were of the diffuse type and those at mitotic prophase were of the continuous type. The chromosome complement at mitotic metaphase was of the gradual and symmetric karyotype. The nucleolar chromosomes were either of the proximal type and or of the interstitial type.

5. *Cryptomeria fortunei* Hooibrenk ex Otto et Dietr., Table 6 and Fig. 6

The chromosome number of $2n=22$ counted in the 32 plants confirmed the previous documents (Toda and Fujimoto, 1983, 1985; Somego and Kikuchi, 1983; Li and Xu, 1984; Xiao and Dong, 1984).

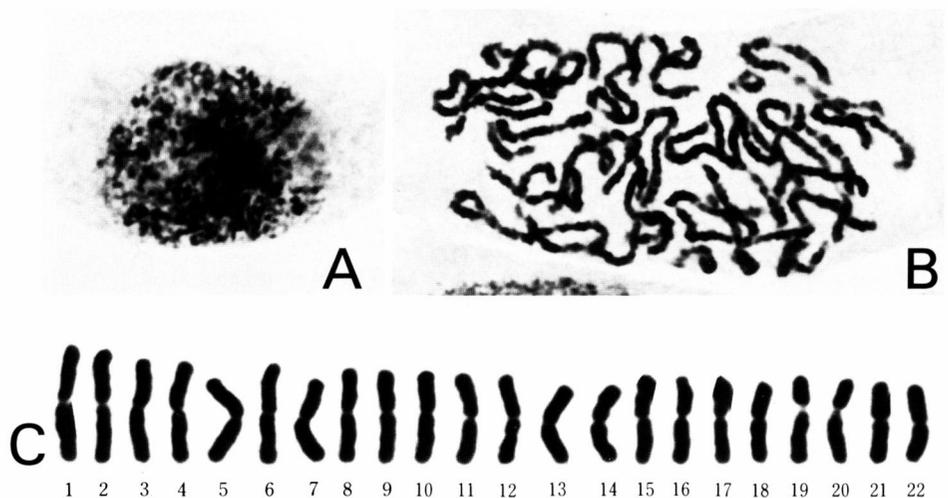


Fig. 6. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Cryptomeria fortunei* ($2n=22$). Bar represents $10 \mu\text{m}$.

The chromosomes at interphase (Fig. 6A), mitotic prophase (Fig. 6B) and metaphase (Fig. 6C) were very similar to those observed in *Cr. japonica*. The chromosomes of the metaphase complement varied in length from $9.6 - 5.9 \mu\text{m}$ (Table 6). The secondary constrictions were located mostly at the proximal region of the chromosome pair 10 but were

located sometimes at the interstitial region of the chromosome pair 6 as observed in *Cr. japonica*. Thus, the karyotype at metaphase given here was very similar to that previously reported by Toda and Fujimoto (1983, 1985), Somego and Kikuchi (1983), Li and Xu (1984) and Xiao and Dong (1984).

6. *Glyptostrobus pensilis* (Staunt.) Rich., $2n=22$, Table 7 and Fig. 7.

The chromosome number in the six plants was $2n=22$, which was identical to that of the previous reports (Toda, 1985; Fang, 1986; Li, 1987b), but was different from $2n=33$ (Price *et al.*, 1974).

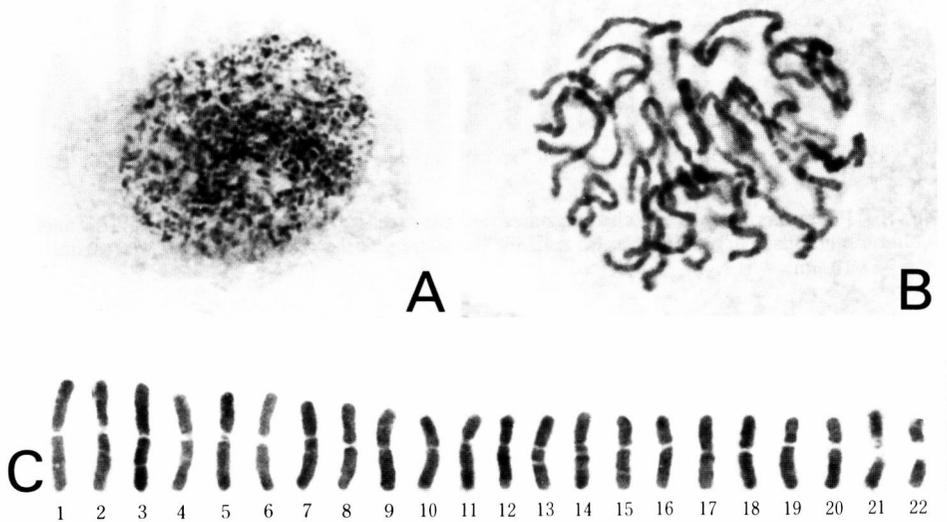


Fig. 7. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Glyptostrobus pensilis* ($2n=22$). Bar represents $10\ \mu\text{m}$.

The chromosomes at interphase and mitotic prophase showed the similarities in chromatin distribution and chromosome condensation to those in *Cryptomeria japonica* (Fig. 7A and B). The chromosomes of the metaphase complement displayed a gradual decrease in length from the longest ($10.7\ \mu\text{m}$) to the shortest ($5.6\ \mu\text{m}$) chromosomes (Table 7, Fig. 7). All the chromosomes exhibited their centromeres at the median regions excepting for four chromosomes (pairs 6 and 10) exhibited the centromeres at the median-submedian regions. The secondary constrictions were located at the proximal regions of the short arm of the chromosome pair 11. The chromosome complement at metaphase was gradual and symmetric. The nucleolar chromosome was the proximal type. The karyotype at metaphase was similar to that previously reported (Toda, 1985; Fang, 1986; Li, 1987b).

7. *Taxodium distichum* (Linn.) Rich., $2n=22$, Table 8 and Fig. 8

All of the clones of this species studied had the chromosome number of $2n=22$ which

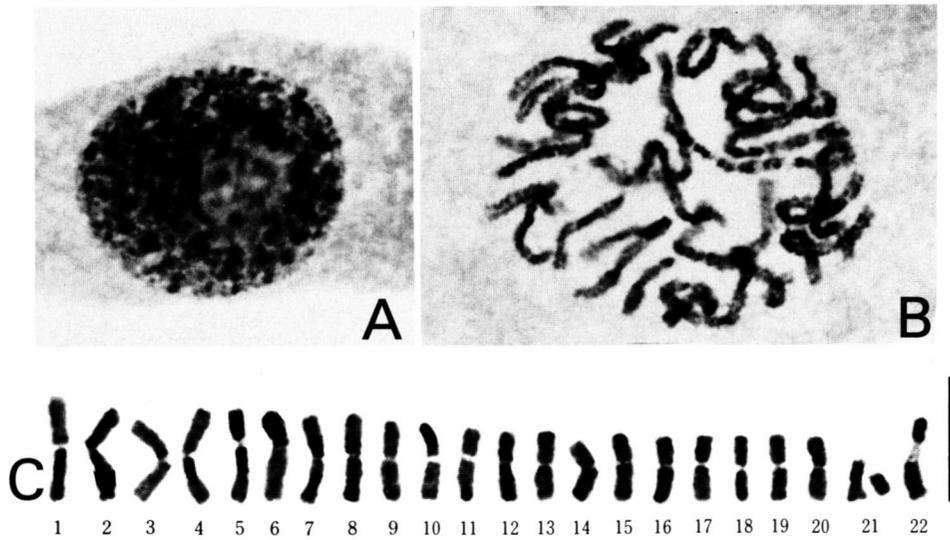


Fig. 8. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Taxodium distichum* ($2n=22$). Bar represents $10\ \mu\text{m}$.

verified the previous documents (Sax and Sax, 1933; Stebbins, 1948; Schlarbaum *et al.*, 1983; Toda, 1985).

The chromosomes at interphase formed small chromomeres and fibrous chromatins (Fig. 8a) and the chromosome structures filled in a nucleus. One or two nucleoli were observed in each nucleus. The prophase chromosomes condensed homogeneously (Fig. 8B) as observed in the other species. In the metaphase complement the chromosomes exhibited a gradual decrease in length from the longest ($10.0\ \mu\text{m}$) to the shortest ($6.0\ \mu\text{m}$) chromosomes (Table 8, Fig. 8C). The chromosomes possessed their centromeres at the median regions excepting three pairs of chromosomes (pairs 3, 6, 11) possessing their centromeres at the median-submedian regions. The morphology of the metaphase chromosome complement was categorized to be the gradual and symmetric karyotype. The secondary constriction was located at the proximal region of the chromosome pair 11. The metaphase karyotype was similar to that reported by Schlarbaum *et al.* (1983) and Toda (1985), except for location of the secondary constriction.

8. *Taxodium ascendens* Brongn., $2n=22$, Table 9 and Fig. 9

The chromosome number of $2n=22$ in a plant of *Taxodium ascendens* was counted here for the first time. The chromosomes at interphase (Fig. 9A) and prophase (Fig. 9B) were of the diffuse type and the continuous type as observed in *T. distichum*. The chromosomes of the metaphase complement exhibited a gradual decrease in length from the longest ($9.4\ \mu\text{m}$) to the shortest ($5.9\ \mu\text{m}$) chromosomes (Table 9, Fig. 9C). The metaphase chromosomes displayed their centromeres at the median regions excepting the chromosome pairs 4, 7 and

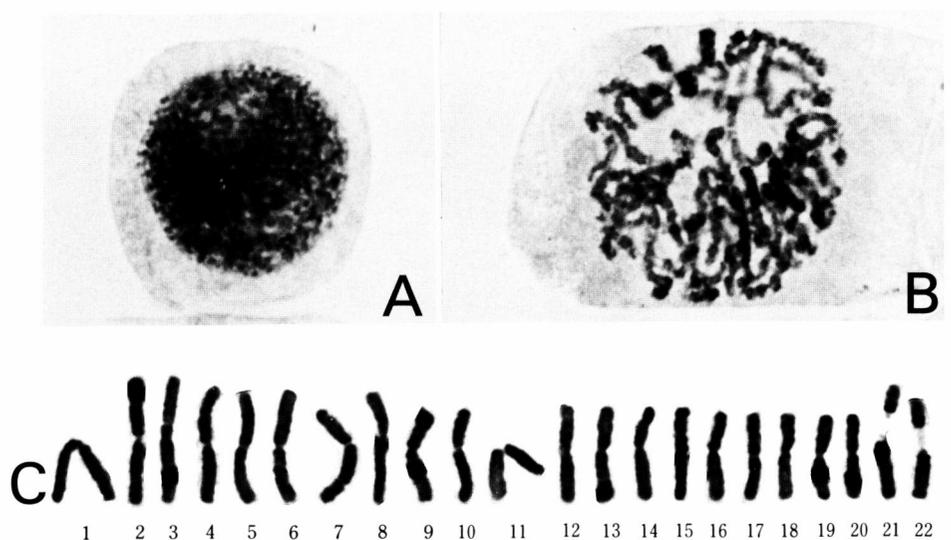


Fig. 9. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Taxodium ascendens* ($2n=22$). Bar represents $10\ \mu\text{m}$.

11 displayed their centromeres at the median-submedian regions. The secondary constriction was presented at the proximal region of the short arm of the chromosome pair 11. The chromosome complement at metaphase performed the gradual and symmetric karyotype.

9. *Sequoiadendron gigantea* (Ldl.) Buchh., $2n=22$, Tables 10 and Fig. 10

Six clones of this species obtained from two sources showed the chromosome number of $2n=24$. This chromosome count verified the previous works by Buchholz (1939), Jensen and Levan (1941), Schlarbaum and Tsuchiya (1975), Baba (1983), Toda *et al.* (1986) and Inaba *et al.* (1987).

The chromosomes at interphase and prophase (Fig. 10A, B) were considered to be the diffuse type and continuous type, which were similar to those in the other species. One or two nucleoli were observed in each nucleus. The chromosomes of the metaphase complement performed a gradual decrease in length from the longest ($10.8\ \mu\text{m}$) to the shortest ($5.1\ \mu\text{m}$) chromosomes (Table 10, Fig. 10C). The chromosomes at metaphase exhibited their centromeres at the median regions and the chromosome pairs 2, 8 and 9 possessed their centromeres at the median-submedian regions. The shortest chromosome pair 11 possessed the secondary constriction at the proximal region of the short arm. The chromosome complement displayed the gradual and symmetric karyotype. The karyotype at metaphase was very similar to that reported by Schlarbaum and Tsuchiya (1975), Baba (1983) and Toda *et al.* (1985).

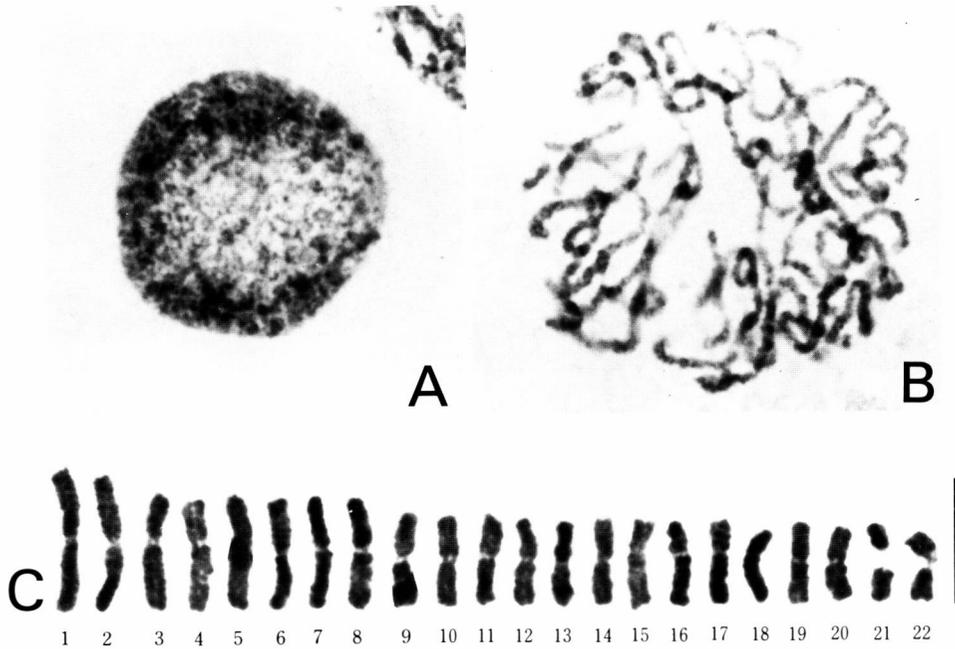


Fig. 10. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Sequoiadendron gigantea* ($2n=22$). Bar represents $10\ \mu\text{m}$.

10. *Sequoia sempervirens* (Lamb.) Endl., $2n=66$, Fig. 11.

The seven clones of this species showed the chromosome number of $2n=66$, which verified the previous reports by Hirayoshi and Nakamura (1943), Yasui (1946), Stebbins (1948), Fozdar and Libby (1968), Saylor and Simons (1970), Schlarbaum and Tsuchiya (1984a) and Toda *et al.* (1986).

The nucleus was $30\text{--}40\ \mu\text{m}$ diameter and larger than that of the other species in the Taxodiaceae. The chromosomes at interphase were homogeneously dispersed throughout the nucleus as numerous small chromomeres and fibrous chromatin (Fig. 11A) and thus, were considered to be of the diffuse type. Two to eight nucleoli were counted in each nucleus. The chromosomes at mitotic prophase were observed as the folded threads with a constant diameter (Fig. 11B) and considered to be of the continuous type. In the metaphase complement the chromosomes displayed a gradual decrease in length. The six shortest chromosomes were quite distinct. The chromosomes exhibited their centromeres at the median regions (Fig. 11C). The chromosomes of the pairs 7–9 had weakly-stained, small satellites at the terminal regions of the short arms. The satellited chromosomes were distinct characters for this species and moreover for *C. lanceolata* in the Taxodiaceae. The karyotype at metaphase was very similar to that reported by Saylor and Simons (1970), Schlarbaum and Tsuchiya (1984a) and Toda *et al.* (1986). However, difference between A and B or A_1 and A_2 genomes was obscure in this observation. The chromosomes at interphase and prophase were considered to be of the diffuse type and the continuous type.

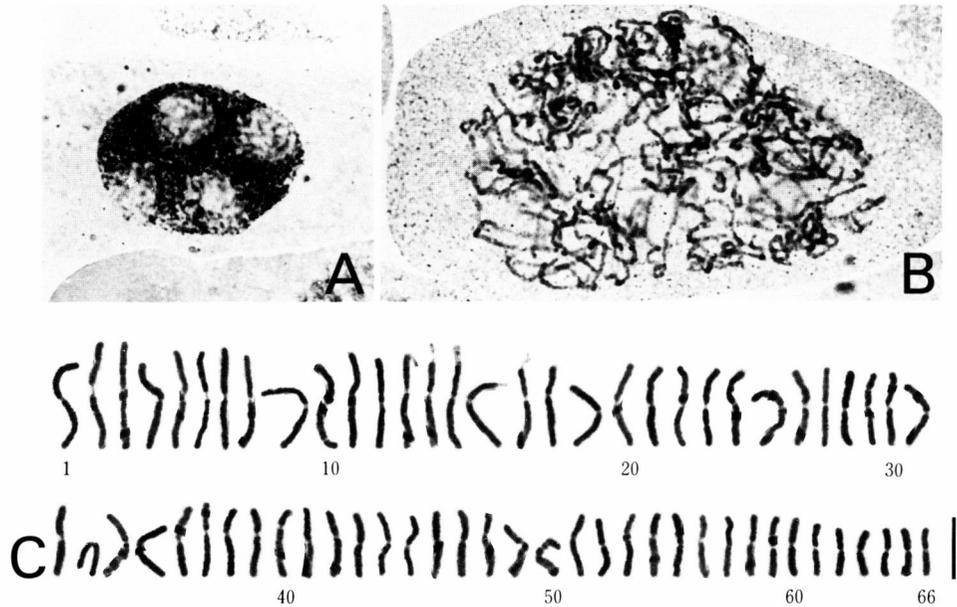


Fig. 11. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Sequoia sempervirens* ($2n=66$). Bar represents $10\ \mu\text{m}$.

The chromosome complement at metaphase performed the gradual and symmetric karyotype. The nucleolar chromosome was of the terminal type.

11. *Metasequoia glyptostroboides* Hu et Cheng, $2n=22$, Table 11 and Fig. 12.

All of the plants of this species studied showed the chromosome number of $2n=22$, which was same as the previous counts by Stebbins (1948) and Schlarbaum *et al.* (1983), Fang (1986), Li (1986a) and Toda *et al.* (1986).

The chromosomes at interphase formed the numerous small chromomeres and fibrous chromatins (Fig. 12A) and thus, were categorized to be of the diffuse type. One to six nucleoli were counted in each nucleus. The chromosomes at mitotic prophase condensed homogeneously as observed in *Cryptomeria* and *Glyptostrobis* and were considered to be of the continuous type (Fig. 12B). The chromosomes of the metaphase complement performed a gradual decrease in length from the longest ($11.1\ \mu\text{m}$) to the shortest ($5.0\ \mu\text{m}$) chromosomes. The chromosomes of the shortest pair were distinct from the other chromosomes. The metaphase chromosomes had their centromeres at the median regions excepting the chromosomes of the pairs 4 and 5 possessed their centromeres at the median-submedian regions (Table 11, Fig. 12C). The secondary constrictions were observed at the proximal regions of three chromosome pairs (8, 9 and 11). The morphology of metaphase complement performed the gradual and symmetric karyotype, which was similar to that reported by Schlarbaum *et al.* (1983), Fang (1986), Li (1986a) and Toda *et al.* (1986).

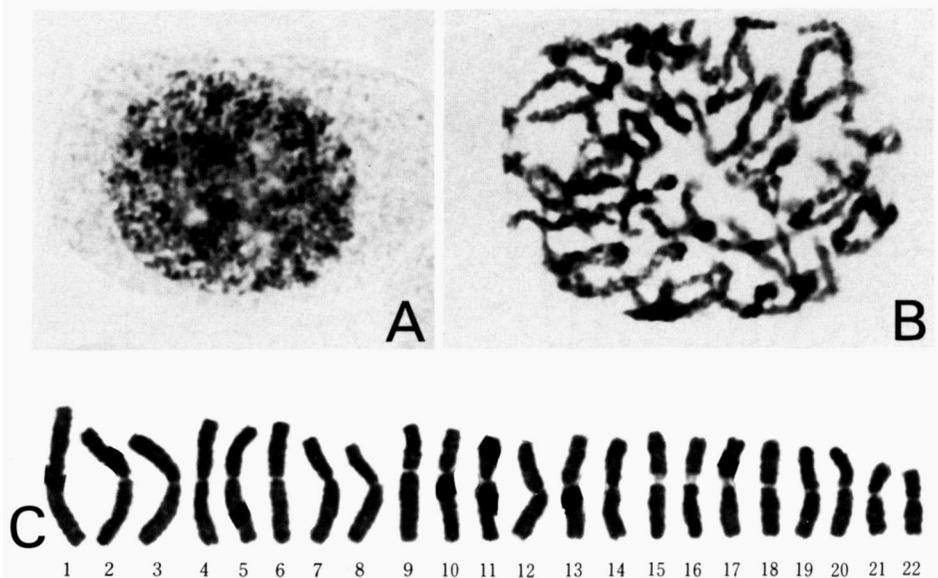


Fig. 12. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Metasequoia glyptostroboides* ($2n=22$). Bar represents $10\ \mu\text{m}$.

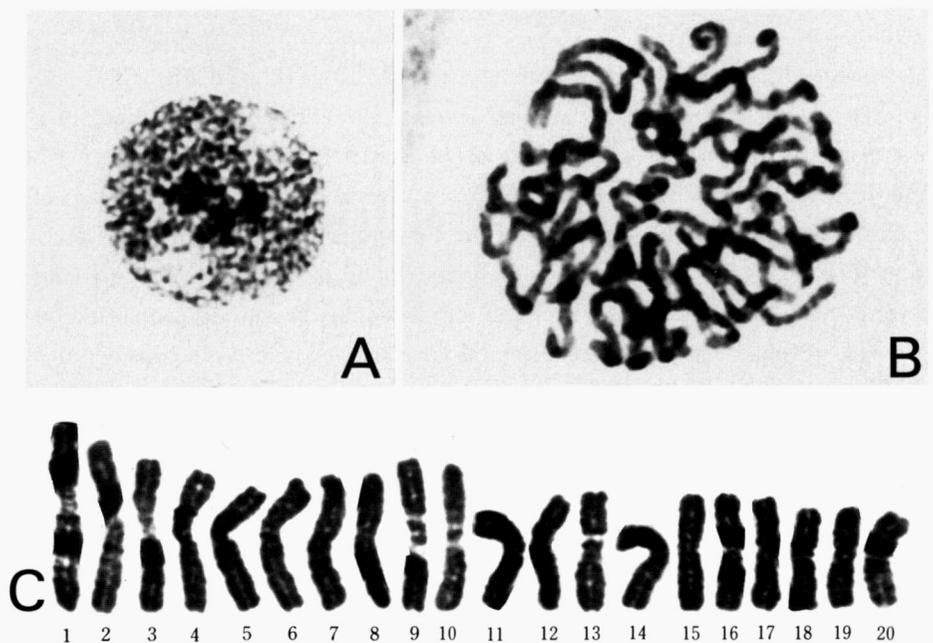


Fig. 13. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Sciadopitys verticillata* ($2n=22$). Bar represents $10\ \mu\text{m}$.

12. *Sciadopitys verticillata* (Thunb.) S. et Z., $2n=20$, Table 12 and Fig. 13

Fifty clones of this species collected from three native localities showed the $2n=20$ chromosomes, which confirmed the previous works (Sax and Beal, 1934; Tahara, 1937; Hirayoshi, 1942; Schlarbaum and Tsuchiya, 1976; Toda, 1985).

The chromosomes at interphase formed several heteropycnotic bodies located at certain region of the nucleus and small chromomeres and fibrous chromatins dispersed over the nucleus (Fig. 13A). The morphology of the interphase chromosomes was categorized to be of the chromocenter type different from that of the other species of the Taxodiaceae. At mitotic prophase any difference in degree of condensation among chromosome segments was not observed (Fig. 13B), indicating the continuous type. In the metaphase complement the chromosomes were aligned gradually in length from the longest (15.9 μm) to the shortest (8.2 μm) chromosomes (Table 12, Fig. 13C). The chromosomes exhibited their centromeres at the median or the median-submedian regions. The secondary constriction was found in the long arm of the chromosome pair 5. The chromosome complement at metaphase performed the gradual and symmetric karyotype. This karyotype at metaphase was similar to the previous reports by Schlarbaum and Tsuchiya (1976) and Toda (1985).

Discussion

The Japanese umbrella pine, *Sciadopitys verticillata* was taxonomically classified into the Taxodiaceae (Pilger and Melchior, 1954; Sporne, 1965) or sometime into the monotypic family Sciadopityaceae (Hayata, 1931). The latter treatment was supported by the investigations on embryogenesis (Tahara, 1937), chromosome morphology (Hirayoshi, 1942; Schlarbaum and Tsuchiya, 1976; Toda, 1985; Li, 1988d) and so on (see Schlarbaum and Tsuchiya, 1985).

This problem was re-examined with respect to the present karyomorphological observations. *Sciadopitys* had the basic chromosome number of $x=10$ different from $x=11$ of the genera of the Taxodiaceae. The basic chromosome number is usually very stable in the conifers within family with a few exceptions such as the Podocarpaceae ($n=10-20$), and *Pseudotsuga menziesii* ($n=13$) and *Pseudolarix amabilis* ($n=22$) in the Pinaceae ($x=12$) (Khoshoo, 1961) Therefore, the basic chromosome number was thought to be an important character of family level in cytotaxonomy of the coniferous plants. The morphology of interphase chromosomes of *Sciadopitys* was of the chromocenter type different from the diffuse type observed in the species of the Taxodiaceae. The total chromosome length of the metaphase complement of *Sciadopitys* was longer than that of any diploid species of the Taxodiaceae. This result could be supported by the data of measurements of DNA amount per genome (Price *et al.*, 1974). The secondary constrictions of *Sciadopitys* were located at the interstitial regions of certain chromosomes, while those of the species of the Taxodiaceae were located at the proximal or terminal regions. According to the above karyomorphological characters *Sciadopitys* was considerably different from the species of

the Taxodiaceae. Thus, *Sciadopitys* should be placed in the independent family Sciadopityaceae. Although Schlarbaum and Tsuchiya (1985) hypothesized that the metaphase karyotype of *Sciadopitys* was derived from that of a pro-taxodiaceous ancestor ($2n=22$) by an unequal translocation and loss of chromosome fragment independently with present taxodiaceous species, any direct interrelationship of karyotypes between *Sciadopitys* and any species of the Taxodiaceae could not be found in this study.

Table 13. Karyomorphological characters in twelve species of the Taxodiaceae

| Species | Chromosome number 2n | Total length (μm) | Chromosome shape | | | TL/TS | L/S | No. of secondary constrictions | No. of uncleoli |
|-------------------------------------|-------------------------|-----------------------------------|------------------|-----|----|-------|------|--------------------------------|-----------------|
| | | | m | msm | sm | | | | |
| <i>Cunninghamia lanceolata</i> | 22 | 192.4 | 14 | 6 | 2 | 1.24 | 2.70 | 2T | 2 |
| <i>Taiwania cryptomerioides</i> | 22 | 201.2 | 12 | 6 | 4 | 1.29 | 2.53 | 2P | 2 |
| <i>Taiwania flousiana</i> | 22 | 116.7 | 12 | 4 | 6 | 1.29 | 2.29 | 2P | 2 |
| <i>Cryptomeria japonica</i> | 22 | 153.3 | 20 | 2 | 0 | 1.13 | 1.65 | 2P(1-2I) | 2-4 |
| <i>Cryptomeria fortunei</i> | 22 | 164.8 | 20 | 2 | 0 | 1.10 | 1.63 | 2P(1-2I) | 2-4 |
| <i>Glyptostrobus pensilis</i> | 22 | 175.2 | 18 | 4 | 0 | 1.18 | 1.91 | 2P | 2 |
| <i>Taxodium distichum</i> | 22 | 164.4 | 16 | 6 | 0 | 1.17 | 1.61 | 2P | 2 |
| <i>Taxodium ascendens</i> | 22 | 169.3 | 16 | 6 | 0 | 1.18 | 1.67 | 2P | 2 |
| <i>Sequoiadendron gigantea</i> | 22 | 166.5 | 16 | 6 | 0 | 1.17 | 2.12 | 2P | 2 |
| <i>Sequoia sempervirens</i> | 66 | — | — | — | — | — | — | 6T | 6-8 |
| <i>Metasequoia glyptostroboides</i> | 22 | 182.5 | 17 | 5 | 0 | 1.20 | 2.20 | 6P | 6 |
| <i>Sciadopitys verticillata</i> | 22 | 227.3 | 17 | 3 | 0 | 1.13 | 1.94 | 2I | 2 |

TL/TS: total length of long arms / total length of short arms, L/S: length of the longest chromosome / length of the shortest chromosome in chromosome complement.
T: terminal secondary constriction, P: proximal secondary constriction,
I: interstitial secondary constriction, —; not measured.

The relationship of karyotypes among the species of the Taxodiaceae extruding *Sciadopitys* was examined. In all species the chromosomes at interphase and mitotic prophase were considered to be commonly of the diffuse type and the continuous type. The metaphase karyotypes among the species were different in degree of symmetry and gradient, number, and location of the secondary constrictions (Table 13). Thus, the species of the Taxodiaceae were divided into five groups as follows:

The first group was composed of *Cryptomeria japonica*, *Cr. fortunei*, *Taxodium ascendens*, *T. distichum*, *Glyptostrobus pensilis*, and *Sequoiadendron gigantea*. It was characterized by the gradual, symmetric karyotype and a pair of proximal secondary constrictions.

The second group was of *Metasequoia glyptostroboides*. It was characterized by the gradual and symmetric karyotype and the six proximal secondary constrictions.

The third group was composed of *Taiwania cryptomerioides* and *T. flousiana*. It was characterized by more gradual and less symmetric karyotype and the proximal secondary constriction in a pair of medium-sized chromosomes.

The fourth group was of *Cunninghamia lanceolata*. It was characterized by more gradual and less symmetric karyotype and the terminal secondary constriction in a pair of large chromosomes.

The fifth group was of *Sequoia sempervirens*. It was characterized by the gradual and symmetric karyotype, hexaploid genome, three pairs of chromosomes with terminal satellites.

Then, the present grouping was compared with the taxonomic treatment by Pilger and Melchior (1954). The first group contained the tribes Taxodieae, Cryptomieae, and a part of Sequoiaeae. Each of the other groups could be correlated with each tribe. Thus, the karyomorphological grouping could be considerably correlated with the taxonomic treatment. Toda and Nagano (1985) divided the karyotypes of the taxodiaceous species into two types; the Köpfchen-type and Telomere-type. The former type was compatible to the groups 1–3 and the latter type was compatible to the groups 4 and 5. Li (1987a,d) reported two phylogenetic trends of *Metasequoia*–*Cunninghamia* and *Cryptomeria*–*Glyptostrobus*–*Taiwania* increasing asymmetry degree according to phylogenetic level. However, phylogenetic relationships among the five groups have not yet been determined, and further investigations are necessary.

Stebbins (1948) observed meiotic chromosomes in pollen mother cells in *Sequoia sempervirens*, somatic chromosomes of *Metasequoia* and outer morphology of *Metasequoia* and reported that the *Se. sempervirens* was autoallopolyploid or segmental allopolyploid and the possibility that *Metasequoia* might actually be a direct descendent of ancient ancestor of the *Se. sempervirens* was a plausible. Recently, Li (1986b, 1987c, 1988a,b,c) hypothesized that *Sequoia* was formed by a hybridization, polyploidization and backcrossing between *Metasequoia* and *Sequoiadendron*. An autoallopolyploid genome (AAAABB) of *Sequoia* was verified by Saylor and Simons (1970), Schlarbaum and Tsuchiya (1984a) and Toda *et al.* (1986). On the basis of morphology of chromosomes with secondary constriction of *Sequoia* and *Metasequoia* Schlarbaum *et al.* (1984a) discussed the lack of evidence for genomic contribution of these species to the hexaploid *Sequoia*. The present observation on karyotype regarding to secondary constricted chromosome supported the Schlarbaum's opinion (Schlarbaum *et al.*, 1984a) and furthermore indicated that any present species in the Taxodiaceae except for *Athrotaxis*, whose karyotype was unknown, might directly involve the formation of *Sequoia* genome.

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Table 2. Measurements of somatic chromosomes of *Cunninghamia lanceolata*, $2n=22$ at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 7.4 | 6.9 | 14.3 | 7.4 | 1.1 | m |
| 2 | 6.7 | 6.3 | 13.0 | 6.8 | 1.1 | m |
| 3 | 6.7 | 5.9 | 12.6 | 6.5 | 1.1 | m |
| 4 | 6.2 | 5.2 | 11.4 | 5.9 | 1.2 | m |
| 5 | 6.1 | 4.0+1.0 | 11.1 | 5.8 | 1.2 | m |
| 6 | 6.1 | 4.0+1.0 | 11.1 | 5.8 | 1.2 | m |
| 7 | 5.9 | 4.9 | 10.8 | 5.6 | 1.2 | m |
| 8 | 5.5 | 5.0 | 10.5 | 5.5 | 1.1 | m |
| 9 | 4.7 | 4.6 | 9.3 | 4.8 | 1.0 | m |
| 10 | 4.2 | 4.0 | 8.2 | 4.3 | 1.1 | m |
| 11 | 3.9 | 3.7 | 7.6 | 4.0 | 1.1 | m |
| 12 | 3.8 | 3.7 | 7.5 | 3.9 | 1.0 | m |
| 13 | 4.5 | 3.0 | 7.5 | 3.9 | 1.5 | msm |
| 14 | 4.5 | 2.9 | 7.4 | 3.8 | 1.6 | msm |
| 15 | 5.0 | 2.4 | 7.4 | 3.8 | 2.1 | sm |
| 16 | 4.6 | 2.5 | 7.1 | 3.7 | 1.8 | sm |
| 17 | 3.7 | 2.7 | 6.4 | 3.3 | 1.4 | msm |
| 18 | 3.5 | 2.6 | 6.1 | 3.2 | 1.4 | msm |
| 19 | 3.5 | 2.6 | 6.1 | 3.2 | 1.4 | msm |
| 20 | 3.7 | 2.4 | 6.1 | 3.2 | 1.5 | msm |
| 21 | 3.3 | 2.3 | 5.6 | 2.9 | 1.4 | msm |
| 22 | 3.0 | 2.3 | 5.3 | 2.8 | 1.3 | msm |

Table 3. Measurements of somatic chromosomes of *Taiwania cryptomerioides*, $2n=22$ at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 7.5 | 6.9 | 14.4 | 7.1 | 1.1 | m |
| 2 | 7.0 | 6.7 | 13.7 | 6.8 | 1.0 | m |
| 3 | 6.2 | 5.0 | 11.2 | 5.6 | 1.2 | m |
| 4 | 5.8 | 5.3 | 11.1 | 5.5 | 1.1 | m |
| 5 | 5.7 | 5.1 | 10.8 | 5.4 | 1.1 | m |
| 6 | 5.6 | 4.9 | 10.5 | 5.2 | 1.1 | m |
| 7 | 5.2 | 5.1 | 10.3 | 5.1 | 1.0 | m |
| 8 | 5.0 | 4.8 | 9.8 | 4.9 | 1.0 | m |
| 9 | 6.1 | 0.2+3.3 | 9.6 | 4.8 | 1.7 | sm |
| 10 | 6.3 | 0.2+3.1 | 9.6 | 4.8 | 1.9 | sm |
| 11 | 4.9 | 3.7 | 8.6 | 4.3 | 1.3 | msm |
| 12 | 4.8 | 3.6 | 8.4 | 4.2 | 1.3 | msm |
| 13 | 4.2 | 4.1 | 8.3 | 4.1 | 1.0 | m |
| 14 | 4.3 | 3.8 | 8.1 | 4.0 | 1.1 | m |
| 15 | 5.2 | 2.6 | 7.8 | 3.9 | 2.0 | sm |
| 16 | 5.1 | 2.5 | 7.6 | 3.8 | 2.0 | sm |
| 17 | 4.1 | 3.4 | 7.5 | 3.7 | 1.2 | m |
| 18 | 4.0 | 3.4 | 7.4 | 3.7 | 1.2 | m |
| 19 | 4.5 | 2.7 | 7.2 | 3.6 | 1.7 | msm |
| 20 | 4.3 | 2.6 | 6.9 | 3.4 | 1.7 | msm |
| 21 | 4.2 | 2.5 | 6.7 | 3.3 | 1.7 | msm |
| 22 | 3.3 | 2.4 | 5.7 | 2.8 | 1.4 | msm |

Table 4. Measurements of somatic chromosomes of *Taiwania flousiana*, 2n=22 at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 6.3 | 5.4 | 11.7 | 7.0 | 1.2 | m |
| 2 | 5.4 | 5.1 | 10.5 | 6.3 | 1.1 | m |
| 3 | 5.4 | 5.0 | 10.4 | 6.2 | 1.1 | m |
| 4 | 5.0 | 4.8 | 9.8 | 5.9 | 1.0 | m |
| 5 | 6.3 | 0.3+3.5 | 9.8 | 5.9 | 1.8 | sm |
| 6 | 6.1 | 0.3+3.3 | 9.4 | 5.6 | 1.9 | sm |
| 7 | 4.5 | 4.3 | 8.8 | 5.3 | 1.1 | m |
| 8 | 4.5 | 4.2 | 8.7 | 5.2 | 1.1 | m |
| 9 | 3.8 | 3.7 | 7.5 | 4.5 | 1.0 | m |
| 10 | 3.8 | 3.4 | 7.2 | 4.3 | 1.1 | m |
| 11 | 3.7 | 3.5 | 7.2 | 4.3 | 1.1 | m |
| 12 | 3.8 | 3.4 | 7.2 | 4.3 | 1.1 | m |
| 13 | 3.8 | 3.2 | 7.0 | 4.2 | 1.2 | m |
| 14 | 4.1 | 2.8 | 6.9 | 4.1 | 1.5 | msm |
| 15 | 3.5 | 2.5 | 6.0 | 3.6 | 1.4 | msm |
| 16 | 3.1 | 2.9 | 6.0 | 3.6 | 1.1 | m |
| 17 | 4.0 | 1.9 | 5.9 | 3.5 | 2.1 | sm |
| 18 | 4.1 | 1.7 | 5.8 | 3.5 | 2.4 | sm |
| 19 | 3.4 | 2.0 | 5.4 | 3.2 | 1.7 | sm |
| 20 | 3.3 | 1.9 | 5.2 | 3.1 | 1.7 | sm |
| 21 | 3.0 | 2.2 | 5.2 | 3.1 | 1.4 | msm |
| 22 | 3.0 | 2.1 | 5.1 | 3.1 | 1.4 | msm |

Table 5. Measurements of somatic chromosomes of *Cryptomeria japonica*, 2n=22 at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 4.9 | 4.5 | 9.4 | 6.1 | 1.1 | m |
| 2 | 4.4 | 4.2 | 8.6 | 5.6 | 1.1 | m |
| 3 | 4.2 | 4.1 | 8.3 | 5.4 | 1.0 | m |
| 4 | 4.1 | 4.0 | 8.1 | 5.3 | 1.0 | m |
| 5 | 4.1 | 3.8 | 7.9 | 5.1 | 1.1 | m |
| 6 | 4.1 | 3.4 | 7.5 | 4.9 | 1.2 | m |
| 7 | 3.8 | 3.6 | 7.4 | 4.8 | 1.1 | m |
| 8 | 4.0 | 3.3 | 7.3 | 4.8 | 1.2 | m |
| 9 | 3.8 | 3.4 | 7.2 | 4.7 | 1.1 | m |
| 10 | 3.6 | 3.5 | 7.1 | 4.6 | 1.0 | m |
| 11 | 3.7 | 3.2 | 6.9 | 4.5 | 1.2 | m |
| 12 | 3.6 | 3.3 | 6.9 | 4.5 | 1.1 | m |
| 13 | 3.6 | 3.2 | 6.8 | 4.4 | 1.1 | m |
| 14 | 3.4 | 3.0 | 6.4 | 4.2 | 1.1 | m |
| 15 | 3.4 | 3.0 | 6.4 | 4.2 | 1.1 | m |
| 16 | 3.4 | 2.8 | 6.2 | 4.0 | 1.2 | m |
| 17 | 3.0 | 2.9 | 5.9 | 3.8 | 1.0 | m |
| 18 | 3.0 | 2.9 | 5.9 | 3.8 | 1.0 | m |
| 19 | 3.5 | 0.4+2.0 | 5.9 | 3.8 | 1.5 | msm |
| 20 | 3.4 | 0.4+2.0 | 5.8 | 3.8 | 1.4 | msm |
| 21 | 3.2 | 2.5 | 5.7 | 3.7 | 1.3 | m |
| 22 | 3.1 | 2.6 | 5.7 | 3.7 | 1.2 | m |

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Table 6. Measurements of somatic chromosomes of *Cryptomeria fortunei*, 2n=22 at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 4.8 | 4.8 | 9.6 | 5.8 | 1.0 | m |
| 2 | 4.6 | 4.6 | 9.2 | 5.6 | 1.0 | m |
| 3 | 4.6 | 4.0 | 8.6 | 5.2 | 1.2 | m |
| 4 | 4.3 | 4.1 | 8.4 | 5.1 | 1.1 | m |
| 5 | 4.2 | 4.2 | 8.4 | 5.1 | 1.0 | m |
| 6 | 4.1 | 4.0 | 8.1 | 4.9 | 1.0 | m |
| 7 | 4.0 | 3.6 | 7.6 | 4.6 | 1.1 | m |
| 8 | 3.8 | 3.7 | 7.5 | 4.6 | 1.0 | m |
| 9 | 3.9 | 3.6 | 7.5 | 4.6 | 1.1 | m |
| 10 | 3.9 | 3.5 | 7.4 | 4.5 | 1.1 | m |
| 11 | 4.0 | 3.4 | 7.4 | 4.5 | 1.2 | m |
| 12 | 3.7 | 3.6 | 7.3 | 4.4 | 1.0 | m |
| 13 | 3.8 | 3.5 | 7.3 | 4.4 | 1.1 | m |
| 14 | 3.7 | 3.5 | 7.2 | 4.4 | 1.1 | m |
| 15 | 3.8 | 3.3 | 7.1 | 4.3 | 1.2 | m |
| 16 | 3.6 | 3.4 | 7.0 | 4.2 | 1.1 | m |
| 17 | 3.5 | 3.4 | 6.9 | 4.2 | 1.0 | m |
| 18 | 3.5 | 3.3 | 6.8 | 4.1 | 1.1 | m |
| 19 | 4.1 | 0.2+2.5 | 6.8 | 4.1 | 1.6 | msm |
| 20 | 4.0 | 0.2+2.2 | 6.4 | 3.9 | 1.7 | msm |
| 21 | 3.3 | 3.1 | 6.4 | 3.9 | 1.1 | m |
| 22 | 3.2 | 2.7 | 5.9 | 3.6 | 1.2 | m |

Table 7. Measurements of somatic chromosomes of *Glyptostrobus pensilis*, 2n=22 at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 5.5 | 5.2 | 10.7 | 6.1 | 1.1 | m |
| 2 | 5.7 | 5.0 | 10.7 | 6.1 | 1.1 | m |
| 3 | 5.1 | 5.1 | 10.2 | 5.8 | 1.0 | m |
| 4 | 4.8 | 4.6 | 9.4 | 5.4 | 1.0 | m |
| 5 | 5.1 | 4.1 | 9.2 | 5.3 | 1.2 | m |
| 6 | 4.8 | 4.1 | 8.9 | 5.1 | 1.2 | m |
| 7 | 4.9 | 3.9 | 8.8 | 5.0 | 1.3 | m |
| 8 | 4.3 | 4.1 | 8.4 | 4.8 | 1.1 | m |
| 9 | 4.1 | 3.9 | 8.0 | 4.6 | 1.1 | m |
| 10 | 4.3 | 3.4 | 7.7 | 4.4 | 1.3 | m |
| 11 | 4.5 | 3.1 | 7.6 | 4.3 | 1.5 | msm |
| 12 | 4.3 | 3.1 | 7.4 | 4.2 | 1.4 | msm |
| 13 | 4.0 | 3.4 | 7.4 | 4.2 | 1.2 | m |
| 14 | 3.9 | 3.2 | 7.1 | 4.1 | 1.2 | m |
| 15 | 4.0 | 3.1 | 7.1 | 4.1 | 1.3 | m |
| 16 | 4.0 | 3.1 | 7.1 | 4.1 | 1.3 | m |
| 17 | 3.6 | 3.5 | 7.1 | 4.1 | 1.0 | m |
| 18 | 3.7 | 3.4 | 7.1 | 4.1 | 1.1 | m |
| 19 | 4.1 | 3.0 | 7.1 | 4.1 | 1.4 | msm |
| 20 | 3.9 | 2.7 | 6.6 | 3.8 | 1.4 | msm |
| 21 | 3.2 | 0.2+2.6 | 5.8 | 3.4 | 1.1 | m |
| 22 | 3.1 | 0.2+2.3 | 5.6 | 3.2 | 1.2 | m |

Table 8. Measurements of somatic chromosomes of *Taxodium distichum*, 2n=22 at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 5.0 | 4.8 | 9.8 | 6.0 | 1.1 | m |
| 2 | 5.0 | 4.6 | 9.6 | 5.8 | 1.1 | m |
| 3 | 4.7 | 4.7 | 6.4 | 5.7 | 1.0 | m |
| 4 | 4.7 | 4.7 | 6.4 | 5.7 | 1.0 | m |
| 5 | 5.4 | 3.3 | 8.7 | 5.3 | 1.5 | msm |
| 6 | 5.2 | 3.5 | 8.7 | 5.3 | 1.5 | msm |
| 7 | 4.4 | 4.2 | 8.6 | 5.2 | 1.1 | m |
| 8 | 4.4 | 4.1 | 6.5 | 5.2 | 1.1 | m |
| 9 | 4.0 | 3.8 | 7.8 | 4.7 | 1.1 | m |
| 10 | 3.8 | 3.7 | 7.5 | 4.6 | 1.0 | m |
| 11 | 4.0 | 2.8 | 6.8 | 4.1 | 1.4 | msm |
| 12 | 3.8 | 3.0 | 6.8 | 4.1 | 1.3 | msm |
| 13 | 3.4 | 3.3 | 6.7 | 4.1 | 1.0 | m |
| 14 | 3.7 | 2.8 | 6.5 | 4.0 | 1.2 | m |
| 15 | 3.6 | 2.8 | 6.4 | 3.9 | 1.3 | m |
| 16 | 3.5 | 2.8 | 6.3 | 3.8 | 1.3 | m |
| 17 | 3.2 | 3.1 | 6.3 | 3.8 | 1.0 | m |
| 18 | 3.5 | 2.7 | 6.2 | 3.8 | 1.2 | m |
| 19 | 3.1 | 3.0 | 6.1 | 3.7 | 1.0 | m |
| 20 | 3.1 | 3.0 | 6.1 | 3.7 | 1.0 | m |
| 21 | 3.6 | 0.2+2.3 | 6.1 | 3.7 | 1.4 | msm |
| 22 | 3.6 | 0.2+2.3 | 6.1 | 3.7 | 1.4 | msm |

Table 9. Measurements of somatic chromosomes of *Taxodium ascendens*, 2n=22 at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 5.2 | 4.8 | 10.0 | 5.9 | 1.1 | m |
| 2 | 5.0 | 4.9 | 9.0 | 5.8 | 1.0 | m |
| 3 | 5.0 | 4.6 | 9.6 | 5.8 | 1.1 | m |
| 4 | 4.5 | 4.3 | 8.8 | 5.2 | 1.0 | m |
| 5 | 4.4 | 4.4 | 8.8 | 5.2 | 1.0 | m |
| 6 | 4.4 | 4.1 | 8.5 | 5.0 | 1.1 | m |
| 7 | 5.0 | 3.4 | 8.4 | 5.0 | 1.5 | msm |
| 8 | 4.8 | 3.5 | 8.3 | 4.9 | 1.4 | msm |
| 9 | 4.1 | 3.5 | 7.6 | 4.5 | 1.2 | m |
| 10 | 4.2 | 3.4 | 7.6 | 4.5 | 1.2 | m |
| 11 | 3.9 | 3.5 | 7.4 | 4.4 | 1.1 | m |
| 12 | 3.9 | 3.4 | 7.3 | 4.3 | 1.2 | m |
| 13 | 4.1 | 3.2 | 7.3 | 4.3 | 1.3 | msm |
| 14 | 4.1 | 3.1 | 7.3 | 4.3 | 1.3 | msm |
| 15 | 3.7 | 3.3 | 7.0 | 4.1 | 1.1 | m |
| 16 | 3.4 | 3.4 | 6.8 | 4.0 | 1.0 | m |
| 17 | 3.4 | 3.3 | 6.7 | 4.0 | 1.0 | m |
| 18 | 3.7 | 3.0 | 6.7 | 4.0 | 1.2 | m |
| 19 | 3.6 | 3.0 | 6.6 | 3.9 | 1.2 | m |
| 20 | 3.5 | 3.1 | 6.6 | 3.9 | 1.1 | m |
| 21 | 3.7 | 0.2+2.2 | 6.1 | 3.6 | 1.5 | msm |
| 22 | 3.7 | 0.2+2.1 | 6.0 | 3.5 | 1.6 | msm |

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Table 10. Measurements of somatic chromosomes of *Sequoiadendron gigantea*, $2n=22$ at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 5.5 | 5.3 | 10.8 | 6.5 | 1.0 | m |
| 2 | 5.4 | 5.4 | 10.8 | 6.5 | 1.0 | m |
| 3 | 5.5 | 3.5 | 9.0 | 5.4 | 1.6 | msm |
| 4 | 5.5 | 3.5 | 9.0 | 5.4 | 1.6 | msm |
| 5 | 4.5 | 4.4 | 8.9 | 5.3 | 1.0 | m |
| 6 | 4.5 | 4.4 | 8.9 | 5.3 | 1.0 | m |
| 7 | 4.5 | 4.3 | 8.8 | 5.3 | 1.1 | m |
| 8 | 4.5 | 4.2 | 8.7 | 5.2 | 1.1 | m |
| 9 | 3.6 | 3.6 | 7.2 | 4.3 | 1.0 | m |
| 10 | 3.7 | 3.3 | 7.0 | 4.2 | 1.1 | m |
| 11 | 3.6 | 3.4 | 7.0 | 4.2 | 1.1 | m |
| 12 | 3.5 | 3.4 | 6.9 | 4.1 | 1.0 | m |
| 13 | 3.6 | 3.3 | 6.9 | 4.1 | 1.1 | m |
| 14 | 3.4 | 3.4 | 6.8 | 4.1 | 1.0 | m |
| 15 | 4.2 | 2.6 | 6.8 | 4.1 | 1.6 | msm |
| 16 | 4.2 | 2.6 | 6.8 | 4.1 | 1.6 | msm |
| 17 | 4.0 | 2.6 | 6.6 | 4.0 | 1.5 | msm |
| 18 | 4.0 | 2.6 | 6.6 | 4.0 | 1.5 | msm |
| 19 | 3.3 | 3.3 | 6.6 | 4.0 | 1.0 | m |
| 20 | 3.0 | 3.0 | 6.0 | 3.6 | 1.0 | m |
| 21 | 2.9 | 0.2+2.2 | 5.3 | 3.2 | 1.2 | m |
| 22 | 2.8 | 0.2+2.1 | 5.1 | 3.1 | 1.2 | m |

Table 11. Measurements of somatic chromosomes of *Metasequoia glyptostroboides*, $2n=22$ at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 5.9 | 5.2 | 11.1 | 6.1 | 1.1 | m |
| 2 | 5.7 | 4.8 | 10.5 | 5.8 | 1.2 | m |
| 3 | 5.3 | 4.8 | 10.1 | 5.5 | 1.1 | m |
| 4 | 5.1 | 4.7 | 9.8 | 5.4 | 1.1 | m |
| 5 | 5.2 | 4.5 | 9.7 | 5.3 | 1.2 | m |
| 6 | 5.1 | 4.3 | 9.4 | 5.1 | 1.2 | m |
| 7 | 5.1 | 3.7 | 8.8 | 4.8 | 1.4 | msm |
| 8 | 5.1 | 3.7 | 8.8 | 4.8 | 1.4 | msm |
| 9 | 5.3 | 3.5 | 8.8 | 4.8 | 1.5 | msm |
| 10 | 5.3 | 3.5 | 8.8 | 4.8 | 1.5 | msm |
| 11 | 4.7 | 3.4 | 8.1 | 4.4 | 1.4 | msm |
| 12 | 4.1 | 4.0 | 8.1 | 4.4 | 1.0 | m |
| 13 | 4.1 | 3.9 | 8.0 | 4.4 | 1.1 | m |
| 14 | 4.1 | 3.8 | 7.9 | 4.3 | 1.1 | m |
| 15 | 4.3 | 3.6* | 7.9 | 4.3 | 1.2 | m |
| 16 | 4.2 | 3.3* | 7.5 | 4.1 | 1.3 | m |
| 17 | 3.9 | 3.4* | 7.3 | 4.0 | 1.2 | m |
| 18 | 3.8 | 3.4* | 7.2 | 3.9 | 1.1 | m |
| 19 | 3.9 | 3.2* | 7.1 | 3.9 | 1.2 | m |
| 20 | 3.6 | 3.5* | 7.1 | 3.9 | 1.0 | m |
| 21 | 3.1 | 2.4 | 5.5 | 3.0 | 1.3 | m |
| 22 | 2.7 | 2.3 | 5.0 | 2.7 | 1.2 | m |

*: with secondary constriction at the proximal region.

Table 12. Measurements of somatic chromosomes of *Sciadopitys verticillata*, $2n=20$ at metaphase

| Chromosome | Long arm length (μm) | Short arm length (μm) | Total length (μm) | Relative length (%) | Arm ratio | Form |
|------------|-----------------------------------|------------------------------------|--------------------------------|---------------------|-----------|------|
| 1 | 8.4 | 7.5 | 15.9 | 7.1 | 1.1 | m |
| 2 | 8.0 | 7.8 | 15.8 | 6.9 | 1.0 | m |
| 3 | 6.6 | 6.4 | 13.0 | 5.7 | 1.0 | m |
| 4 | 6.3 | 6.3 | 12.6 | 5.5 | 1.0 | m |
| 5 | 6.3 | 6.1 | 12.4 | 5.5 | 1.0 | m |
| 6 | 6.8 | 5.5 | 12.3 | 5.4 | 1.2 | m |
| 7 | 6.1 | 5.9 | 12.0 | 5.3 | 1.0 | m |
| 8 | 6.3 | 5.7 | 12.0 | 5.3 | 1.1 | m |
| 9 | 5.2+2.0 | 4.8 | 12.0 | 5.3 | 1.5 | msm |
| 10 | 5.4+1.4 | 5.1 | 12.0 | 5.3 | 1.3 | msm |
| 11 | 5.5 | 5.3 | 10.8 | 4.7 | 1.0 | m |
| 12 | 5.9 | 4.6 | 10.5 | 4.6 | 1.3 | m |
| 13 | 6.1 | 4.2 | 10.3 | 4.5 | 1.5 | msm |
| 14 | 5.6 | 4.7 | 10.3 | 4.5 | 1.2 | m |
| 15 | 5.2 | 5.0 | 10.2 | 4.5 | 1.0 | m |
| 16 | 5.3 | 4.7 | 10.0 | 4.4 | 1.1 | m |
| 17 | 5.3 | 4.4 | 9.7 | 4.3 | 1.2 | m |
| 18 | 4.5 | 4.3 | 8.8 | 3.9 | 1.1 | m |
| 19 | 4.4 | 4.2 | 8.6 | 3.8 | 1.1 | m |
| 20 | 4.2 | 4.0 | 8.2 | 3.6 | 1.1 | m |