Silvical Characteristics of Eastern White Pine

(*Pinus strobus*)

by Robert W. Wilson Jr.
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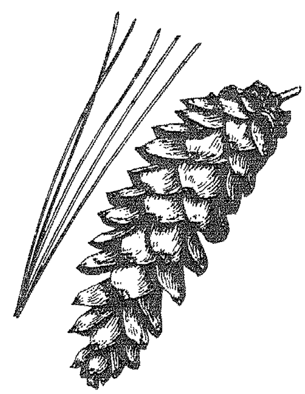

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Preface

MUCH of the silvical information about our forest trees is widely scattered and sometimes difficult to find. To make this material more readily available, the U. S. Forest Service is assembling information on the silvical characteristics of the important native forest tree species of the United States. It is expected that this information will be published as a conprehensive silvics manual.

This paper presents the silvical characteristics of one species —eastern white pine. In contains the essential information that will appear in the general manual but has been written with particular reference to the species in the Northeast. Similar reports on other species have been prepared by the Northeastern Forest Experiment Station and several of the other regional experiment stations of the U. S. Forest Service.

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About the Authors . . .

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The White Pine

THE eastern white pine is at maturity the most majestic of the eastern conifers. And no other tree has played so great a role in the history of the American people. White pine was the first product exported from this country. It became a cause in the rebellion that led to our War of Independence. It gave rise to the great lumbering industry in the brawling days of the legendary Paul Bunyan, the great logging camps, and the log rafts that once choked the rivers of the East. The logging, milling, and construction industries based on white pine created towns and cities, provided livelihoods for hundreds of thousands of laborers and artisans, and made financial empires for some entrepreneurs.

The first European explorers who probed the coasts of North America were awed by the great forests of white pine that covered vast areas of the land. Trees 150 feet tall were fairly common; some have been reported as tall as 240 feet, some as large as 12 feet in diameter.

The exploitation of this forest wealth began even before the land was peopled. In 1605 Captain George Weymouth of the British royal navy, after exploring the coast of Maine, carried home with him samples of this magnificent timber—and with a particular purpose in mind: shipmasts. England, for all her naval power, had to import pine from the Baltic countries and piece it together into masts. So here was a kind of timber that the British wanted badly.

Captain Weymouth also took white pine seed home with him. Established in England, white pine became known there as Weymouth pine. In our country the species has been called eastern white pine, northern white pine, northern pine, soft pine, pumpkin pine, and simply white pine.

The first colonists were quick to make use of this forest resource. The first sawmill in America, near the present site of Berwick, Maine, was set up in 1623—to saw white pine. By 1700 the British were so concerned over the supply of white pine mast trees that they tried to reserve them. Pines 24 inches or more in diameter in the accessible coastal region were marked with the King's Broad Arrow (fig. 1), and severe penalties were imposed on any who cut them. The colonists—in Maine and New Hampshire at least—were as aroused over this as other colonies were over the tax laws, and there was much bootleg cutting of these best trees. When the trouble with England came to a head, the lumbermen almost to a man went to the patriot side.

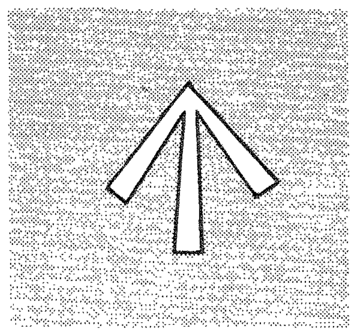


Figure 1.—The King's Broad Arrow, used to mark white pine mast trees reserved for the royal navy, helped to stir New England colonists to rebellion.

From its colonial beginning, the lumbering industry grew steadily, and became one of the mainstays of the Northeastern economy. Fleets of ships were built to carry white pine lumber all over the world. The tree was so important to the people of Maine that they made it their State Tree. As the better timber along the coastal waterways was cut, the industry moved westward, through New England, New York, and Pennsylvania, and then farther westward into the Lake States. When the sources of white pine dwindled in the Lake States (about 1910), the big lumbering companies moved on to other species and other regions.

Until relatively recent times, white pine was the pre-eminent commercial species in the forests of eastern North America. And for good reason: for white pine is the most generally useful wood that this country has had. The wood is light, and for its lightness relatively strong; it is stable, attractive, and easily worked. The wonderfully clear wood of virgin old-growth white pine was so easily carved that it was called pumpkin pine—and found its way into the graceful doorways of New England houses, ships' figureheads, and cigar-store Indians.

Even to merely list the products made of white pine would require several pages. It was for a long time the universal building material in the northern states from the Atlantic to the Rockies. Modest dwellings and stately mansions, barns, schools, churches, hotels, commercial structures in infinite variety—all were commonly built of white pine. White pine was used to build the famous covered bridges of the East—and to make match sticks.

Though now eclipsed in lumber volume production by other species, white pine still is in high demand because of its unparallelled qualities. The natural beauty of the tree itself excites the admiration of all who love trees. The many fine qualities of the tree and its wood have held a strong popular interest since the days when Europeans first landed in this country. And no doubt the white pine will continue for a long time to hold a special place in the affections of the American people.

Habitat Conditions

White pine ranges across southern Canada from Manitoba to Newfoundland, throughout our Northern and Eastern States from Minnesota and northeastern Iowa to the Atlantic Coast, and southward along the Appalachians to northern Georgia and Alabama (fig. 2).

CLIMATIC

The climate over the range of white pine is cool and humid. The distribution of white pine coincides reasonably well with that portion of eastern North America where the July temperature averages between 62 and 72° F. *(94)*. Annual precipitation varies from about 20 inches in northern Minnesota to about 80 inches in northwestern Georgia. In the area surrounding the Great Lakes about two-thirds of the precipitation occurs during the warm season—April to September. Elsewhere, half of the precipitation occurs during the warm season. The length of the growing season varies from 100 to 200 days *(94)*.

Over the range of white pine precipitation is about 1 to 1½ times the evaporation from shaded free-water surfaces *(92)*. According to Thornthwaite *(88)*, average annual potential evapotranspiration is between 17 and 28 inches, of which 56 to 68 percent occurs in the warm season. There is a moisture surplus in all seasons.

SOILS

Soils within the natural range of white pine are derived from granites, gneisses, schists, standstones, and—less commonly—from phyllites, slates, shales, and limestones. Since most of the area was covered by the Wisconsin glaciation, the soils are young, relatively coarse-textured, and have weakly developed profiles *(93, 96)*. In New England some of the uplands have a cap of silty material over the glacial till. From central Pennsylvania southward and in southwestern Wisconsin the soils are much older, generally are finer textured, and have well-developed profiles. In Canada, white pine occurs more commonly on glacio-fluvial and aeolian materials than on tills and lacustrine deposits *(39)*.

White pine has grown on practically all the soils within its range *(25)*. It has been most closely associated with somewhat excessively drained and well drained sandy soils. Such soils are good enough to permit fair growth rates of white pine but not good enough for strong competition from aggressive hardwoods *(39)*. White pine occurs also on loams and silty soils with either good or impeded drainage when there is no hardwood competition during the establishment period—as on old fields and pastures, and on burns and blow-downs. However, these richer soils are usually occupied by hardwoods, with some white pine in mixtures. Less commonly white pine has been found on clayey soils and on poorly drained or very poorly drained soils with surface mounds *(2, 8, 12, 13, 40, 49, 98)*. The species commonly is associated with a moderate degree of soil podsolization *(39)*.

As availability of soil moisture and soil nutrients increases, the quality of a soil for the growth of white pine tends to increase. On the basis of site studies at different places over the species' range, researchers have expressed this relationship indirectly by various combinations of soil and topographic characteristics—

texture and thickness of the A and B horizons, depth and permeability of the underlying rock or pan, depth to water table, natural drainage class, topographic position, slope percent, and aspect *(20, 26, 42, 49, 55, 74, 84, 98, 103)*.

The form and distribution of the white pine root system varies with some of these same soil characteristics. The normal root system has only the vestige of a tap root. Several (usually three to five) large roots spread outward and downward in the soil, giving the tree a firm anchor under most conditions *(25)*. From a zone below the root collar a mass of smaller lateral roots spreads horizontally in all directions, branching ultimately into the so-called feeding roots *(27, 86)*.

Large lateral roots reach greater depths in deep soils than in soils that are relatively shallow to an impenetrable layer. In deep coarse-textured soils "sinker roots", which branch from the laterals and grow straight down, seem to be fairly common; but they are seldom found in other soils. Most of the feeding roots are concentrated in the upper part of the soil material—the H, A, and B

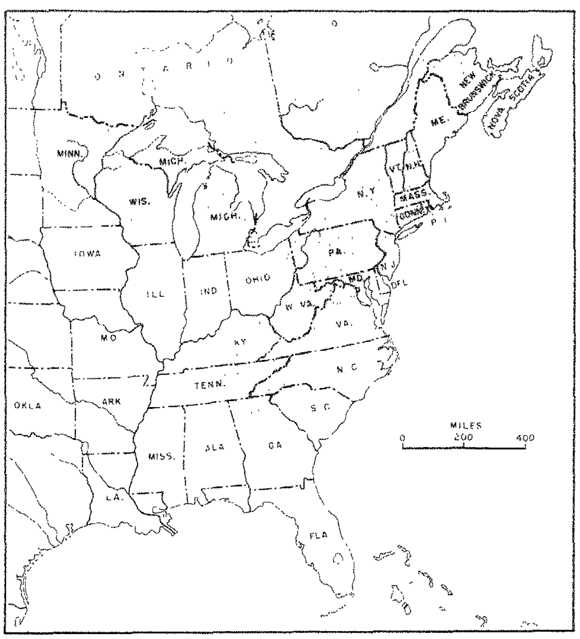


Figure 2.—The natural range of eastern white pine.

horizons *(27, 44)*. Such soil properties as fine texture, good structure and consistency, relatively high available moisture at field capacity, high total exchange capacity, high content of exchangeable bases, high total nitrogen, and high organic matter—in short, the properties that make up soil fertility—all favor the concentration of fine feeding roots.

PHYSIOGRAPHIC

In New England and New York white pine generally grows at elevations between sea level and 1,500 feet, or occasionally higher. In Pennsylvania the range is from 500 to 2,000 feet *(2)*. In the southern Appalachians white pine occurs in a band along the mountains between 1,200 and 3,500 feet above sea level, occasionally reaching 4,000 feet *(3, 6, 14)*. In Pennsylvania and the southern Appalachians most white pine is found on northerly aspects, in coves, and on stream bottoms. Elsewhere within its climatic range, occurrence is seldom restricted by altitude, aspect, and slope position.

BIOTIC

White pine is distributed naturally through part or all of six forest regions *(79)*. It is a major component of the white pine-northern red oak, white ash, white pine, and white pine-hemlock types (fig. 3) and is an element in 15 others. It may be associated with other conifers, including hemlock *(Tsuga canadensis)*, red spruce *(Picea rubens)*, white spruce *(Picea glauca)*, balsam fir *(Abies balsamea)*, northern white cedar *(Thuja occidentalis)*, pitch pine *(Pinus rigida)*, jack pine, *(Pinus banksiana)*, red pine *(Pinus resinosa)*, and shortleaf pine *(Pinus echinata)*. Common hardwood associates are gray birch *(Betula populifolia)*, paper birch *(Betula papyrifera)*, sweet birch *(Betula lenta)*, yellow birch *(Betula alleghenienis)*, American beech *(Fagus grandifolia)*, sugar maple *(Acer saccharum)*, red maple *(Acer rubrum)*, white ash *(Fraxinus americana)*, American basswood *(Tilia americana)*, bigtooth aspen *(Populus grandidentata)*, quaking aspen *(Populus tremuloides)*, pin cherry *(Prunus pensylvanica)*, black cherry *(Prunus serotina)* northern red oak *(Quercus rubra)*, black oak

Figure 3.—A 100-year-old stand of mixed white pine and hemlock in New York.

(Quercus velutina), white oak *(Quercus alba)*, chestnut oak *(Quercus prinus)*, and the hickories *(Carya spp.)*.

The value of ground vegetation as indicators of white pine sites is somewhat clouded by the different vegetation types recognized by various authors *(29, 33, 34, 85)*, and by the effect of catastrophic events on the vegetation types. However, on dry sites of low productivity the vegetation type is usually composed mainly of one or more species of the genera *Vaccinium, Gaultheria, Diervilla, Comptonia, Pteridium, Lycopodium, Andropogon,* and *Cladonia.* The moist, rich sites of high productivity support a ground vegetation made up principally of several species in the genera *Oxalis, Mitchella, Arisaema, Aralia,* and *Dennstaedtia.* Intermediate sites have ground vegetation containing varying proportions of the above, along with *Cornus, Maianthemum,* and *Pteridium.*

Life History

SEEDING HABITS

Flowering and Fruiting

In the vicinity of Ithaca, New York (latitude 42° north), new flowers are first noticeable about May 1, and pollination takes place about June 1; but fertilization does not occur until 13 months later *(22)*. The cones (fig. 4) mature the following fall—two growing seasons after flower initiation. White pine cones ripen comparatively early in the season; in central Massachusetts, for instance, they are ripe by late August *(61)*. Occasionally some cones mature in which fertilization has not taken place *(63)*.

Trees may start to bear female flowers at 5 to 10 years of age *(71, 72)*. In the Philadelphia area, quantity production of female flowers does not begin until the trees are about 20 feet tall. At that size 200 to 300 flowers may be produced in one year; the number is only a little greater on larger or older trees. Few or no male flowers appear during the early flowering years. Femaleness persists even among older trees 1 to 2 feet in diameter, although trees of this size do produce small to moderate amounts of pollen *(101)*.

Figure 4.—Mature cones of white pine, on a down tree. This was an unusually good seed crop.

Casual observations in southwestern Maine and New Hampshire suggest that flowering is heavier in that area. Trees 50 or more years old have often yielded well in excess of 400 cones. In some years such trees bear male flowers so profusely that heavy clouds of pollen are formed.

The pattern of flowering in white pine is uncertain. In the Philadelphia area the better-flowering trees tend to produce about the same number of female flowers every year, with some exceptions; male flowers, however, do not appear annually *(101)*.

Seed Production and Dissemination

Good seed years are reported to occur every 3 to 5 years, and some seed is produced in most intervening years *(95)*. However, at the Massabesic Experimental Forest in southern Maine and at other New England locations only one light seed crop has matured in the 15-year period 1948-62, and virtually no seed was produced in the other 14 years. The major cause for these failures probably has been the white pine cone beetle (*Conopthorus coniperda* (Schw.)). During recent years entire crops of 1-year-old cones have been weeviled by this insect and have dropped to the ground by midsummer of the second growing season. In breeding work with both unbagged and continuously bagged white pine flowers, Wright and Gabriel (*102*) concluded that the heavy mortality among unbagged flowers was caused mainly by this insect, although they also recognized squirrels and a lepidopteran coneworm as minor causes of mortality.

Optimum seedbearing age is between 50 and 150 years (*95*). In a comprehensive study of white pine seed production in Germany it was found that a 90-year-old stand produced 78 pounds of seed per acre; a comparable 60-year-old stand produced only one-fifth as much. In these stands dominant trees produced twice as many cones as codominant trees (*52*).

Most of the seed produced is dispersed within the month after cone maturity (*95*). The seed will travel at least 200 feet within a white pine stand (*46*) and more than 700 feet in the open (*99*).

There are about 2 pounds of cleaned seed in 100 pounds of fresh cones, and the seeds number 27,000 per pound—the range is from 20,000 to 53,000 (*95*). In a study of 250 different parents from all parts of the white pine range the number of good seeds per sound cone varied from 0 to 73[1]. The poorest seed sets were found in stands at the extremes of the species range.

VEGETATIVE REPRODUCTION

White pine does not reproduce vegetatively under natural conditions. However, small cuttings of the last season's twigs taken in late winter from trees 2 to 6 years old will root rather readily (*17, 18*). Within 9 years outplanted cuttings have developed the same form and size as seedlings, with a root system approaching that of seedlings (*65*).

Side grafts of scions on 3- or 4-year-old white pine stocks appear to be a more reliable method of vegetative propagation than rooted cuttings (*1, 35*).

[1] Wright, Jonathan W. Unpublished office report, Northeastern Forest Experiment Station, Upper Darby, Pa.

SEEDLING DEVELOPMENT

Establishment

Germination of white pine seed is highly variable; laboratory germinative capacities from 0 to 96 percent (average, 64 percent) have been reported *(95)*. Some of the variation is related to seed weight—heavy seeds germinate better than light seeds; some is related to seed origin—seeds from some mother trees germinate better than those from others (83). Embryo dormancy is general; it can be broken by exposure to moisture at temperatures of 40 to 50° F. for 30 to 60 days *(95)*.

Seedbed requirements for white pine regeneration have been concisely stated by Smith *(78)*:

> The variable influence of seedbed conditions on germination and early survival of white pine seedlings is confined almost entirely to areas exposed to direct sunlight. These variations are due chiefly to differences in the efficiency with which seedbed materials dissipate heat received from the sun. Seedbeds which lose heat slowly attain high surface temperatures. Extreme dessication associated with these temperatures causes significant reductions in germination. Heat injury also kills many seedlings on such seedbeds.

Under the condition of full exposure to sunlight, the favorable seedbeds are moist mineral soil, polytrichum moss, or a short-grass cover of light to medium density. Dry mineral soil, pine litter, lichen, and very thin or very thick grass covers are unfavorable *(78, 82, 91)*.

Unfavorable seedbed conditions can be corrected by scarification or can be overcome by shade. However, dense low shade such as that cast by slash piles or hardwood brush is inimical to later survival, and the shade from young stands of gray birch or pitch pine will reduce white pine growth in the later stages. Overstory shade resulting from a form of shelterwood cutting provides good protection during the early stages of growth and is least damaging to later stages *(78, 82)*.

Early Growth

After the establishment period, light intensity becomes critical to the survival and growth of white pine seedlings. At light intensities of less than 10 to 13 percent of full sunlight, survival is uniformly poor; at least 20 percent of full sunlight seems to be required to keep the seedlings alive *(76, 90)*. As light intensity increases above this point, growth increases proportionately up to full sunlight unless some other condition becomes limiting *(56, 57, 59, 76, 78)*.

Figure 5.—Eastern white pine seedlings growing successfully under the partial shelter of parent seed trees.

Although young white pine seedlings can survive for several weeks in soils with moisture below the wilting coefficient *(78)*, growth at a given light intensity is best in the absence of root competition. Growth is better when only an overstory offers root competition than when both an understory and an overstory are competing *(76)*.

Either an excess or a deficiency of nutrients will also limit growth. In greenhouse and nursery trials it has been shown that the optimum supply of nitrogen is 300 p.p.m. (parts per million); of phosphorus, 350 p.p.m.; of potassium, 150 p.p.m.; and of calcium, 200 p.p.m. *(56, 57, 58)*. Definite symptoms of nutrient deficiency seldom occur in white pine growing under field conditions; however, in certain areas of low-nutrient outwash quartz sands, such symptoms may appear, particularly in plantations *(39)*. Potassium commonly is the most critically deficient element in these areas.

Seed weight and seed source affect early growth *(83)*. The largest seedlings generally come from the heaviest seed; the correlation decreases after the first year but is still significant at the end of the third year. Growth differences attributed to different mother trees continue unabated through the third year.

Early growth of white pine is comparatively slow. Open-grown trees are about 5 inches high when 3 years old. They are 12 inches high when 5 years old and usually reach 4.5 feet in height only after 8 to 10 years' growth. After that, height growth may be rapid (fig. 5). Between the tenth and the twentieth years open-grown dominant trees have grown as much at 4.5 feet in height in a single year. Annual increments of 3 feet are not uncommon, but average height growth of dominant trees during this period is about 16 inches annually.

SAPLING STAGE TO MATURITY

By the time dominant trees on medium-quality sites are between 20 and 30 years of age, height growth is about 20 inches annually (fig. 6). At 50 years current annual height growth drops to 14 inches and at 100 years to 5 inches *(25)*. A minimum rate of 2 to 3 inches is reached at about 165 years of age *(81)*; this rate is apparently sustained for the life of the tree.

Figure 6.—A natural stand of sapling white pines about 30-35 years old. This stand had about 3,200 pine stems per acre.

Diameter growth is subject to wide variation with differences in stand density, site quality, and the age and development of individual trees. It may be as rapid as 1 inch per year or as slow as 1 inch in 40 years. Dominant trees will ordinarily grow at the rate of 5 to 10 rings per diameter-inch to an age of 250 years *(81)*. In fully stocked stands on average sites, average tree diameter increases at a nearly uniform rate of 1 inch every 5 to 7 years *(25, 81)*.

Periodic annual cubic-foot yield in fully stocked unmanaged stands culminates at about 40 years of age (190 cubic feet per

Figure 7.—Mature white pines in Maine. A long-lived tree, white pine may exceed 450 years in age.

Figure 8.—The bark characteristic of mature white pine. In young trees the bark is smooth and glossy, and a characteristic green-black color.

acre) on average sites *(25)*, while mean annual yield is greatest at about 60 years (140 cubic feet per acre). (See table 1.)

White pine is a long-lived tree (fig. 7 and fig. 8). It commonly reaches 300 years of age when undisturbed; maximum age may exceed 450 years *(81)*. It is capable of attaining very large size. One white pine cut in Lycoming County, Pennsylvania, in 1899 was reported to be 12 feet in diameter at the butt and 200 feet tall *(69)*. Trees 40 inches in diameter and 150 feet tall were not unusual in the virgin forests of Pennsylvania, Michigan, and New England *(81)*.

Table 1.—*Estimated yield of fully stocked pure white pine stands*[1]

(In thousands of board feet, International ¼-inch rule, trees 7 inches d.b.h. and larger)

Age (years)	Site index 45	55	65	75
50	8	18	28	38
100	40	52	68	78

[1] Compiled from Frothingham (*25*), Gevorkiantz and Zon (*29*), McCormack (*49*), Pinchot and Graves (*68*), and Tarbox and Reed (*87*).

Enemies

Many destructive agents attack eastern white pine. Some kill the tree. Others, though they do not kill, do limit the regeneration or growth of the species or affect the quality of the tree or its wood.

The white-pine weevil (*Pissodes strobi*) is a native insect that attacks and kills the terminal shoots of eastern white pines (fig. 9). The tree is seldom killed unless it is very small; usually one or two of the lateral branches from the highest living whorl turn upward to become new terminal shoots. However, this usually produces a crook in the bole, which ultimately affects log quality; sometimes it causes a forked tree (fig. 10). This type of injury also causes loss in stem length *(47)*. Sometimes 2 or even 3 years' growth is affected. Weevil damage generally is less severe among trees growing as an understory than among trees grown in the open, but growth of course is reduced in understory situations.

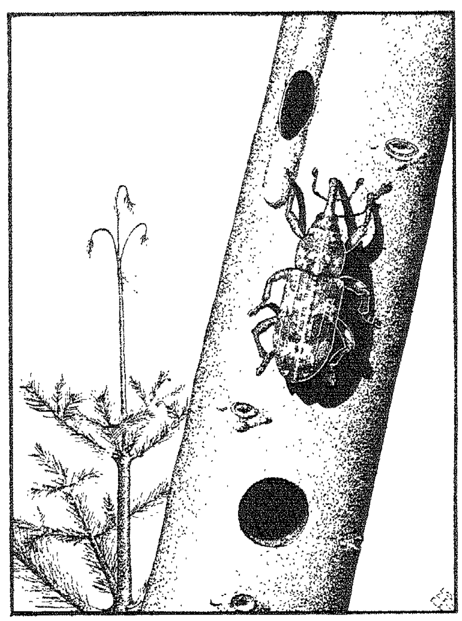
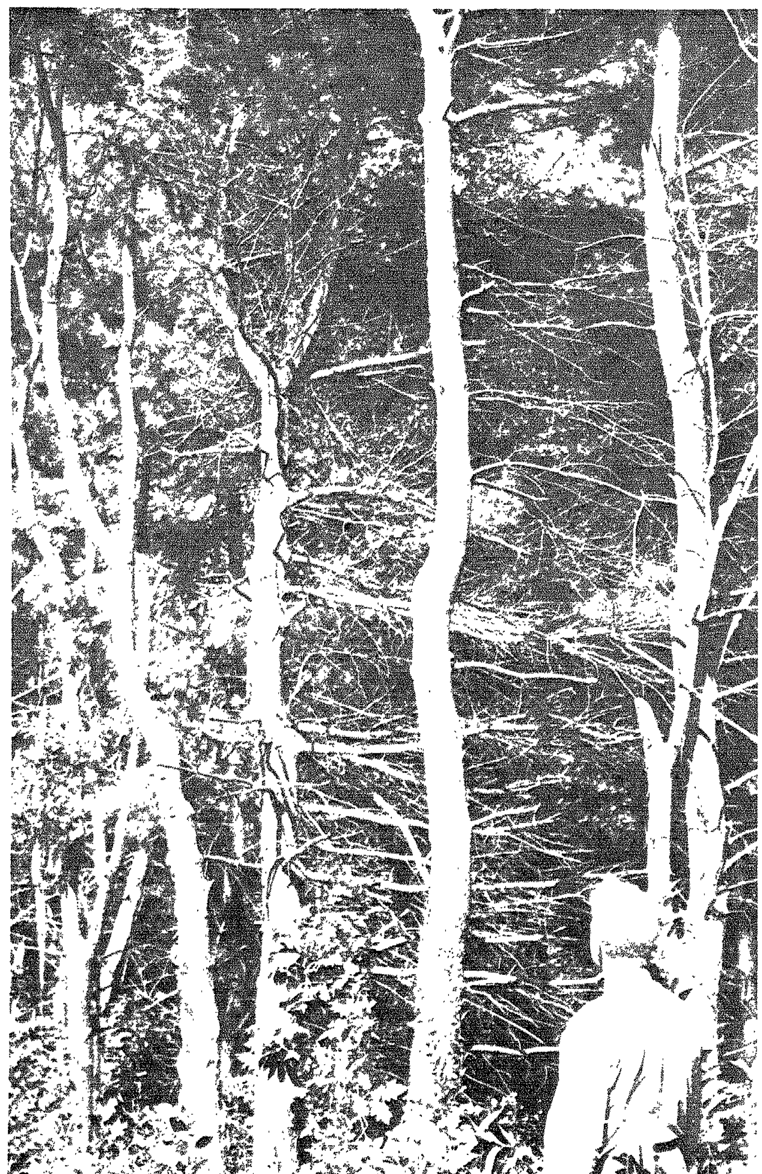


Figure 9.—The white-pine weevil is the most serious insect enemy of white pine. It attacks and kills the terminal shoots.

Figure 10.—Damage done by the white-pine weevil. Though the weevil seldom kills the tree, it causes crooks and forks that spoil the timber quality.



The Pales weevil (*Hylobius pales*) is an insect that often attacks white pine seedlings in areas where pine timber has been cut recently. These weevils breed in the fresh stumps and slash of pine cuttings; and they attack nearby live seedlings, girdling them and usually killing them. Most of the damage occurs during the first 3 years after a cutting, and among seedlings less than 5 years old *(5, 10, 24)*.

White pine blister rust, a disease caused by an introduced fungus (*Cronartium ribicola*), has proved to be highly virulent throughout the range of white pine (fig. 11). The fungus uses Ribes plants (currants and gooseberries) as an alternate host, and control is effected by eradicating the Ribes. White pine trees are susceptible to this disease from seedling stage to maturity. Where it is not controlled, blister rust can cause severe losses both in regeneration and in immature timber stands *(7, 54)*.

Red ring rot caused by the fungus *Fomes pini* is the most important rot that infects white pines. Losses are greater in older trees but do not build up rapidly *(32, 97)*. Decay is restricted to the heartwood, to which the disease gains entrance through

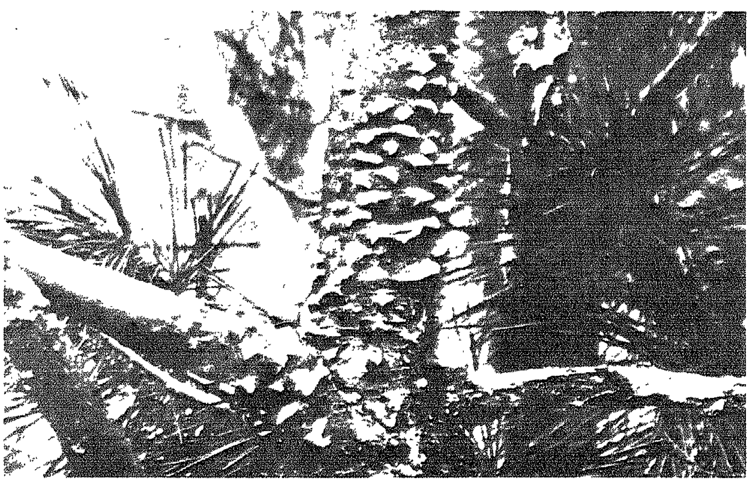


Figure 11.—Blister rust, a fungus disease that uses Ribes plants (currants and gooseberries) as an alternate host, can cause severe losses in immature stands.

wounds, dead limbs, or weeviled tips *(32, 64)*. *Stereum sanguinolentum*, a wound parasite, is probably the third most destructive fungus associated with white pine. It often gains entrance to trees through pruning wounds *(41, 77)*.

Polyporus schweinitzii is one of the most common and destructive root rots *(7)*. And a root rot caused by *Fomes annosus* is found particularly in plantations of white pines (and other conifers). Thinnings increase the incidence of this disease *(37, 39, 60)*; the fungus readily infects the stumps, spreads through the root system, and then infects nearby trees through root contacts.

Fire is also an enemy. Because the bark on exposed roots and the younger portion of the stems in second-growth white pine stands is thin, fire resistance in such stands is low. Losses are invariably heavy after a fire, and fire-caused mortality continues for several years *(48)*. Old trees have thicker bark and are at least moderately resistant to fire.

White pine is relatively windfirm if permitted full development, but in dense stands wind damage may be expected from the occasional severe storm, particularly after a recent partial cutting *(15)*. Wind-deformed trees are subject to later compression failures in the bole *(51)*.

In some localities and in some years deer, rabbits and hares, squirrels, mice, porcupines, the pine grosbeak, and various sawflies will cause extensive damage to needles, buds, twigs, or bark of seedlings and small saplings. The damage done by these agents usually is not fatal, but reductions in growth and deformation of the stem frequently result.

Reaction to Competition

The white pine has been classified as intermediate in tolerance *(4, 39)*. It will endure moderate shade and makes moderate demands on the soil. In competition with light-foliaged species like the birches and pitch pine, white pine will sooner or later gain dominance in the stand—in most cases *(80, 82, 89)*. However, against the stronger competition of such species as the aspens, oaks, and maples, white pine usually fails to gain a place in the upper canopy and eventually dies *(23, 28. 43, 45, 50, 104)*.

In the seedling stage white pine is very susceptible to competition because its capacity for rapid height growth is low in relation to that of most of its associates. If the white pine survives to the sapling stage, its potential rate of height growth increases and its ability to compete is greatly improved *(21. 80)*.

At either stage, the amount of response to release depends primarily upon how strong the competition has been and how long the pine has been in a subordinate position. In general, pines less than 30 years old with at least one-third of their height in live crown will respond well. But response declines proportionately with increasing age and decreasing crown length.

Opinion on the ecological status of white pine is varied *(9, 30, 31, 62)*. However, it is clear that white pine may function as a pioneer, as exemplified by its role as the old-field pine of New England. It may function as a physiographic climax on the dryer, sandier soils. It may function as a long-lived intermediate; and it is a component of the climatic climax forest throughout its range.

Pure stands of white pine almost never stagnate. Because of variations in inherent vigor, and in age of the trees in the stand, and in the microsites they occupy, good differentiation into crown and diameter classes practically always occurs. The expression of dominance is best on the better sites, at the greater stand densities, and in natural stands as compared to plantations *(16)*.

Trees in pure second-growth stands of white pine are noted for their limbiness. In such stands the limbs live for about 15 years and persist on the trunk for more than 25 years after they die. In the first 16-foot log of these trees there is an average of about 60 limbs *(66)*.

Racial Variation

The existence of geographic races or local ecotypes in white pine has not been established; however, there appears to be some genetic variation in growth rate. In seed-source tests at the Harvard Forest with seedlings of different geographic origins, growth was best among the local sources: growth decreased in clinal fashion with increasing distance of the seed source from the test locality *(67)*. And in a range-wide provenance test of white pine recently begun by the Northeastern Forest Experiment Station, distinct differences among seedlings of different provenances showed up in the nursery *(75)*.

Casual observations have indicated that there is geographic variation in growth rate, branchiness, drought resistance, and recovery from weevil damage between the southern Appalachians and Canada (36). Genetic variation in blister rust resistance between individual trees has been established *(38, 53, 73)*. Rehder *(70)* lists five horticultural varieties of white pine, and a naturally occurring dwarf form has been described *(11)*.

White pine will cross rather easily with most of the other 5-needle pines in the series *Strobi*. In fact, nearly all of the species in this series will cross with each other. This implies that the differentiation of these species has come about more from geographic separation than through genetic processes *(19, 100)*.

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