FagaceaeCBeech family

Quercus L.

oak

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Growth habit, occurrence, and use. The oaksCmembers of the genus *Quercus*Cinclude numerous species of deciduous and evergreen trees and shrubs and make up the single most economically important genus of hardwoods in North America. *Quercus* is also the largest genus of trees native to the United States (Little 1979) and has recently been designated as the Anational tree@ by the National Arbor Day Foundation. About 500 species are widely distributed throughout the temperate regions of the Northern Hemisphere in both the Eastern and Western Hemispheres as well as southward through Central America to the mountains of Colombia and through Turkey to Pakistan (Sargent 1965). There are about 58 tree and 10 shrub species native to the United States, 104 species in Mexico, and another 30 in Central America and Colombia. At least 70 hybrids have been described, and there are probably many more (Little 1979). Information on hybrids and genetic variation has been summarized for 25 species in Burns and Honkala (1990).

Oaks are divided into 2 subgenera: *Lepidobalanus* (white oaks) and *Erythrobalanus* (black oaks). These subgenera differ in several ways, but most importantly for seed considerations, they differ in time required for fruit maturation, chemical composition of their stored food reserves, and degree of dormancy. In this book, 48 taxa are considered (table 1). Oaks are valuable for a very wide range of products and uses: construction timber, furniture, interior trim, and flooring; watershed protection, wildlife habitat and food, and ornamental plantings; as well as tannins and other extractives and cork. Consequently, many oak species are widely planted for a variety of purposes. For additional information on growth habit, uses, ecology, and silviculture of individual oak species, consult Burns and Honkala (1990).

Flowering and fruiting. Flowering is monoecious. The staminate flowers are borne in clustered aments (catkins) and the pistillate flowers in solitary (or in 2- to many-flowered) spikes in the spring (February to May) before or coincident with emergence of the leaves. Staminate flowers develop primarily from leaf axils of the previous year and range in length from 3 to 35 cm, depending on the species. Pistillate flowers develop from axils of leaves of the current year. The fruit is a nut, commonly called an acorn (figure 1). Acorns of white oaks mature in the year of flowering, whereas acorns of black oaks mature at the end of the second year after flowering (Sargent 1965). Acorns are 1-seeded, or rarely 2-seeded, and occur singly or in clusters of 2 to 5. They are subglobose to oblong, short-pointed at the apex, and partially enclosed by a scaly cup (the modified involucre) at their base. Removal of the cup discloses a circular scar that is often useful in judging acorn maturity. Acorns range in size from 6 mm in length and diameter for willow oak to 50 mm in length and 38 mm in diameter for bur oak (Sargent 1965). Fruit ripening and seed dispersal occur in the autumn, from late August to early December (Olson 1974; Radford and others 1964; Sargent 1965). The embryo has 2 fleshy cotyledons, and there is no endosperm (figure 2). Acorns are generally green when immature and turn yellow, brown, or black when ripe.

The oaks vary widely in initiation of seed bearing and frequency of large crops (table 2). Acorn production by coppice shoots of chestnut oak only 3 and 7 years old indicates that seed production may start earlier on trees of sprout origin, although coppice sprouts of scarlet and black oaks of comparable ages did not bear seeds (Sharik and others 1983). Environmental factorsCsuch as late spring freezes (Neilson and Wullstein 1980), high humidity during pollination (Wolgast and Stout 1977), or summer droughts (Johnson 1994)Cwill reduce the acorn crop, but some inherent periodicity seems to exist in many species. Most species produce good crops (Amast years@) 1 year out of 3 or 4 (Beck 1977; Christisen and Kearby 1984; Downs and McQuilkin 1944; Goodrum and others 1971). Sork and others (1993) reported good acorn crops in Missouri every 2, 3, and 4 years for black, white, and northern red oaks, respectively. In central California, a study of acorn production in valley, blue, and California black oaks and canyon live and coast live oaks (Koenig and others 1994) found no mast production patterns at the population level. Crop failures occurred frequently, but may have been more related to pollination and fertilization success than to inherent patterns. Cecich (1993) concluded that most of the potential seed crop in oaks in Missouri is lost when pistillate flowers abort between the time of pollination and fertilization. Really good crops of California black oak acorns were found to occur only every 8 years or so (McDonald 1992). The following yield averages on an area basis have been reported: 3.2 to 1,620 kg/ha (2.9 to 1,448 lb/ac) for white oak in Illinois (Johnson 1975); 208 kg/ha (186 lb/ac) for southern Appalachian oaks (Beck 1977); and 560 kg/ha (500 lb/ac) for Oregon white oak in California (Stein 1990).

Collection and cleaning of acorns. Collecting acorns of high quality requires an awareness of the indices of acorn maturity. Natural dissemination from the tree is a sure sign of maturity, of course, but collections are often made before this time to reduce losses to deer, rodents, and other predators that quickly eat fallen acorns. Good indices of maturity for most species are (1) change in pericarp color from green to yellow, brown, or black; (2) a cup scar colored pink, lemon, orange, or white; and (3) cups that slip easily from the acorns without resistance (Bonner and Vozzo 1987; Lotti 1959). Ripe acorns may be collected from August to December from the ground or they can be shaken from trees onto canvas or plastic sheets after ripening. Mechanical tree shakers can be very effective with oaks where the terrain or stand conditions permit it. Collecting acorns from downed trees in logging operations also can be successful if the trees were cut after the acorns had matured. Acorn should be collected from the ground within a few days after dispersal to avoid losses to predators, desiccation of the acorns, and early germination of the non-dormant species (primarily the white oaks). California black oak also requires prompt collection because mold often infects fallen acorns (McDonald 1990).

To avoid desiccation, which can quickly reduce acorn quality, acorns should be floated in water after collection, preferably at the end of each collection day. This action will maintain high moisture contents and permit removal of trash and unsound acorns, because sound acorns will sink and the other material will float. For acorns collected from the groundCmoisture conditions at time of collection can affect the flotation process. If the ground is very dry, many good acorns may float initially, and the lot may have to stay in the water overnight to allow sound acorns enough time to take up moisture and sink. In contrast, when the ground is wet, many unsound acorns may be heavy enough to sink in water, and a few hours of drying at ambient temperature can help the separation. Water flotation is never 100% effective, but common sense and attention to detail will enable collectors to make dramatic improvements in the quality of their acorns. Another way to allow for different acorn moisture conditions may be to use salt solutions to change the density of the water. In a test with water oak and willow oak (Johnson 1983), 230 g of salt/liter of water for unsaturated acorns and 285 g/l for saturated acorns, led to recovery of up to 11% more good acorns. The acorns were not in the salt solutions long enough to take up the chemical, and a quick rinse after recovery removed surface salt. In the dry climate of California, acorns of blue oak dry so quickly that collection directly from the tree may be the only way to ensure seed quality (McCreary and Koukoura 1990). A loss of only 10% acorn moisture resulted in almost 40% less germination for blue oak.

Data on acorn size and weight are summarized in table 3. For many years, nurseries did little sizing of acorns, but now that is changing, at least in the South. Numerous nurseries now size acorns with screens or other devices (Bonner and Vozzo 1987) to gain in uniformity of germination and bed density. Positive correlations between acorn size and leaf area have been reported for northern red, chestnut, white, and bear oaks (Farmer 1980) and also between acorn size and shoot growth for English and durmast oaks (Kleinschmit and Svolba 1979).

In years when light crops are produced, the percentage of acorns that are infested with insect larvae will be large, and flotation offers a simple way to remove these damaged acorns. The major insect pests of acorns in the United States are the acorn weevils (*Curculio* spp.), filbertworms (*Melissopus latiferranus* Walsingham), and acorn moths (*Valentinia* spp.) (Baker 1972; Gibson 1972, 1982; Oliver and Chapin 1984; Vozzo 1984). A cynipid wasp that causes galls on acorns of European turkey oak and English oak is a major pest in Europe, causing 30 to 50% losses of the acorn crop each year in the United Kingdom (Collins and others 1983). Prevention of infestation is not possible, so infested acorns must be removed from the lots. Some collectors kill the larvae of acorn weevils by immersing the acorns in hot water (48 °C) for 40 minutes (Olson 1974). This temperature is dangerously close to conditions that will damage the acorns, however, so caution must be used. In a study with live oak, germination and seedling growth dropped dramatically after hot water treatments of 7.5 to 60 minutes (Crocker and others 1988). Because none of these insects attacks other acorns during storage, the infestation cannot spread. Only in cases of exporting acorns to other countries where seed health regulations require treatment would this treatment be completely justified.

Storage. Acorns are recalcitrant seeds; they cannot tolerate desiccation below a rather high minimum moisture content and are therefore very difficult to store. Oaks are by far the most commercially important group of recalcitrant species in the temperate zone. The lethal moisture contents vary by species, but range from 15 to 20% in black oaks and 25 to 30% in white oaks. Most species of the black oak group can be stored for 3 years by maintaining high acorn moisture levels (above 30%) and storing just above freezing (1 to 3 °C) in containers that allow some gas exchange with the surrounding atmosphere (Bonner 1973; Bonner and Vozzo 1987; Suszka and Tylkowski 1982). Most species will germinate in storage under these conditions, but pre-sprouting does not prevent sowing or production of plantable seedlings (Bonner 1982). White oak acorns can be stored in a similar fashion, but safe moisture levels are 45 to 50%. White oaks germinate in storage much more readily than black oaks, and do not survive as well. As a practical matter, storage of white oak acorns for more than 6 months is seldom attempted in this country. Acorns of English oak have been successfully stored for 3 years in Europe by lowering the moisture levels slightly and mixing them with dry sawdust or peat (Suszka and Tylkowski 1980). Acorns of the same species are routinely stored for 3 years in Denmark also by lowering the moisture content slightly and storing the acorns right at freezing in open containers with no medium. In the case of another white oak, partial drying of California scrub oak acorns significantly improved viability retention over 8 months (Plumb and McDonald 1981). The partial drying may be beneficial because it reduces the incidence of fungi on the surface of the acorns.

Acorns can be stored in plastic bags, drums, or even boxes as long as the containers are not completely sealed and the acorns do not get too dry. Some European species can be stored by immersion in water (Jones 1958), and Nuttall oak has been successfully stored overwinter submerged in water at 3 to 5 °C (Johnson 1979). If drums or boxes are used, it is wise to insert a plastic bag liner. Respiration is rapid in seeds with high moisture levels, and oxygen will be depleted and carbon dioxide increased dramatically in just a few weeks. Plastic bags at least 4 mils thick are useful for storage; tops should be loosely folded over, not sealed. There is some evidence that white oaks should be stored in thinner bags (1.75 mils) because of their greater requirement for oxygen (Rink and Williams 1984). Most species can actually tolerate temperatures a few degrees below freezing (Suszka and Tylkowski 1980), but storage below –5 °C is usually fatal.

Pregermination treatment. Acorns of the white oak group generally have little or no dormancy and will germinate almost immediately after falling. These species should usually be planted in the fall. They will quickly put down radicles, but epicotyl dormancy occurs in some species and prevents shoot growth until the following spring. Epicotyl dormancy has been noted in English oak (Wigston 1987) and in eastern and southern white and chestnut oaks (Farmer 1977). White oaks in the warmer climate of CaliforniaCcoast and canyon live oaks, and blue, California scrub, and valley oaksCapparently do not have epicotyl dormancy (Matsuda and McBride 1989). Acorns of bur oak from the northern portion of the range actually require 60 days of cold, moist stratification for prompt germination (Tinus 1980). Acorns of the black oak group exhibit variable dormancy that is apparently imposed by the pericarp, the embryo, or both (Hopper and others 1985; Jones and Brown 1966; Peterson 1983), and stratification is usually recommended before spring sowing or certain types of germination tests. Epicotyl dormancy has been reported in at least one black oak speciesCbear oak (Allen and Farmer 1977). If proper procedures are followed for storage of black oak acorns, the storage conditions will also serve to complete the stratification requirement, and additional treatment is not necessary (Bonner and Vozzo 1987). If additional stratification is needed, imbibed acorns should be held for 4 to 12 weeks at temperatures of 2 to 5 °C. The acorns may be mixed with peat or other media, but this is not necessary. Most managers stratify in plastic bags without medium, turning the bags each week or so to prevent pooling of excess moisture in the bags (Bonner and Vozzo 1987). Acorns of the black oak group sown in the fall or early winter need not be stratified before to sowing.

Germination tests. The standard official laboratory test procedure for all oaks is to soak the acorns in water for 48 hours; cut off a third of the acorn at the cup scar end; remove the pericarp from the top half; and place it on thick, moist blotters at alternating temperatures of 20 to 30 °C (ISTA 1993). No other pretreatments are necessary, and germination should be complete within 14 days. Germination can also be tested with intact acorns in sand, peat, or other media in greenhouse flats. In such tests, stratification may be necessary for black oak species (table 4). Germination is hypogeal (figure 3) and is generally complete in 3 to 5 weeks. Rapid estimates of viability can also be made with cutting tests, radiography, or tetrazolium staining (Belcher and Vozzo 1979; Bonner and Vozzo 1987). Cutting tests are reliable on freshly collected acorns, and radiography is very good for quick determination of insect infestation. Tetrazolium staining can also provide information on seed vigor, but acorn chemistry and morphology present some problems in this test (Bonner 1984).

Nursery practice. Numerous research studies have shown that success in planting oaks depends on production of vigorous seedlings through low sowing densities and undercutting in the beds (Schultz and Thompson 1990). Container production in greenhouses is also practiced for a few species (Tinus 1980). Fall-sowing of oaks is preferable to spring-sowing in many instances if weather allows bed preparation in the fall. Fall-sowing eliminates the need for a large storage capacity for acorns and avoids the problems of fungi and early germination in storage. One disadvantage to fall-sowing in the southern part of the country is that mild winters may not completely satisfy the stratification requirement of dormant black oaks, and germination in the spring may be slow and erratic. Another disadvantage is prolonged exposure to predators, such as grackles (*Quiscaluis* spp.) and blue jays (*Cyanocitta cristata*), that dig up acorns from the beds. If spring sowing is used (very common in the South), the acorns should be stratified.

Acorns should be drilled in rows 20 to 30 cm (8 to 12 in) apart and covered with 6 to 25 mm (3 to 1 in) of firmed soil. The planting depth should at least be equal to the average acorn diameter. Desirable seedbed densities are 100 to 160 seedlings/m^2 (10 to 15/ft^2) (Williams and Hanks 1976), or less. For cherrybark oak, a study of bed densities from 43 to 108/m^2 (4 to 10/ft^2) showed that the lowest density produced more plantable seedlings per weight of seed, even though nursery costs were approximately 20% higher (Barham 1980). Another study with this same species found that 86/m^2 (8/ft^2) produced the greatest number of plantable seedlings (Hodges 1996). Fall-sown beds should be mulched with sawdust, ground corncobs, burlap, straw, or similar materials. Where high winds may blow the mulch, some sort of anchoring devices, such as bird netting, must be used. Mulches reduce erosion and frost heaving and provide some protection against rodents and birds. In the spring, after frost danger is past, the straw and hay mulches should be removed, but sawdust can remain on the beds. Partial shade has been found to improve germination of Nuttall (Johnson 1967) and cherrybark oaks (Hodges 1996) but is not commonly used for other oaks. The common planting stock for oaks is a 1+0 seedling.

Oaks can also be direct-seeded in the field but must be covered to control predation by animals. Spot-seeding at depths of 2 to 5 cm (1 to 2 in) have been successful for bur, chestnut, white and pin oaks in Kentucky (Cunningham and Wittwer 1984); white, northern red, and black oaks in Tennessee (Mignery 1975); and cherrybark, Nuttall, sawtooth, Shumard, and water oaks in Mississippi (Francis and Johnson 1985; Johnson 1984; Johnson and Krinard 1985). Rapid germination will also reduce losses to rodents and birds, so acorns direct-seeded in the spring should be stratified. In recent years, large areas have been seeded to oaks in the Mississippi River floodplain in Mississippi and Louisiana. Results have been mixed; some operations have been successful and others have not, but the reasons for failure have not always been understood. In these sites, control of competing vegetation is often necessary in the first few years.

Oaks in general are extremely difficult to propagate vegetatively on a commercial scale, although a few successes have been reported. Grafting and budding have been somewhat successful for ornamental selections (Dirr and Heuser 1987), and some advances have been made in tissue culture of certain oaks (Chalupa 1990; Gingas 1991).

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Table 1C*Quercus*, oak: nomenclature and occurrence

Scientific name & synonym(s)	Group*	Common names	Occurrence
***Q. acutissima* Carr.**	white	**sawtooth oak**	E Asia & Japan; introduced to E US
***Q. agrifolia* Née**	black	**California live oak,** coast live oak, encina	Coast ranges from central to S California
***Q. alba* L.**	white	**white oak,** fork-leaf white & stave oaks	SW Maine to N Wisconsin; S to N Florida & E Texas
***Q. arizonica* Sarg.**	white	**Arizona white oak,** Arizona oak, roble	SW Texas to New Mexico, Arizona, & N Mexico at 1,500B3,000 m
***Q. bicolor* Willd.**	white	**swamp white oak,** cow oak	SW Maine to N Wisconsin S to Tennessee & Missouri
***Q. cerris* L.**	white	**European turkey oak,** turkey oak	S Europe to W Asia; introduced to central US
***Q. chrysolepis* Liebm.**	white	**canyon live oak,** canyon, maul, goldcup, & live oaks	Mtns of SW Oregon, S to S California & N Mexico; local in mtns. of Nevada & Arizona
***Q. coccinea* Muenchh.**	black	**scarlet oak,** black & Spanish oaks	SE Maine to Michigan; S to Georgia, S Alabama & Missouri
***Q. douglasii* Hook. & Arn.**	white	**blue oak,** California blue, iron , & mountain white oaks	Foothills of Sierra Nevada & Coast Ranges of California
***Q. dumosa* Nutt.**	white	**California scrub oak**, scrub oak	Coast Ranges & offshore islands of California & Baja California
***Q. ellipsoidalis* E. J. Hill**	black	**northern pin oak,** black, jack, & Hill oaks	Michigan to SW North Dakota; S to Iowa & NW Ohio
***Q. emoryi* Torr.**	black	**Emory oak,** black oak, bellota, roble negro	Mtns of Trans-Pecos Texas, SW New Mexico, SE & central Arizona, & N Mexico
***Q. falcata* Michx.** *Q. triloba* Michx.	black	**southern red oak,** Spanish & red oaks	SE New York to S Missouri; S to N Florida & SE Texas
***Q. gambelii* Nutt.** *Q. vreelandii* Rydb. *Q. utahensis* (A. DC.) Rydb.	white	**Gambel oak,** Rocky Mtn. white & Utah white oaks, encino	Colorado and Wyoming, W to Utah & S to Arizona, New Mexico, Texas, & NW Oklahoma
***Q. garryana* Dougl. ex Hook.**	white	**Oregon white oak,** Garry, post, Oregon, Brewer, & shin oaks	British Columbia; S in mtns to central California

***Q. grisea* Liebm.**	white	**gray oak**	SW Texas to New Mexico, Arizona, & N Mexico
***Q. ilicifolia* Wangenh.**	black	**bear oak,** scrub oak	S Maine, W to New York; S to West Virginia, SW Virginia, & W North Carolina
***Q. imbricaria* Michx.**	black laurel oak	**shingle oak,** Carolina, & Arkansas; local	Pennsylvania, S to S Michigan; North in Louisiana & Alabama
***Q. incana* Bartr.**	black	**bluejack oak,** sandjack, bluejack, shin, & turkey oaks	Coastal plain from Virginia to central Florida; W to Louisiana, E Texas, Oklahoma, & Arkansas
***Q. kelloggii* Newberry**	black	**California black oak,** black & Kellogg oaks	SW Oregon; S through Coast Ranges & Sierra Nevada to S California
***Q. laevis* Walt.** *Q. catesbaei* Michx.	black	**turkey oak,** scrub & Catesby oaks	Coastal plain from SE Virginia to central Florida, & W to Louisiana
***Q. laurifolia* Michx.** swamp, laurel, diamond-leaf oaks	black Florida; W to E Texas & S Arkansas	**laurel oak,** Darlington,	Coastal plain from SE Virginia to S water, &
***Q. lobata* Née**	white	**California white oak,** valley, valley white, weeping, & water oaks; roble	Valleys & foothills in California; also Santa Cruz & Santa Catalina Islands
***Q. lyrata* Walt.**	white	**overcup oak,** swamp post, water white, & swamp white oaks	Coastal plain from Delaware to Florida; W to E Texas & SW Indiana
***Q. macrocarpa* Michx.**	white	**bur oak,** mossycup, blue oak, mossy- overcup, & scrub oaks	S New Brunswick & Manitoba; S to Tennessee & SE Texas
***Q. marilandica* Muenchh.**	black	**blackjack oak,** barren & jack oaks; blackjack	New York, W to Ohio, Iowa, & Oklahoma; S to Texas & NW Florida
***Q. michauxii* Nutt.** *Q. prinus* L.	white	**swamp chestnut oak**, cow & basket oak	Coastal plain from New Jersey to N Florida; W to E Texas; N in Mississippi Valley to S Illinois & Indiana
***Q. muehlenbergii* Engelm.**	white	**chinkapin oak**, rock, yellow, chestnut, yellow chestnut, & rock chestnut oaks	W Vermont & New York to Minnesota & SE Nebraska; S to NW Florida & central Texas
***Q. nigra* L.**	black	**water oak**, possum	Coastal plain from New Jersey to

		& spotted oaks	S Florida, W to E Texas, & N in Mississippi Valley to SE Oklahoma
***Q. pagoda* Raf.** *Q. falcata* var. *pagodaefolia* Ell.	black	**cherrybark oak,** bottomland red, Elliott, & swamp red oaks	SE New Jersey to E Oklahoma; S to N Florida & E Texas
***Q. palustris* Muenchh.**	black	**pin oak,** swamp, water, Spanish, & swamp Spanish oaks	Massachusetts & Vermont to S Michigan; S to NE Oklahoma, Tennessee, & central North Carolina
***Q. petraea* (Mattusch) Liebl.** *Q. sessiliflora* Salisb.	white	**durmast oak**, sessile oak	Europe & W Asia; planted in central & NE US
***Q. phellos* L.**	black	**willow oak**, pin, peach, & swamp willow oaks	Coastal plain from New Jersey to N Florida; W to E Texas & S Illinois
***Q. prinus* L.** *Q. montana* Willd.	white	**chestnut oak,** rock chestnut, rock, & tanbark oaks	SW Maine & S Ontario; S to central Georgia & NW Mississippi
***Q. robur* L.**	white	**English oak**, pedunculate oaks	Europe, N Africa, & W Asia; naturalized in SE Canada & NE US
***Q. rubra* L.** *Q. borealis* Michx.f.	black	**northern red oak**, red, common red, eastern red, & gray oaks	Cape Breton Island & Nova Scotia; W to Ontario & S to eastern Oklahoma & Georgia
***Q. shumardii* Buckl.**	black	**Shumard oak,** spotted, Schneck, swamp red, & Shumard red oaks	Coastal plain, mostly, from North Carolina to N Florida; W to central Texas, Kansas, & S Illinois
***Q. sinuata* Walt.** *Q. durandii* Buckl.	white	Durand oak, Durand white, bluff, & bastard oaks	Coastal Plain from North Carolina to N Florida & W to Texas, Oklahoma, & NE Mexico
***Q. stellata* Wangenh.**	white	**post oak,** iron oak	SE Massachusetts to SE Iowa, & S to central Florida & Texas
***Q. suber* L.**	white	**cork oak**	SW Europe & N Africa; planted in California
***Q. texana* Buckl.** *Q. nuttallii* Palmer	black	**Nuttall oak**, red, Red River, & pin oak	Gulf Coastal Plain from Alabama to SE Texas; N in Mississippi Valley to SE Missouri
***Q. turbinella* Greene**	white	**shrub live oak,** turbinella & scrub oaks; encino	SW Colorado & Utah; S to S California, Arizona, & northern Mexico
***Q. turbinella* var. *ajoensis* (C.H. Muller) Little**	white	**shrub live oak,** Ajo oak	SW Arizona & N Mexico

***Q. vaccinifolia* Kellog**	white	**huckleberry oak**	SW Oregon to central California
***Q. variabilis* Bl.** *Q. chinensis* Bge.[not Abel] *Q. serrata* Carruth. [not Thunb.]	black	**oriental oak**	N China, Korea, & Japan; planted in central & NE US
***Q. velutina* Lam.**	black	**black oak**, yellow, smooth-bark, quercitron, & yellow-bark oak; quercitron	SW Maine to SE Minnesota; S to N Florida & E Texas
***Q. virginiana* P. Mill.**	white	**live oak**, Virginia live oak; encino	Coastal Plain from SE Virginia to S Florida (including Florida Keys); W to S Texas
***Q. wislizenii* A. DC.**	black	**interior live oak**, highland live & Sierra live oaks	Foothills of Sierra Nevada & Coastal Ranges in California, S to Mexico

Sources: Little (1979), Olson (1974), Sargent (1965).

* White oaks belong to subgenus *Lepidobalanus;* black oaks belong to subgenus *Erythrobalanus.*

Table 2C*Quercus,* oak: height, seed-bearing age, and seed crop frequency

Species	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yrs)	Interval between seed crops (yrs)
Q. acutissima	15	1862	5	C
Q. agrifolia	23	1849	15	C
Q. alba	30	1724	20	4B10
Q. arizonica	12	C	C	C
Q. bicolor	30	1800	20	3B5
Q. cerris	30	1735	C	C
Q. chrysolepis	30	1877	20	2B4
Q. coccinea	30	1691	20	3B5
Q. douglasii	18	C	C	2B3
Q. dumosa	6	C	C	C
Q. ellipsoidalis	21	1902	C	2B4
Q. emoryi	18	C	C	C
Q. falcata	27	1763	25	1B2
Q. gambelii	15	C	C	C
Q. garryana	21	1873	C	2B3
Q. grisea	20	C	C	C
Q. ilicifolia	6	1800	C	C
Q. imbricaria	21	1724	25	2B4
Q. incana	12	C	C	C
Q. kelloggii	26	1878	30	2B3
Q. laevis	9	1834	C	1B2
Q. laurifolia	27	1786	15	1
Q. lobata	30	1874	C	2B3
Q. lyrata	24	1786	25	3B4
Q. macrocarpa	30	1811	35	2B3
Q. marilandica	15	C	C	C
Q. michauxii	30	1737	20	3B5
Q. muehlenbergii	24	1822	C	C
Q. nigra	24	1723	20	1B2
Q. pagoda	34	1904	25	1B2
Q. palustris	24	1770	20	1B2
Q. petraea	30	Long	40	5B7
Q. phellos	30	1723	20	1
Q. prinus	24	1688	20	2B3
Q. robur	34	Long	20	2B4
Q. rubra	30	1724	25	3B5
Q. shumardii	34	1907	25	2B3
Q. sinuata	23	C	C	C
Q. stellata	18	1819	25	2B3
Q. suber	24	1699	12	2B4
Q. texana	30	1923	5	3B4
Q. turbinella	3	C	C	3B5
Q. vaccinifolia	1	1895	C	C
Q. variabilis	24	1861	C	2
Q. velutina	27	1905	20	2B3
Q. virginiana	18	1739	C	1
Q. wislizenii	18	1874	C	5B7

Sources: Burns and Honkala (1990), Olson (1974), Sargent (1965), Smith (1993), Sork and others (1993), Vines (1960).

Table 3C*Quercus,* oak: seed yield data

	Seed wt/fruit vol		No. of cleaned seeds				
			Range		Average		
Species	kg/hl	lb/bu	/kg	/lb	/kg	/lb	Samples
Q. acutissima	C	C	210B245	95B110	85	187	2
Q. agrifolia	C	C	C	C	200	440	1
Q. alba	58B129	45B100	155B465	70B210	98	215	23
Q. bicolor	C	C	200B385	90B175	265	120	3
Q. cerris	C	C	130B320	60B145	240	110	4
Q. chrysolepis	C	C	110B310	50B150	C	C	C
Q. coccinea	39B77	30B60	230B890	105B405	520	235	4
Q. douglasii	C	C	120B330	55B180	220	100	4
Q. dumosa	C	C	C	C	220	100	1
Q. ellipsoidalis	C	C	450B640	205B290	540	245	11
Q. falcata	42B64	33B50	705B1,730	320B785	1,190	540	9
Q. garryana	50	39	165B220	75B100	185	85	3
Q. ilicifolia	C	C	C	C	1545	700	1
Q. imbricaria	C	C	695B1,750	315B795	915	415	11
Q. incana	C	C	500B1,500	225B680	C	C	C
Q. kelloggii	C	C	115B325	52B145	210	95	49
Q. laevis	C	C	C	C	870	395	1
Q. laurifolia	C	C	860B1,520	90B690	1,235	560	3
Q. lobata	C	C	165B525	75B237	285	130	4
Q. lyrata	C	C	285B340	130B154	265	120	6
Q. macrocarpa	39B45	30B35	90B300	40B135	165	75	8
Q. michauxii	51B80	40B62	75B430	35B195	125	55	35
Q. muehlenbergii	60B66	47B51	580B1,145	265B520	870	395	4
Q. nigra	57B72	44B56	510B1,545	230B700	640	290	226
Q. pagoda	C	C	925B1,640	420B745	690	312	41
Q. palustris	C	C	705B1,190	320B540	475	220	33
Q. petraea	C	C	130B650	60B295	375	170	9
Q. phellos	59B60	46B47	600B1,530	270B695	835	380	183
Q. prinus	C	C	120B430	55B195	220	100	5
Q. robur	C	C	200B495	90B225	285	130	10
Q. rubra	28B134	22B104	165B565	75B255	235	105	55
Q. shumardii	64	50	170B280	80B130	220	100	27
Q. sinuata	53	47	C	C	6,400	290	1
Q. stellata	69	54	440B1,400	200B635	840	380	9
Q. suber	C	C	110B220	50B100	165	75	13
Q. texana	67	52	125B315	55B145	220	100	83
Q. turbinella	C	C	660B770	300B350	715	325	2
Q. vaccinifolia	33	26	1630B2,910	740B1,320	2,270	1,030	2
Q. variabilis	C	C	165B275	75B125	230	105	12
Q. velutina	53B63	41B49	275B882	125B400	540	245	7
Q. virginiana	71	55	530B1,125	240B510	775	350	4
Q. wislizenii	36	28	100B152	100B150	275	125	3

Sources: Burns and Honkala (1990), Olson (1974), Toumey and Korstian (1942), Van Dersal (1938).

Table 4C*Quercus,* oak: germination test conditions and results

Species	Cold stratification (days)	Germination test conditions				Germinative rate		Germination	
		Medium	Temp (°C) Day	Night	Duration (days)	Ave. (%)	Days	(%)	Samples
Q. acutissima	C	C	C	C	C	C	C	98	1
Q. agrifolia	0	C	C	C	15B40	C	C	73	1
Q. alba	0	Kimpac	30	20	30B98	39B93	10B41	50B99	21
Q. bicolor	0	Sand	21B35	10B16	60B240	65B95	80B120	78B98	3
Q. cerris	0	Germinator	22	20	30	C	C	33B76	3
Q. chrysolepis	0B60	Peat/loam	30	20	56B60	C	C	56B75	2
Q. coccinea	30B60	Kimpac	30	20	30B60	97	16	94B99	7
Q. douglasii	0	Sand	30	20	30	C	C	70B72	4
Q. durmosa	30B90	Sand	30	20	28	C	C	80B90	3
Q. ellipsoidalis	60B90	Sand	30	21	30B60	80B93	18B26	95	5
Q. falcata	30B90	Sand	23B27	23B27	30B57	62B74	22B36	75B100	8
Q. gambelii	14	C	C	C	C	92	15	92	1
Q. garryana	0	Loam	30	21	90	C	C	77B100	4
Q. ilicifolia	60B120	Sand/perlite	30	20	36B81	C	C	86B94	12
Q. imbricaria	30B60	Sand	24	16	30	C	C	28B66	2
Q. kelloggii	30B45	Sand	30	21	30B40	C	C	95	1
Q. laevis	60B90	Sand	27	23	7	C	C	82	2
Q. laurifolia	0	Soil			108	C	C	50	1
	14B90	Sand	27	23	30B90	C	C	45B92	6
Q. lyrata	0	Sand	21B35	10B16	160	82	100	84	1
	42	Sand	27	23	128	C	C	82	4
Q. macrocarpa	30B60	Sand	30	20	40	28-85	25-45	45	11
Q. marilandica	90	C	C	C	C	C	C	91	1
Q. michauxii	0	Soil	32	21	50B84	23B48	40B60	49	2
	30	Soil	32	21	50	86	22	98	1
Q. muehlenbergii	0	Kimpac	30	20	45	95	8	98	4
Q. nigra	30B60	Sand/peat, Kimpac	30B32	20B21	52B73	54B80	31B73	60B94	12
Q. pagoda	60B120	Sand/perlite	30	20	30B40	85B90	21B38	86B98	11
Q. petraea	0	Sand	30	20	30	C	C	65B74	7
Q. phellos	30B90	Soil, Kimpac	32	21	45B100	41	55	67	4
	0	Soil	32	21	90	83	47	89	1
Q. prinus	0	Sand	27	18	60	72B78	40	82	3
Q. robur	0	Sand	25	16	30B60	C	C	81	4
Q. rubra	30B45	Sand	30	20	40B60	39B85	13B42	58	11
	70	Sand/peat	20	20	20	80	10	100	1
Q. shumardii	60B120	Soil, Kimpac	32	21	29B50	53B66	21B28	72B82	3
Q. sinuata	0	Kimpac	30	20	30	81	21	87	4
Q. stellata	0	Sand, Kimpac	30	20	45B60	42B93	10B45	54B98	7
Q. suber	0	Sand	27	27	20B30	C	C	73-100	5
Q. texana	60B90	Soil	32	21	58B87	C	C	60B69	20
Q. turbinella		Sand	38	5	C	C	C	95	2
Q. vaccinifolia	0	Loam	23	19	180	38	30	43	1
Q. variabilis	0	Sand	25		28	55	28		2
Q. velutina	30B60	Sand	27	18	30B50	C	C	47	5
Q. virginiana	0	Kimpac	30	20	C	92	8	97	4
Q. wislizenii	30B60	Sand/peat	30	20	69	C	C	75	1

Sources: Dirr and Heuser (1987), Korstian (1927), Larsen (1963), Olson (1974), Swingle (1939).