Discrimination of hybrids between Quercus variabilis and Q. acutissima by using stellate hairs, and analysis of the hybridization zone in the Chubu District of central Japan

著者	Hiroki Shozo, Kamiya Takahiro
著者別表示	広木 詔三, 神谷 高浩
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Shozo Hiroki[1] and Takahiro Kamiya[1,2] : **Discrimination of hybrids between *Quercus variabilis* and *Q. acutissima* by using stellate hairs, and analysis of the hybridization zone in the Chubu District of central Japan**

[1]Graduate School of Information Science, Nagoya University, Nagoya 464–8601, Japan ;
[2]Present address : Kiyosu-cho Kamijo 1–2–6, Nishikasugai-gun, Aichi Prefecture 452–0944, Japan

Abstract

To discriminate between *Quercus variabilis*, *Q. acutissima*, and their hybrids, we sampled 152 individuals in secondary forests in Japan, including a plantation of *Q. acutissima* in Nagoya City. We compared and identified the species and their hybrids on the basis of the density of stellate hairs on the undersurfaces of leaves. The density was high in *Q. variabilis*, zero in *Q. acutissima*, and low in their hybrids. We also studied the distribution patterns of the two species and found that *Q. variabilis* grows at lower altitudes in warmer regions than does *Q. acutissima*, and that a hybridization zone exists where the ranges of the two species overlap. We discuss differences in the distributions of the species on the basis of life-history features such as seed germination and seedling establishment. The results suggest that the main range of distribution of *Q. acutissima* corresponds to Kira's Warm Temperate Deciduous Forest Zone, and that the unusual distribution pattern of *Q. acutissima* in warmer regions such as Kyushu may have resulted from planting of the species.

Key words : distribution, hybrid, *Quercus acutissima*, *Quercus variabilis*, stellate hairs.

Introduction

Quercus is a prolific genus of trees, and *Quercus* species frequently tend to hybridize (Stebbins et al. 1947 ; Palmer 1948 ; Stebbins 1950 ; Muller 1952). Recently, a number of studies on *Quercus* hybrids and hybridization zones have been published (Manos 1993 ; Dodd and Kashani 2003 ; Dodd and Afzal-Rafii 2004).

Quercus variabilis Blume and *Q. acutissima* Carruth. are closely related species within the *Cerris* section of the genus. Both species are widely distributed throughout Asia and grow in Japan, Korea, Taiwan, and China (Kitamura and Murata 1979 ; Menitsky 2005). Kitamura and Murata (1979) described hybrids between these species in Japan and northeastern China and named them *Q. acutissima* × *Q. variabilis*. They suggested that the hybrids are rare, and noted that Japan's Shimane Prefecture is the main region where the hybrids occur. Sano (1990) compared the morphological characteristics of *Q. variabilis* and *Q. acutissima*, and reported the existence of hybrids of these species in Hiroshima Prefecture. Recently, in a preliminary survey in Iijima Town in Nagano Prefecture, central Japan, where the distributions of these species overlap, we found probable hybrids with characteristics intermediate between the two species. This finding suggested that hybridization between the two species may not be as rare as was formerly reported.

Quercus variabilis and *Q. acutissima*, along with *Q. serrata*, are major components of secondary forests in hilly regions of Japan. According to Horikawa's species distribution map (Horikawa 1976), *Q. variabilis* is distributed mainly from central to western Japan and is absent from the warmest regions such as the southern part of the Kii Peninsula, southern Shikoku, and most of Kyushu. On the other hand, *Q. acutissima* occupies a wider range, being distributed from cooler regions such as the Kanto District and the southern Tohoku District to quite warm regions, including almost all of Kyushu (Horikawa 1972). Matsubara and Hiroki (1980) surveyed the distribution of *Q. vari-*

abilis in the Chubu District of central Japan and showed that dense forests of *Q. variabilis* develop in hilly zones from Aichi Prefecture to Gifu Prefecture, but that the abundance of this species decreases rapidly at higher altitudes. In Nagano Prefecture, the abundance of *Q. variabilis* was high in Iida City, but gradually decreased farther north or at higher altitudes. In contrast, the abundance of *Q. acutissima* is quite low in Aichi Prefecture and the southern part of Nagano Prefecture, though this cannot be seen in Horikawa's maps. Thus, we expected that, in Nagano Prefecture, *Q. acutissima* would replace *Q. variabilis* as altitude increased, with an intermediate zone in which the distributions of the two species overlapped.

The leaf forms of *Q. variabilis* and *Q. acutissima* are quite similar, with spine-like serrations, and so are the acorns and cupules. However, these species clearly differ in trichome formation and in the development of the cork layer. *Quercus variabilis* has stellate hairs on the undersurface of the leaf and develops a thick cork layer within the bark. *Quercus acutissima* has no stellate hairs on its leaves and develops only a thin cork layer. It is usually easy to distinguish between the species by the color of the leaf undersurface (white in *Q. variabilis* and green in *Q. acutissima*) and the color and thickness of the bark (pinkish-white and thick in *Q. variabilis* versus blackish and thin in *Q. acutissima*). However, identification becomes difficult where hybrids with various degrees of intermediate morphology occur.

Trichomes can be important characteristics in the identification of *Quercus* species. Sano (1990) demonstrated the existence of intermediate types between the two species based on the abundance of stellate hairs and bark traits. Hardin (1979) showed that similar patterns of trichomes occurred within the same *Quercus* section or series, and that the presence of particular types of trichomes could be a clue to the existence of hybrids. Manos (1993) demonstrated that five *Quercus* species in the *Protobalanus* section showed similar but not identical trichome types, suggesting that individuals with intermediate trichome types might be hybrids. Spellenberg (1995) reported *Q. basaseachicensis* to be a hybrid between *Q. rugosa* and *Q. depressipes* on the basis of their trichomes. Whereas *Q. rugosa* had stellate hairs and large multicellular vermiform hairs, *Q. depressipes* lacked stellate hairs and had minute vermiform hairs, and *Q. basaseachicensis* had only medium-sized vermiform hairs.

Here, we aimed to reveal the existence of hybrids between *Q. variabilis* and *Q. acutissima* based on the density of stellate hairs and to demonstrate the existence of a hybridization zone in Nagano Prefecture where the distribution ranges of the two species overlap. We did not use bark traits as a criterion for identifying hybrids, because the thickness of the cork layer varies continuously among hybrids between the two species (Sano 1990).

Materials and methods

We selected five sampling areas with developed secondary forests in Aichi Prefecture (the Higashiyama hills in Nagoya City) and Nagano Prefecture (Iida City, Iijima Town, Ina City, and Toyoshina Town; Figure 1). We selected one sampling site in each area except Toyoshina Town, where we selected three sites separated by more than 10 km. We added one more sampling site at Nagoya Castle Park (in Nagoya City), where *Q. acutissima* grows in an apparently artificial forest.

We selected 152 individuals of *Q. variabilis* and *Q. acutissima*, including intermediate types, from these sampling sites and sampled 3 to 8 leaves from each of them (Table 1). We tentatively sorted the 152 individuals into three types, the *Q. variabilis* type, the *Q. acutissima* type, and the intermediate type, based on the color of the undersurface of the leaf, which reflects the density of hairs.

Leaves with a low density of stellate hairs appear green or nearly green on their undersurfaces. Using a binocular microscope (Olympus, Tokyo, Japan) at ×29 magnification, we counted the number of stellate hairs on the undersurfaces of leaves of 106 individuals whose leaf undersurfaces appeared green or nearly green. To standardize our measurements, we chose the area of the lamina between the 9th and 10th veins from the base of the leaf, on the right-hand side

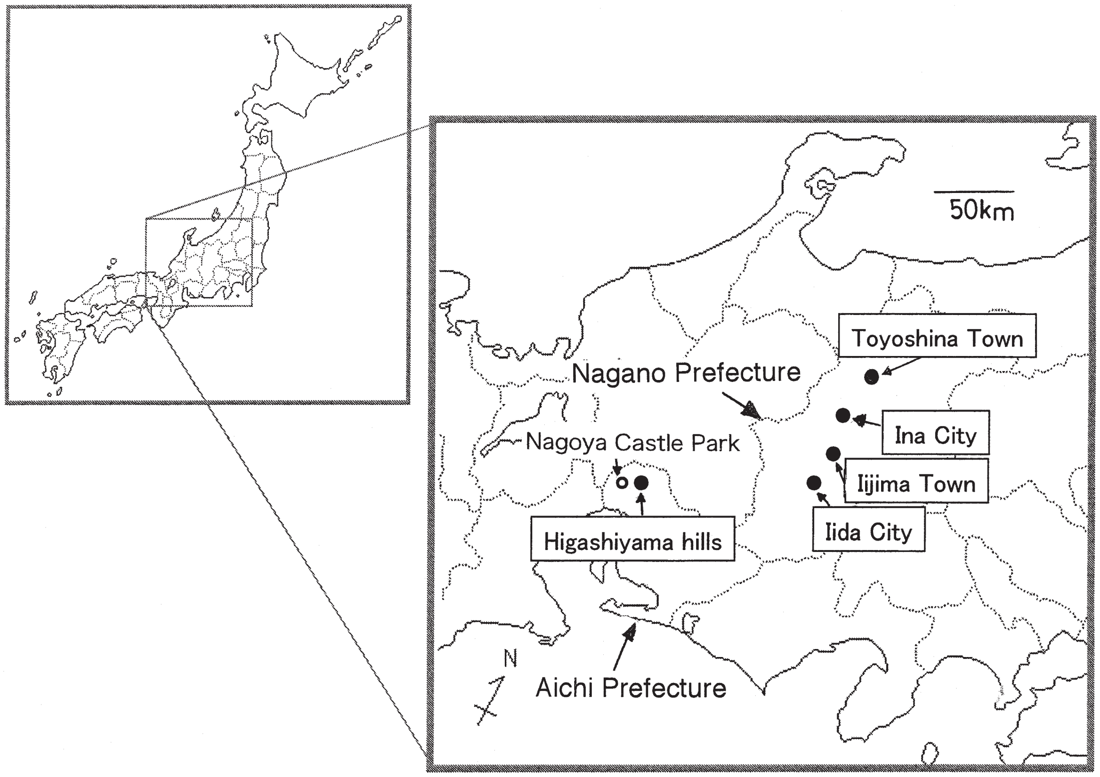

Fig. 1. Locations of the 5 sampling areas in Aichi and Nagano Prefecture and one site at Nagoya Castle Park in Nagoya City.

Table 1. Sampling sites and number of samples

Locality of sampling site	Altitude (m)	Number of individuals
Aichi Prefecture		
Nagoya City		
Higashiyama hills	50–65	20
Nagoya Castle Park	0	24
Nagano Prefecture		
Iida City	590–620	21
Iijima Town	680–750	13
Ina City	800–1500	15
Toyoshina Town		
Hikarujoyama	610–650	17
Toyoshina	640–650	26
Oshinoyama	545–570	16
Total		152

of the leaf, as the measurement location. We measured the density of stellate hairs in 3 leaves per individual, and, to improve our estimates of variability, we measured 4 to 8 leaves per individual for the intermediate types obtained from Iijima Town.

We obtained a leaf with a white undersurface from an individual from the Higashiyama hills and photographed the surface with a camera (an automatic photographic apparatus from Olympus) attached to a microscope equipped with a 1–mm micrometer. We then counted the number of stellate hairs within an area of 0.75×1.07 mm using a hand-held counter. We performed this measurement three times for this single leaf of this particular individual.

We identified sampled individuals with high, zero, and intermediate degrees of stellate hair densities as *Q. variabilis*, *Q. acutissima*, and hybrids, respectively.

Furthermore, we analyzed the distribution pattern of the 152 individuals from Aichi Prefecture to Nagano Prefecture.

Results

The 152 individuals were tentatively classified into 46 individuals of the *Q. variabilis* type with white leaf undersurface, 103 of the *Q. acutissima* type with green undersurface, and 3 of the intermediate type with whitish green or almost green undersurface.

Of the 103 trees of the tentative *Q. acutissima* type, 16 had stellate hairs and were subsequently identified as hybrids (only 8 trees from Iijima Town are shown in Table 2). The rest of the individuals identified as *Q. acutissima* from Nagoya Castle Park and Nagano Prefecture had no stellate hairs. An individual identified as *Q. variabilis* from the Higashiyama hills had roughly 38,000 stellate hairs per square centimeter.

The other 19 individuals from the Higashiyama hills site identified as *Q. variabilis* had white leaf undersides and a seemingly thick cork layer in their bark. In Nagano Prefecture, 26 individuals also identified as *Q. variabilis* also had white leaf undersides.

Thus, we identified 46 trees as *Q. variabilis*, 87 as *Q. acutissima*, and 19 as hybrids.

The densities of stellate hairs varied greatly within an individual tree and among the 8 individuals identified as hybrids from Iijima Town (Table 3). Among those 8 individuals, 6 were tentatively judged to be *Q. acutissima* at first,

Table 2. Discrimination of hybrids between *Quercus variabilis* and *Q. acutissima* based on the density of stellate hairs

Sampling site	Number of samples	Density of stellate hairs ($1/cm^2$)	Identification
Higashiyama hills	1	37700±6840*	*Q.variabilis*
Iijima Town	8	117±284**	hybrid
Nagoya Castle Park	24	0	*Q. acutissima*
Nagano Prefecture	63	0	*Q. acutissima*

*mean and standard deviation in three measurements in one leaf
** mean and standard deviation in eight individuals

Table 3. Mean and range of the density of stellate hairs ($1/cm^2$) in eight putative hybrids from Iijima Town

	Individuals							
	a	b	c	d	e	f	g	h
Mean	0.12	0.35	1.79	4.24	7.93	9.29	95.5	816
Range	0–0.61	0–0.64	0.67–4.26	0.85–12.5	0–21.4	0.27–17.6	25.0–176	275–2620

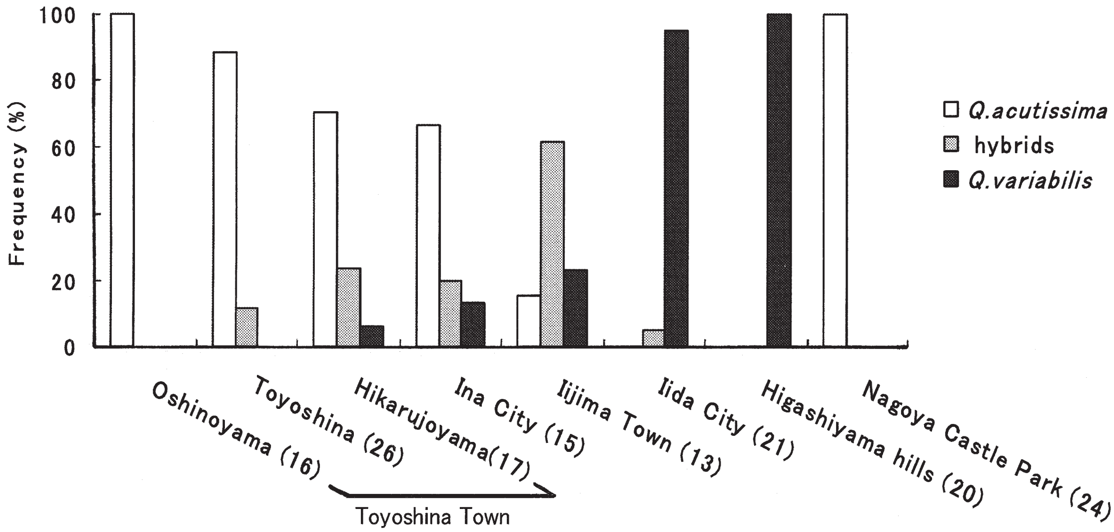

Fig. 2. Frequency of occurrence of *Quercus variabilis*, *Q. acutissima*, and their hybrids at the 8 sampling sites. The numbers in the parentheses represent the number of individuals sampled.

but had stellate hairs ranging from none to very few.

The distribution ranges of *Q. variabilis* and *Q. acutissima* overlapped a little in Nagano Prefecture (Fig. 2) : *Q. variabilis* was abundant in the Higashiyama hills in Nagoya City (Aichi Prefecture) and in Iida City (Nagano Prefecture), but its numbers decreased markedly moving northward from Iida City (leftward on the chart). In contrast, numbers of *Q. acutissima* gradually increased moving northward from Iijima Town and at higher elevations. Hybrids occurred throughout the range where the two species coexisted.

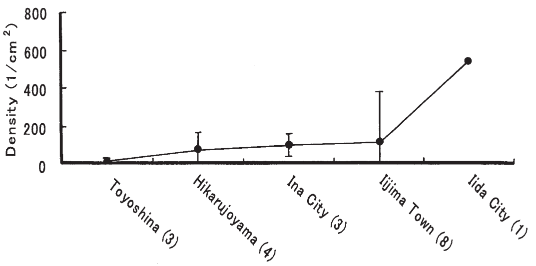

Fig. 3. Variation in the densities of stellate hairs in hybrid individuals found within the zone of hybridization. The numbers in parentheses represent the number of individuals sampled. Vertical bars represent the standard deviations of the densities.

The densities of stellate hairs in hybrids were lower where *Q. acutissima* was most abundant and higher where *Q. variabilis* was most abundant (n=19, Fig. 3). The hybrid from Iida, where *Q. variabilis* was abundant, had a mean density of about 600 stellate hairs per square centimeter.

Discussion

We identified 19 individuals as hybrids. Although *Q. acutissima* leaves are thought to have no stellate hairs, Sano (1990) reported the existence of 2 individuals with small amounts of stellate hairs in Hiroshima Prefecture and suggested that these might be hybrids. Thus, in future we need to study whether individuals with sparse stellate hairs fall within the normal range of variation for *Q. acutissima*, by studying its pure populations in the southern Tohoku District.

Our study showed that a zone of hybridization exists where the distribution ranges of *Q. variabilis* and *Q. acutissima* overlap between Iida and Toyoshina in Nagano Prefecture. We did not examine the bark traits of the populations in Nagano Prefecture, and we identified *Q. variabilis* solely by visual observation of the white leaf undersurface, which indicates a high density of stellate hairs. Thus, some hybrids may have erroneously been included in the populations that we identified as *Q. variabilis*. Sano (1990) described the existence of hybrids which had leaves densely covered with stellate hairs on their undersurfaces and the *Q. acutissima*-type bark. Additional investigation is necessary to reveal the variation in both bark thickness and density of stellate hairs in both species.

Among the hybrids, the density of stellate hairs was lower in areas where *Q. acutissima* was abundant and higher in areas where *Q. variabilis* was abundant. This suggests that backcrossing may have occurred between the hybrids and the parent species.

Our finding that *Q. variabilis* is distributed primarily in the warmer parts of the Chubu District is consistent with the conclusions of Matsubara and Hiroki (1980), who reported that *Q. variabilis* is abundant up to elevations from 400 to 500 m and that its presence at higher altitudes is limited to forest edges and sunny sites. Ishizuka et al. (1983) also reported that this species was present at sunny sites and in dry microhabitats below an elevation of 390 m near Yamagata in the southern part of the Tohoku District. The high densities of stellate hairs in *Q. variabilis* may be an adaptive characteristic for survival in dry, warm habitats; this hypothesis is supported by the development of a thick cork layer by this species. Dense leaf hairs are an adaptive characteristic for plants growing in dry habitats, because the hairs reduce moisture loss by creating a boundary layer of air around the leaf that reduces air motion and traps moisture (Ricklefs and Miller 2000). Similarly, the thick cork layer of *Q. variabilis* may be an adaptation to heat stress, considering the fact that *Q. suber*, which has thick cork layers, occurs in dry Mediterranean regions with low precipitation in the hot summer (More and White 2002).

The distribution of *Q. variabilis* seems to be strongly related to temperature. Matsubara and Hiroki (1980) estimated that the range of the species falls between 82 and 146 in the Warmth Index of Kira (1949): this index ranges from 85 to 180 for the warm temperate climate region where evergreen broad-leaved forests dominate. This, together with our present results, suggests that the main distribution of *Q. variabilis* corresponds closely to an area within the warm temperate climate region. In contrast, our results show that *Q. acutissima* is prevalent in such areas as Matsumoto, where the Warmth Index is about 91. *Quercus acutissima* is rarely found at elevations below 500 m in the Chubu District, except in plantations such as the one in Nagoya Castle Park. These facts suggest that the distribution of *Q. acutissima* corresponds to an area within the Warm Temperate Deciduous Forest Zone, as proposed by Kira (1949), where low winter temperatures restrict the growth of broad－leaved evergreen trees.

This difference in distribution between the two species can be explained by differences in their life histories. Hiroki and Matsubara (1982) compared the growth stages from seed to seedling in *Q. variabilis* and *Q. acutissima* and found differences in the patterns of seed germination and seedling growth. The seeds of *Q. variabilis* germinate in the year of seedfall so seedlings can establish before winter, whereas the seeds of *Q. acutissima* overwinter and do not germinate until the following spring, avoiding severe winter temperatures. These life-history features correspond well to the observed geographical distribution of each species: *Q. variabilis* in warmer regions and *Q. acutissima* in cooler regions.

Given these life-history traits, the distribution of *Q. acutissima* in warmer regions such as southern Kyushu is curious. Miyawaki (1981) regarded almost all of the *Q. acutissima* forests in Kyushu as plantations for the provision of logs used for growing *Lentinus edodes* (shiitake mushrooms). *Quercus acutissima* is also said to have been planted to support the production of wood charcoal (Matsubara and Hiroki 1980). The wood of *Q. acutissima* is much better for charcoal production than that of *Q. variabilis* (Kishimoto 1976), and ancient documents show that charcoal was produced from *Q. acutissima* in the Edo era in the upper reaches of the Ina River in the Hokuetsu area of Hyogo and Osaka Prefectures (Hattori et al. 2005). Thus, the contribution of humans to the expansion of *Q. acutissima*'s distribution cannot be discounted.

Although acorns of *Q. variabilis* and *Q. acutissima* are also dispersed by animals such as rodents or jays (Hiroki and Matsubara 1982;

Chung and Chung 2002), the role of humans in the dispersal of large acorns also cannot be neglected. Hiroki and Ichino (1991) suggested that the distributional range of *Castanopsis sieboldii* expanded as a result of dispersal by humans, who used the nuts as food. It is also known that the distribution of *Castanea sativa* expanded rapidly around the Mediterranean about 3000 years ago by human interference (Fineschi et al. 2000).

Genetic analyses have shown the development of hybridization zones in areas where the distributions of *Quercus* species overlap in western North America (Howard et al. 1997; Dodd and Kashani 2003; Dodd and Afzal-Rafii 2004) and in Mexico (González-Rodríguez et al. 2004). We thus need to conduct more precise investigations into the formation of hybrids between *Q. variabilis* and *Q. acutissima* based not only on their morphological characteristics, but also on genetic analyses, to clarify the details of their hybridization, including such factors as the survival of hybrid seedlings.

References

Chung, M.Y. and Chung, M.G. 2002. Fine-scale genetic structure in populations of *Quercus variabilis* (Fagaceae) from southern Korea. Can. J. Bot. **80**: 1034–1041.

Dodd. R.S. and Afzal-Rafii, Z. 2004. Selection and dispersal in a multispecies oak hybrid zone. Evolution **58**: 261–269.

Dodd, R.S. and Kashani, N. 2003. Molecular differentiation and diversity among the California red oak (Fagaceae; *Quercus* section *Lobatae*). Theor. Appl. Genet. **107**: 884–892.

Fineschi, S., Taurchini, D., Villani, F. and Vendramin, G.G. 2000. Chloroplast DNA polymorphism reveals little geographical structure in *Castanea sativa* Mill. (Fagaceae) throughout southern European countries. Mol. Ecol. **9**: 1495–1503.

González-Rodríguez, A., Arias, D.M., Valencia, S. and Oyama, K. 2004. Morphological and RAPD analysis of hybridization between *Quercus affinis* and *Quercus laurina* (Fagaceae), two Mexican red oaks. Amer. J. Bot. **91**: 401–409.

Hardin, J.M. 1979. Patterns of variation in foliar trichomes of eastern North American *Quercus*. Am. J. Bot. **66**: 576–585.

Hattori, T., Minamiyama, N. and Matsumura, T. 2005. A historical study on the Ikeda-zumi (Ikeda-charcoal) and the fuelwood forest in the upper reaches of the Ina River, Hyogo and Osaka Prefecture. Vegetation Sci. **22**: 41–51. (in Japanese with English summary)

Hiroki, S. and Ichino, K. 1991. The distribution of *Castanopsis cuspidata* and its allies examined from a viewpoint of fruit shape. Phytogeogr. Taxon. **39**: 79–86. (in Japanese with English summary)

Hiroki, S. and Matsubara, T. 1982. Ecological studies on the plants of Fagaceae III. Comparative studies on the seed and seedling stages. Jpn. J. Ecol. **32**: 227–240. (in Japanese with English summary)

Horikawa, Y. 1972. Atlas of the Japanese Flora: an Introduction to Plant Sociology of East Asia. 500 pp. Gakken, Tokyo.

Horikawa, Y. 1976. Atlas of the Japanese Flora II: an Introduction to Plant Sociology of East Asia. pp. 501–862. Gakken, Tokyo.

Howard, D.J., Preszler, R.W., Williams, J., Fenchel, S. and Boecklen, W.J. 1997. How discrete are oak species? Insights from a hybrid zone between *Quercus grisea* and *Quercus gambelii*. Evolution **51**: 747–755.

Ishizuka, K., Shoji, Y. and Aoki, H. 1983. *Quercus variabilis* forest in the vicinity of Yamagata, northeast Japan, with special reference to the topography. In Contemporary Ecology of Japan (ed. by the Committee of Contemporary Ecology of Japan). pp. 169–175. Kyoritsu, Tokyo. (in Japanese)

Kira, T. 1949. Forest Zones of Japan. Ringyo-Gijutsu-Kyokai, Tokyo and Sapporo. 41 pp. (in Japanese)

Kishimoto, S. 1976. Sumi. 219 pp. Marunouchi Publ., Tokyo. (in Japanese)

Kitamura, S. and Murata, G. 1979. Color Illustrated Book of Woody Plants of Japan Vol. II. 545 pp. Hoikusha, Osaka. (in Japanese)

Manos, P.S. 1993. Foliar trichome variation in *Quercus* section *Protobalanus* (Fagaceae). Sida **15**: 391–403.

Matsubara, T. and Hiroki, S. 1980. Ecological studies on the plants of Fagaceae. II. Distribution of *Quercus variabilis* Blume and characteristics of its seedling stage. Jpn. J. Ecol. **30**: 85–98. (in Japanese with English summary)

Menitsky, Y.L. 2005. Oaks of Asia. 549 pp. Science Publ., Enfield.

Miyawaki, A. (ed.) 1981. Vegetation of Japan Vol. 2 Kyushu. 484 pp. Shibundo, Tokyo. (in Japanese with English summary)

More, D. and White, J. 2002. The Illustrated Encyclopedia of Trees. 800 pp. Digitronix, Bradford.

Muller, C.H. 1952. Ecological control of hybridization in *Quercus*: a factor in the mechanism of evolution. Evolution **6**: 147–161.

Palmer, J.W. 1948. Hybrid oaks of North America. J. Arnold Arboretum **29**: 1–48.

Ricklefs, R.E. and Miller, G.L. 2000. Ecology (4th. ed.). 822 pp. W.H. Freeman and Company, New York.

Sano, T. 1990. Morphological comparison of bark and foliage of *Quercus acutissima* with those of *Quercus variabilis*. Bull. Hiroshima Pref. For. Exp. Stn. **24**: 87–98. (in Japanese with English summary)

Spellenberg, R. 1995. On the hybrid nature of *Quercus basaseachicensis* (Fagaceae, Sect. *Quercus*). Sida **16**: 427–437.

Stebbins, G.L., Jr. 1950. Variation and Evolution in Plants. 643 pp. Columbia Univ. Press, New York.

Stebbins, G.L., Jr., Matzke, E.B. and Epling, C. 1947. Hybridization in a population of *Quercus marilandica* and *Quercus ilicifolia*. Evolution **1**: 79–88.

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広木詔三[1]・神谷高浩[2]：アベマキ，クヌギおよび両種の雑種の星状毛による識別と中部日本における両種の交雑帯の解析

愛知県名古屋市東山丘陵（名古屋市名城公園の植栽による24個体を含む）から長野県の飯田市から豊科町にかけての二次林において，形態的中間形を含むアベマキとクヌギの152個体から葉を採集し，そのうち107個体について，双眼実体顕微鏡を用いて葉裏の星状毛の密度に基づいて種あるいは雑種の同定を行った。その結果，葉裏の星状毛の数がおよそ38,000（1/cm^2）に達したもの（1個体）はアベマキ，および星状毛がまったく認められなかったもの（87個体）はクヌギ，そして星状毛が低密度で認められたもの（19個体）は雑種と判定した。星状毛が密生しており葉裏が白くアベマキと判定された45個体を加えた152個体の地理的分布を解析した結果，名古屋市名城公園の植栽されたクヌギ24個体を除いて，アベマキは標高の低い愛知県から長野県の飯田市にかけて分布し，飯田市から標高の高い地域にかけてクヌギの分布が増大し，雑種はアベマキとクヌギの分布が重なる地域に出現して交雑帯を成していた。

アベマキの分布域は，ほぼ暖温帯域内に対応するが，それに対してクヌギの天然分布域は，吉良の暖帯落葉樹林に対応することが示唆された。この結果をもとに，クヌギの日本における分布が九州等の温暖な地域にも分布する異常さを人為との関連において考察を行った。

([1]〒464–8601　名古屋市千種区不老町　名古屋大学情報科学研究科；[2]現住所　〒452–0944　愛知県西春日井郡清洲町上條1–2–6)