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Cytotaxonomical problems in the Asiatic flora

Hiroshi Hara

(Department of Botany, Tokyo Univeristy)

It is my utmost pleasure to have a chance to speak in this symposium. Today I am going to talk about some cytotaxonomical problems mostly based on the data on the Asiatic plants. History of cytotaxonomy is not very old, and it started about 50 years ago.

In Japan, Prof. N. Shimotomai has published a paper in 1933 on chromosome number and distribution of the genus *Chrysanthemum*, and it is considered not only as a pioneer work in this field but also as one of the finest example of polyploidy in flowering plants. About 15 species of *Chrysanthemum* in a wide sense are growing wild in Japan, and they form a complete series of polyploids from diploid to decaploid with the basic number of 9. It is noteworthy that all octaploids and decaploids are coastal plants, although one diploid, *C. nipponicum* also occurs on the coast. A famous Japanese flowering *Chrysanthemum*, *C. morifolium* Hemsl., is now considered to have been derived from a hybrid between *C. indicum* L. and *C. zawadskii* Herbach var. *latilobum* (Maxim.) Kitamura, and has generally $2n = 54$ chromosomes (hexaploid).

From these examples, it is clear that polyploidy plays an important role in differentiation of species. However, problems in cytotaxonomy are not always so simple as in this case, and, as is usual in biology, generalization based on a few examples is difficult and often even dangerous. I wish to show you various interesting examples, sometimes even unexpected examples regarding cytotaxonomical problems mostly based on my data gathered during these 30 years.

Even in woody plants, polyploidy often plays an important role in differentiation. The first example is the genus *Aucuba* (Cornaceae) endemic to temperate Asia. As shown in Table 1, all taxa found in continental Asia are diploid, and *Aucuba* has differentiated there at diploid level, and diploid *A. japonica* seems to have spread eastwards to Japan. Then tetraploid *A. japonica* including var. *borealis* have differentiated in Japan extending their distributions northwards to SW. Hokkaido. It is said that polyploids often have a wider range of tolerance as compared with diploids. Tetraploid *A. japonica* var. *japonica* is surely much more vigorous than any other diploid taxa of *Aucuba*, and is more hardy in winter. As you know well, this tetraploid *A. japonica* is now widely cultivated also in Europe and North America, and grows well even in shady places or in a pot, and is easily propagated by cutting. I will tell you an episode. When I first visited Himalayan mountains in 1960, I saw *Aucuba*

Table. 1. *Aucuba* species with chromosome number and distribution.

Species	2n	Distribution
<i>Aucuba japonica</i> Thunb.		
var. <i>japonica</i>	32	Honshu, E. Shikoku
var. <i>borealis</i> Miy. et Kudo	32	SW. Hokkaido, Japan-Sea side of Honshu
var. <i>ovoidea</i> Koidzumi	16	W. Honshu, Shikoku, Kyushu, S. Korea
var. <i>australis</i> Hara et Kurosawa	16	Amami-Oshima, Ryukyu
<i>A. chinensis</i> Benth.	16	Taiwan, China
<i>A. omeiensis</i> Fang	16	W. China
<i>A. eriobotriaefolia</i> Wang	16	W. China
<i>A. himalaica</i> Hook. f et Thoms.	16	Himalaya, W. China.

planted in hedge in Botanic Garden of Darjeeling, and at once thought that the plants must be *A. himalaica*. But the curator of the Botanic Garden told me that the plants in hedge is nothing but *A. japonica* from Japan, and it is difficult to cultivate *A. himalaica* even at Darjeeling, and he showed me a single tree of *A. himalaica* carefully planted in rock garden.

Another similar example is *Helwingia* (Araliaceae) also endemic to temperate Asia. The genus is conspicuous in having flowers in the centre of leaves, and is sometimes referred to Cornaceae or sometimes treated as an independent family, Helwingiaceae. *Helwingia himalaica* Hook. f. et Thoms. of Himalayas and W. China was proved to be diploid with $2n = 38$ chromosomes, and bears red fruits. *Helwingia chinensis* Batalin also has resulted in red fruits. While *H. japonica* (Thunb.) F. G. Dietrich var. *japonica* of Japan is high polyploid with $2n = 114$ chromosomes, and bears black fruits. *H. japonica* var. *parvifolia* Makino distributed mostly on the Pacific side of Japan has $2n = 38$ chromosomes, and there occurs also a race with $2n = 76$ chromosomes. *H. japonica* subsp. *liukiensis* (Hatusima) Hara et Kurosawa and subsp. *formosana* (Kanahira et Sasaki) Hara et Kurosawa are both diploid, and also *H. japonica* var. *hypoleuca* Hemsl. ex Rehder from Central China is diploid. Also in China there occur a few other races of *H. japonica*.

The genus *Duchesnea* (Rosaceae) with strawberry-like fruits and yellow flowers includes two species. *Duchesnea indica* (Andr.) Focke is distributed from Himalayas to Japan. It is weedy, and has bright red glossy fruiting receptacle and almost smooth achenes, and is high polyploid with $2n = 84$ chromosomes (Fig. 1b). Whereas *D. chrysantha* (Zoll. et Moritz.) Miq. from Indo-China, Japan and Malaysia has pinkish white fruiting receptacle and distinctly rugose achenes, and is diploid with $2n = 14$ chromosomes (Fig. 1a). Very rarely a natural hybrid between these two species is observed in Japan. An European botanist has once suggested that *Duchesnea indica* may be derived from *Potentilla* by polyploidy, but such a hypothesis cannot be held because we now know a diploid *Duchesnea*.

Rosa rugosa Thunb. characteristic to the coast of northern East Asia is diploid with $2n = 14$ chromosomes. *R. nipponensis* Crepin closely resembling *R. rugosa* is growing in subalpine region of Honshu and Shikoku, and is also diploid. While closely allied *R.*

Duchesnea

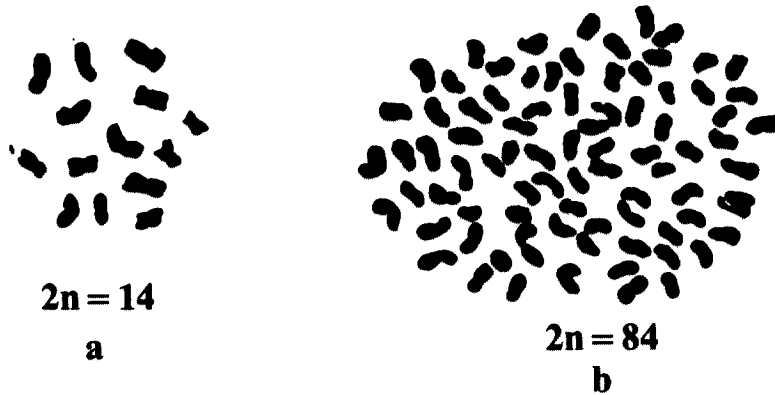


Fig. 1. Somatic chromosomes of *Duchesnea chrysantha* (a), and *D. indica* (b).

acicularis Lindley widely distributed from Europe, Siberia, N. China, Korea, Japan and Alaska is octaploid with $2n = 56$ chromosomes, and its subsp. *sayi* (Schw.) Lewis of North America is hexaploid with $2n = 42$ chromosomes.

In Korea and Japan with rich temperate flora, both diploids and polyploids are frequently found from coast to alpine region. But in some cases polyploids are recorded only in Japan. For example, *Adoxa moschatellina* L. is widely distributed in Europe, temperate Asia, and North America, and its chromosome number has been reported always as $2n = 36$ in Europe, Siberia, and North America. But in Japan the plants with $2n = 54$ (or 45) chromosomes have been recorded from Hokkaido and Honshu several times.

In some plant groups, polyploidy seems to be correlated with some particular characters. *Ranunculus acris* L., although variable, is widely distributed from Europe, Siberia, east to alpine region of Japan, and its allied species, *R. japonica* Thunb. occurs commonly in E. Siberia, China, Korea, and Japan. These species are consistently diploid with $2n = 16$ chromosomes. But in Japan are found 4 races with 28 or 42 somatic chromosomes which can be referred to *R. grandis* Honda. It is noteworthy that these races occur in northern coastal regions, and also sporadically in northern and central parts of Honshu, and all of them have long creeping stolons, while *R. acris* and *R. japonicus* have never stolon.

Anemone Hepatica L. in a wide sense is widely distributed in Europe, Asia, and North America, Except for Japan, it has always been reported to be diploid with $2n = 14$ chromosomes, and has tricolpate pollen grains. *Anemone Hepatica* var. *pubescens* Hiroe found scatteredly in western Honshu and Shikoku has leaves hairy on both sides, $2n = 28$ chromosomes, and polyrugate pollen grain. This is a remarkable example that polyploidy seems to be related with the pattern of pollen grains (Fig. 2). *Anemone maxima* Nakai endemic to the East Sea (Japan-Sea) side of Korea has very large leaves and large flowers and fruits, but is diploid.

In the genus *Agrimonia* (Rosaceae), tetraploids and octaploids have been recorded in

Fig. 2. Pollen grains of *Anemone Hepatica* var. *japonica* (Nakai) Ohwi (a), and var. *pubescens* Hiroe (b).

East Asia as shown in Table 2. In these examples, the size of pollen grains shows no remarkable difference between tetraploid and octaploid races. However, it is striking that polyploidy seems to be correlated with the type of crystal of calcium oxalate in leaf-tissue. The crystal of calcium oxalate of tetraploid is solitary, while that of octaploid is clustered.

Table 2. Asiatic species of *Agrimonia* and chromosome number.

Species	2n	Distribution
<i>Agrimonia nipponica</i> Koidzumi	28	Japan, Quelpaert
<i>A. coreana</i> Nakai	28	Ussuri, N. China, Korea, Japan
<i>A. pilosa</i> Ledeb.		
subsp. <i>pilosa</i>	28	E. Europe, Siberia, N. China
subsp. <i>japonica</i> (Miq.) Hara	56	Indo-China, China, Ussuri, Korea, Japan
var. <i>nepalensis</i> (D. Don) Nakai	56	Himalaya, Indo-China, China

The genus *Panax* (Araliaceae) includes *P. Ginseng* C. A. Meyer which tuberous roots are highly esteemed drugs. *P. Ginseng* has $2n = 48$ (44) chromosomes, and its roots contain sapogenins consisting of a large quantity of dammarane-type triterpenes. While *P. pseudoginseng* Wallich of Nepal has carrot-like roots, stipules at the base of petioles, large flattish seeds, and $2n = 24$ chromosomes, but contains only a trace of dammarane, and a large quantity of oleanane-type triterpenes. Its subsp. *himalaicus* Hara of Himalayas, N. Burma, Tibet, and China has generally long-creeping rhizomes with subglobose nodes, and $2n = 24$ chromosomes, and contains oleanane-type triterpenes. While its subsp. *japonica* (Meyer) Hara of Japan has thick creeping rhizomes, ovoid seeds, $2n = 48$ chromosomes, and oleanane-type triterpenes.

The *Rubia cordifolia* group includes several distinct races, although often treated as a single species. As schematically shown in Fig. 2. The Himalayan plants are clearly separated from the others by the mode of germination, and they have epigeal cotyledons. Whereas

in *R. cordifolia* L. in the strict sense and *R. Argyi* (Lév.) Hara (*R. Akane* Nakai), the cotyledons remain underground enclosed in the seed coat. It is interesting that polyploids are observed in both types of germination independently.

Besides polyploidy, aneuploidy (dysploidy) is sometimes observed in some plant groups. The genus *Chionographis* (Liliaceae) endemic to East Asia includes two Japanese species, *C. japonica* (Willd.) Maxim. and *C. Koidzumiana* Ohwi. *Chionographis japonica* is distributed in Japan from Central Honshu, Shikoku, and Kyushu, and Quelpaert, and has $2n=24$ chromosomes. But near the north-eastern border of its distribution 3 races with $2n=42$ or 44 chromosomes have been found.

Its subsp. *minoensis* Hara and subsp. *Hisauchiana* (Okuyama) Hara with 42 somatic chromosomes are smaller in size than subsp. *japonica*, and grow in very limited area. Their

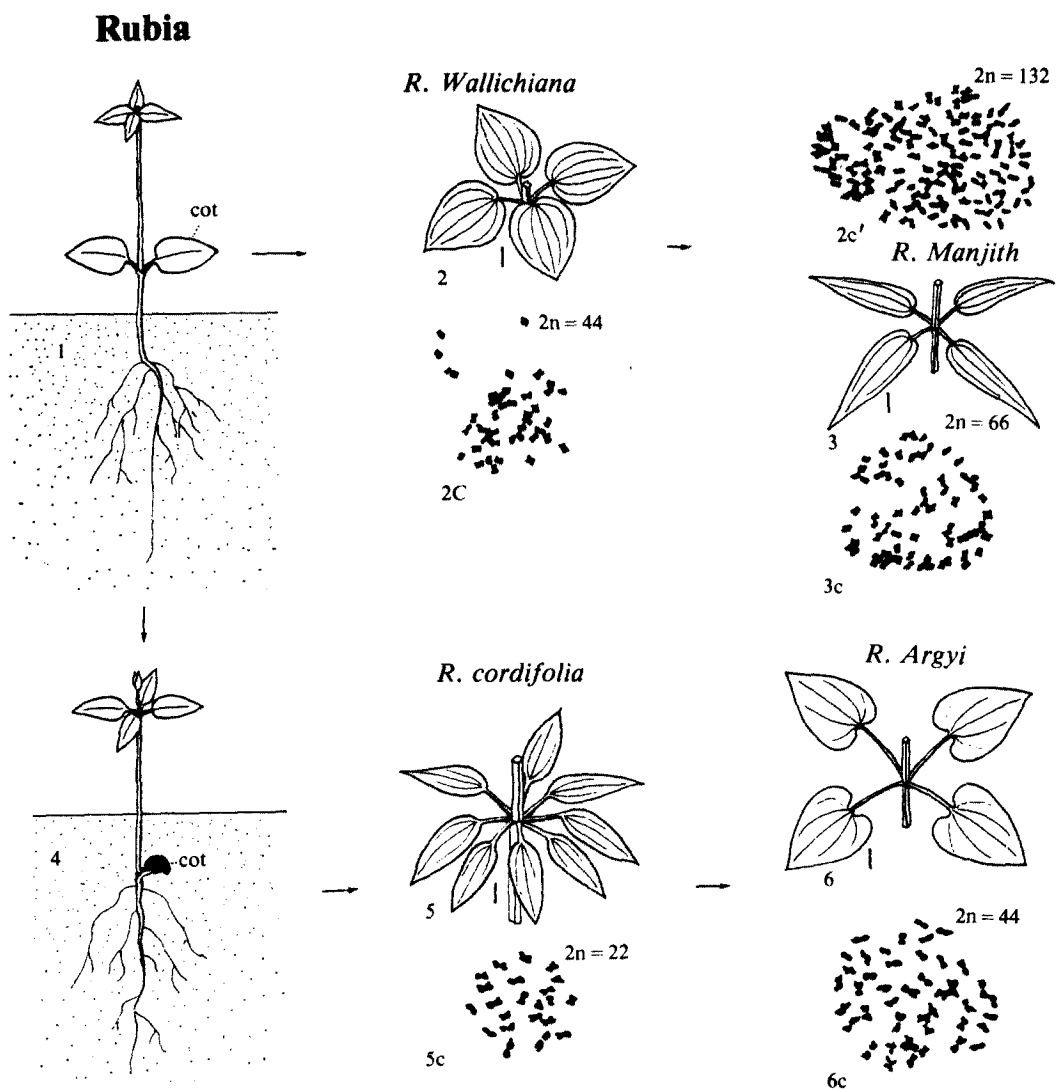


Fig. 3. Diagram showing interrelationships of species in the *Rubia cordifolia* group.

reduction division are regular (Fig 4, a & b), and its pollen grains are normal, and fertile seeds are produced freely. Possibly they are amphiploids of old origin, and $n=21$ can be considered to have been established as the secondary basic number.

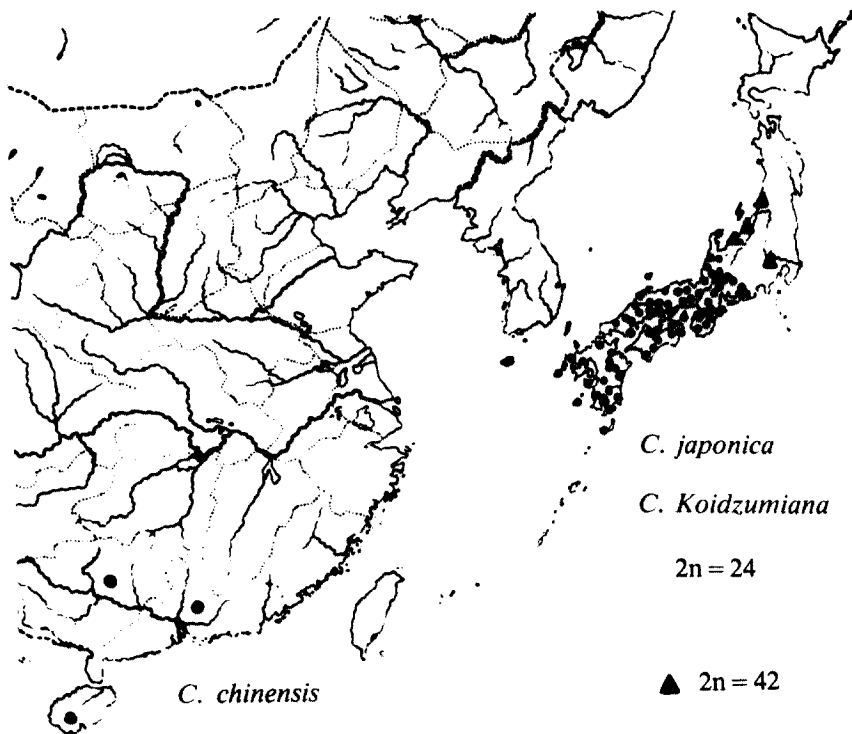


Fig. 4. *Chionographis*. Gametic chromosomes of *C. japonica* subsp. *japonica* (a), and subsp. *minoensis* (b), and the distribution map.

Chelidonium majus L. subsp. *majus* (Papaveraceae) is distributed from Europe and Siberia east to Dahuria, and has $2n = 12$ chromosomes. Its subsp. *asiaticum* Hara occurs in Ochotsk, China, Korea, and Japan, and has $2n = 10$ chromosomes. Its 10 chromosomes form a ring at maturity division, the pollens are 70% sterile, and the ovules are 80% abortive, so can be considered as a structural hybrid.

In the genus *Carex* (Cyperaceae) aneuploidy is commonly observed in the Asiatic species. More complicated case of polyploidy and aneuploidy was fully studied in *Scilla scilloides* (Lindl.) Druce (Liliaceae). In Japan, the following cytotypes have been recorded: $2n = 18$ (BB), 26 (ABB), 27 (BBB), 33, 34 (AABB), 35, 36 (ABBC), 41, and 44 (AABBC).

In this case 3 different genomes, $A = 8$, $B = 9$, $C = 10$, can be presumed, and cytotypes above mentioned are mostly explained by different combinations of those genomes. A primitive cytotype with AA genomes is expected to occur in continental Asia.

Also two or more basic numbers are sometimes established in one genus. For example in the genus *Lysimachia* (Primulaceae), the basic numbers are generally 6, 7, and 9. But *L. japonica* Thunb. common in China, Korea and Japan has $2n = 20$ chromosomes with the basic number 5. The basic numbers of *Chrysosplenium* (Saxifragaceae) are 6, 7, and 9. In Sect. *Alternifolia* a polyploid series with the basic number 6 is observed having $2n = 24, 36, 48, 96$, and 120 chromosomes. While in Himalayas and China, *C. lanuginosum* Hook. f. et Thoms, with $2n = 14$ chromosomes is found. It is also remarkable that the chromosomes of *C. lanuginosum* are much larger than those of species with the basic number 6.

Probably I have talked too much about chromosome number. Of course it is important to study karyotype. For example karyotype has been thoroughly analysed in the genus *Trillium*, and some other genera of Liliaceae, and Ranunculaceae having larger chromosomes. But in plant groups with very small chromosomes, it is difficult to study karyotype accurately. Moreover B-chromosomes or accessory chromosomes are also frequently observed in various plant groups. Recently DNA contents or C-banding of chromosomes are also used for detailed karyotype analysis. But those data are still few, and it is still difficult to introduce those data directly to taxonomy or plant geography.

Another important problem is hybridization. It is well known that in some plant groups such as *Salix*, *Rubus*, etc. natural hybrids are commonly found. Moreover, introgressive hybridization seems to occur sometimes in the fields. For example, in the southern part of Central Honshu, *Weigela decora* (Nakai) Nakai and *W. floribunda* (Sieb. et Zucc.) K. Koch (Caprifoliaceae) hybridize freely, and there occur a series of intermediate forms between the two species so-called 'hybrid swarms'.

Also apogamy is often observed in such plant groups as *Taraxacum*, *Boehmeria*, *Rubus*, etc., and is an important mean of propagation. Sometimes a triploid race without fertile seeds is distributed widely in Japan. Such examples are *Iris japonica* Thunb., *Lilium lanceolatum* Thunb., *Ixeris dentata* (Thunb.) Nakai, etc.

From a view point of differentiation and evolution, mechanism of cytogenetical isolation is important. However, in some plant groups, in spite of differences in chromosome number or karyotype, many morphologically and geographically distinct species hybridize rather freely. In *Rhododendron*, many hybrids have been produced by artificial crossing for hor-

ticultural purpose. In orchids more than 30,000 artificial hybrids have been recorded. But natural hybrids are not so common. Thus in these plant groups they have greatly differentiated morphologically without cytogenetical isolation.

On the contrary, some cytotypes within the same species do not hybridize. The cause of incompatibility is variable, sometimes failure of pollination, fertilization or seed-formation, but in many cases the exact cause is unclear.

In recent years cytogenetics have advanced greatly, and various modern techniques have been introduced. But in higher plants the interrelationship between various phenotypic characters and genes has scarcely been studied. In the field of cytotaxonomy it is still essential to carry out more intensive studies and collect more data on various plant groups in order to settle many problems regarding differentiation and speciation.

Fortunately we are living in temperate Asia with very rich flora consisted of many botanically interesting plants as compared with Europe or North America. Prof. Yong No Lee and others have already published many papers on cytotaxonomy of Korean plants, but there still remain many plants which have never been studied cytogenetically. In some cases the plants from continental Asia are very important, and give us a clue to settle the problem of differentiation in Asiatic plants.

Dear Korean botanists! I recommend you to go out to the field, and study the living plants. Then you can learn much more from the nature. After that you may return to your laboratory to study them. I do hope and believe that more intimate collaboration between Korean and Japanese taxonomists will be promoted on this significant occasion, and will last forever.

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