Quercus rubra L. Northern Red Oak

Fagaceae Beech family

Ivan L. Sander

Northern red oak *(Quercus rubra)*, also known as common red oak, eastern red oak, mountain red oak, and gray oak, is widespread in the East and grows on a variety of soils and topography, often forming pure stands. Moderate to fast growing, this tree is one of the more important lumber species of red oak and is an easily transplanted, popular shade tree with good form and dense foliage.

Habitat

Native Range

Northern red oak (fig. 1) is the only native oak extending northeast to Nova Scotia. It grows from Cape Breton Island, Nova Scotia, Prince Edward Island, New Brunswick, and the Gaspé Peninsula of Quebec, to Ontario, in Canada; from Minnesota south to eastern Nebraska and Oklahoma; east to Arkansas, southern Alabama, Georgia, and North Carolina. Outliers are found in Louisiana and Mississippi *(17)*.

Climate

In the wide area over which northern red oak grows, mean annual precipitation varies from about 760 mm (30 in) in the Northwest to about 2030 mm (80 in) in the southern Appalachians. Annual snowfall ranges from a trace in southern Alabama to 254 cm (100 in) or more in the Northern States and Canada. Mean annual temperature is about 4" C (40° F) in the northern part of the range and 16" C (60° F) in the extreme southern part. The frost-free period averages 100 days in the North and 220 days in the South (24).

Soils and Topography

In the north, northern red oak grows on cool moist Boralf and Orthod Spodosols. Elsewhere it grows on warm, moist soils including Udalf Alfisols, Dystrochrept and Fragiochrept Inceptisols, Udoll Mollisols, Rhodic Paleudult, Humic and Mesic Hapludult Udult Ultisols, and small areas of Udipsamment Entisols. The most widespread soils are the Udalfs and Udolls (33).

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These soils are derived from glacial material, residual sandstones, shale, limestone, gneisses, schists, and granites. They vary from clay to loamy sands and some have a high content of rock fragments. Northern red oak grows best on deep, well-drained loam to silty, clay loam soils *(24)*.

Although northern red oak (fig. 2) is found in all topographic positions, it always grows best on lower and middle slopes with northerly or easterly aspects, in coves and deep ravines, and on well-drained valley floors. It grows at elevations up to 1070 m (3,500 ft) in West Virginia and up to 1680 m (5,500 ft) in the southern Appalachians *(24)*.

The most important factors determining site quality for northern red oak are depth and texture of the A soil horizon, aspect, and slope position and shape. The best sites are found on lower, concave slopes with a northerly or easterly aspect, on soils with a thick A horizon, and a loam to silt loam texture. Other factors may affect site quality in localized areas such as depth to water table in southern Michigan and annual precipitation up to 1120 mm (44 in) in northwestern West Virginia *(2,24)*.

Associated Forest Cover

Northern Red Oak (Society of American Foresters Type 55) is the forest cover type that includes pure stands of this tree or stands in which it is predominant (6). The species is a major component of White Pine-Northern Red Oak-Red Maple (Type 20) in the Northern Forest Region, and it is a principal species in White Oak-Black Oak-Northern Red Oak (Type 52) in the Central Forest Region. Northern red oak is listed as an associated species in the following forest types:

17 Pin Cherry
18 Paper Birch
19 Gray Birch-Red Maple
21 Eastern White Pine
22 White Pine-Hemlock
23 Eastern Hemlock
25 Sugar Map&Beech-Yellow Birch
26 Sugar Maple-Basswood
27 Sugar Maple
28 Black Cherry-Maple
40 Post Oak-Blackjack Oak
42 Bur Oak
43 Bear Oak
44 Chestnut Oak
45 Pitch Pine

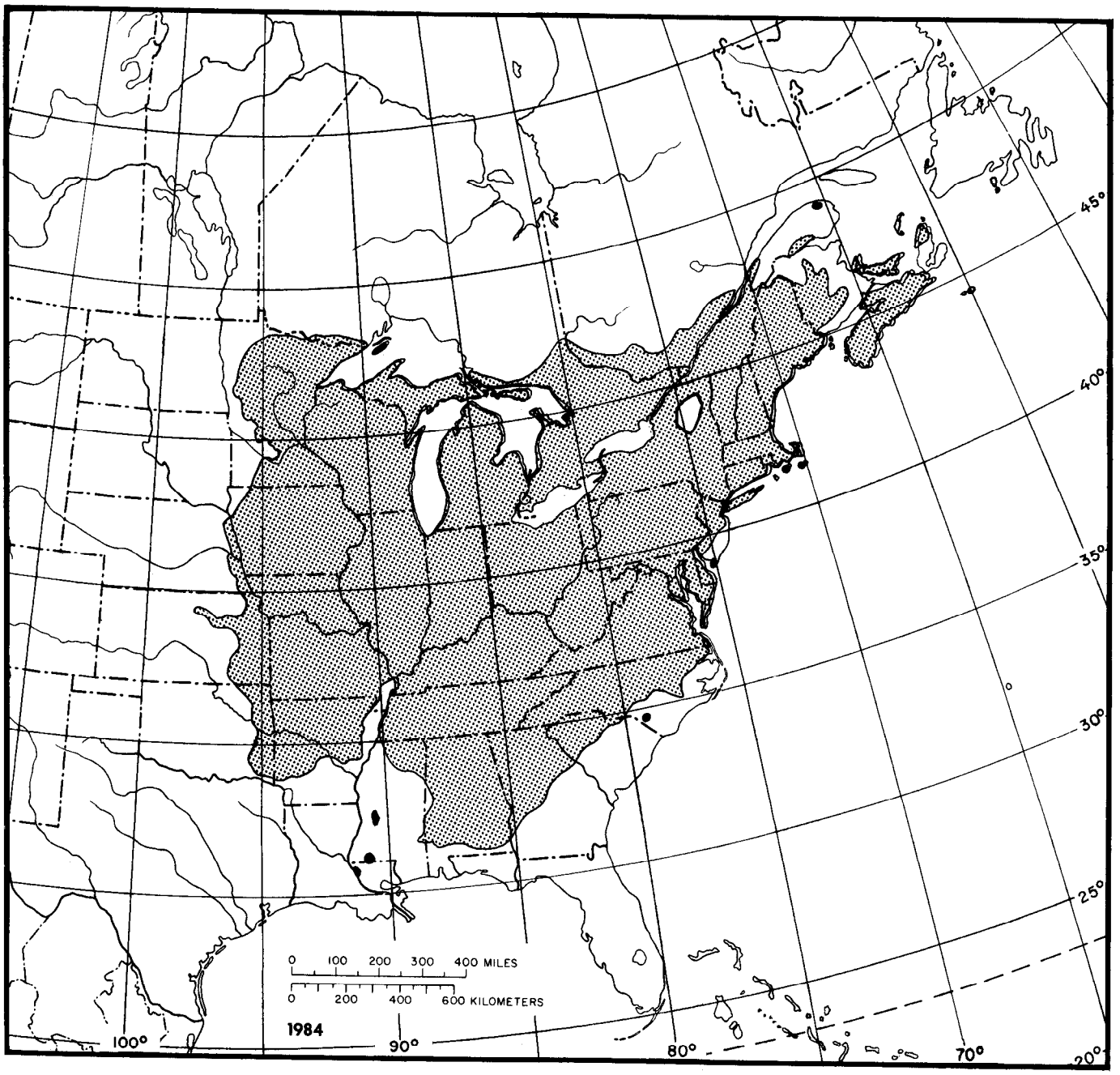

Figure *l-The native range of northern red oak.*

46 Eastern Redcedar
51 White Pine–Chestnut Oak
53 White Oak
57 Yellow-Poplar
58 Yellow-Poplar-Eastern Hemlock
60 Beech-Sugar Maple
82 Loblolly Pine-Hardwood
108 Red Maple
110 Black Oak

Numerous other tree species are associated with northern red oak. These include white ash *(Fraxinus americana)* and green ash *(F. pennsylvanica)*; bigtooth aspen *(Populus grandidentata)* and quaking

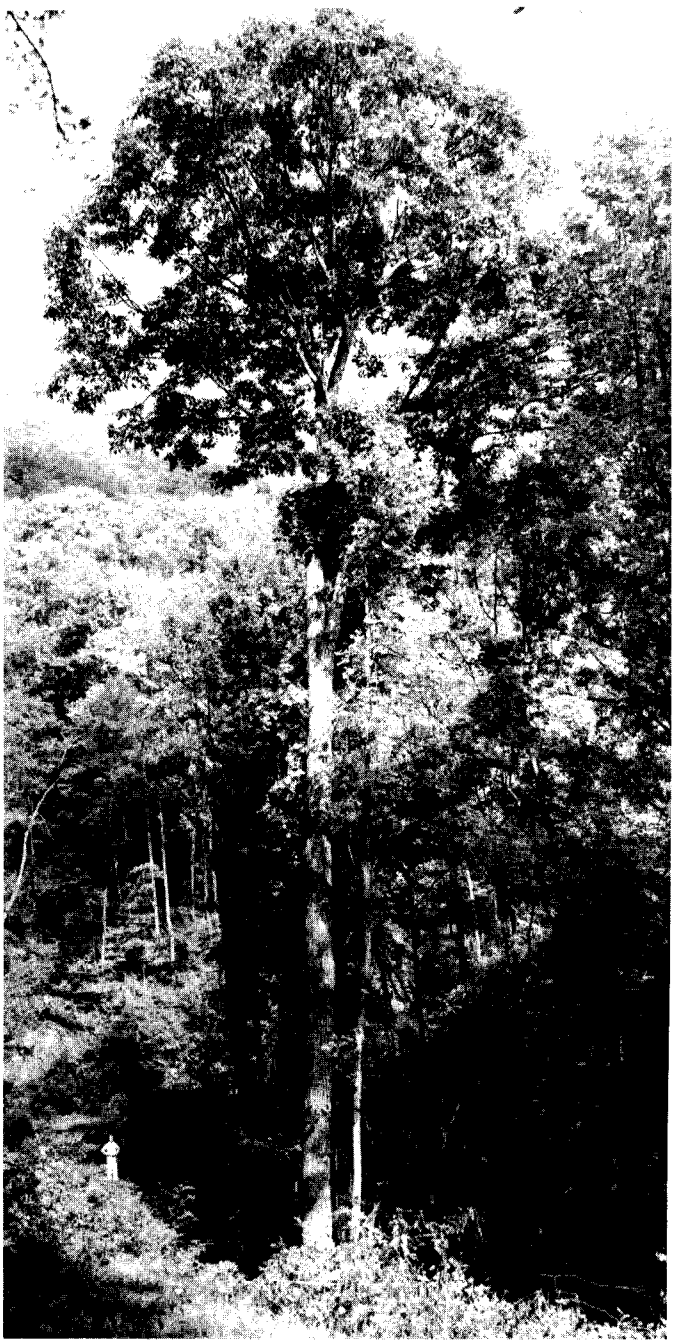

Figure *2-A mature northern red oak growing in the southern Appalachians at an elevation of 945 m (3,100 ft). The tree is 90 cm (35 in) in d. b.h. and 46 m (151 ft) tall.*

aspen *(I? tremuloides);* American elm *(Ulmus americana)* and slippery elm *(U. rubra);* pignut hickory *(Carya glabra)*, bitternut hickory *(C. cordiformis)*, mockernut hickory *(C. tomentosa)*, and shagbark hickory *(C. ovata)*; scarlet oak *(Quercus coccinea)*, southern red oak *(Q. falcata)*, post oak *(Q. stellata)*, and chinkapin oak *(Q. muehlenbergii);* northern white-cedar *(Thuja occidentalis);* yellow buckeye *(Aesculus octandra)*; cucumber magnolia *(Magnolia acuminata)*; hackberry *(Celtis occidentalis)*; butternut *(Juglans cinerea);* black walnut *(J. nigra)*; blackgum *(Nyssa sylvatica)*; and sweetgum *(Liquidambar styraciflua)* (5).

Some of the more important small trees associated with northern red oak include flowering dogwood *(Cornus florida)*, sour-wood *(Oxydendrum arboreum)*, American holly *(Ilex opaca)*, eastern hophornbeam *(Ostrya virginiana)*, American hornbeam *(Carpinus caroliniana)*, redbud *(Cercis canadensis)*, pawpaw *(Asimina triloba)*, sassafras *(Sassafras albidum)*, persimmon *(Diospyros virginiana)*, American bladdernut *(Staphylea trifolia)*, and downy serviceberry *(Amelanchier arborea)*. Shrubs common in forest stands containing northern red oak include *Vaccinium* spp., mountain-laurel *(Kalmia latifolia)*, rosebay rhododendron *(Rhododendron maximum)*, witch-hazel *(Hamamelis virginiana)*, beaked hazel *(Corylus cornuta)*, spice bush *(Lindera benzoin)*, and *Viburnum* spp. The most common vines are Virginia creeper *(Parthenocissus quinquefolia)*, poison-ivy *(Toxicodendron radicans)*, greenbrier *(Smilax* spp.), and grape *(Vitis* spp.) (5).

Life History

Reproduction and Early Growth

Flowering and Fruiting-Northern red oak is monoecious. The staminate flowers are borne in catkins that develop from leaf axils of the previous year and emerge before or at the same time as the current leaves in April or May. The pistillate flowers are solitary or occur in two- to many-flowered spikes that develop in the axils of the current year's leaves. The fruit is an acorn or nut that occurs singly or in clusters of from two to five, is partially enclosed by a scaly cup, and matures in 2 years. Northern red oak acorns are brown when mature and ripen from late August to late October, depending on geographic location *(30)*.

Seed Production and Dissemination-In forest stands northern red oak begins to bear fruit at about age 25 but usually does not produce seeds abundantly until about age 50. Good to excellent seed crops are produced at irregular intervals, usually every 2 to 5 years (30).

Acorn production is highly variable among trees even in good seed years. Some trees are always poor producers while others are always good producers.

Crown size seems to be the most important tree characteristic affecting acorn production. Dominant or codominant trees with large, uncrowded crowns produce more acorns than trees with small, restricted crowns (24).

Even in good years only about 1 percent of the acorns become available for regenerating northern red oak, and as many as 500 or more acorns may be required to produce one l-year-old seedling. Many acorns are consumed by insects, squirrels, small rodents, deer, and turkey and other birds. They can eat or damage more than 80 percent of the acorn crop in most years and virtually 100 percent of the crop in very poor seed years *(19,24,28)*. The large acorns are generally dispersed over only short distances. Gravity and the caching activities of squirrels and mice are the primary means of dispersal.

Seedling Development-Northern red oak seedlings that are established naturally or by planting at the time an old stand is clearcut, regardless of how large the clearcut area, do not grow fast enough to compete with the vigorous woody sprouts and other vegetation *(4,29)*. The species will be present in new reproduction stands in proportion to the amount of advance reproduction present before complete overstory removal. To compete successfully in new stands, stems of northern red oak advance reproduction must be large and have well-established root systems. Thus, achieving successful northern red oak reproduction depends on creating conditions necessary for establishing seedlings and for their survival and growth *(27,29)*.

Northern red oak acorn germination is hypogeal (30). It occurs during the spring following seedfall. Best germination occurs when the acorns are in contact with or buried in mineral soil and covered by a thin layer of leaf litter. Acorns on top of the leaf litter or mixed with litter generally dry excessively during early spring and lose their viability before temperatures are favorable for germination *(24,28)*.

Although available soil moisture can be a critical factor affecting first year survival of northern red oak seedlings, it is usually adequate at the time acorns germinate\ Germination is followed by vigorous and rapid taproot development, and if the taproot is able to penetrate the soil, seedlings survive considerable moisture stress later in the growing season. Northern red oak seedlings are less drought tolerant than white or black oak seedlings, however *(24,31)*.

Light intensity appears to be the most critical factor affecting not only first year survival, but also survival and growth in subsequent years *(20,28)*. Northern red oak reaches maximum photosynthesis at about 30 percent of the light intensity in the open (21). Light intensity under forest stands is often much lower, however, at about 15 cm (6 in) above the ground, where the new seedlings are competing. Light intensity at this level under forest stands in Missouri has been documented to be 10 percent or less of that in the open, a level too low to allow seedlings to survive and grow.

Once established under a forest stand, northern red oak seedlings seldom remain true seedlings for more than a few years. Conditions such as fire, poor light, poor moisture conditions, or animal activity kill the tops, but not the roots. One or more dormant buds near the root collar then produce new sprouts. This dieback and resprouting may occur several times; the result is a crooked, flat-topped, or forked stem. Such stems have root systems that may be from 10 to 15 years or more older than the tops *(29)*.

Northern red oak shoot growth is episodic. When moisture, light, and temperature conditions are favorable, multiple shoot growth flushes will occur in the same growing season. The first flush is generally the longest and each flush is followed by a distinctive rest period. Most of the annual root elongation occurs during the rest periods (22).

Growth of northern red oak advance reproduction, seedlings, and sprouts is slow and generally restricted to one growth flush under undisturbed or lightly disturbed forest stands; at best it averages only a few centimeters annually (28).

Vegetative Reproduction-Northern red oak sprouts readily. More than 95 percent of the northern red oaks in new production stands are sprouts, either from advance reproduction or from stumps of cut trees. New sprouts from advance reproduction arise when old stems are damaged during logging. Height growth of new sprouts is related to the size of the old, damaged stem; the larger the old stem, the faster the new sprout will grow *(25,26)*. New sprouts grow rapidly and are usually straight and well formed.

Northern red oak stumps sprout more frequently than black oak or white oak stumps but about the same as scarlet and chestnut oak stumps (27). Sprouting frequency is related to parent tree size with more small stumps sprouting than large ones. Large stumps tend to produce more sprouts than small ones but by about age 20 to 25 the number of living sprouts per stump averages four or five regardless of parent tree or stump size. Northern red oak stump sprouts grow rapidly, averaging about 61 cm (24 in) or more annually for about 30 years *(14)*. These stump sprouts can be a valuable component of new reproduction stands particularly if they originate at or near the ground line. Sprouts of low origin are much less likely to develop decay than

sprouts that originate high on the stump *(24)*, but they tend to develop severe crook or sweep at the base. Early clump thinning may be desirable to improve potential quality although it is not needed to maintain good growth.

Sapling and Pole Stages to Maturity

Growth and Yield-Mature northern red oaks are usually from 20 to 30 m (65 to 98 ft) tall and 61 to 91 cm (24 to 36 in) in d.b.h. in undisturbed stands on good sites. Forest-grown trees develop a tall, straight columnar bole and large crowns. Open-grown trees tend to have short boles and spreading crowns (24).

Average diameter growth of northern red oak for a range of ages, sites, and stand conditions in the Central States is about 5 mm (0.2 in) annually *(9)*. On good sites in the Appalachians, dominant and codominant northern red oaks in even-aged stands may attain average annual diameter growth rates of about 10 cm (0.4 in) and on average sites about 6 mm (0.25 in) by age 50 or 60 (32).

Growing space requirements are not known for northern red oak in pure stands, but average requirements have been developed for mixed oaks in even-aged stands. Competition for growing space begins when the available space in a stand is equal to the total of the maximum requirements of all the trees in the stand. This is the lowest level of stocking for full site utilization and is about 60 percent of full stocking. The minimum growing space for a tree 15.2 cm (6 in) in d.b.h. to survive averages about 8.5 m^2 (92 ft^2). If that tree is in the open or completely free from competition, the maximum amount of growing space it can use is 14.4 m^2 (155 ft^2). For a tree 53.3 cm (21 in) in d.b.h., minimum and maximum growing spaces are 26.5 m^2 (285 ft^2) and 45.7 m^2 (492 ft^2), respectively. Experience in using the stocking standards developed by Gingrich *(8)* indicates that a northern red oak tree requires less growing space than trees of other oak species with the same diameter *(10,18)*. How much less growing space is required has not been determined, however.

Yields of unthinned, 80-year-old oak stands in the Central States that contain northern red oak range from 75.6 m^3/ha (5,400 fbm/acre) on site index 16.8 m (55 ft) sites (base age 50 years) to 175.0 m^3/ha (12,500 fbm/acre) on site index 22.9 m (75 ft) sites. At age 70, oak stands that are first thinned at age 20 and then thinned regularly to the lowest level of stocking for full site utilization at about lo-year intervals will yield about 102.9 m^3/ha (7,350 fbm/acre) on site index 16.8 m (55 ft) sites and about 278.3 m^3/ha (19,880 fbm/acre) on site index 22.9 m (75 ft) sites (9). In southern Michigan, the average yields of 80-year-old unmanaged stands containing northern red oak ranged from 12.6 m^3/ha (900 fbm/acre) to 3.5 m^3/ha (250 fbm/acre) on poor sites and from 154.0 m^3/ha (11,000 fbm/acre) to 280.0 m^3/ha (20,000 fbm/acre) on good sites *(1)*.

Rooting Habit-No information available.

Reaction to Competition-Northern red oak is classed as intermediate in shade tolerance. It is less tolerant than some of its associates such as sugar maple *(Acer saccharum)*, beech *(Fagus grandifolia)*, basswood *(Tilia americana)*, and the hickories but more tolerant than others such as yellow-poplar *(Liriodendron tulipifera)*, white ash, and black cherry *(Prunus serotina)*. Among the oaks, it is less shade tolerant than white and chestnut and about equal with black and scarlet (24).

Northern red oak responds well to release if the released trees are in the codominant or above average intermediate crown classes *(11)*. The best response to thinning or release is obtained if the thinning or release is made before an even-aged stand containing northern red oak is 30 years old. Trees in well-stocked stands 30 years old and older generally have small, restricted crowns and are unable to make efficient use of the growing space provided by thinning or release (24). In Arkansas, 50-year-old released crop trees averaged a 40-percent increase in diameter growth over unreleased trees in the 10 years immediately following release. Although diameter growth increased the first year after release, the greatest responses ocurred in years 5-10 when growth of the released trees averaged about 0.5 cm (0.2 in) annually and was about twice that of unreleased trees *(11)*. Epicormic branching can be prolific on northern red oak following heavy thinning in stands older than about 30 years, Trees around the perimeter of openings created by harvesting may also develop many epicormic branches, because the boles of northern red oak in fully stocked stands contain numerous dormant buds. When the boles are suddenly exposed to greatly increased light, these buds begin to grow (27).

Damaging Agents-Wildfires seriously damage northern red oak by killing the cambial tissue at the base of trees, thus creating an entry point for decay-causing fungi. Wildfires can be severe enough to top kill even pole- and sawtimber-size trees. Many of the top-killed trees sprout and thus create new even-aged stands, but the economic loss of the old stand may be great (24). Small northern red oak seedlings may be killed by prescribed fires *(13)*, but larger

stems will sprout and survive, even if their tops are killed.

Oak wilt *(Cerutocystis fagacearum)* is a potentially serious vascular disease of northern red oak and kills trees the same year they are infected. It usually kills individuals or small groups of trees in scattered locations throughout a stand but may affect areas up to several hectares in size. Oak wilt is spread from tree to tree through root grafts and over longer distances by sap-feeding beetles *(Nitidulidae)* and the small oak bark beetles *(Pseudopityophthorus* spp.) *(12,231.*

Shoestring root rot *(Armillaria mellea)* attacks and may kill northern red oaks that have been injured or weakened by fire, lightning, drought, insects, or other diseases. Cankers caused by *Strumella* and *Nectria* species damage the bole of northern red oak and although trees are seldom killed, the infected trees are generally culls for lumber. Foliage diseases that attack northern red oak but seldom do serious damage are anthracnose *(Gnomonia quercina),* leaf blister *(Taphrina* spp.), powdery mildews *(Phyllactinia corylea* and *Microsphaera alni)*, and eastern gall rust *(Cronartium quercuum) (12).*

The carpenterworm *(Prionoxystus robiniae),* Columbian timber beetle *(Corythylus columbianus),* oak timber-worm *(Arrhenodes minutus)*, red oak borer *(Enaphalodes rufulus)*, and the twolined chestnut borer *(Agrilus bilineatus)* are important insects that attack the bole of northern red oak. These insects tunnel into the wood, seriously degrading products cut from infested trees (3).

The most destructive defoliating insect attacking northern red oak is the imported gypsy moth *(Lymantria dispar).* This insect repeatedly defoliates trees and has killed oaks including northern red oak in a wide area in the northeastern United States. Northern red oak can recover from a single defoliation but may be weakened enough for some disease or other insects to attack and kill them. Other defoliators that attack northern red oak are the variable oakleaf caterpillar *(Heterocampa manteo)*, the orangestriped oakworm *(Anisota senatoria),* and the browntail moth *(Nygmia phaeorrhoea).* The Asiatic oak weevil *(Cyrtepistomus castaneus)* attacks northern red oak seedlings and has the potential to seriously affect seedling growth because the larvae feed on the fine roots while the adults feed on the foliage.

Much damage is done to northern red oak acorns by the nut weevils *(Curculio* spp.), gall-forming cynipids *(Callirhytis* spp.), the filbertworm *(Melissopus latiferreanus),* and the acorn moth *(Valentinia glandulella)* (7). In years of poor acorn production, these insects can destroy the entire crop.

Special Uses

Northern red oak has been extensively planted as an ornamental because of its symmetrical shape and brilliant fall foliage.

The acorns are an important food for squirrels, deer, turkey, mice, voles, and other mammals and birds.

Genetics

Population Differences

Several traits related to geographic origin were identified for northern red oak in a 14-year provenance test in the North- Central States. Time of flushing is earliest for trees of northwestern origin. The trend is then eastward and southward. Autumn leaf coloration is earliest for provenances from northern latitudes and then progresses southward. Provenances from regions at the western edge of the northern red oak range, where periods of high summer temperatures and drought are common, survived better under such conditions than other provenances. Much variation in height growth was present and performance of the provenances was not consistent in all tests. The only consistent difference was the slower growth of the northern provenances in areas farther south. The within-family variation was so great it obscured any real differences in geographic origin *(15).*

Races

The nomenclature for northern red oak was confused for some time. The scientific names *Quercus borealis* Michx. f. and *Q. borealis* var. *maxima* (Marsh.) Sarg. were adopted after 1915 by some authors, but in *1950, Quercus rubra* L., the name in universal use before 1915, was restored *(17).*

Hybrids

Northern red oak hybridizes readily with other species in the subgenus *Erythrobalanus* and the following hybrids have been named: *Quercus x columnaris* Laughlin *(Q. palustris x rubra); Q. x fernaldii* Trel. *(Q. ilicifolia x rubra); Q. x heterophylla* Michx. f. *(Q. phellos x rubra); Q. x hawkinsiae* Sudw. *(Q. velutina x rubra); Q. x riparia* Laughlin *(Q. shumardii x rubra); and Q. x runcinata* (A. DC.) Engelm. *(Q. imbricaria x rubra).*

Northern red oak also hybridizes with blackjack oak *(Q. marilandica)* and with northern pin oak *(Q. ellipsoidalis) (17).*

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