A cytotaxonomical study on the tribe Ophiopogoneae in Korea

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韓國産 麥冬亞傘属(Ophiopogoneae)의 細胞分類學的研究

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Abstract

5 taxa of genus Liriope and Ophiopogon under tribe Ophiopogoneae in Korea were examined cytologically together with some morphological and geographical characters in order to solve their affinity and phylogeny.

Judging from the basic chromosome number, \( x = 18 \), L. spicata is hexaploid as \( 2n = 108 \), L. platyphylla, O. japonicus and O. japonicus var. umbrosus tetraploid as \( 2n = 72 \), and O. jaburan diploid as \( 2n = 36 \). From the viewpoint of morphology, and their same basic number and karyotypes genus Liriope and Ophiopogon may be derived from an ancestor through structural changes of chromosomes, and each species seems to have been mainly evolved through polyploidy instead of structural changes of chromosomes within each genus. In addition, O. japonicus var. umbrosus and L. spicata seem to be the most cytologically advanced taxa in each genus, and it appears that each genus shows a trend of phylogenetic decrease in chromosome size in the more advanced taxa. The taxa which are farther distributed to the north may have tendencies to have high levels of ploidy, and to become dwarfish in all of their morphological characters. These phenomena are thought to result from the adaptation to environment.
Introduction

Tribe Ophiopogonaceae under subfamily Ophiopogonoideae of family Liliaceae consists of genus *Liriope* (L.), *Ophiopogon* (O.) and *Pelisanthes*, and 18 species in the tribe have been known in the world (Engler, 1964). They range mainly from the subtropical zones to the temperate zones of Indochina and East Asia, but there are only 2 genera of *Liriope* and *Ophiopogon* in Korea.

In Korean Ophiopogoneae after that Palibin(1901) published *Mondo Koreana* (L. *spicata*; Ohwi, 1953, 1972) for the first time, Nakai(1911) reported 2 species and 2 varieties of *L. graminifolia* (L. *platyphylla*; Makino, 1969), *L. graminifolia var. densiflora* (L. *platyphylla*; Wang and Tang, 1951), *L. spicata var. koreana* (L. *spicata*; Ohwi, 1953, 1972) and *O. japonicus*. Finally he (1952) rearranged in 2 species of *L. koreana* (L. *spicata*; Ohwi, 1953, 1972) and *L. muscari* (L. *platyphylla*; Wang and Tang, 1951) in *Liriope* and 4 species of *M. jaburan*, *M. japonicum*, *M. gracile* and *M. taquetii* in *Mondo* (Ophiopogon); Nakai, 1952). In addition, Korean Ophiopogoneae were so far reported by Mori(1921), Lee, Y. N.(1976) and Lee, T. B. (1979) for 4 species of *L. platyphylla*, *L. spicata*, *O. japonicus* and *O. jaburan*. Chung (1957) added 1 variety of *M. japonicus var. umbrosus* to the above 4 species, and Park and Park (1972), Kitamura et al. (1980) and so forth *L. minor* again. In the present study 5 taxa of *L. platyphylla*, *L. spicata*, *O. jaburan*, *O. japonicus*, and *O. japonicus var. umbrosus* in Korea were treated.

Cytological study on this tribe has been progressed by Matsuura and Suto(1935), Satô(1942, 1953), Oinuma(1949), Westfall(1950) and Sharma and Chaudhuri(1964) using the plants of *L. koreana* (L. *spicata*), *L. minor*, *L. muscari* (L. *platyphylla*), *O. jaburan* and *O. japonicus* in China, Japan and India. Their results were limited to the examination of chromosome number, and karyotype analysis has been partially studied. But Korean samples, to say nothing of *O. japonicus var. umbrosus* have never been cytotaxonomically examined yet. Especially, in this tribe polyploidy prominently appears in accordance with the different taxa and the different localities (Satô, 1942; Oinuma, 1949; etc.). This phenomenon is thought to be very important and interesting from the standpoint of the speciation. In the present study the above-mentioned 5 taxa were examined cytologically together with some morphological and geographical characters in order to solve their affinity and phylogeny.

Materials and Methods

Experimental plants which were collected in the field from April 1982 to August 1983 (Table 1) and planted at the seedbed and greenhouse of Hannam University were used on their complete growth. Examined individuals were prepared into the voucher specimens, which were preserved in the Natural Museum of Hannam University.

The chromosomes from root tips were observed following the method of Ko and Kim (1985). Well-dispersed chromosome sets of metaphase in mitosis were chosen for the analysis of
Table 1. Materials and Localities

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Localities</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L. spicata</em></td>
<td>Is. Wando, Mt. Halla, Mt. Geryong</td>
</tr>
<tr>
<td></td>
<td>Mt. Daedun.</td>
</tr>
<tr>
<td><em>L. platyphylla</em></td>
<td>Is. Wando, Mt. Halla</td>
</tr>
<tr>
<td></td>
<td>Mt. Daedun.</td>
</tr>
<tr>
<td><em>O. japonicus</em></td>
<td>Is. Wando, Mt. Halla</td>
</tr>
<tr>
<td></td>
<td>Mt. Daedun.</td>
</tr>
<tr>
<td><em>O. japonicus var. umbrosus</em></td>
<td>Mt. Halla</td>
</tr>
<tr>
<td><em>O. jaburan</em></td>
<td>Mt. Halla</td>
</tr>
</tbody>
</table>

Chromosomal morphology, and their length was calculated with standardized scale improvised for the purpose. Chromosomes were classified into Long(L, 1.18 and more), Medium (M, 1.17-0.70), and Short(S, 0.69 and less) on the basis of relative length. Arm ratio and centromeric indices as metacentric(m, 1.00-1.70), submetacentric(sm, 1.71-3.00) and subtelocentric(st, 3.01-7.00) were adopted from the method of Leven et al. (1964), and secondary constriction was inscribed as SC.

Morphological characteristics were observed in the plants which had grown up enough to identify accurately.

**Observation and Results**

Chromosomes of the examined 5 taxa of Korean Ophiopogonae ranged from 8.64 microns to 1.08 microns in length. They are classified into Long(L.), Medium(M.) and Short(S.) on the basis of Relative Length(RL.), and then diverse karyotypes could be described as stated below.

**Type**

Long (1.18 and more)

- **Type A.** Metacentric chromosome.
- **Type A'.** Metacentric chromosome with secondary constriction.
- **Type B.** Submetacentric chromosome
- **Type B'.** Submetacentric chromosome with secondary constriction.
- **Type C.** Subtelocentric chromosome.
- **Type C'.** Subtelocentric chromosome with secondary constriction.
  - Medium (1.17 — 0.70)
- **Type D.** Metacentric chromosome.
Type E. Submetacentric chromosome.
Type F. Subtelocentric chromosome.
    Short (0.69 and less)
Type G. Metacentric chromosome.
Type H. Submetacentric chromosome.

Details of chromosome characteristics of each taxon are given together with table 2.

1) _L. spicata_
Voucher specimen: Jeju Aewol (Kim, Y. O. Jun. 19, 1983).

\[ 2n = 108 = 3(18) \text{ L } + 12(72) \text{ M } + 3(18) \text{ S } = A_{8}^{m} + B_{12}^{m} + D_{36}^{m} + E_{30}^{m} + G_{18}^{m} \] (Fig. 6).

2) _L. platyphylla_

\[ 2n = 72 = 4(16) \text{ L } + 12(48) \text{ M } + 2(8) \text{ S } = A_{4}^{m} + B_{8}^{m} + C_{10}^{m} + D_{36}^{m} + E_{12}^{m} + G_{12}^{m} \] (Fig. 7).

3) _O. japonicus_

\[ 2n = 72 = 4(16) \text{ L } + 11(44) \text{ M } + 3(12) \text{ S } = A_{2}^{m} + B_{4}^{m} + C_{10}^{m} + D_{30}^{m} + E_{20}^{m} + E_{12}^{m} + G_{12}^{m} \] (Fig. 8).

4) _O. japonicus_ var. _umbrosus_
Voucher specimen: Jeju Haga (Kim, Y. O. Jun. 18, 1983).

\[ 2n = 72 = 4(16) \text{ L } + 11(44) \text{ M } + 3(12) \text{ S } = A_{2}^{m} + B_{3}^{m} + C_{12}^{m} + C_{20}^{m} + C_{12}^{m} + D_{30}^{m} + E_{20}^{m} + F_{4}^{m} + G_{12}^{m} \] (Fig. 9).

5) _O. jaburan_

\[ 2n = 36 = 5(10) \text{ L } + 12(24) \text{ M } + 1(2) \text{ S } = A_{2}^{m} + B_{2}^{m} + C_{4}^{m} + C_{20}^{m} + D_{10}^{m} + E_{12}^{m} + F_{4}^{m} + H_{2}^{m} \] (Fig. 10).

Table 2. Summarized karyo-morphological features of the taxa investigated here.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Chromosome (chr.) no.</th>
<th>Size range (μ)</th>
<th>Metacentric chr. no.</th>
<th>Submetacentric chr. no.</th>
<th>Submetacentric chr. no.</th>
<th>SC. chr. no.</th>
<th>Average length (μ)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L. spicata</em></td>
<td>108</td>
<td>1.08-1.93</td>
<td>11(66)</td>
<td>7(42)</td>
<td>—</td>
<td>6</td>
<td>2.13</td>
</tr>
<tr>
<td><em>L. platyphylla</em></td>
<td>72</td>
<td>1.19-5.22</td>
<td>12(48)</td>
<td>5(20)</td>
<td>1(4)</td>
<td>4</td>
<td>2.61</td>
</tr>
<tr>
<td><em>O. japonicus</em></td>
<td>72</td>
<td>1.44-6.92</td>
<td>8(32+2)</td>
<td>7(28)</td>
<td>2(8+2)</td>
<td>4</td>
<td>2.99</td>
</tr>
<tr>
<td><em>O. japonicus</em> var. <em>umbrosus</em></td>
<td>72</td>
<td>1.36-5.98</td>
<td>7(28+2)</td>
<td>3(12)</td>
<td>—</td>
<td>4</td>
<td>2.24</td>
</tr>
<tr>
<td><em>O. jaburan</em></td>
<td>36</td>
<td>2.99-8.64</td>
<td>6(12)</td>
<td>8(16)</td>
<td>4(8)</td>
<td>2</td>
<td>4.45</td>
</tr>
</tbody>
</table>
Discussion

Of the treated 5 taxa of Korean Ophiopogoneae the somatic chromosome numbers of 4 taxa were already found by using the materials of foreign growth but the number of *O. japonicus* var. *umbrosus* has not been examined (Table 3).

Table 3. Chromosome numbers of tribe *Ophiopogoneae*

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Present result (2n)</th>
<th>Previous reports (2n)</th>
<th>Localities &amp; Habitats</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L. spicata</em></td>
<td>108</td>
<td>108 Satô (1942)</td>
<td>Japan</td>
</tr>
<tr>
<td><em>L. platyphylla</em></td>
<td>72</td>
<td>72 Westfall (1950)</td>
<td>China</td>
</tr>
<tr>
<td></td>
<td></td>
<td>72 Oinuma (1949)</td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>108</td>
<td></td>
</tr>
<tr>
<td><em>O. japonicus</em></td>
<td>72</td>
<td>36 Satô (1942)</td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>72</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>72 Shrma and Chandhuri (1964)</td>
<td>India</td>
</tr>
<tr>
<td><em>O. japonicus</em> var.</td>
<td>72</td>
<td>36 Matsuura and Suto (1935)</td>
<td>Japan</td>
</tr>
<tr>
<td><em>umbrosus</em></td>
<td></td>
<td>36 Satô (1953)</td>
<td></td>
</tr>
<tr>
<td><em>O. jaburan</em></td>
<td>36</td>
<td>36 Matsuura and Suto (1935)</td>
<td>Japan</td>
</tr>
</tbody>
</table>

Satô (1942) who used Japanese plant illustrated the chromosome number of *L. spicata* as $2n = 108$ like the result of authors (Fig. 1). Judging from the basic chromosome number of *Liriope* and *Ophiopogon*, or $x = 18$ (Darlington and Wylie, 1955; Fedorov, 1969), this species seems to be hexaploid.

In *L. platyphylla* chromosome number, $2n = 72$ (Fig. 2) is correspondent with the results from Japanese species by Oinuma (1949) and Chinese one by Westfall (1950) but the report of $2n = 108$ by Oinuma (1949) was not observed in this study. *L. spicata* and *L. platyphylla* are mainly classified by the length of scape, the fasciculated degree, the presence of stolen root, the length and width of leaf and so forth as key characters but in practice the fasciculated degree and the width of leaf, which Ohwi (1953, 1972) chose as key characters, that is, 4-7 mm. for *L. spicata* and 8-12 mm. for *L. platyphylla* do not indicate the distinct discontinuity between them as shown in fig. 11. Therefore about the result of $2n = 108$ the possibility of mistake on identification of other species can not be excluded at all, and if it should be true, the plant will have to be recognized as a new taxon cytologically.

Chromosome number of *O. japonicus*, $2n = 72$ (Fig. 3) is congruent with the results of Sharma and Chaudhuri (1964) and Satô (1942), who also reported $2n = 36$ using Japanese samples at the same time. These plants are thought to be diploidy, and together with their
localities to be importantly dealt with from the viewpoint of speciation.

*O. japonicus* var. *umbrosus* is explicitly different from the elementary species in the length of leaf (Fig. 12) and pedicel (Kitamura et al., 1980). Its chromosome number was found as 2n = 72, tetraploidy, in the present study for the first time (Fig. 4).

In *O. jaburan* it is agreed to the present result (Fig. 5) that taxonomists such as Suto (1935) and Satô (1953) refered to 2n = 36 or diploidy, in Japanese species.

In general the tribe Ophiopogoneae is divided into genus *Liriope* and *Ophiopogon* on the basis of ovary position, alternatively superior ovary for *Liriope* and semi-inferior ovary for *Ophiopogon* (Hutchinson, 1959). Most taxonomists like Bessey (1915) and Cronquist (1968) and so on regarded partly inferior ovary as an intermediate from hypogyny to epigyny. Also, from the cytotaxonomical viewpoint all chromosomes of *Liriope* are symmetrical except 1 pair of subtelocentric chromosomes (type C) in *L. platyphylla* (Fig. 6, 7) but the constituents of *Ophiopogon* have 3 or 4 pairs of asymmetrical chromosomes (Table 2). Kim (1975), Mehra
and Sachdeva (1976), and Ko and Kim (1985) looked upon all of the nearly symmetrical chromosomes as a primitive character in the evolution. Accordingly *Liriope* may be more primitive than *Ophiopogon* from the morphological and cytological points of view, and they may be derived from the common ancestor presuming from their same basic chromosome number, $x = 18$.

Within the genus *Liriope*, *L. spicata* is distributed in the subtropical and the temperate zones of Japan, China, Formosa, Indochina and Korea, where it extends to Pyungnam Province, and *L. platyphylla* in the warm temperate zones of Japan, China, Formosa and Korea, where it to Kangwon Province (Chung, 1957). Therefore the former ranges more widely farther up north than the latter.

In addition, while *L. spicata* is hexaploidy as $2n = 108$, *L. platyphylla* tetraploidy as $2n = 72$. As karyotypes of both species are compared, almost chromosomes are symmetrical except 1 pair of chromosomes (type C) in *L. platyphylla* (Table 2). But both species show the dif-
ferences in the average length of chromosome, alternatively *L. spicata*, 2.13 microns and *L. platyphylla*, 2.61 microns (Table 2). Swanson et al. (1981) said that the more primitive groups have larger chromosomes than the more advanced ones in the monocots. Putting the aforementioned characters together, it appears that *L. spicata* is more advanced than *L. platyphylla*.

Besides, morphological characters of *L. spicata* such as the width and length of leaf, the number of leaf veins, the length of pedicels, the number of flowers in each fascicle, the size of seeds and so on are more or less smaller than those of *L. platyphylla* (Ohwi, 1953; Makino, 1969; Lee, 1979; Kitamura et al., 1980; Satake et al., 1982). The reason why *L. spicata* has a tendency to show dwarfism in the above characters together with polyploidy may result from the adaption to environment of the northern parts.

*O. jaburan* is distributed in the subtropical and the warm temperate zones such as the southern parts of Korea and Japan but *O. japonicus* in the subtropical, and the warm and cool temperature zones such as Korea, Japan and China, and *O. japonicus* var. *umbrosus* in the subtropical and the temperate zones such as Korea, Japan and China (Kitamura et al., 1980). Hence *O. jaburan* is distributed farther down south than the other 2 taxa.

From the cytological viewpoint karyotype of *O. jaburan*, diploidy (Fig. 10), consists of 5 pairs of L, 12 pairs of M and 1 pair of S, while *O. japonicus* and *O. japonicus* var. *umbrosus*, both tetraploidy, of 4 pairs of L, 11 pairs of M and 3 pairs of S. Accordingly, it is thought of an appropriate that genus *Ophiopogon* is treated with group I of *O. jaburan*, and group II of *O. japonicus* and *O. japonicus* var. *umbrosus* seperately. In addition, 3 taxa did not show so much distinct differences in their karyotypes based on the position of centromere (Table 2). But it is very particular and interesting for *O. japonicus* var. *umbrosus* to have chromosomal types of A and C, and A and B, 2 chromosomes in each type, between the chromosomes from number 1 to number 4, respectively (Figs. 8, 9). From this fact the likelihood for aneuploids may not be excluded at all and will have to be further studied. As a result, the group I of *O. jaburan* may be more primitive than the group II of *O. japonicus* from such respects as the average length of chromosome (Table 2), geography and polyploidy.

In the morphological characters like the numbers of leaf veins, the length of pedicels, the size of seeds and so forth (Ohwi, 1953; Makino, 1969; Lee, 1979; Kitamura et al., 1980; Satake et al., 1982) *Ophiopogon* tends to show dwarfism in accordance with polyploidy as aforementioned in *Liriope*.

Within the group II of *Ophiopogon*, *O. japonicus* is distributed from Quelpart Island to Kyungki Province while *O. japonicus* var. *umbrosus* from Quelpart Island to Kochang County, Junbuk Province (Chung, 1957). Consequently the latter ranges farther down south than the former. Cytologically, both taxa, tetraploidy have the same karyotype on the basis of relative length of chromosomes, and also the nearly similar distribution of symmetrical and asymmetrical chromosomes (Figs. 8, 9), from which they exhibit very close relationship.
But the average length of chromosomes of *O. japonicus* var. *umbrosus* is the shortest of the 3 taxa of *Ophiopogon* as 2.24 microns (Table 2), and the distributional area of *O. japonicus* var. *umbrosus* is more limited than that of the elementary spieces. Hence, the former may be more advanced than the latter cytologically and geographically.

As a whole, it is apparent that the structural changes of chromosomes played an important role in the differentiation of tribe Ophiopogoneae into the genera of *Liriope* and *Ophiopogon* at the early stage of its evolution, and that the polyploidy instead of the structural changes of chromosomes has an effect on the evolution of each genus.

**References**


Explanation of Plates

Plate 1. Photomicrographs of the somatic chromosomes

Fig. 1. L. spicata
2. L. platyphylla
3. O. japonicus
4. O. japonicus var. umbrosus
5. O. jaburan

Plate 2-4. Karyotypes of somatic chromosomes

Fig. 6. L. spicata
7. L. platyphylla
8. O. japonicus
9. O. japonicus var. umbrosus
10. O. jaburan
Plate 1
Plate 3