Quercus phellos L. Willow Oak

Fagaceae Beech family

Bryce E. Schlaegel

Willow oak (Quercus *phellos),* also known as peach oak, pin oak, and swamp chestnut oak, grows on a variety of moist alluvial soils, commonly on lands along water courses.

This medium to large southern oak with willowlike foliage is known for its rapid growth and long life. It is an important source of lumber and pulp, as well as an important species to wildlife because of heavy annual acorn production. It is also a favored shade tree, easily transplanted and used widely in urban areas.

Habitat

Native Range

Willow oak (fig. 1) is found mainly in bottom lands of the Coastal Plain from New Jersey and

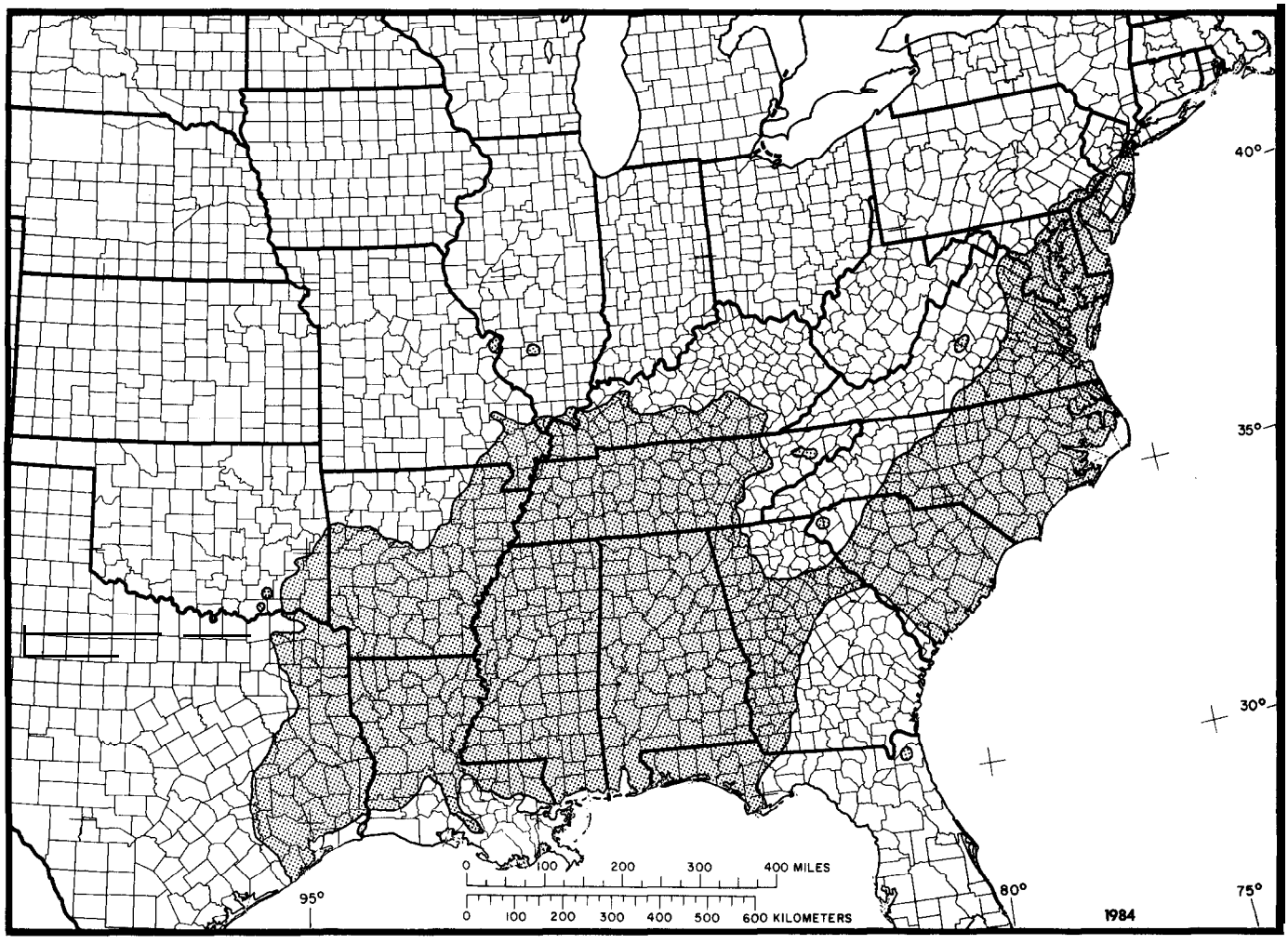

Figure *1-The native range of willow* **oak.**

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southeastern Pennsylvania south to Georgia and northern Florida; west to eastern Texas; and north in the Mississippi Valley to southeastern Oklahoma, Arkansas, southeastern Missouri, southern Illinois, southern Kentucky, and western Tennessee *(14)*.

Climate

The climate in which willow oak grows is humid and temperate, characterized by long, hot summers and mild, short winters. It grows mainly in the zone where daily normal temperatures are above 0" C (32" F). Frost-free days number 180 to 190 in the north-northeastern range and 300 in the south-southwestern range (29). Average summer temperatures vary from 21" to 27" C (70" to 80" F), with extremes of 38" to 46" C (100" to 115" F). Average winter temperatures range from -4" to 13" C (25" to 55" F) with extremes to -29" C (-20" F). Average annual temperatures throughout the range are 10" to 21" C (50" to 70" F).

Across the entire range, surface winds in the summer are off the Gulf of Mexico and winter winds are variable. Normally there are about 2,700 hours of sunshine annually in willow oak's range. Relative humidity at noon ranges from 60 to 70 percent in January and 50 to 70 percent in July.

Annual precipitation varies from 1020 to 1520 mm (40 to 60 in) and is fairly evenly distributed throughout the year; there is slightly more precipitation in the summer in the southeastern portion of the range. Greatest precipitation is in the central Gulf area. Average annual snowfall varies from 0 to 127 cm (0 to 50 in) over the range. The normal number of days with snow cover of at least 2.5 cm (1 in) varies from 0 to 40.

Soils and Topography

Willow oak grows on a variety of alluvial soils and is found on ridges and high flats on first bottoms of major streams. On second bottoms it grows on ridges, flats, and sloughs and can be very common in some minor stream bottoms. It develops best on clay loam ridges of new alluvium. Studies show that site quality of willow oak decreases from the higher to the lower topographic positions within a floodplain.

Willow oak is rarely found on upland sites but is occasionally seen on hardpan areas of very old terraces and on hammocks or bays. Trees on these sites are usually of poor quality.

In addition to topography, willow oak quality and growth rate are affected by soil characteristics and available moisture. In the Mississippi Delta, site quality decreases within each topographic position as clay content 30 to 46 cm (12 to 18 in) below the soil surface increases. For the non-Delta region in the South, site quality decreases within a topographic position as available potassium in the top 15 cm (6 in) of soil increases (26).

The best soils for willow oak growth are those that are deep (more than 1.2 m or 4 ft), without a pan, and relatively undisturbed *(1)*. They are medium textured, silty or loamy, with no compaction in the surface for 30 cm (12 in) and are granular in the rooting zone below.

In contrast, the worst soils are shallow, have an inherent pan, or have been intensively cultivated for more than 20 years. They are fine textured, clayey, with a strongly compacted surface for 30 cm (12 in) and have a massive structure in the rooting zone.

Moisture must be readily available in the soil during the growing season for best willow oak growth. The ideal water table depth is 0.6 to 1.8 m (2 to 6 ft), while depths less than 0.3 m (1 ft) and greater than 3 m (10 ft) are unsuitable. Radial growth is not affected by standing water during the growing season (February to July) (4) but is greatly increased if the water table is artificially raised by impoundments to within 1.2 m (4 ft) of the soil surface (5).

For best growth, the topsoil should be at least 15 cm (6 in) deep, with more than 2 percent organic matter. Optimally, soil pH in the rooting zone should be 4.5 to 5.5. The site quality worsens as the topsoil becomes more shallow, organic matter decreases, and pH departs from optimum. The soils on which willow oak is most commonly found are in the orders Inceptisols and Alfisols.

Associated Forest Cover

Willow oak is an important tree in the forest cover types Willow Oak-Water Oak-Diamondleaf Oak (Society of American Foresters Type 88) and Sweetgum-Willow Oak (Type 92). It is also a minor associate in Loblolly Pine-Hardwood (Type 82), Swamp Chestnut Oak-Cherrybark Oak (Type 91), Sugarberry-American Elm-Green Ash (Type 93), and Overcup Oak-Water Hickory (Type 96) (22). Other trees associated with willow oak are water oak *(Quercus nigra),* red maple *(Acer rubrum)*, cedar elm *(Ulmus crassifolia)*, eastern cottonwood *(Populus deltoides)*, honeylocust *(Gleditsia triacanthos),* and persimmon *(Diospyros virginiana).*

Swamp-privet *(Forestiera acuminata)*, roughleaf dogwood *(Cornus drummondii),* hawthorn *(Crataegus* spp.), and American hornbeam *(Carpinus caroliniana)* are major shrub or small tree associates.

Life History

Reproduction and Early Growth

Flowering and Fruiting-Willow oak is monoecious; male and female flowers are in separate catkins on the same tree. Staminate flowers are in slender yellow-green hairy catkins, pistillate flowers are tiny, in few flowered clusters at junction of leaf stems. Flowering occurs from February to May, about a week before the leaf buds open.

Late freezes, after the flower and leaf buds have opened, kill the flowers and defoliate the trees. New leaves develop after the freeze, but a second crop of flowers is not produced.

Seed Production and Dissemination-Seed production starts when the tree is about 20 years old. The acorns are small, 10 to 15 mm (4 to 0.6 in) in length, about as broad as long, occurring solitary or in pairs (28). They mature between August and October of the second year after flowering. The first acorns to fall usually are not mature, as indicated by failure of the cup to detach easily. Good mature acorns are heavy and have a bright color with a brown micropylar end (3).

Good seed crops are produced nearly every year. Mature trees produce between 9 and 53 liters (0.25 to 1.5 bu) or about 5.2 to 31.3 kg (11.5 to 69 lb) of acorns per year. Since willow oak averages 603 seeds per liter (21.250/bu) *(27)*, the number of seeds per tree ranges from about 5,400 to 31,900. Seeds are disseminated by animals and, in areas subject to overflow, by water.

Prolonged submersion of willow oak acorns reduces their germination ability slightly, but not enough to affect the species capability to regenerate an area *(13)*.

The acorns can be stored under moist, cold conditions. For germination, acorn moisture content must not drop below 40 percent; a 50 percent moisture content is preferable. Seeds should be stored at temperatures of 2" to 4" C (35" to 40" F) for 60 to 90 days before planting.

Seedling Development-Seeds germinate the spring following seedfall. Germination is hypogeal (27). The best seedbed is a moist, well-aerated soil with an inch or more of leaf litter. Early height growth is moderate; on good sites in the southern part of the range, seedlings average 1.4 m (4.5 ft) in 2 years.

Willow oak normally reproduces as a single tree or in very small groups. Reproduction occurs in small to large openings created either naturally or as a result of logging. Successful regeneration usually is the result of the presence of advance regeneration before the stand is disturbed. If willow oak regeneration does not exist on the ground before disturbance, there is little chance that successful regeneration of this species will occur. Seedlings are very intolerant of saturated soil conditions except during the dormant season, when they can tolerate complete submergence without appreciable mortality. After spring foliation, complete submergence longer than 5 to 7 days can be fatal, but seedling mortality usually does not occur unless saturation periods exceed 60 days *(10)*. During saturation periods, some secondary roots are killed and no adventitious shoots are formed, height growth essentially halts. ***After*** the saturation period ends, growth of roots and shoots resumes.

Although willow oak exhibits only medium tolerance to shade, seedlings may persist for as long as 30 years under a forest canopy. They continually die back and resprout. As a result they may become misshapen. These seedling-sprouts respond to release ***(12).***

Vegetative Reproduction-Willow oak readily sprouts from stumps of small trees. Sprouts from advance reproduction are a principal method of natural regeneration. Larger diameter stumps do not sprout readily

Cuttings taken from young parent trees can be propagated if treated with indoleacetic acid; success decreases with increasing age of the parent tree. Untreated cuttings fail completely. Layering and budding are not effective as a means of vegetative reproduction.

Sapling and Pole Stages to Maturity

Growth and Yield-Willow oak is medium size to large, attaining 24 to 37 m (80 to 120 ft) in height and commonly 100 cm (39.5 in) in d.b.h. On good sites it makes moderately rapid growth (fig. 2). Diameter growth is dependent upon tree size. In unmanaged stands on good sites, trees 15 to 30 cm (6 to 12 in) in d.b.h. averaged 6.6 cm (2.6 in) diameter growth in 10 years ***(18).*** In the 36 to 46 cm (14 to 18 in) class, they grew 7.9 cm (3.1 in) in 10 years; in the 51 to 71 cm (20 to 28 in) class, 7.1 cm (2.8 in). Dominant crop trees in a well-stocked managed stand probably average 8.9 to 10.2 cm (3.5 to 4.0 in) in d.b.h. growth in 10 years, with a maximum of 15.2 cm (6 in) *(7,26)*.

Willow oak commonly exists as a major component in mixed bottom-land stands. In a fairly typical stand near Stoneville, MS, willow oak basal area averages 7.1 m^2/ha (31 ft^2/acre) out of a total of 21.1 m^2/ha

Figure *2-A willow oak stand of excellent quality on a good site near Greenwood, MS.*

(92.0 ft²/acre) *(19).* The same willow oak component of the stand averages 57 273 kg/ha (51,100 lb/acre) of total dry fiber, 64 percent of which is contained in the bole; 87 percent of the total is contained in trees larger than 43.2 cm (17 in).

Willow oak has been successfully planted in stream bottoms or branch heads. After 17 years, trees averaged 10.9 cm (4.3 in) in d.b.h. and 14 m (46 ft) in height (6).

Rooting Habit-Where it occurs on alluvial soils, willow oak feeder roots are concentrated in the aerated layer above free water. Here they form extensive ectomycorrhizal associations that aid the tree in taking up nutrients and water and offer some protection against root diseases. Roots do not penetrate into the zone of free-standing water. In the soil region of best growth, root growth usually begins during early March.

Since complete soil saturation during the growing season inhibits root growth of seedlings, it probably has the same effect on mature trees. Production of ectomycorrhizae also is inhibited under saturated soil conditions, but once the excess soil moisture in the upper root zone dissipates, both root and mycorrhizae growth resume (9). Permanent standing water, however, kills the root system and ultimately the tree.

Reaction to Competition-A straight, tall, slender trunk is common. Not a rapid pruner on good sites, it is a very ineffective natural pruner on poor sites.

A tendency exists for the production of epicormic branches if the dormant buds along the main stem are stimulated to grow by some disturbance. Among the causal disturbances are breakage of the tree crown, wounding of the stem, drought, flooding, suppression, and unsuitable sites *(16).* Release stimulates epicormic branching on intermediate or suppressed trees, but dominant or codominant trees are much less susceptible. Thinning should aim at releasing undamaged trees pole size and larger that occupy dominant and codominant positions.

Although slow to heal from artificial pruning, live-branch wounds initially heal more rapidly than dead-branch wounds, but up to 4 years are required for healing more than 96 percent of either kind of wound *(11).*

Willow oak is a subclimax species and is classed as intolerant of shade. All trees, except those of poor vigor, respond well to release.

Damaging Agents-Squirrels, birds, and insects (mainly acorn weevils) reduce the fruit crop, as do hogs.

A principal enemy of willow oak is fire. Seedlings and saplings are killed by even a light burn; hot fires kill larger trees. Trees not immediately killed by the fire are often wounded and become susceptible to butt rot fungi.

A common canker on bottom-land willow oaks is caused by ***Polyporus hispidus*** (25). This insidious fungus grows rapidly, cankers lengthening 10 to 15 cm (4 to 6 in) per year, and may cause as much as 25 percent cull in some areas. Cankered trees should be removed as soon as possible, both to salvage the log and to remove the tree as a source of infection *(15).*

Perhaps the most serious insect pests are the trunk borers. They cause serious degrade in saw log quality. Three of the more common are the red oak borer *(Enaphalodes rufulus),* carpenterworm *(Prionoxystus robiniae),* and living-beech borer (Goes *pulverulentus) (23,24).*

Willow oak has been shown to be susceptible to acid rain, the foliage showing yellow or brown necrotic zones when exposed to simulated rain of less than 3.2 pH (20).

Special Uses

Since it produces an acorn crop almost every year, willow oak is an important species for wildlife food production. In addition to being a major supplier of food for game animals such as ducks, squirrels, deer, and turkey, willow oak supplies many other animals. Blue jays and red-headed woodpeckers are major consumers, while grackles, flickers, mice, and flying squirrels utilize the tree itself (8).

A favored shade tree, it is widely planted as an ornamental. It is also a good species to plant along margins of fluctuating-level reservoirs (21). Willow oak can be harvested when quite young and utilized as biomass *(17).* Pulp yields per unit volume of young versus old trees do not differ greatly and chemical demand in pulping is not greatly increased (2).

Willow oak is being utilized in hardwood plantations, since it gives a good combination of pulping characteristics and growth rate.

Genetics

No racial variations of willow oak are known, but the following hybrids are recognized *(14): Quercus phellos x nigra* (*Q. x capesii* W. Wolf); *Q. phellos x velutina* (*Q. x filialis* Little); *Q. phellos x ilicifolia* (*Q. x giffordii* Trel.); *Q. phellos x rubra* (*Q. heterophylla* Michx. f.); *Q. phellos x falcata* (*Q. x ludoviciana* Sarg.); *Q. phellos x shumardii* (*Q. x moultonensis* Ashe); *Q. phellos x marilandica* (*Q. rudkinii* Britton); *Q. phellos x palustris* (*Q. x schociana* Dieck.).

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