SILVICAL CHARACTERISTICS of NORTHERN RED OAK

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This is the third of a series of 17 papers dealing with the silvical characteristics of forest trees important in the Central States region. The following species are included in this series:

Ohio buckeye
Yellow buckeye
Northern red oak
Black oak
Chinkapin oak
Pin oak
White oak
Swamp white oak
Bur oak
Butternut
Black walnut
Shellbark hickory
Sycamore
Honeylocust
Hackberry
Black locust
Eastern redcedar

Papers covering additional important American species will be issued by other Forest Experiment Stations of the U. S. Forest Service.

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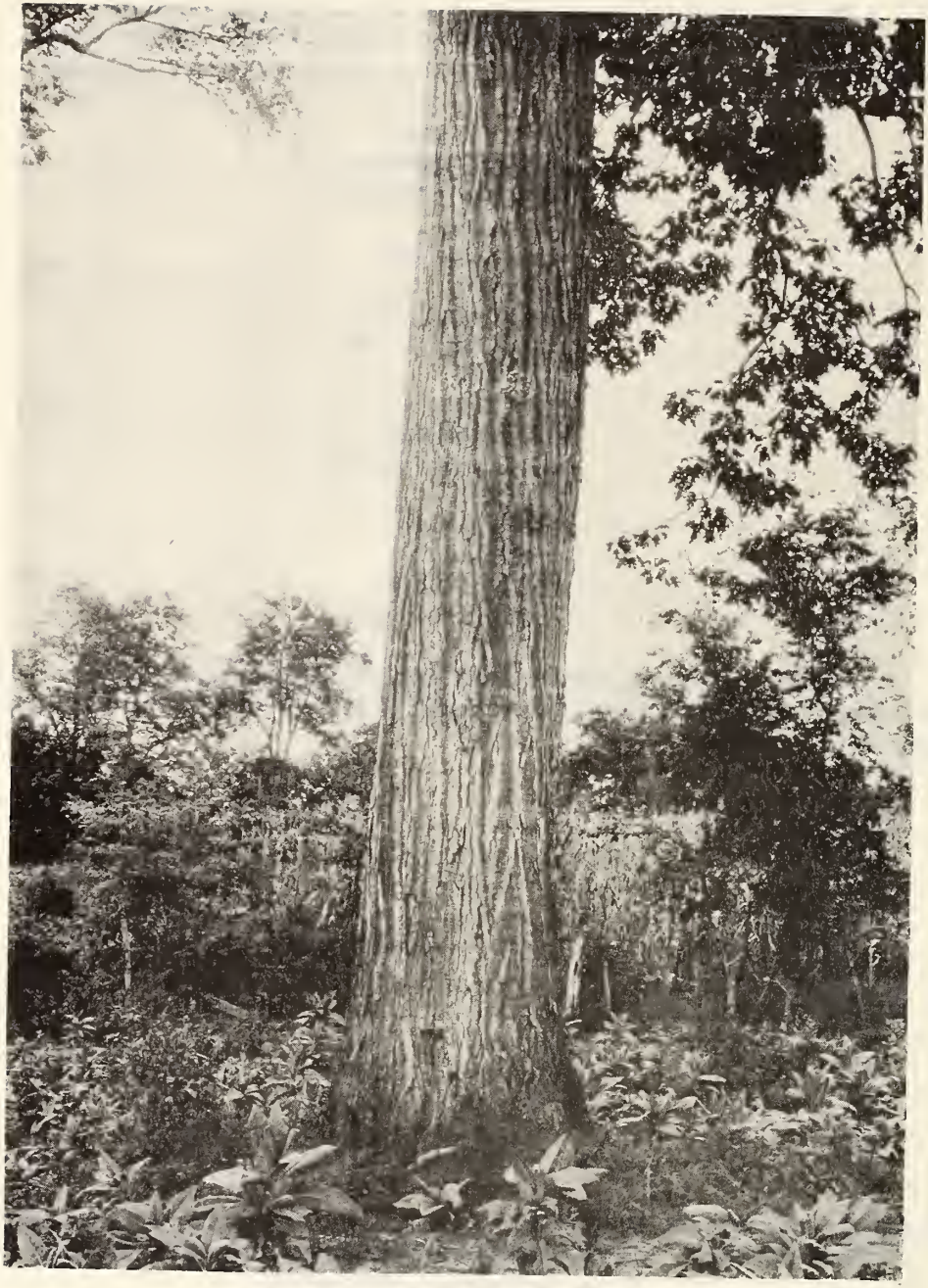

Silvical Characteristics of Northern Red Oak

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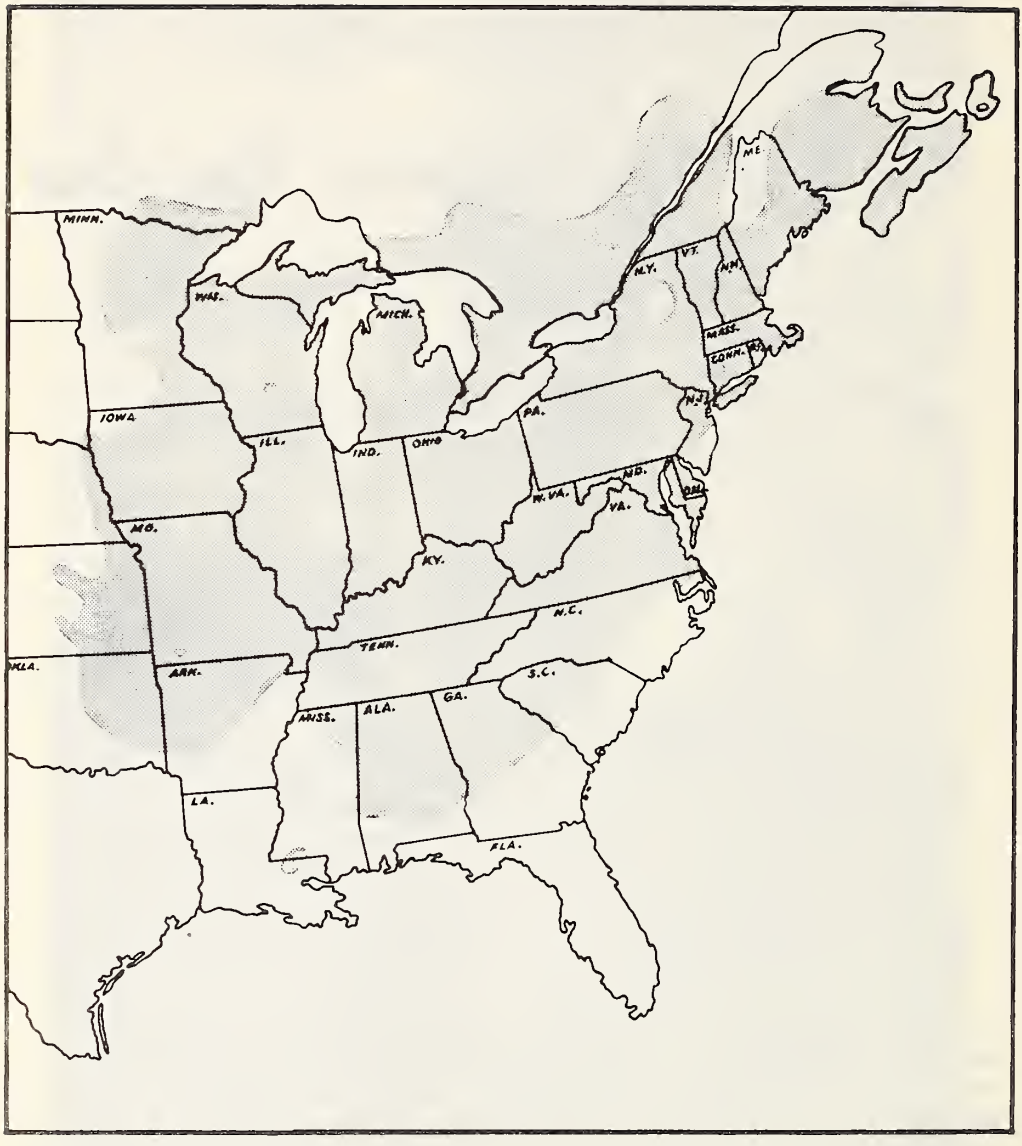
Northern red oak (Quercus rubra L.) is probably the most commercially important and widespread of the eastern red oaks. It is the most valuable species of the red oak group for lumber. Because of the brilliant autumnal color of the leaves and the symmetrical form of the tree, it is widely used as an ornamental. Northern red oak is also known as gray oak, common red oak, eastern red oak, mountain red oak, and red oak.



The botanical range of northern red oak covers the entire eastern portion of the United States except the South Atlantic and Gulf Coastal plains. It also extends into Canada--from southern Ontario eastward to Nova Scotia (18, 26).1/

1/ Numbers in parentheses refer to Literature Cited, page 12.

SITE

Climate

Northern red oak grows in a humid climate (34). The mean annual precipitation varies from 30 inches in the northwestern part of the range to 80 inches in the southern Appalachian Mountains. Average annual snowfall varies from 1 inch in Alabama to 100 inches in Maine. Mean annual temperature is 40 degrees Fahrenheit in the northern part of the range and 60 degrees in the southern part. The frost-free period or growing season ranges from 100 days in the north to 220 days in the extreme southern part of the range (38).

In the Ohio Valley and on the west slope of the Alleghenies, where northern red oak grows best, rainfall averages 40 inches per year, half of which occurs during the growing season. Mean annual temperature is 55 degrees and the frost-free period averages 160 days (37).

Soils

Northern red oak grows in a wide variety of soils, ranging from clay to loamy sands and from deep, stone-free soil to shallow, rocky soil (28). It grows best, however, on deep, moist, and well-drained soils of medium texture (2, 17, 42).

Depth of soil has an important affect on site quality (2, 14, 25, 37, 40). Gysel and Arend (17) found that the texture of the subsoil and the position of moist substrata layers (layers within approximately 4 to 10 feet of the surface) affected the growth of oak in southern Michigan. Scholz (30) found that on the Black Rock Forest, site quality for red oak was better on clay loams than on either heavy clay loams or clays. Available soil moisture also affects site quality (2, 25).

Physiography

Although northern red oak will grow on any kind of terrain, it is most frequently found on northerly and easterly aspects, lower and middle slopes, coves and ravines, and valley floors (28). Aspect and position on the slope have been found to be important physiographic factors affecting red oak site quality (2, 14, 25, 37, 40). Gysel and Arend (17) found that in addition to slope position, the general type of topography (flat, rolling, hilly) influenced site quality in southern Michigan.

Figure 1.--Mixed oak stand with red oak predominating.

Associated Species

The Society of American Foresters (34) lists northern red oak as the type name when the species is pure or predominant. Northern red oak is a major associate in four forest cover types in the Northern and Central Regions. It is present as a minor associate in 20 other types. Northern red oak is a component of subclimax to climax forest cover types (6, 34). It usually occurs in mixture with other species (fig. 1), but pure stands may occur locally.

Many different species of trees and shrubs are found in association with northern red oak. The important associated species include the following:

Commercial Species	Non-Commercial Species	Shrubby Species
Ash	Flowering dogwood	Greenbrier
Basswood	American holly	Hydrangea
American beech	Eastern hophornbeam	Leatherwood
Black cherry	American hornbeam	Mountain-laurel
Elm	Redbud	Pawpaw
Eastern hemlock	Sassafras	Rosebay rhododendron
Hickory	Downy serviceberry	Witch-hazel
Maple		
Black oak		
Chestnut oak		
Scarlet oak		
White oak		
Eastern white pine		
Yellow-poplar		

There are no particular animal associates of northern red oak. Acorns of the oaks in general are an important food for squirrels, deer, and turkey (12).

LIFE HISTORY

Seeding Habits

Flowering and Fruiting.--Northern red oak is monoecious with both male and female flowers developing before or with the leaves in April and May. The male flowers are borne in catkins in the axils of the previous year's leaves. The female flowers are solitary or occur in two, to many-flowered spikes. They are produced in the axils of the current year's leaves (39).

The fruit, an acorn or nut, matures in 2 years and ripens in September and October (39).

Seed production and dissemination.--Northern red oak may begin to fruit as young as 25 years old however, it usually does not produce seed abundantly until after trees are 50 years old. Good seed crops are usually produced every 2 to 5 years (39).

The yield of acorns per tree is extremely variable. Results of studies conducted in Georgia and North Carolina (13) show that the average 16-inch tree produced 800 acorns per year. Trees 20 to 22 inches in diameter produced 1,600 acorns; larger trees showed a decline in yearly production.

Seed is disseminated at the time the fruit ripens (39). Animals and gravity are the chief agents of dispersion. Except for the acorns transported by animals or those that roll down steep slopes, the dissemination range is narrow.

Vegetative Reproduction

Northern red oak sprouts readily and prolifically from young stumps. Many second-growth stands are of seedling-sprout or coppice origin (31).

Seedling Extablishment and Development

Establishment.--The acorns of northern red oak germinate the spring after seed fall (39). Germination does not take place until the natural dormancy of the acorns has been broken by overwintering in the litter (1, 39). Acorns germinate best in a moist, well-aerated soil covered by a layer of leaf litter (22). Average germination capacity is about 58 percent (39).

Insects and animals have an important effect on the germination of acorns. Downs and McQuilkin (13) found that the well-developed acorns that fell from the tree averaged 46 percent sound, 30 percent damaged by insects, and 24 percent damaged by squirrels and birds. Insects and animals also destroyed a large percentage of the sound acorns after they had fallen. In an Iowa study (23), 68 percent of the acorns planted in the soil were destroyed by rodents and all of those left on top of the litter were destroyed

Scholz (33) found that ground scarification, either with an Athens disc or by hand scalping, resulted in an increase in northern red oak reproduction.

Some form of partial cutting is probably the best silvicultural practice to use in obtaining northern red oak regeneration. The two-cut shelterwood system or small-group selection is recommended by Downs and McQuilkin (13). Korstian (22) recommends the selection system where the oldest and largest trees are removed for uneven-aged stands, and the shelterwood system for even-aged stands.

Because such a large percentage of acorns are destroyed, adequate regeneration of red oak apparently depends largely on the occasional years of high seed production (13).

Early Survival.--Available moisture is the critical factor affecting early survival and growth. Germination is followed by vigorous and rapid tap-root development. If this tap root penetrates the soil, the seedlings will withstand much dryness while still very small. Optimum growth, however, takes place where there is abundant moisture throughout the growing season (22).

In Iowa tests (1), seedlings whose stems had become woody recovered after 24 hours of freezing at 20 degrees Fahrenheit. It was thought that this treatment would probably be as severe as any that newly established seedlings would have to endure in late spring at the northern limits of the range of northern red oak.

In Wisconsin (22), northern red oak seedlings survived best on northeast slopes (table 1).

In West Virginia and Maryland hardwood stands composed of 30 percent or more of oak species (41), reproduction of red oak was abundant on site index classes of 50 and 60 but fell off above and below these classes. The decrease was abrupt below site index 50 and a more gradual decrease was noted above site index 60.

Table 1.--Survival of northern red oak on various sites having various ground cover

(In percent)

Age	Site and ground cover competition		
	Upland ridge, light grass sod	Deep ravine, dense fern	Upper northeast slope woody shrubs
1	9.4	26.7	27.7
5	6.7	6.1	25.0

Sapling Stage To Maturity

Growth and Yield.--Typical northern red oak grows to be a medium-sized tree 70 to 90 feet tall and 2 to 3 or more feet in diameter (8, 18). On the west slope of the Alleghenies and in the Ohio River Valley it may attain a height of 160 feet and a diameter of 5 feet (28). Under forest conditions it develops a tall, straight, columnar bole and prunes itself well. Open-grown trees tend to have short boles and large spreading crowns (18).

On the Harvard Forest northern red oak trees have averaged 0.2 inch per year in diameter growth over a 70-year period (27). In the Tennessee Valley the average rate of diameter growth for the species was found to be 1.71 inches (10), and in North Carolina it was 2.53 inches (7). On good sites (site index 70) in West Virginia and Maryland the 10-year diameter growth averaged 1.56 inches (41).

In southern Michigan, Gysel and Arend found the average annual volume growth of dominant and codominant trees to be 0.45 cubic foot per tree on good sites (site index 70) and 0.61 cubic foot per tree on very good sites (site index 80). Gross volume of trees at 80 years of age averaged 35 cubic feet (130 board-feet) on good sites and 54 cubic feet (210 board-feet) on very good sites (17).

Tables 2 and 3 show yields obtained from mixed-oak stands in several locations.

In West Virginia and Maryland, Weitzman and Trimble (41) found vigor and site quality to be the chief influences on red oak growth. Their studies show that average 10-year diameter growth of northern red oak varied from 0.48 inch for low-vigor trees on site index 60 to 2.87 inches for high-vigor trees in site index 80.

Table 2.--Yield of mixed oak stands

Location	Site Index	Age	Volume per acre
		Years	Cubic feet
Northern Michigan[1] (21)	45	80	2,120
Arkansas (2)	70	58	2,265
Iowa[2] (14)	55	75-80	3,022
	60	75-80	4,470
"Upland" (29)	70	80	3,730
	80	80	5,340

1/ On sandy soils.
2/ Corrected to 100-percent density.

Table 3.--Gross yields per acre of 80-year-old, normal oak stands in southwestern Wisconsin (16)

Unit	Site quality[1]				
	Very poor	Poor	Medium	Good	Very good
Cubic feet	2,000	2,550	3,300	3,950	4,600

1/ Sites were classified on the basis of the average volume of dominant and codominant trees in each stand.

Reaction to Competition.--Northern red oak is rated as being intermediate to intolerant of shade. It is less tolerant than eastern hemlock, sugar maple, American beech, basswood, and the hickories, but more tolerant than the ashes, yellow-poplar, and black cherry. Among the oaks it appears to be less tolerant than white oak but more tolerant than black and scarlet oak (3, 36).

In a Wisconsin study (33) early height growth of northern red oak seedlings varied according to the type of ground cover competition (table 4). It was brought out in this study that northern red oak seedlings are able to survive under relatively poor light conditions and vigorous root competition longer than is commonly believed.

Table 4.--Early height growth of northern red oak seedlings under variable conditions of ground cover competition (In inches)

Age	Upland ridge, light grass sod	Deep ravine, dense fern	Upper northeast slope woody shrubs
1	3.3	3.8	4.0
5	6.1	7.1	8.1

Northern red oak responds well to release (11, 31). Scholz (31) found from a study of stumps that northern red oak trees in the overstory apparently showed little tendency to shift from one crown class to another, which suggests that the species asserts dominance very early in life. In a study on crown development, Holsoe (19) found the ratio of crown diameter to crown length increases in northern red oak as the trees grow larger thus enabling it to crowd out less tolerant trees.

Epicormic branching following partial cutting in old-growth Appalachian hardwoods is not serious in northern red oak. However, second-growth timber in general is more susceptible to epicormic branching than old-growth (20).

ENEMIES AND HAZARDS

Fire will kill seedlings and saplings and damage older trees. The seedlings and saplings may recover by sprouting. Although fire will rarely kill large pole-and-sawtimber-size trees, it will leave scars which are ideal entry points for rot-causing fungi. Decay caused by these fungi is one of the most serious diseases affecting northern red oak (4).

Another serious disease of northern red oak is oak wilt, a vascular disease caused by the fungus Ceratocystis fagacearum. This disease will kill northern red oak trees during the same year they are infected. Much damage has been done in individual woodlots in Illinois, Iowa, and Wisconsin (5, 15). However, it more commonly kills individuals or small groups of trees scattered throughout a stand. Spread of oak wilt is accomplished through root grafts and probably by insects, birds, and animals. Partial control may be possible by removing and destroying dead and dying trees (5).

Cankers caused by Strumella and Nectria species are rather serious diseases of northern red oak. They affect the bole of the tree, rendering much of it worthless as lumber (4).

Less serious diseases that attack northern red oak are anthrocnose (Gnomonia quercina), leaf blister (Taphrina species), powdery mildews (Phyllactinia corylea and Microsphaera alvi), and leaf rust (Cronactiem quercum) (4).

Many insects attack northern red oak but rarely kill any trees. The greatest damage is done by a group of trunk-boring insects. The tunnels made by species of Goes, Prionoxystus, and Romaleum cause serious defects which degrade the products cut from infested trees.

The gypsy moth (Porthetria dispar), the browntail moth (Nygmia phaerrhoea) and the orange-striped oak worm (Anisota senatoria) cause considerable damage to northern red oak by defoliation. Other insects that feed on the leaves are species of Cameramia, Heterocampa, Bucculatrix, Archips and Synmerista. Acorns are damaged by nut weevils (Curculio species), moth larvae (Valentinia glandulella and Melissopus latiferreanus), and gall-forming cynipids (Callirhytis species) (9, 22).

RACES AND HYBRIDS

Formerly two races were recognized. These were Quercus borealis and Q. borealis var. maxima. The distinquishing characteristics were size and shape of the acorns. The acorns of Q. borealis were smaller, narrower, and had a deeper cup than those of Q. borealis var. maxima (18). Both of these names have been discontinued and Q. rubra, an earlier name, restored (24).

The following hybrids are recognized (24):

Q. fernaldii (Q. illicifolia x rubra)
Q. hawkinsiae (Q. rubra x velutina)
Q. heterophylla (Q. phellow x rubra)
Q. runcinata (Q. imbricaria x rubra)

TREE SPECIES MENTIONED

White ash	-	*Fraxinus americana* L.
Basswood	-	*Tilia* spp.
American beech	-	*Fagus grandifolia* Ehrh.
Black cherry	-	*Prunus serotina* Ehrh.
Flowering dogwood	-	*Cornus florida* L.
Elm	-	*Ulmus* spp.
Eastern hemlock	-	*Tsuga canadensis* (L.) Carr.
Hickory	-	*Carya* spp.
American holly	-	*Ilex opaca* Ait.
Eastern hophornbeam	-	*Ostryra virginiana* (Mill.) K. Koch
American hornbeam	-	*Carpinus caroliniana* Walt.
Maple	-	*Acer* spp.
Black oak	-	*Quercus velutina* Lam.
Chestnut oak	-	*Q. prinus* L.
Scarlet oak	-	*Q. coccinea* Muenchh.
White oak	-	*Q. alba* L.
Pawpaw	-	*Asimina triloba* (L.) Dunal
Eastern white pine	-	*Pinus strobus* L.
Eastern redbud	-	*Cercis canadensis* L.
Sassafras	-	*Sassafras albidum* (Nutt.) Nees
Downy serviceberry	-	*Amelanchier arborea* (Michx. f.) Fern.
Yellow-poplar	-	*Liriodendron tulipifera* L.

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