

July, 1984  
 Kor. Jour. Pl. Tax.  
 Vol. 14, No. 2, 71-85

## A biosystematic study on natural populations of *Quercus mongolica* Fischer in Korea and Japan

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### 韓國과 日本産 신갈나무 天然集團의 種分類學的 研究

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#### Abstract

It was intended to investigate a relationship between *Quercus mongolica* and its variety, var. *grosseserrata*, occurring to Korea and Japan. Through studies on chemical and morphological characters of 300 specimens collected from 12 natural populations in Korea and Japan, the following results were obtained. 1) The paper chromatography profiles of flavonoids (phenolic compounds) and the leaf morphological characters were closely related to each other. 2) *Quercus mongolica* var. *grosseserrata* in Japan exhibited a regression line ( $Y=0.824X+16.650$ ,  $R=0.64$ ), which linked with *Q. mongolica* and *Q. serrata*, using LDP (leaf depth percentage) and leaf angle (Figure 5). 3) The width/length ratio in fruits of pure line was significantly higher (nearly 1.0) than that of putative hybrids. 4) The leaf shape in Japan followed closely the obovateness along northward, and in Korea was found that they showed two groups within same populations, that was, elliptical and obovate leaf form. 5) Minor phenolic variation between populations was detected in Korea and Japan, could be used effectively as a determinant of hybrids. 6) *Q. mongolica* originated in the northern part of Asia migrated gradually toward south and east, which developed into 4 groups, 1. Mt. Halla-Jiri region, 2. the other Korean region, 3. Hokkaido region, 4. the other Japanese region by mixing *Q. serrata* (Figure 1). 7) It was proved that *Quercus x grosseserrata* Bl. was right treatment than a variety of *Q. mongolica*. Those collected in Japan, however, appeared to be closer to *Q. serrata*, while those in Korea were closer to *Q. mongolica* in appearance.

#### Introduction

The genus *Quercus* is a large group which has a wide range of geographical distribution in the northern hemisphere. Most recent studies of putative hybrids in *Quercus* dealt with many sets of characters (leaf, acorn, cup, twig, bud and petiole). Hicks and Burch (1977), Jensen and Eshbaugh (1976 a,b) and Rushton (1978, 1979) used numerical analysis to determine the putative hybrid popu-

lations. Tucker (1974) studied the parallel evolution of the new world oaks to be a more highly sensitive index of the environmental condition than did the taxonomic affinities of the species involved, emphasizing type of the habitats (environmental condition) to affect numerous extant taxa.

Li and Hsiao (1974, 1975, 1976 a,b) performed surveys of phenolics, mainly flavonoids, in leaves, staminate catkins and young twigs to examine subgeneric and serial relationship within the genus. Knops and Jenson (1980) studied red oak with morphological and chromatographic data sets. In other respect, Taylor and Boss (1975) studied geographical distribution of *Q. garryana* in the State of Washington.

*Quercus mongolica* is a member of the subgenus *Lepidobalanus* and is easily hybridized with northern Asian oaks. Its present range covers Ussuri, Amur, Manchuria, Mongolia, Hupeh, Shantung, Shensi, Saghalien, Hokkaido, Southern Kuriles, Honshu and Korea. In earlier study, numerous publications dealt with varieties of *Q. mongolica* in morphology. In 1838 and 1854, Fischer and Turczaninov, Russian botanist, reported *Q. mongolica* in Bulletin de la Société Impériale des Naturalistes (de Moscou). Other workers, especially Japanese botanists, who were interested in Korean flora described a number of various species of *Quercus* but did not present a new arrangement (Nakai-1915, 1952, Uyeki-1939). Kitamura and Horikawa (1951) discovered that *Quercus mongolica* var. *grosseserrata* in Japan with round dentate leaves were rarely found, while var. *grosseserrata* with acute dentate leaves were common. In 1961, Lee in his monographs of the subgenus *Lepidobalanus*, treated the species in serial arrangement and grouped *Lepidobalanus*, as 6 basic species in Korea based on morphological characters, i.e., trichome, leaf shape and fruit types. Further, unlike earlier studies of *Q. mongolica*, he considered *Q. mongolica* var. *grosseserrata*, var. *funnebris*, var. *laciniata*, var. *mandshurica* and var. *tomentosa* as individual hybrids. Moreover, *Q. mongolica* var. *grosseserrata* in Japan was interpreted as a highly variable species derived from hybridization between *Q. mongolica* and *Q. serrata*. But several fossils of *Q. mongolica* var. *grosseserrata* were already found in the upper Pliocene epoch in Japan (Kitamura and Horikawa 1951).

Main objectives of this study were 1) to determine the range of morphological variation of *Q. mongolica* var. *grosseserrata*, 2) to detect the minor phenolic variation between populations of *Q. mongolica* and *Q. mongolica* var. *grosseserrata* both in Korea and in Japan, 3) to trace migratory routes of the both taxa, and 4) to explain the ecological relationship of *Q. mongolica* and *Q. mongolica* var. *grosseserrata* on the basis of their habitats.

## Materials and Methods

### 1. Source of Materials

Five populations in Korea and seven populations in Japan were selected for this study. Individuals (30-40 trees 1000m above sea level to eliminate the possibilities of gene flow or hybridization by other oak species, Rushton-1978) within each population were sampled randomly. Sampling was done from July to August in 1983. One or two-year old branches were sampled from each tree. All trees were within range of 20-30cm in DBH. From each tree, branches including leaves and fruits were collected from the lower part of crown (2-3m), and were fully exposed to the sun. Leaves and twigs

were pressed and acorns were dried without pressing to avoid distortion. Localities and date of collection of materials for this study were presented in Figure 1 and Table 1.

Voucher specimens were deposited in the Herbarium of Kwanak Arboretum. Some of specimens and materials for this study were received from the following institutions: Asahikawa Regional Forest Branch (No. 6), Hokkaido University Botanic Garden (No. 7), Tohoku University Botanic Garden (No. 8), Koishikawa Botanic Garden (No. 9), Kyoto Botanic Garden (No. 10), Kyushu (Mt. Kuzu, Mt. Katamuki-No. 11), U.S. National Arboretum (Island of Dogo-No.12), Arboretum des Barres (France), Guelph Arboretum (Canada), Uppsala University Botanic Garden (Sweden), Trompenburg Arboretum (Netherland), and Royal Botanic Garden (Kew and Edinburgh).

## 2. Methods

### a. Morphological Analysis

Thirty or forty leaves, which were sampled from thirty trees in each population (in case of Japanese populations, from fifteen or thirty trees).

\* Leaf depth percentage: The expression of lobe depth as a percentage of leaf width, which Causen and Wigston (1975) examined, were calculated as illustrated in Figure 2.

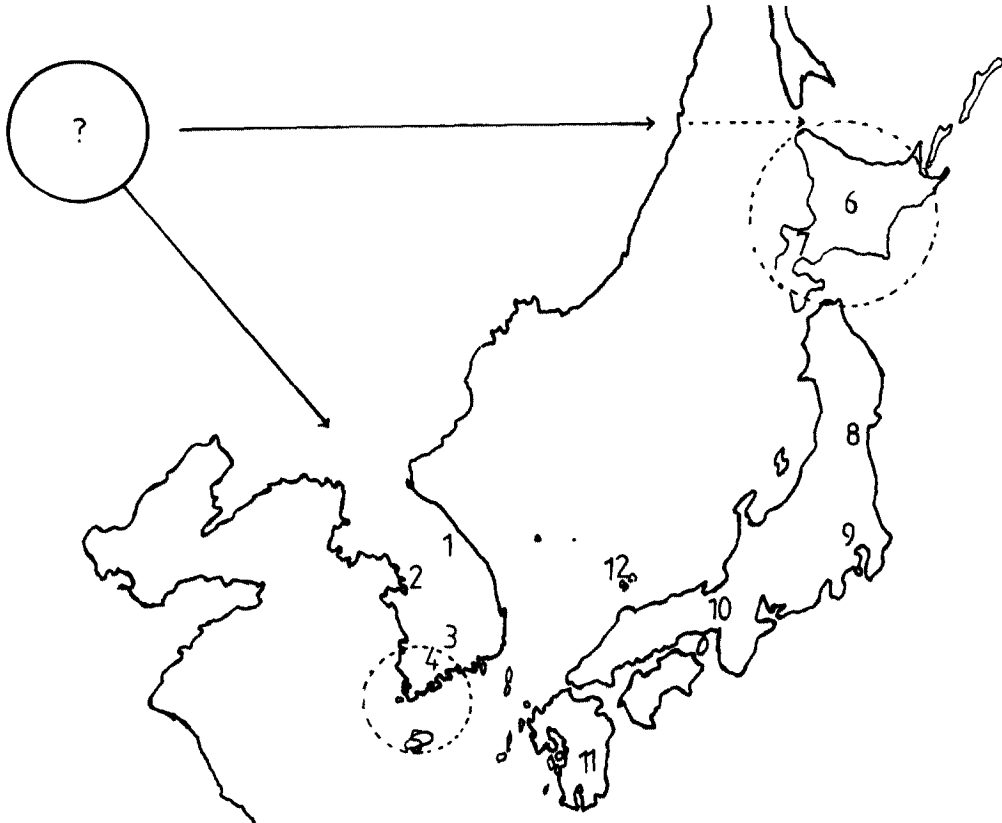


Figure 1: A map of Korean peninsula and island of Japan showing locations of study sites and hypothetical migratory routes of *Quercus mongolica* in Far East Asia.

Table 1. Localities of materials used for this study.

Locality (Population number)	Date of collections	Collector
1. Mt. Jeom-bong	August 9, 1983	Chang
2. Mt. Kwanak	July 17, 1983	Chang
3. Mt. Gaya	July 7, 1982	Chang
4. Mt. Jiri	July 2, 1983	Chang
5. Mt. Halla	August 1, 1983	Chang
6. Asahikawa*	September ?, 1983	Kikuchi
7. Iburi*	August 23, 1983	Takahashi
8. Sakunami*	August 3, 1983	Tohda
9. Tokyo*	September ?, 1982	Yamazaki
10. Kyoto*	July 4, 1983	Kobata
11. Kyushu*	August 4, 1983	Mashiba
12. Island of Dogo*	?	Yinger
Netherland*	July 20, 1983	van Hoey Smith
Canada	August 23, 1983	Ambrose
Sweden	June 9, 1983	Iwarson
France	September ?, 1983	Durand

\*shows *Quercus mongolica* var. *grosseserrata*.

\* Co-ordinate expression of leaf shape: Consider the equation as Figure 3 (Wigston 1975).

For C set at zero, the equation can be simplified to that of an ellipse: for values of C between zero and unity, increasing values of C create increasing distortion of the ellipse into an obovate shape.

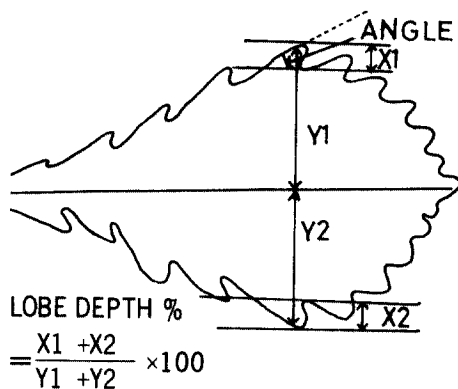


Fig. 2. Lobe depth percentage and angle.

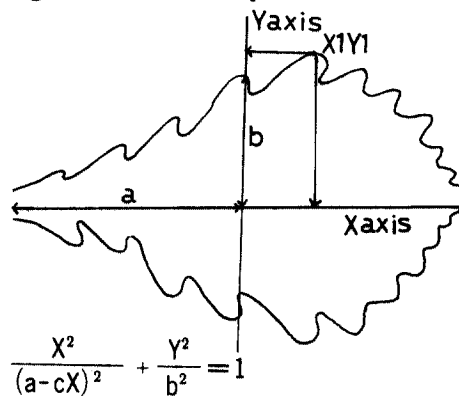


Fig. 3. The geometry of a distorted ellipse and obovate leaf (provided  $0 < c < 1$ )  $c=0$  gives an ellipse, all other values give a cuspid curve.

### b. Association

At the time when specimens were collected for character analysis, observations on associated vegetation were made and recorded. These observations were descriptive in nature and did not involve quantitative sample analysis (Taylor and Ross 1975).

### c. Chemical Analysis

Leaf samples including petioles were dried at 45-50°C for 48 hours and then they were ground to 40 mesh in a Wiley Mill. Ground leaves (3 gm from each population) were extracted with 25ml of 99% methanol for 72 hours at 4°C and suction-filtered. The filtrate was evaporated to dryness "in vacuo" by rotary evaporator (30-35°C) and the residue was redissolved in 6ml of methanol (2ml/gm dry weight of the leaves). Following centrifugation, compounds were separated on Whatman 2 MM paper (40×40cm sheet) by two-dimensional descending chromatography, initiating in t-butanol : acetic acid : water (3:1:1) for 24 hours and then in 15% acetic acid for 4hours at 15°C. Compounds were located by viewing the chromatograms under ultraviolet light (360 nm) before and after exposure to ammonia hydroxide and by color reaction when sprayed with 2% aluminum chloride in ethanol (Li and Hsiao 1974, Taylor and Patterson 1980).

## Results

### 1. Morphological Leaf Characters

For *Quercus mongolica* var. *grosseserrata*, it was found that leaf size was 6-20cm in length and 4-15cm in width (Okuyama *et al.* 1979, Ohwi 1961 ; Lee 1961 --- length mean 12.9cm, width 7.5cm). However, the range of leaf size of *Q. mongolica* was found to be 10-20cm in length and 4.5-8cm in width. There was a considerable overlap in the leaf size (length and width) of *Q. mongolica* with that of *Q. serrata*.

Based on photocopies and leaf fragment of *Q. mongolica* from Royal Botanic Garden's Herbarium (Kew and Edinburgh), the leaf lobe of Russian and Chinese specimens seemed to have dentate form, but the leaf margin of Korean specimens had rounded lobes (crenate) to serrate and Japanese specimens had serrate lobe that were common in everywhere except Hokkaido region.

From the morphological analysis, all of *Q. mongolica* and *Q. mongolica* var. *grosseserrata* revealed wide variation for leaf characteristics. The scattered diagrams, using two quantitative characters (leaf depth percentage and leaf angle), were presented in Figure 4 and Figure 5. In Figure 5, as expected, *Q. mongolica* var. *grosseserrata* exhibited regression line ( $Y=0.824X+16.650$ ,  $r=0.64$ ), which linked with *Q. mongolica* and *Q. serrata*. *Q. mongolica* var. *grosseserrata* in southern area of Japan showed much greater affinity to *Q. serrata*.

In case of Korean populations, *Q. mongolica* clustered into a related group (Figure 4).

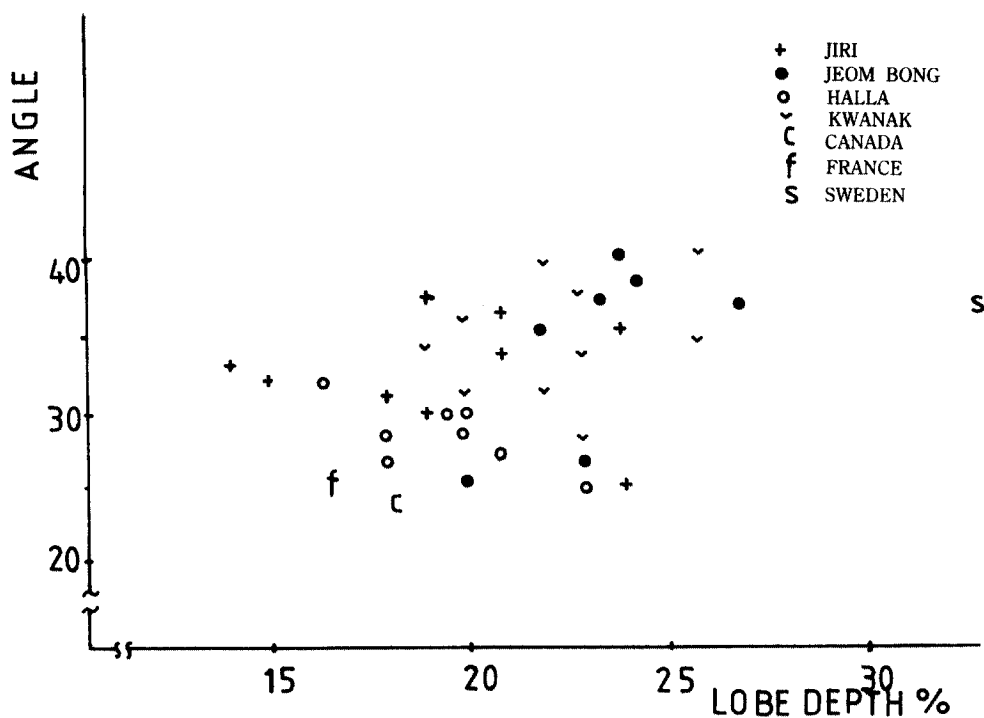


Fig. 4. Scattered diagram of selected populations in *Quercus mongolica* in Korea.

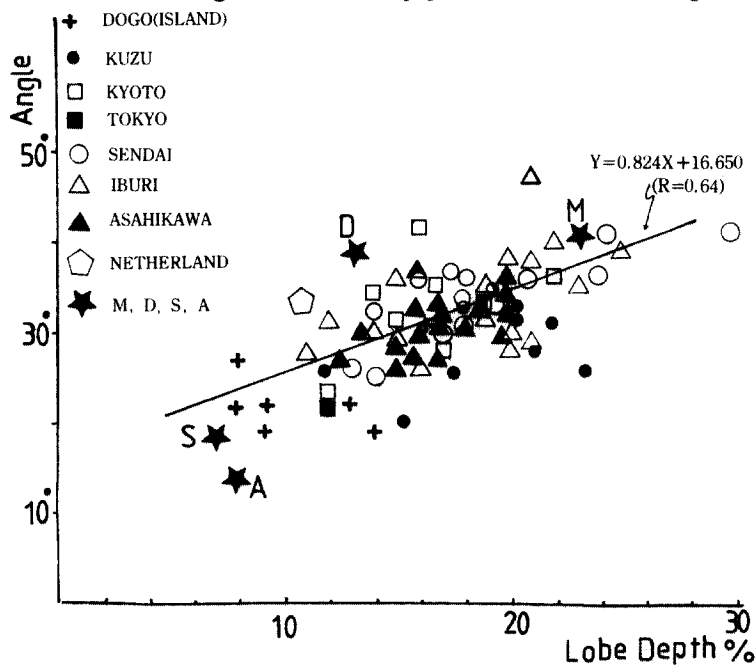


Fig. 5. Scattered diagram of selected populations in *Quercus mongolica* var. *grosseserrata* in Japan.

M : *Q. mongolica*    D : *Q. dentata*    S : *Q. serrata*    A : *Q. aliena*

## 2. Trichomes

Typical specimens of *Q. mongolica* have scarcely hair in its lower leaf surface. *Q. mongolica* in Mt. Halla, representing abaxial pubescence, was recognized but was usually neglected in taxonomic description (unpublished), because it was the remnants of hybrid between *Q. mongolica* and *Q. serrata*. That was described by Nakai (1915) as small leaf and simple hair, normally presenting on the abaxial surface of *Q. serrata* (nominated as *Quercus mongolica* var. *funebri*s). Also the authors observed these small leaves with simple hairs when examining the specimens in Mt. Jiri (Nogodan area). Commonly *Q. grosseserrata* in Korea was recognized as putative hybrids, presenting a similarity of parental characteristics and demonstrating intermediate between the presumed parents. *Q. mongolica* var. *grosseserrata* in Japan had its typical and large serrate lobe, exposing small, somewhat stellate hair, and simple hairs of *Q. serrata*. The resemblance between *Q. mongolica* var. *grosseserrata* in Japan and *Q. serrata* was greater than that between *Q. mongolica* in Mt. Halla and *Q. serrata*.

## 3. Associated Vegetation

The forests in Korea were dense and dominated by *Quercus mongolica* including *Tilia*, *Acer* and *Abies*. *Rhododendron*, *Euonymus*, *Rhus*, *Weigela*, *Betula*, *Syringa* and *Lindera* were common members of the shrub stratum. Among the ecological studies on the oak communities in Japan, Sakai and Chiba (1979) said that the habitats of *Abies sachalinensis* in Hokkaido were closely related to those of *Q. mongolica* var. *grosseserrata*. It was clear during field trip that populations studied formed and constituted habitats of rather tightly associated individuals between *Quercus mongolica* and *Abies* species (*A. koreana*, *A. nephrolepis* and *A. holophylla*). An extremely interesting phenomenon was to find *A. koreana* which was endemic species of Mt. Jiri and Mt. Halla. Regarding Halla-Jiri populations, Nakai (1935) conferred that the habitats of the brest in Mt. Jiri were very similar to that of the brest in Mt. Halla, that was, common species between two populations distributed continuously (for example, *Tilia taquetii*).

Concerning the distributions of *Q. dentata* and *Q. serrata* in Japan, *Q. dentata* distributed mainly on Hokkaido and *Q. serrata* occurred from southern area of Hokkaido to Kyushu (Hayahi 1969). The specimens of *Q. mongolica* var. *grosseserrata* in Hokkaido were examined for trichome characters as the triple hybrids, i.e., *Q. mongolica* var. *grosseserrata* x *Q. dentata*, which were nominated as *Q. dentato-serratoides* in Korea (Lee 1961c). The distributions of these *Quercus* species provided some insight into the status of triple hybrids showing affinity for *Q. dentata* with variation toward *Q. serrata*. It was very interesting that there were two kinds of *Q. mongolica* var. *grosseserrata* in Hokkaido region. One was rounded leaf margin and the other was serrated lobe. Some Japanese taxonomists treated the former as *Q. mongolica* and the latter as *Q. mongolica* var. *grosseserrata* (Kitamura and Horikawa 1951, Ohwi 1961). But this seemed to be incorrect because of their stellate hair of *Q. serrata* in lower leaf surface.

## 4. Fruit Characters

The ratio (width/length) of acorns were based on measurements of 25-40 acorns from 3 populations (5 sub-populations). Figure 6 showed the pattern of variation of acorns. This provided some insight into the status of *Q. mongolica* in Mt. Gaya, showing affinity for *Q. serrata* with variation (according

to Lee (1961) the ratio of *Q. serrata* presented 0.6). The result suggested that, although not complete, the W/L ratio of pure line be significantly higher (nearly 1.0) than that of putative hybrids. From the analysis of leaf trichome, the result obtained supported that *Q. mongolica* in Mt. Gaya was hybrid between *Q. mongolica* and *Q. serrata*.

### 5. Leaf Shape Index

Table 2, 3 and Figure 7 showed values of C (elliptical/obovateness form) calculated as the leaf index the value of C was determined by minimized Chi-squared. Figure 7 showed that the leaf shape of Japanese populations followed closely the obovateness along northward. But Hokkaido populations (Iburi and Asahikawa) appeared to be dissimilar with the other populations. Also Figure 5 showed that the angle of the leaf teeth (Figure 2) in these regions were much lower than those of others. But all C values of *Q. mongolica* in Korea were found that they showed two groups, that was, 0.01-0.09, 0.17-0.19. So this result supported that the leaf shape of *Q. mongolica* in Korea was more obovateness than that of *Q. mongolica* var. *grosseserrata* in Japan. But it is very difficult to establish any reliable criterion concerning Korean populations by these values.

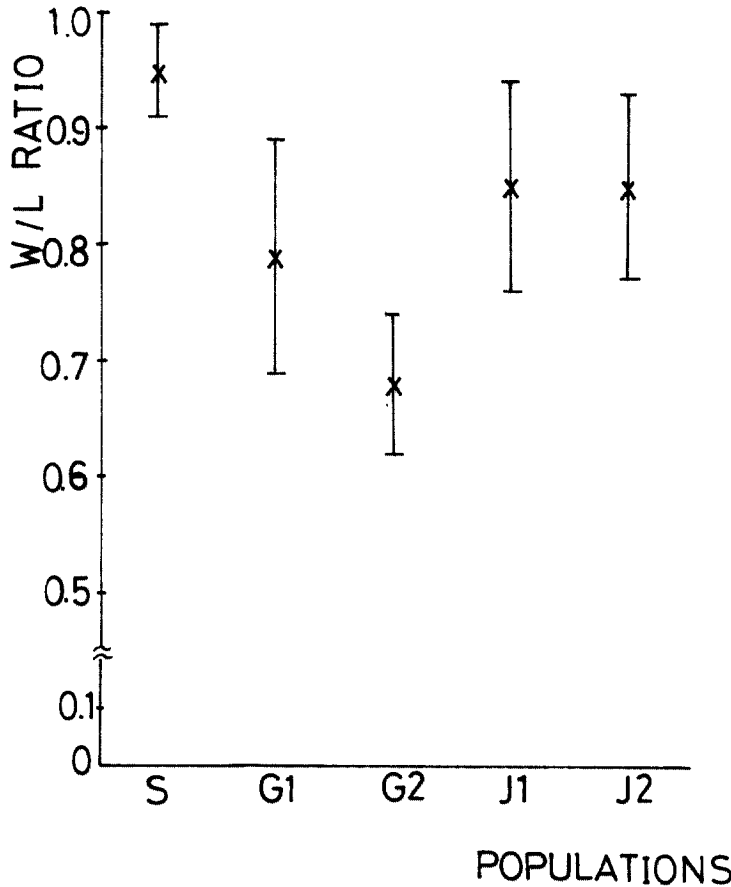


Fig. 6. Means and standard deviations of reflecting inter-and intrapopulation variation. (Width/length ratio of acorns) S-Seolak(1000m), G1-Gaya(1000m), G2-Gaya(1400m), J1-Jiri(450m-500m), J2-Jiri(1000m)



Table 2. C value measured by the equation in *Quercus mongolica* var. *grosseserrata* in Japan.

Locality	C value	% of Pop.
1. Kyushu (Mt. Katamuki, Mt. Kuzu)	0.01 0.09 (0.19, 0.29)	75% 10%
2. Dogo (Island)	0.01 0.08-0.09	50% 25%
3. Tokyo	0.08-0.09	-
4. Kyoto	0.01 0.09	53% 10%
5. Sendai (Sakunami)	0.01-0.02 0.08-0.09	34% 52%
6. Iburi (Hokkaido)	0.01-0.02 0.08-0.09	45% 45%
7. Asahikawa (Hokkaido)	0.01-0.02 0.08-0.09	60% 25%
8. Netherland	0.01	-

Table 3. C value in *Q. mongolica* in Korea and other C value

Locality	value	Locality	value
1. Mt. Halla	0.07-0.09 0.19-0.29	4. Mt. Jeombong	0.07
2. Mt. Jiri	0.03-0.09 0.19-0.29	5. Sweden	0.28-0.48
3. Mt. Kwanak	0.01 0.17	6. Canada	0.09
		7. Liaotung*	0.06-0.09

\* *Quercus mongolica* var. *liaotungensis* (from Arnold Arboretum)

## 6. Chemical Analysis

A total 18 compounds were observed and characterized. Table 4 showed Rf values and color determinations for each of the spots. Also Figure 8 presented composite chromatography derived by the methods outlined above. Spots 1,5,7,8,11,12,13 were present more often in *Q. mongolica* and *Q. serrata*. Spots 4,16,17,18 provided marker for *Q. mongolica* and spots 2,17 were present in *Q. mongolica* var. *grosseserrata*. Spots 16, 17 were found more strongly in *Q. mongolica* var. *grosseserrata* than *Q. mongolica*.

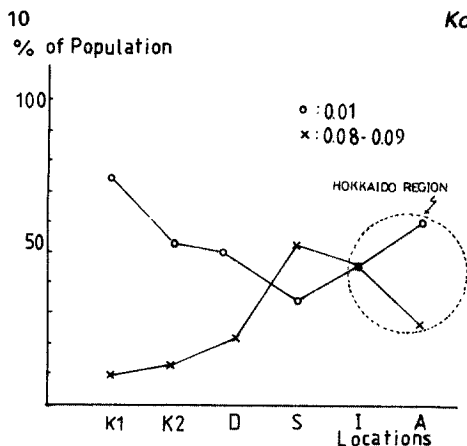


Fig. 7. Leaf shape index of *Quercus mongolica* var. *grosseserrata* in Japan (K1: Mt. Kuzu, K2: Kyoto, D: Island of Dogo, S: Sendai, I: Iburi, A: Asahikawa). The LSI value of Hokkaido region is very different from that of other regions (0.01:elliptical, 0.08-0.09: obovate form).

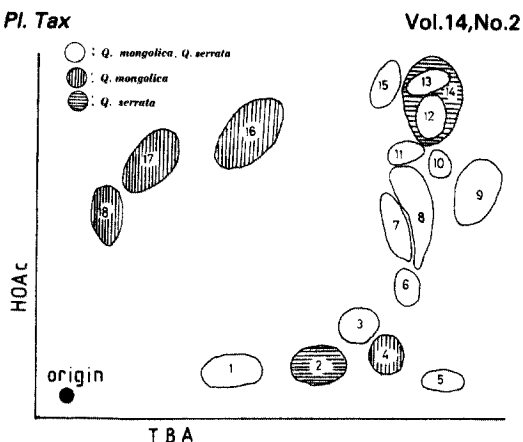


Fig. 8. Composite chromatograms for *Quercus mongolica*, *Q. serrata*, and *Q. mongolica* var. *grosseserrata* with flavonoids.

Spot 14 was the important spot in the chromatograms of *Q. serrata* and spot 4 was of *Q. mongolica*. However, spot 14 was present, and spot 4 was completely absent in the chromatograms of *Q. mongolica* var. *grosseserrata*. By the way, *Q. mongolica* in Mt. Halla was intermediate between *Q. mongolica* and *Q. mongolica* var. *grosseserrata* (spot 4 was present). It was believed that *Q. mongolica* var. *grosseserrata* might be one of the parent species of *Q. serrata*. It was concluded that hybrids did occur, and flavonoids could be used effectively as a determinant of hybrid in this study. In addition, of all the plants analysed chemically, minor phenolic variation between populations could be obtained.

Finally, most of the results proved that *Q. mongolica* var. *grosseserrata* had intermediate pattern of *Q. mongolica* and *Q. serrata* in morphological and chemical data. The use of chemical data and trichome characters in conjunction with associated vegetation clearly indicated that different population types could be recognized. The classification of populations into different types should be rigorous.

### Discussion

*Quercus* is a genus of the upper Cretaceous and Cenozoic. Because of the wide variation in leaf form, not only between species but within the same species, the geographical history of *Quercus* is somewhat confused (Arnold 1949). On account of this reason, the original derivation of *Quercus mongolica* in Eastern Asia is uncertain. However, the most widely accepted hypothesis for origin of *Q. mongolica* is that they migrated down to the Manchuria, Ussuri and Amur River with the drying and cooling climated of the late Tertiary and were splitted by the Okhotsk Sea and Eastern Sea of Korea (Japanese Sea). The continental element followed Hupeh, Shantung to Korea. The island element migrated throught Saghalien to Hokkaido and Honshu (Figure 1).

Table 4. Phenolic pigments --- their positions and descriptions.

Compounds	Rf value	U.V.	U.V. +NH <sub>4</sub> OH	U.V. +NH <sub>4</sub> OH+AlCl <sub>3</sub>	Vis w/NH <sub>4</sub> OH
No <sup>a</sup>	TBA/HOAC				
1	0.25/0.13	p.Fl	p.Fl	p.Fl	No
2	0.38/0.13	p.Fl	p.Fl	p.Fl	No
3	0.45/0.25	p.Fl	p.Fl	p.Fl	No
4	0.13/0.55	b.Y	b.Y	v.b.G	No
5	0.60/0.05	b.PI.	b.PI.	b.PI.	Y
6	0.53/0.3	---	v.d.Y	v.d.Y	No
7	0.45/0.45	---	v.b.PI.	v.b.Y	No
8	0.50/0.55	v.b.PI.	v.b.PI.	v.b.Y	Y
9	0.68/0.55	---	v.w.Y	v.w.Y	No
10	0.60/0.65	---	v.d.Y	v.d.Y	No
11	0.50/0.70	v.b.Fl	v.b.Fl	v.b.Fl	No
12	0.58/0.78	v.b.Fl	v.b.Fl	v.b.Fl	No
13	0.53/0.80	v.b.G	v.b.G	v.b.G	No
14	0.58/0.79	v.b.Fl	v.b.Fl	v.b.Y	v.d.Pi
15	0.48/0.80	---	v.w.Fl	v.w.Fl	v.b.Pi
16	0.33/0.70	---	v.w.Y	v.w.Y	v.b.B
17	0.15/0.65	---	v.b.B	v.w.B	v.b.Pi
18	0.10/0.63	---	v.w.B	v.w.B	v.w.B

a. Numbers correspond to those used in Fig. 8.

b. Color key: G: Green, Fl: Fluorescence, B: Brown, Y: Yellow, Pi: Pink, b: bright, v: very, w: weak, p: pale, d: dull.

Early hybridization between *Q. mongolica* and *Q. serrata* from Kitamura and Horrikawa's paper (1951), conferring that they found the living fossils of *Q. serrata* and *Q. mongolica* var. *grosseserrata* from upper Pliocene and Pleistocene epoch in Japan, would have given rise to *Q. mongolica* var. *grosseserrata* of maritime climated and *Q. mongolica* with continental distribution. Perhaps disjunction and subsequent speciation occurred during the period of glaciation in Japan and Island of Jeju (Mt. Halla) (Kim 1982). Pollen records confirmed that *Q. mongolica* var. *grosseserrata* was widely distributed in Japan during the Pleistocene (Miura and Yamanaka 1981, Mochida and Yamanaka 1981). Presumably *Q. mongolica* made such a migration and with post-Pleistocene warming, Japanese populations became isolated and divergent somewhat. At the present time, *Q. mongolica* in Mt. Halla is restricted to a few isolated population. Its gene pool is undoubtedly limited because of geographically restricted gene flow and resultant inbreeding.

Other modern species of oaks may well have similar length histories. As different environments became more extreme in late Tertiary and Pleistocene time, better adapted forms were selected in

each type of habitat. Thus, although cases of parallelism were to be found in a number of different types of habitats, as might be expected, the most extreme forms of leaf adaptation and some of the most interesting examples, were found in most extreme habitat (Tucker 1974). Based on this concept, it is proposed that natural populations of *Q. mongolica* and *Q. mongolica* var. *grosseserrata* in Korea and Japan divided into 4 groups: 1) Mt. Halla-Jiri population, 2) the other Korean populations, 3) the Hokkaido population, 4) the other Japanese populations (Figure 1). From the chemical results and morphological data, notably trichome characters, Japanese populations and Mt. Halla-Jiri population occur together in association with *Abies koreana* and *Q. mongolica* var. *grosseserrata* in Hokkaido population with *A. sachalinensis*. Hokkaido population includes some evidences to subdivide among Japanese populations, i.e. 1) Trichome characters (Triple hybrid), 2) habitat (*A. sachalinensis*), 3) morphological characters (LDP with angle, LSI value, existence of round and serrate lobe), 4) the possibility of gene flow with *Q. dentata*.

It seemed to be probable that Japanese populations have been controlled by some genes of *Q. serrata* with cumulative effects. It seemed highly probable that *Q. mongolica* in Japan during the Pleistocene period were already introgressed with *Q. serrata*. In other words, parallelism between *Q. mongolica* and *Q. mongolica* var. *grosseserrata* was occurred, where *Abies* species with *Q. mongolica* evolved commonly along the same habitat, became relict endemics.

Also there is another interesting and provocative explanation for these distribution patterns. If the populations were remnants of more extensive and continuous oak forest, it might be expected that phenolic patterns of individuals within populations should be very similar and those of isolated populations should be more distinct. This was especially true in such small breeding populations with random drift decrease of genetic variability due to inbreeding or due to gene flow, i.e., by introgression. Evidence supporting introgression was conformed to see the specimens of Dogo region in Japan. The leaf form and shape of *Q. mongolica* var. *grosseserrata* in this region showed very similar to those of *Q. serrata*. (see Figure 9).

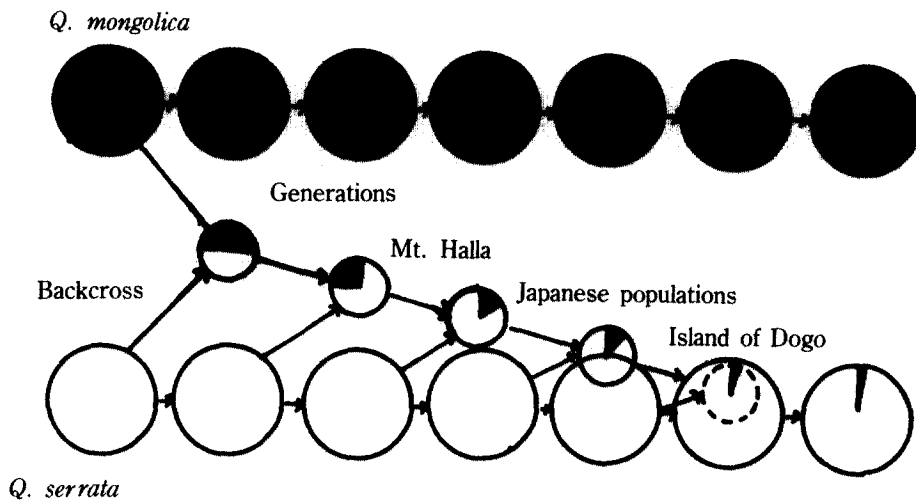


Fig. 9. Introgression of *Q. mongolica* and *Q. x grosseserrata* in Korea and Japan based on the results of morphological and chemical analysis (After Benson 1962).

Considering all the evidence compiled in this study, it is concluded that the differences between *Q. mongolica* and *Q. mongolica* var. *grosseserrata* including *Q. grosseserrata* are not sufficient to justify separation into distinct species. The three taxa have similar phenolic chemistry: They overlap in all morphological characters examined. However, for a taxonomic convenience, and because slight and possible consistent differences do exist, it is suggested that *Q. mongolica* var. *grosseserrata* be changed at the hybrids, therefore becoming *Quercus* x *grosseserrata* Bl, supporting Lee's treatment (1961). Finally, the Japanese populations should be placed in hybrids for reasons discussed in this paper.

### Acknowledgement

We are grateful to the followings who have sent materials and contributed to this work: Dr. T. Yamazaki (Koishikawa Botanic Garden, Former Professor of University of Tokyo), Dr. H. Takahashi (Hokkaido University Botanic Garden, Assistant), Dr. H. Tohda (Tohoku University Botanic Garden, Assistant), Dr. K. Kobata (The Kyoto Botanical Garden, Director), Mr. T. Kikuchi (Asahikawa Regional Forest Branch-Office, the Chief of the Plan Department), Mr. S. Mashiba, Dr. J.R.P. van Hoey Smith (Arboretum Trompenburg, Director), Dr. J.D. Ambrose (University of Guelph Arboretum, Curator), Dr. M. Iwarson (University of Uppsala Botanical Garden), Mr. B. Yinger (U.S. National Arboretum, Curator of Asian Collections), Dr. R. Durand (Arboretum des Barres), Mrs. J. Cowley (Royal Botanic Garden, Kew), Dr. I. C. Hedge (Royal Botanic Garden, Edinburgh, Curator) and Dr. C. Nozzolillo (University of Ottawa, Professor).

### 適 要

本 研究는 東亞地域에 分布하는 신갈나무와, 물참나무의 類緣關係를 究明하기 위하여 우리나라와 日本의 12個 天然集團에서 300점의 標本을 採集하여, 形態學的 測定과 化學的 分析을 통하여, 다음과 같은 結果를 얻었다.

1. 化學的(페놀類) 分析結果와 形態學的 調查 結果는 서로 비슷한 傾向이 나타났다.
2. 日本產 물참은 LDP(鋸齒 深度率)와 角度를 座標上에 標示한 바 신갈과 物참을 連結하는 回歸式上에 分布하였다.  
( $Y=0.824X + 0.650$ ,  $R=0.64$ )
3. 열매의 나비와 길이의 比는 신갈에 가까운 純種일수록 1.0에 가까웠고 雜種性일 경우 그 값은 감소하였다.
4. 우리나라와 日本에서 자라는 신갈나무 集團을 4個 地域으로 區分하였다. 즉, 1) 智異山-漢拏山 2) 韓半島 3) 北海道 4) 日本 中部와 南部地域.
5. 日本產의 葉形은 北으로 갈수록 倒卵形에 가까웠고, 우리나라의 境遇는 同一集團內에서도 橢圓形과 倒卵形 2가지 形이 나타났다.
6. 韓國과 日本產 모두 phenol의 minor 成分이 地理的 分布에 따라 變異가 나타났고, 특히 日本產의 경우 物참과 신갈의 中間性이, 漢拏山의 境遇 日本산 물참과 신갈의 中間性을 보여 주었다.

7. 물참나무는 신갈나무의 變種이 아니라 신갈나무와 졸참나무의 雜種의 起源으로 보는 것이 妥當하며, 日本産은 졸참나무에 보다 가까와지고, 우리나라産은 신갈나무에 보다 가깝게 나타났다.

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