OAKS OF EUROPE AND ASIA
OCCURENCE, ECOLOGY AND AMENITY VALUES

by Dr. Stelian Radu

Introduction: Species Diversity and Classification

The oaks constitute one of the most important groups of trees in the world, as timber trees, as ornamentals, as well as for products like acorns, tannin, cork and others. From an ecological and forestry point of view, oak trees represent a biological richness in forest ecosystems and have an important economic role in the production function of the forest.

Oak grouped together, according to different authors (Neger and Munch, 1950), comprises 200-600 species, which are spread over the northern hemisphere, mainly on four continents: North America, Europe, Asia and North Africa. The difference in the numbers are partly explained by the definition of hybrid forms as separate species, partly by the species concept (classical or biological) and by subdivision of ecological forms into species (Kleinschmit, 1993). Schenk (1939), Krüssmann (1962), Wright (1962) and more recently, Nixon (1993) have detailed these figures by continents and climatic zones as follows:

a) North America - Eastern part - 60 spp.
   North America - Western part - 25 spp.
   Highland Mexico and Central America - 150 to 200 spp.
b) Temperate Europe and North Africa - 8 to 12 spp.
c) Montane subtropical Eurasia, from Middle East to China and South east Asia - 150 spp.
d) Northern South America (Columbia) - 1 spp.

Although some authors recognize many additional European oak species, the biological diversity of oaks is still much more important in North America and Asia than in Europe.

According to Krüssmann (1978), the genus is subdivided into three subgenera: Cyclobalanopsis, Erythrobalanus and Lepidobalanus, with 1 to 7 sections in each.[3] Recently Nixon (1993) presented an infrageneric classification of genus *Quercus* which broadly follows that of Camus (1938), but utilizes Loudon's (1838) sectional names, which have priority for some taxa Camus recognizes. This classification recognizes two subgenera, Cyclobalanopsis and Quercus, the latter with three sections: Lobatae (red oaks), Protobalanus (intermediate oaks, golden cup oaks) and Quercus (white oaks), including Ilex and Cerris groups.

In this paper, we will give a short and general review of 64 Eurasian oaks, mostly from forestry and amenity points of view.

Synopsis of Species

The taxonomy, occurrence and some bio-morphological traits (shape, height, leaves and fruit maturation) of these alphabetically ordered species are presented in Table 1. The list-

[3]Editor's Note: Since this article has been written the three subgenera have been renamed. Please refer to Guy Sternberg's article for current nomenclature.

ing and the table are neither perfect nor complete. We had insufficient information about some Asian oaks like *Q. edithiae* Skan and *Q. fargesii* Franchet (from China), *Q. gilva* Bl. (from Japan) and *Q. koreana* Nakai. *Quercus aegilops* is another complex and confusing taxon. This concise table can be expanded with other tree characteristics like morphology of leaves, bark and fruits; main ecological requirements of species (concerning the temperature, humidity and soils); forestry and amenity values and possibility of introduction in North America; some of these characteristics are presented throughout the paper.

Table 1 LIST OF EURASIATIC OAK SPECIES

#	Scientific Name Synonym Common Name	Natural Range	Category	Habit	Height	Leaves	Fruiting Maturity
1	Q. araxina Grossh. Q. infectoria petiolaris Medw.	Caucasus	A5	t/sh	?	deciduous	1
2	Q. acuta Thunb. Japanese evergreen oak	Japan	C1	tree	(20')30' - 40'	evergreen	1
3	Q. acutissima Carruth Q. serrata Sieb & Zucc. Sawtooth oak	Japan, Korea, China, Himalayas	C3	tree	20'-40'(50')	deciduous	2
4	Q. aliena Bl.	Japan, Korea, China	C3	tree	65'	deciduous	1
5	Q. alnifolia Poech.	Cyprus	A2	t/sh	?	evergreen	1
6	Q. aquifolioides Rehd & Wils.	W. China	C2	t/sh	?	evergreen	1
7	Q. baronii Skan.	W. China	C2	t/sh	?	semi-evergreen	1(2)
8	Q. brantii Lindl.	Armenia, Iran	B	tree	35'	deciduous	1(2)
9	Q. calliprinos Webb. Q. fenzlii Kotschy Q. palaestina Kotschy	Asia Minor	A2		?	evergreen	1
10	Q. canariensis Willd. Q. mirbeckii Durien Canary oak	Spain, N. Africa	A3	tree	80' - 115'	deciduous	1
11	Q. castaneifolia C.A. Mey.	Caucasus, Iran, Algeria	A5	tree	80'	deciduous	2
12	Q. cerris L. Turkey oak	S. Europe, SW Asia	A1	tree	115'	deciduous	2
13	Q. congesta Presl.	S. France	A3	tree	50'	deciduous	1
14	Q. coccifera L. Kermes Oak	Mediterranean Coast (Spain to Syria)	A2	shrub	10'	evergreen	2
15	Q. crenata Lam. Q. X hispanica Lam.	Italy, S. Greece	A3	tree	95'	semi-evergreen	1

#	Scientific Name Synonym Common Name	Natural Range	Category	Habit	Height	Leaves	Fruiting Maturity
16	Q. dalechampii Ten.	Balkans, Asia Minor, S. Italy	A4	tree	100'	deciduous	1
17	Q. delawayi Franch	SW China	C3	tree	30'	deciduous	1
18	Q. dentata Thunb. Q. obovata Bge. Daimyo oak	Japan, Korea, NW China	C3	tree	80'	deciduous	1
19	Q. ehrengergii Kotschy	Asia Minor, Lebanon, Syria, China	A3	t/sh	?	deciduous	1
20	Q. engleriana Seemen Engler's oak	China	C1	tree	30'	evergreen	1
21	Q. erucifolia Stev.	Caucasus	A5	tree	?	deciduous	1
22	Q. fabri Hance	Korea, China	C3	tree	80'	deciduous	1
23	Q. faginea Lam. Q. lusitanica Webb.	S. Europe	A3	tree	65'	deciduous	1
24	Q. frainetto Ten. Q. conferta Kit. Hungarian oak	S. Italy, Balkans, Hungary, Turkey	A1	tree	120'	deciduous	1
25	Q. fruiticosa Brot.	SW Europe, North Africa	A3	shrub	5'	deciduous	1
26	Q. gilliana Reh. & Wils.	W. China	C1	tree	25'	evergreen	1
27	Q. glandulifera Bl. Q. serrata Thunb. Glandbearing oak	Japan, Korea, China	C3	tree	45'	deciduous	1
28	Q. glauca Thunb.	Japan, Korea, Himalayas	C1	tree	40'-50'	evergreen	1
29	Q. haas Kotschy	Asia Minor	B	tree	50'	semi-evergreen	1
30	Q. hartwissiana Stev. Q. armeniaca Kotschy	Caucasus, Turkey	A5	tree	35'-80'	deciduous	1
31	Q. iberica Bieb.	Caucasus, Asia Minor	A5	tree	65'-130'	deciduous	1
32	Q. ilex L. Holly or Holm oak	S. Europe	A2	tree	60'	evergreen	1
33	Q. imeretina Stev.	Caucasus	A5	tree	80'	deciduous	1
34	Q. infectoria Oliv.	Greece, Cyprus, Asia Minor	A2	tree	60'	semi-evergreen	1
35	Q. lamellosa Sm.	N. India, Nepal, Bhutan	D	tree	80'	evergreen	1
36	Q. leuchotrichocarpa A. Camus	Himalayas, Burma	D	tree	80'	evergreen	1

#	Scientific Name Synonym Common Name	Natural Range	Category	Habit	Height	Leaves	Fruiting Maturity
37	Q. liaotungensis Koidz.	Manchuria, Mongolia, China	C3	tree	30'	deciduous	1
38	Q. libani Oliv. Lebanon oak	Syria, Asia Minor	B	tree	30'	decid.-semi	2
39	Q. longipes Stev.	Caucasus	A5	tree	45'-60'	deciduous	1
40	Q. lusitanica Lam. Lusitanian or Portuguese oak	Spain, Portugal, Morocco	A3	tree	65'	deciduous	1
41	Q. macranthera Fish & Mey.	Caucasus, Armenia, N. Iran	A5	tree	65'	deciduous	1
42	Q. macrolepis Kotschy Q. aegilops Lam. non L.	S. Italy, Greece, Asia Minor	A4	tree	35'-65'	deciduous	1
43	Q. mas Thore.	SW France, N Spain	A3	tree	?	deciduous	1
44	Q. mongolica Fisch. Mongolian oak	E. Siberia, Korea, Japan, Mongolia, Manchuria	C3	tree	100'	deciduous	1
45	Q. myrsinifolia Bl.	Japan, E. China	C1	tree	35'-50'	evergreen	1
46	Q. oxyodon Mig.	China	C2	tree	25'	evergreen	1
47	Q. pedunculiflora K. Koch Greyish oak	Balkans, Asia Minor, SE Romania	A4	tree	130'	deciduous	1
48	Q. petraea (Matt.) Liebl.	Europe, W. Asia	A1	tree	130'	deciduous	1
49	Q. phillyraeoides Gray.	China, Japan	C1	tree	20' - 30'	evergreen	1
50	Q. polycarpa Schur.	SE Europe, Asia Minor	A4	tree	85'	deciduous	1
51	Q. pontica K. Koch Armenian oak	Armenia, Caucasus	A5	sh/t	less than 20'	deciduous	1
52	Q. pubescens Willd. Q. languignosa Thuill. Pubescent oak	S. Europe, Caucasus, W. Asia	A1	tree	20' - 50'	deciduous	1
53	Q. pyrami Kotschy	Asia, Minor, Sicily	B	tree	80'	deciduous	1
54	Q. pyrenaica Willd. Q. toza DC	SW Europe, Italy	A1	tree	35' - 50'	deciduous	1
55	Q. robur L. Q. pedunculata English oak	Europe, N. Africa, SW Asia	A1	tree	75' - 150'	deciduous	1

#	Scientific Name Synonym Common Name	Natural Range	Category	Habit	Height	Leaves	Fruiting Maturity
56	Q. rotundifolia Rehd. Q. ballotta Desf.	S. Europe, N. Africa	A2	tree	65'	evergreen	1
57	Q. semecarpifolia Sm.	Himalayas, China	C1	tree	95'	evergreen	1
58	Q. stenophylla Mak.	Japan, Korea	C1	tree	35' - 50'	evergreen	1
59	Q. suber L. Q. occidentalis Gray Cork oak	S. Europe, N. Africa	A2	tree	20-' - 30'	evergreen	1
60	Q. trojana Webb. Q. macedonica A. DC Macedonian oak	Balkans, Greece	A4	tree	20' - 25'	decid./semi	1
61	Q. vallonea Kotschy Q. aegilops L.	Balkans, Greece, Asia Minor	A4	tree	50' - 80'	deciduous	1
62	Q. woronowi Maleev.	Caucasus	A5	tree	?	deciduous	1
63	Q. variabilis Bl. Oriental Cork oak	N. China, Korea, Japan	C3	tree	65'	deciduous	2
64	Q. virgiliana Ten.	SE Europe	A4	tree	50'	deciduous	1

Quercus petraea X *polycarpa* with Dumitru Pirlia, Forest Guard, Bejan Forest, Near Deva, Romania. © Guy & Edith Sternberg

These Eurasiatic oaks species are grouped by occurrence and climatic conditions because of the great diversity of Eurasia (relief, climate and vegetation) as follows (see Table 2 for U.S. Hardiness Zones):

A = Europe, with its 38 oak species is a great resource of oaks for planting North America because it includes 5 difference groups of these trees:

A1 = 6 species with large occurrence: *Q. robur, Q. petraea, Q. pubescens, Q. frainetto, Q. cerris* and *Q. pyrenaica*

A2 = 7 Mediterranean evergreen species with 5 large trees *(Q. ilex, Q. rotundifolia, Q. suber, Q. calliprinos,* and *Q. infectoria)* and 2 small trees or shrubs *(Q. alnifolia* and *Q. coccifera)*

A3 = 8 Mediterranean deciduous species: *Q. faginea, Q. crenata, Q. lusitanica, Q. mas, Q. congesta, Q. canariensis, Q. fruticosa* and *Q. ehrenbergii*

A4 = 7 Balkanian or East-Mediterranean deciduous species: *Q. trojana, Q. macrolepis, Q. polycarpa, Q. dalechampii, Q. pedunculiflora, Q. virgiliana* and *Q. vallonea*

A5 = 10 Caucasian species: *Q. castaneifolia, Q. hartwissiana, Q. macranthera, Q. iberica, Q. pontica, Q. longipes, Q. imeretina, Q. erucifolia, Q. wornowi* and *Q. araxina*

B = Asia Minor (Turkey), Armenia and Iran where mainly 4 species are located: *Q. haas, Q. brantii, Q. libani* and *Q. pyrami* (all deciduous)

C = East Asia (China, Korea, Japan, and partly Russia) with 20 species is the second oak genetic resource in Eurasia. Asiatic oaks can be grouped as followed:

C1 = 8 species of evergreen trees: *Q. semecarpifolia, Q. stenophylla, Q. glauca, Q. myrsinifolia, Q. acuta, Q. phyllyreoides, Q. engleriana* and *Q. gilliana*

C2 = 3 species of evergreen, small trees or shrubs: *Q. aquifolioides, Q. baronii* and *Q. oxyodon*

C3 = 9 species of deciduous trees: *Q. mongolica, Q. dentata, Q. fabri, Q. variabilis, Q. aliena, Q. acutissima, Q. glandulifera, Q. delavayi* and *Q. liaotungensis*

D = Himalayas, N. India, Nepal and Burma with 2 evergreen species: *Q. lamellosa* and *Q. leucotrichophora*

Table 2

RECOMMENDED OAK SPECIES AND DONOR SOURCES
FOR INTRODUCTIION IN DIFFERENT U.S. HARDINESS ZONES

Sources and Category of Oak Trees	HARDINESS ZONES (Rehder & Wyman)					
	4	5	6	7	8	9
A1 European deciduous	*petraea*	*robur* *frainetto*	*cerris* *pubescens* *pyrenaica*			
A2 Mediterranean deciduous				*suber* *calliprinos*	*coccifera* *alnifolia* *infectoria*	*ilex* *rotundifolia*
A3 Mediterranean deciduous				*crenata* *canariensis* *faginea* *lusitanica* *fruticosa*		
A4 Balkanian or East Medit. deciduous		*polycarpa* *pedunculiflora* *virgiliana*	*trojana* *dalechampi* *vallonea*	*macrolepis*		
A5 Caucasian deciduous		*macranthera* *pontica* *imeretina* *longipes* *araxina* *woronowii*		*castaneifolia*		
B Asia Minor, Armenia, Iran deciduous		*libani* *haas* *brantii*	*pyrami*			
C1 China, Korea, Japan evergreen				*emecarpifolia* *acuta* *engleriana*	*glauca* *gilliana* *myrsinifolia* *phillyreoides* *oxyodon* *stenophylla*	
C2 China, Korea Japan evergreen				*aquifolioides* *baronii*		
C3 China, Korea, Japan deciduous	*mongolica* *liaotungensis*	*variabilia* *aliena* *grandulifera* *dentata*	*acutissima* *fabri*			
D Himalayan evergreen					*lamellosa* *leucotrichophora*	

Discussion of Primary Species

In Europe oak species are concentrated in Atlantic (North), continental and Mediterranean climatic regions. This continent shows a great diversity of climates and relief forms (see Table 3). As a consequence, oaks with a large range *(Q. robur, Q. petraea, Q. pubescens)* present a great ecological and morphological diversity in the form of leaves, bark and acorns.

Table 3

EUROPEAN CLIMATIC REGIONS (Walter et al., 1975)

Climatic Region	Occurence	Climate	Species
Boreal	Finland, N. Sweden & Norway	Cold temperate, low winter temperature with Gulf Stream influence	*Picea abies, Pinus sylvestris*
Boreal Temperate	Southern Sweden & Southern Norway, Lithuania	Transitional	Deciduous species
Northern Atlantic	British Isles, Denmark, Netherlands, Belgium Southern Sweden, Germany, France, S. Norway	Moist, windy, moderate temperature, transitional	*Quercus robur, Q. petraea, Q. pubescens, Q. ilex*
Subatlantic	Poland, Germany, Slovakia, Czech Republic, Austria, Northeast France, Luxembourg	Typically temperate, large seasonal differance, less wind	*Picea abies, Pinus sylvestris Fagus sylvatica*
Continental	Hungary, Romania	From typically temperature to semi-arid	*Q. robur, Q. petraea, Q. cerris, Q. frainetto, Q. pubescens, Q. pedunculiflora*
Mountainous	Pyrenees, Alps, Tatras, Carpathian, Balkan	Steep climatic gradients	*Picea abies, Pinus sylvestris, Abies alba, Larix decidua*
Higher Mediterranean	Portugal, Spain, Southern France, Italy, Greece (400-1000m)	More humid	*Acer sp., Quercus species*
Lower Mediterranean	Portugal, Spain, France, Corsica, Sardinia, Sicily, Greece	Dry summers, periodic extensive drought, winter rainfalls	*Q. ilex, Q. suber, Q. rotundifolia, Pinus halepensis, Pinus pinaster, Castanea satvia*

Some species of oaks, like *Q. robur, Q. petraea, Q. cerris* and others have an important economic value in Europe and they represent about 9 percent of the growing stock in forests and 27 percent of broad-leaved forests respectively .

Q. robur and *Q. petraea* have been long cultivated, especially as forest trees, for ship construction, acorns, tannin, fuel wood, charcoal, railroad ties and furniture. It should be noted that *Q. robur* has 18 synonyms and *Q. petraea* has 25 (Krahl-Urban). The art and technique of modern silviculture were born in France - in oak forests - more than 300 years ago. Colbert gave active encouragement for oak forest conservation in 1661; around 1700 Carl XII established oak stands in Sweden with seeds from Poland; and Peter I (Russia) established the first oak reserves for ship wood.

For its span of life (maximum longevity is 600 years), constant growth and timber, *Q. robur* is considered "the aristocrat" of the forests and "the diamond" of the woods. As a sacred tree, oak was dedicated since antiquity to Jupiter. The Jupiter oak in Fontainbleau forest is 600 years old, has a top height of 114.83 feet and dbh of 6.33 feet.

There are famous oak forests in France (Fontainbleau, Troncais, Chambord, Berce, Compiegne); in Germany (Spessart); in Austria (Wienerwald); in Slovenia *(Q.robur* var. *tardissima);* in Slovakia and Poland (Bialogwieza); in Romania (Bejan); and in the Ukraine and Russia (Schipov, Tellerman, Tulskiezaseki, Trostianetzk). These forests are preserved as protected areas and conserved as forest resources. There are also many memorial trees in different European countries.

Mediterranean oak species

Approximately 31 oak species grow in different countries around the Mediterranean Sea. The most prevalent are the evergreen oaks, *Q. ilex* and *Q. suber* (see Table 4).

Q. ilex (Holm oak) is a preforest and forest species which has a large geographical range from Morroco to Turkey. *Q. rotundifolia* is considered by some taxonomists as a subspecies of *Q. ilex* in the western part of this range. Holm oak has a noteworthy ecological adaptability, growing from the edge of the sea on the northern side of the Mediterranean Sea (as a wind and salt resistant species), up to an altitude of 2500-2600 meters in the Atlas Mountains, in semi-arid and damp bioclimates, on limestone or siliceous soils.

Table 4

OCCURENCE OF MEDITERRANEAN OAKS

Scientific Name	Spain	Portugal	France	Italy	Turkey	Cyprus	Greece	Syria & Lebanon	Israel	Lybia	Tunsia Algeria Morocco
Q. alnifolia						√					
Q. calliprinos									√		
Q. canariensis	√										
Q. castaneifolia											√
Q. cerris				√	√		√	√			
Q. coccifera	√				√		√	√			
Q. congesta			√								
Q. dalechampii				√							
Q. ehrenbergii								√			
Q. faginea (Q. lusitanica)	√	√									√
Q. frainetto				√	√		√				
Q. fruiticosa											√
Q. hartwissiana					√						
Q. x hispanica				√			√				
Q. ilex	√			√	√		√				√
Q. infectoria					√	√	√				
Q. ithaburensis									√		
Q. libani					√			√			
Q. macrolepis (Q. aegilops)				√	√		√	√			
Q. mas	√		√								
Q. petraea	√			√	√		√				
Q. pubescens					√	√		√			
Q. pyrami				√							
Q. pyrenaica	√	√		√							
Q. robur	√	√		√							
Q. rotundifolia			√								√
Q. suber (Q. occidentalis)	√	√		√							√
Q. trojana					√		√				
Q. vallonea					√		√				
Q. virgiliana				√							

Querus suber (Cork oak) is well known in Portugal, Spain, Tunisia, Algeria and Morroco as the main cork producers. The bark of *Q. suber* is periodically stripped (without damage to the tree) at intervals of 9 to 18 years. *Q. suber* is subdivided into four infraspecific taxa, depending upon lifespan of leaves and acorn development (1 or 2 years).

Caucasian oak species

The Caucasus is an area of very high mountains, hills and plains surrounded by the Black, Azov and Caspian Seas and characterized by a great diversity in altitude [-28 to 5633 meters (Elbrus)], climate, soils and vegetation. The Caucasus is known as a very rich genetic center for plants with 6500 species, more than half of all the European flora. Oak species here have small ranges and many taxa are disputable as species. The most important are: *Q. castaneifolia, Q. macranthera, Q. hartwissiana and Q. iberica.* Close to *Q. robur* are: *Q. longipes, Q. imeretina, Q. woronowii,* and *Q. araxina.*

Eastern Asiatic oak species

Oaks are found growing here in two different forest domains: deciduous oak forest and evergreen forest in China, Korea and Japan. The principal species in the first category are *Q. mongolica, Q. acutissima, Q. dentata, Q. glandulifera,* and *Q. variabilis.* The better known among the evergreen oaks are *Q. glauca, Q. semecarpifolia, Q. acuta, Q. myrsinifolia* and *Q. stenophylla.*

The deciduous oak species are used for charcoal, rail ties, furniture, cork *(Q. variabilis)* and tannin *(Q. dentata).* The more important cultivated street trees originating in Eastern Asia are the following: *Q. acutissima, Q. aliena, Q. dentata, Q. mongolica* and *Q. variabilis.* In Korea, *Q. acutissima* is the most abundant species and has the widest ecological range among other oaks.

All these species have a great amenity value. Unfortunately, we do not have adequate references about *Q. gilva* Bl., considered the most decorative evergreen tree of Japan.

Variability and Hybridization of Oaks

The distinction of species in the *Quercus* complex is still a matter of debate. In Western Europe, several species have been reported as potentially interbreeding, the most widespread being *Q. robur* and *Q. petraea.* The prevalent opinion has been in favor of the common occurrence of hybrids between the different species, producing many morphologically intermediate forms between pure parental species due to hybridization and introgression. For instance, *Q. robur* has the highest variability of all broad-leaved tree species, mainly in the size of leaves, their shape, crenature, structure and leaf color (see Table 5).

The knowledge of the infraspecific variability of the oak species can be done using molecular markers as tools to study genetic variability, and by long-term progeny tests. Analysis of morphological variation combined with the study of molecular diversity should be the basis of modern dendrology for the discrimination of species, ecotypes and introgression zones.

Hybridization within the genus *Quercus* appears to be extensive due to the small-scale or long-scale introgression. The majority of the reports on hybrids are based on an analysis of morphological data alone, while other forms of evidence have only been used occasionally.

Table 5

CULTIVARS OF *QUERCUS ROBUR* L. (Krüssmann, 1962)

1. **Growth Forms**
   a. Columnar & Pyramidal:
      'Cupressoides', 'Fastigiata', 'Fastigiata Cuccullata', 'Fastigiata Purpurea';
   b. Pendant:
      'Pendula';
   c. Spherical:
      'Umbraculifera';
   d. Contorted Forms
      'Contorta', 'Tortuosa'.

2. **Leaf Forms**
   e. Edge of leaves finely indented and linear-shaped:
      'Asplenifolia', Filicifolia', 'Pectinata', 'Strypemonde';
   f. Bulging stretched spoon forms:
      'Cucullata', 'Cucullata Macrophylla', 'Heterophylla';
   g. Unlobed leaves:
      'Salicifolia'.

3. **Multi-colored Leaf Forms**
   h. Red leaves:
      'Atropurpurea', 'Purpurascens';
   i. Yellow leaves:
      'Concordia'
   k. White to yellow variegated leaves;
      'Albomarmorata', 'Argenteomarginata', 'Argenteopicta', 'Argenteovariegata', 'Aureobicolor', 'Furst Scharzenberg', 'Maculata', 'Puverulenta'.

In the last few decades, natural hybrids have been recorded in France, Romania and other countries. They refer to isolated hybrids, small hybrid swarms (Bejan), and also to large-scale introgression (France). The success of natural crosses depends upon synchronization in flowering phenology between trees.

Artificial hybridization started 60 years ago in the Ukraine where Piatnitsky made over 200,000 pollinations representing 47 different interspecific crosses, and 24 of these from 9 species were considered successful.

The Decline of Oaks

Oak forests manifest periodical decline in Europe, due to some viral or fungus diseases (including the wilt disease), insect defoliation, drought and air pollution. Oak wilt is known to affect all species of oaks, but it is most serious among the red oak group. In Europe this disease seems to be produced by the fungus *Ophiostoma* spp., but the main enemy of the oak forests is the human.

Introduction of Exotic Oaks

Oaks are among the most majestic trees, and the native as well as the introduced species are used everywhere as excellent specimens in parks, as shade trees on streets and in forests.

Unlike the American oaks, noted for their brilliant autumn color, oaks native to Europe, like many other European plants, usually have no special autumn color the leaves sometimes drop before turning brown. However, it is possible to find many handsome ornamental trees among the Eurasian oaks.

Perhaps the most important ornamental oaks originating in Europe are: *Q. robur, Q. petraea, Q. frainetto, Q. ilex,* and *Q. suber.* From Caucasus and Asia Minor the most important are *Q. macranthera, Q. libani,* and *Q. castaneifolia.* From Eastern Asia, the most important cultivated shade trees are *Q. acutissima, Q. dentata, Q. mongolica* and *Q. variabilis* (see Table 6).

VARIABILITY OF SOME EUROASIATIC OAKS (Krüssmann, 1962; Kolesnikov, 1960)

Species	Group	Varieties	Forms	Cultivars
Q. acuta Thunb.	c1			'Albinervis'
Q. aliena Bl.	c3	acuteserrata (Maxim) smaller leaves		
Q. castaneifolia CA Mey	a5	austriaca (Willd) Loud. -oval leaves haliphloeos Lam & DC - larger leaves pseudocerris Boiss - very variable tournefortii (Willd) Koch - lyre form leaves		'Argenteovariegata', 'Aureovariegata', 'Laciniata', 'Pendula'
Q. glauca Thunb.	c1		gracilis Rehd. & Wils.	
Q. x hispanica Lam.	a3			'Ambrozyana', 'Crispa', 'Dentata', 'Diversifolia', 'Heterophylla', 'Latifolia', 'Lucombeana'
Q. ilex L.	a2	angustifolia DC- narrow leaves	microphylla Trabut. longifolia Loud.	'Aureovariegata', 'Crispa', 'Fordii', 'Gramuntia', 'Integrifolia', 'Latifolia'
Q. macranthera Fisch & Mey.	a5		pinnatifida Medw.	
Q. mongolica Fisch.	c3	grosserrata (Bl.) Rehd. & Wils. smaller and sharp lvs.		
Q. petraea Liebl.	a1			'Albovariegata', 'Aurea', 'Aureovariegata', 'Cochleata', 'Columna', 'Falkenbergensis', 'Giesleri', 'Insecata', 'Lacinata', 'Mepilifolia', 'Muscaviensis', 'Pinnata', 'Purpurea', 'Pendula'
Q. pubescens Willd.	a1	pendula Nichlos.	crispata (Stev.) Schwarz	'Pinnatifida'
Q. pyrenaica Willd.	a1			'Pendula'
Q. suber L.	a2	occidentalis (Gray) Archang. winter green leaves		

For introducing and testing the exotic oaks, it is necessary (Wright, 1962) to select source regions with similar climates; study the growth and amenity value of oaks in those regions; and accommodate the site preferences of species to be introduced. Some details are given in these graphs.

It is very important to choose, in the frame of a given species, the appropriate provenances. One provenance of acorns must be collected from a minimum 10-20 trees belonging to the same species to assume adequate genetic representation.

It is better to introduce from 3 (small-range species) to 20 (large-range species) provenances of each species and to test the new species under three or four different conditions. Of course, such a program requires decades to accomplish.

Propagation of Oaks

From a forestry point of view, oak stands have been traditionally regenerated by so-called natural regeneration techniques, by natural sowing and stump sprouting.

From a gardening point of view, for the moment, exotic oaks can be tested for adaptability and amenity, and introduced into the United States only by seed. According to the quarantine regulations, seeds of a given plant may be enterable with certification but the plant itself or vegetative parts thereof may not be imported without a special permit issued by the Department of Agriculture. Unfortunately, according to this law, the entry of plant material (seeds, buds, cuttings, scions and layers) for *Quercus* spp. from Japan is prohibited. Another difficulty is that seedlings of oak species cannot be grown easily in containers due to their long taproots.[4]

Acorns belong to the so-called "recalcitrant" category of seeds, which lose germinative capacity if their humidity diminishes under 40 percent, and they do not survive low temperatures. Oak seed production is characterized by occasional years of surplus, interspersed by several years with little or no seeds. For this reason, acorns can be stored over more than one winter only if they are maintained at a temperature of -1°C(30°F) and at moisture content of not less than about 40 percent. They require soaking in water at 41°C for three hours before storage to prevent damage by the fungus *Ciboria batschiana.*

A balanced root system can be formed in the moment of seeding by breaking of the emergent young root. Otherwise, the pruning of roots is necessary in a nursery in order to produce many fine roots at the base of the plant, thus making it much easier to transplant with a much better chance of survival.

Vegetative propagation by cutting, grafting and budding requires special facilities (plastic greenhouses, mist or fog system, lighting equipment, heating, etc.), skill, time and money. Despite all of these, oaks can be economically reproduced by cutting or grafting of understocks of close affinity. In France and other European countries oak plants are produced from cuttings in climatized greenhouses, by forestry stations and some nurseries.

Oaks can be veneer-grafted in the early spring in the nursery and in the greenhouse. Grafts used by Russian scientists for the best oak phenotypes include: pocket type (Sidorenko & Belousov), bark graft, veneer graft, cleft graft, whip graft and others. Recently, Borzan multiplied a seedling of *Q. robur* with variegated leaves using a special device for grafting. *Quercus suber* has been used in Spain for bark grafting in cork oak and holm oak with 4-5 year old stocks and also through side grafting in 2 year old stock. Top grafting often suffers from rejection of graft unions.

Conclusion

Despite their economic and social importance and worldwide distribution, oaks have received very scant attention in the past, particularly in terms of studies of genetic diversity.

[4]Editor's note: There have been many techniques developed to facilitate the handling of oaks and increasing their chances of transplanting. See article by Coggeshall for further information.

The genus *Quercus* has several peculiarities that are still to be solved; these include their taxonomy, the extent of introgression within different sections, and appropriate breeding strategies.

The development of recent biotechnological and molecular techniques has opened new fields for investigation.

From a practical point of view, a more close cooperation between oak cultivators is necessary.

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