Pinus strobus L. Eastern White Pine

Pinaceae Pine family

G. W. Wendel and H. Clay Smith

Eastern white pine *(Pinus strobus),* also called northern white pine, is one of the most valuable trees in eastern North America. Before the arrival of white men, virgin stands contained an estimated 3.4 billion m^3 (600 billion fbm) of lumber. By the late 1800's most of those vast stands had been logged. Because it is among the more rapid growing northern forest conifers, it is an excellent tree for reforestation projects, landscaping, and Christmas trees and has the distinction of having been one of the more widely planted American trees.

Habitat

Native Range

Eastern white pine (fig. 1) is found across southern Canada from Newfoundland, Anticosti Island, and Gaspé peninsula of Quebec; west to central and western Ontario and extreme southeastern Manitoba; south to southeastern Minnesota and northeastern Iowa; east to northern Illinois, Ohio, Pennsylvania, and New Jersey; and south mostly in the Appalachian Mountains to northern Georgia and northwestern South Carolina. It is also found in western Kentucky, western Tennessee, and Delaware. A variety grows in the mountains of southern Mexico and Guatemala.

Climate

The climate over the range of white pine is cool and humid. The distribution of white pine coincides reasonably with that part of eastern North America where the July temperature averages between 18" and 23" C (65" and 74" F).

Annual precipitation ranges from about 510 mm (20 in) in northern Minnesota to about 2030 mm (80 in) 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 ranges from 90 to 180 days.

Throughout the range of white pine, precipitation is about 1 to 1.5 times the evaporation from shaded free water surfaces *(71).* Annual potential evapotranspiration is between 430 and 710 mm (17 and 28 in), of which 56 to 68 percent occurs in the warm season. There is a moisture surplus in all seasons.

Average depth of frost penetration ranges from about 25 cm (10 in) in the southern Appalachians to more than 178 cm (70 in) in parts of central and northern Minnesota. Average annual snowfall ranges from 13 cm (5 in) in northern Georgia to more than 254 cm (100 in) in New England and southern Canada *(51).*

Soils and Topography

The major soil orders found in the white pine range are Inceptisols, Ultisols, Spodosols, Entisols, and Alfisols *(14,50,66)*. In New England the important subgroups are excessively drained or somewhat excessively drained sandy deposits or stratified sand and gravel deposits. Most of the parent materials are glaciofluvial deposits-subgroups Typic Udorthents, Typic Haplorthods, and Typic Udipsamments; glacial tills-subgroups Lithic Dystrochrepts and Lithic Haplorthods; or weathered igneous rocks (loose crystalline fragments mainly from weathered Conway granite&subgroup Lithic Haplorthods *(42)*.

In northern Minnesota, Eutroboralfs, Haplorthods, Udipsamments, and Hapludalfs are among the most common of the great groups *(2)*. They are similar to the soils of New England and are more or less freely drained and have developed on glacial outwash or till material.

Dystrochrepts, Fragiodults, and Normudults are the major great groups occupied by white pine in the central Appalachian Mountains (45). These soils are weathered from acid shales and sandstones, either in place (residual soils), deposited on lower slopes (colluvial material), or along stream terraces (alluvial material). The soils are generally well drained and have a coarse loamy to a fine loamy texture.

Soils within the range of white pine are derived from granites, gneisses, schists, and sandstones, and less commonly from phyllites, slates, shales, and limestones. In the northern part of the Lake States and southern Canada, white pine is usually confined to soils derived from basalts, gabbro, diabase, and granites (70). Most of the area was covered by the Wisconsin glaciation so the soils are young and have weakly developed profiles *(67)*. In New Hampshire, white pine is found on granite-derived soils and on metamorphic crystalline schists (42). From central Pennsylvania south and in southwestern Wisconsin,

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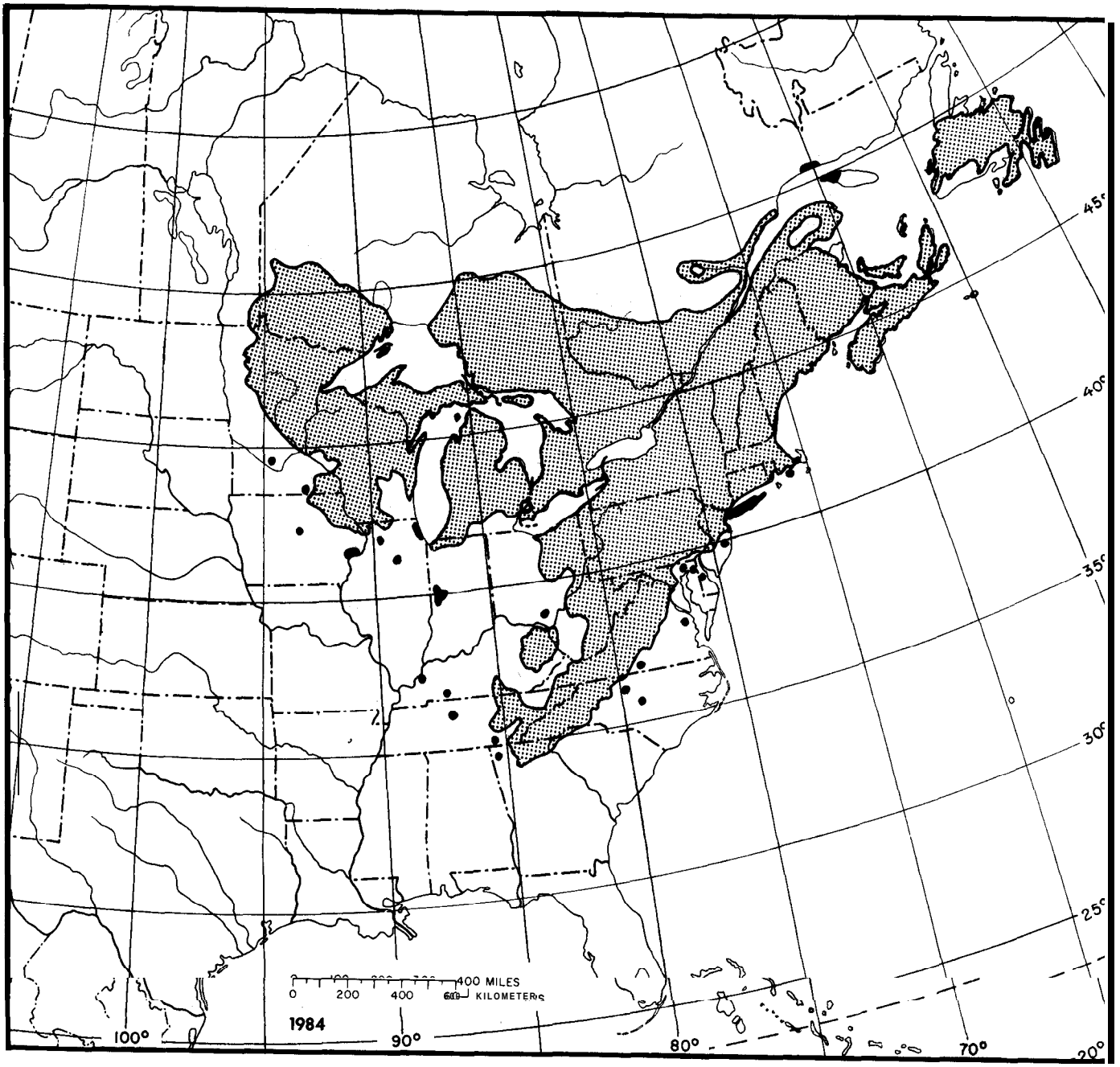

Figure *l-The native range of eastern white pine.*

the soils are much older, generally are finer textured, and have well developed profiles.

White pine grows on nearly all the soils within its range *(71),* but generally competes best on well drained sandy soils of low to medium site quality. These soils permit fair growth of white pine but not hardwoods. On these sandy sites, white pine regenerates naturally, competes easily, and can be managed most effectively and economically *(40,47).* On medium-textured soils (sandy loams), it will outproduce most other native commercial species in both volume and value *(47).* White pine also grows on fine sandy loams and silt-loam soils with either good or impeded drainage when there is no hardwood com-

petition during the establishment period-as on old fields and pastures, burns, and blowdowns. It has been found on clay soils and on poorly drained or very poorly drained soils with surface mounds. It can be very productive on these sites but usually occurs only as individual trees or in small groups (47). This pine should not be planted in heavy clay soils. Poorly drained bottom land sites and upland depressions are also poor choices for planting *(6)*.

At various places within white pine's range, site quality has been related to combinations of soil and topographic characteristics such as texture and thickness of the A and B horizons, depth and permeability of the underlying rock or pan, depth to the water table, natural drainage class, topographic position, slope percent, and aspect. In the unglaciated regions of Ohio and central Indiana, site quality for white pine increases as the soil becomes coarser in texture and declines as the moisture equivalent and wilting percentage increase in the A and B horizons *(71)*. But thickness of the A horizon had the greatest influence on rate of growth.

In Massachusetts white pine site quality increased with the increase in silt and clay fraction of the A horizon, with higher pH value of the B or C horizon, with increased stone and gravel fraction greater than 2 mm (0.08 in) in the A horizon, with greater nitrogen content in the A horizon, and with higher percent organic matter in the B horizon (46). In general, the higher site indices are associated with the poor soil drainage classes. On reclaimed soils, white pine should not be planted on sites with a pH of less than 4.0 (6).

In New Hampshire, the average height of dominant and codominant trees increased as the soil tended to be less well drained *(7,71)*. Site productivity in Maine showed the following responses: increase with a reduction in soil drainage; increase with pH increases in surface mineral horizons; decrease with increased content of stones larger than 0.6 cm (0.25 in) in the C horizon, but increase with the contents of stones in surface horizon; increase with thickness of the A horizon; increase with soil depth to a bulk density of 1.40 or greater; increase with increasing availability of soil moisture in the upper 76 cm (30 in) of soil (59).

In the southern part of its range, white pine grows best on soils along rivers and streams and grows somewhat more slowly on well drained sites (22). The growth of white pine in plantations in eastern Tennessee was found to decrease with increased plasticity of the B horizon *(71)*.

Pine often grows better than some of its associates on poor soils or sites, such as in northeastern Iowa where white pine was 8 site index points better than oaks on the poor soils *(71)*. In a comparison of site index and growth of 10 species in the southern Appalachians, white pine exceeded all species in growth, except on the best sites, where yellow-poplar outranked it in height only In New England, white pine frequently pioneers on abandoned agricultural land but only on the well-drained to excessively drained deposits-outwash, sandy tills, and shallow bedrock. White pine may form part of the climax (edaphic) on the driest of these materials or may alternate with oak (42).

In New England and New York, white pine generally grows at elevations between sea level and 460 m (1,500 ft), occasionally higher. In Pennsylvania, the elevation ranges from 150 to 610 m (500 to 2,000 ft) *(71)*. In the southern Appalachians, white pine grows in a band along the mountains between 370 and 1070 m (1,200 and 3,500 ft) above sea level, occasionally reaching 1220 m (4,000 ft). In Pennsylvania and the southern Appalachians, most white pine is found on northerly aspects, in coves, and on stream bottoms. Elsewhere, aspect seldom restricts its occurrence *(71)*.

Associated Forest Cover

White pine is a major component of five Society of American Foresters forest cover types (70): Red Pine (Type 15), White Pine-Northern Red Oak-Red Maple (Type 20), Eastern White Pine (Type 21), White Pine-Hemlock (Type 22), White Pine-Chestnut Oak (Type 51). None of these are climax types, although the White Pine-Hemlock type may just precede the climax hemlock types, and Type 20 is very close to a climax or an alternating type of climax on the sandy outwash plains of New England (42). White pine occurs in 23 other forest types:

1	Jack Pine
5	Balsam Fir
14	Northern Pin Oak
18	Paper Birch
19	Gray Birch-Red Maple
23	Eastern Hemlock
24	Hemlock-Yellow Birch
25	Sugar Maple-Beech-Yellow Birch
26	Sugar Maple–Basswood
30	Red Spruce-Yellow Birch
31	Red Spruce-Sugar Maple-Beech
32	Red Spruce
33	Red Spruce-Balsam Fir
35	Paper Birch-Red Spruce-Balsam Fir
37	Northern White-Cedar
39	Black Ash-American Elm-Red Maple
44	Chestnut Oak
45	Pitch Pine
53	White Oak

57 Yellow-Poplar
59 Yellow-Poplar-White Oak-Northern Red Oak
60 Beech-Sugar Maple
108 Red Maple

White pine also grows with pitch pine *(Pinus rigida)*, jack pine *(P. banksiana)*, shortleaf pine *(P. echinata)*, sweet birch *(Betula lenta)*, bigtooth aspen *(Populus grandidentata)*, quaking aspen *(P. tremuloides)*, black cherry *(Prunus serotina)*, black oak *(Quercus velutina)*, white oak *(Q. alba)*, and various hickories *(Carya* spp.). The ground vegetation in a white pine stand varies greatly, as evidenced by the number of forest cover types in which it is a major or minor component. Beneath pure or nearly pure stands of white pine, understory plants usually are sparse compared to those in the pine-hardwood mixtures *(70)*.

In general, on dry sites the understory vegetation is usually of one or more species of blueberries *(Vaccinium* spp.), teaberry *(Gaultheria procumbens)*, dwarf bush-honeysuckle *(Diervilla lonicera)*, sweetfern *(Comptonia peregrina)*, bracken *(Pteridium aquilinum)*, clubmoss *(Lycopodium* spp.), and broomsedge *(Andropogon virginicus)*. The moist, rich sites support a ground vegetation made up principally of several species of woodsorrel *(Oxalis)*, partridgeberry *(Mitchella repens)*, wild sarsaparilla *(Aralia nudicaulis)*, jack-in-the-pulpit *(Arisaema* spp.), and hay-scented fern *(Dennstaedtia punctilobula)*. Intermediate sites have ground vegetation containing various amounts of the above with *dogwood (Cornus* spp.) and false lily-of-the-valley *(Maianthemum canadense)*.

Life History

Reproduction and Early Growth

Flowering and Fruiting-White pine is monoecious. The male strobili are oval, 8 to 10 mm (0.3 to 0.4 in) long and occur mostly on the basal part of new shoots and mostly on older lateral branches in the lower crown. At the time of pollen shed, they are light brown to brown. Female flowers are found most often in the upper crown, primarily at the apical end of the main branches in the position of subterminal or lateral buds *(39)*. At the time of pollination, they are green, and 5 to 38 mm (0.2 to 1.5 in) long. In the northeastern United States, flowering occurs between May and June. The male flowers develop from one to several weeks before the female flowers.

Trees may start to bear female flowers when 5 to 10 years old *(71)*. In the Philadelphia area, quantity production of female flowers does not begin until the trees are about 6 m (20 ft) tall. At that size, 200 to 300 flowers may be produced in 1 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 on older trees 30 to 61 cm (12 to 24 in) in diameter, although trees of this size a0 produce small to moderate amounts of pollen *(71)*.

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 every year *(71)*. Fertilization occurs about 13 months after pollination, and cones mature usually during August and September of the second year (39). Trees have borne cones at 5 to 10 years of age, but good seed production cannot be expected until the trees are 20 to 30 years old *(30)*.

Seed Production and Dissemination-Good seed years are thought to occur every 3 to 5 years, a few seeds being produced in most intervening years. However, at the Massabesic Experimental Forest in southwestern Maine, and at other New England locations, there was virtually no seed produced for 7 years and no good seed crop for 10 years. The major cause of these failures probably is the white pine cone beetle *(Conophthorus coniperda)*.

Cones are green when immature and turn yellow-green to light brown when ripe. Cones that float in linseed oil are considered ripe. Cones should be collected from trees having superior growth and form. Widely spaced dominant trees with full crowns produce the most seeds per cone (39).

In a comprehensive German study of white pine seed production, it was found that a 90-year-old stand produced about 73 kg of seeds per hectare (65 lb/acre); a comparable 60-year-old stand produced only one-fifth as much. In these stands, dominant trees produced twice as many cones as coclominant trees (71). In Maine, intermediate density stands 27.6 m^2/ha (120 ft^2/acre) produced 4,430,000 viable seeds per hectare (1,793,220/acre) in a good seed year *(29)*. In high density stands 42.9 m^2/ha (187 ft^2/acre), seedfall was 36 percent less and in low density stands 18.4 m^2/ha (80 ft^2/acre), seedfall was 30 percent less than in the intermediate density stands.

There are 58,400 seeds per kilogram (26,500/lb) with a range from 38,600 to 116,800/kg (17,500 to 53,000/lb) (39). In a study of 250 different parents from all parts of the white pine range, the number of good seeds per cone ranged from 0 to 73. The lowest sets were found in stands at the extremes of the range.

Most of the seeds are dispersed within the month following cone maturity. The seeds travel at least 60 m (200 ft) within a white pine stand and more than 210 m (700 ft) in the open ***(71).*** Gray squirrels were found responsible for much of the white pine reproduction under mature red oak stands in southern New Hampshire; they bury and recover the seeds (3).

Seedling Development-Embryo dormancy is common in white pine, and for nursery sowing, stratification of seeds for 60 days at 1" to 5" C (33" to 41° F) is recommended (39).

Germination is epigeal. Bare mineral soil is not necessary for seed germination; seeds can germinate and survive on both disturbed and undisturbed litter layers (6). Under full exposure to sunlight, moist mineral soil, polytrichum moss, or a shortgrass cover of light to medium density are favorable seedbeds. Dry mineral soil, pine litter, lichen, and very thin or very thick grass covers are unfavorable ***(71).***

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 adverse to later survival and the shade of young stands of gray birch *(Betula **populifolia)*** or pitch pine reduces growth in the later stages. Overstory shade resulting from a form of shelterwood cut provides good protection during the early stages of growth and is least damaging to later stages *(71).*

Experience in North Carolina shows that during years of heavy seedfall white pine seedlings develop well in shade cast by logging debris. Some seedlings may die during a hot dry June, however. Thus, the roughest tracts are reserved and regenerated by natural methods during years of high seedfall only (52). On medium to fair sites in the central Appalachians, white pine seedlings can be underplanted in hardwood stands with reasonable success (69). The hardwoods, mostly oaks and hickories, permit enough light to reach the seedlings so some height growth occurs. Normally 3 to 5 years are required for white pine to become established, and if the pines are released 5 to 10 years later, a high proportion outgrow the competing vegetation. Similar results have been reported for 9- to 20-year-old underplanted white pine in Maine, Canada, and South Carolina *(16,28,71).*

White pine seedlings in the vicinity of recent pine timber cuttings often are attacked by the pales weevil ***(Hylobius pales).*** This insect breeds in the fresh stumps and slash; nearby seedlings are girdled and usually killed. Most of the damage occurs during the first 3 years after a cutting and among seedlings less than 5 years old ***(71).***

After the establishment period, light intensity becomes critical to the survival and growth of white pine seedlings. At light intensities 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. As light intensity increases above this point, growth increases proportionately up to full sunlight unless some other condition becomes limiting ***(71).*** Diameter growth of planted white pine increased with increased light in clearcut stands in the Piedmont of South Carolina (23). Height growth of underplanted seedlings after 2 years did not differ from that of seedlings planted in a clearcut.

Although young seedlings can survive for several weeks in soils with moisture below the wilting coefficient, 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 ***(71).*** Mineral soil seedbeds plus light intensities greater than 20 percent full sunlight but less than full sunlight support vigorous seedling growth by reducing surface soil temperatures and providing better soil moisture conditions ***(41).*** The survival of white pine 2-2 stock was increased on shallow old pasture soils in eastern Ontario when wedge-shaped pieces of peat saturated with water were placed at the bottom of the planting holes to provide water and prevent desiccation during drought periods ***(61).*** Two-O stock stored in a refrigerator can be planted until mid-June without significant reduction in survival rate. However, seedlings planted in July and August will not be hardened off by the first fall frost *(56).*

In some early greenhouse and nursery trials with young seedlings, the optimum supply of nitrogen was shown to be 300 p/m; phosphorus, 350 p/m; potassium, 150 p/m; and calcium, 200 p/m *(71).*

Early white pine growth is slow. Open-grown trees are about 13 cm (5 in) high when 3 years old; 30 cm (12 in) high when 5 years old; and 137 cm (54 in) high when 8 to 10 years old. Thereafter, height growth may be quite rapid. Between 10 and 20 years old, open-grown dominant trees have grown as much as 137 cm (54 in) in height in a single year. Annual increments of 91 cm (36 in) are not uncommon, but average height growth of dominant trees during this period is about 41 cm (16 in) ***(71).*** Usually terminal growth occurs within a 30-day period (6) and normally is completed by July 1 (56).

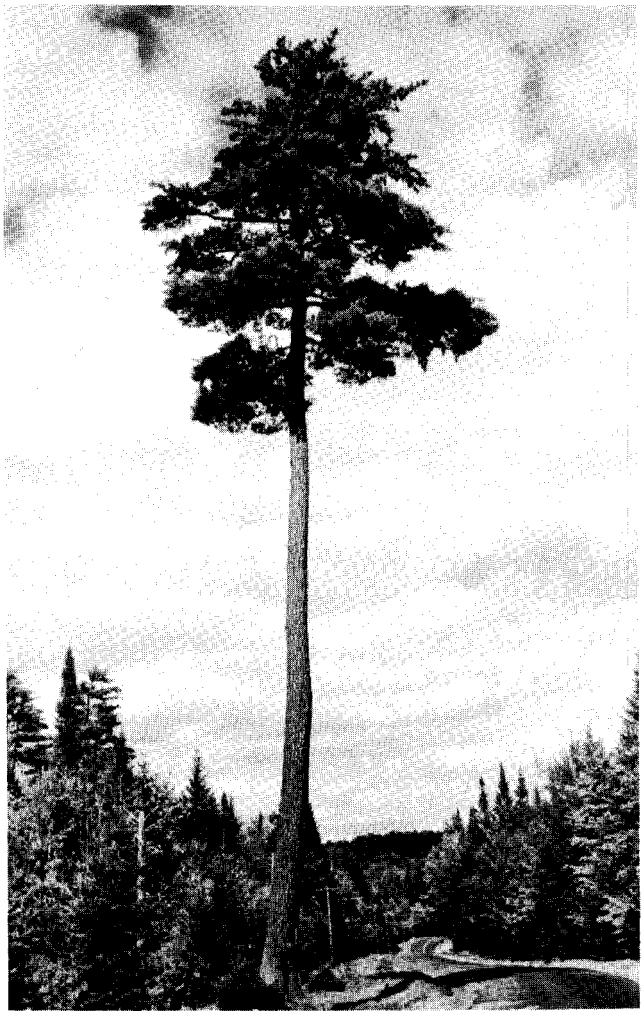

Figure 2—*Eastern white pine, preserved when stand along the Androscoggin River scenic drive in northern New Hampshire was cut.*

Vegetative Reproduction-White pine does not reproduce vegetatively under natural conditions *(31)*. Small cuttings of the last season's twigs, taken in late winter from trees 2 to 6 years old, root fairly readily, however. Within 9 years, outplanted cuttings have developed the same form and size as seedlings, and the root system approaches that of seedlings *(71)*. Also, trees from rooted cuttings performed as well or better than seedling-origin trees when comparing survival, height, and d.b.h. after 40 years *(62)*.

When June-collected cuttings from 17- and 30-year-old white pine were treated with 0.1 percent indolebutyric acid (IBA) and the fungicide Benlate, 60 and 45 percent, respectively, all of the cuttings produced roots in 16 weeks (36). Cuttings from secondary branches of 13-year-old white pines treated with 5 percent benomyl and 25 percent captan fungicides resulted in root formation on 36 percent of the cuttings. When 0.1 percent or 0.5 percent IBA was added, rooting was 31 percent (64). Multiapplications of N^6 benzyladenine at 1,000 p/m to white pine needle fascicles produced roots on 22 percent of all clones tested in 1975 *(17)*.

Scions from the crown of mature trees can be grafted on young stock *(31)*. Side grafts of scions on 3- or 4-year-old white pine stocks seem to be a more reliable method of vegetative propagation than rooted cuttings *(71)*. Buds from main terminal or lateral terminal positions should be used in grafting if early erect growth is desired *(1)*.

Sapling and Pole Stages to Maturity

Growth and Yield-White pine (fig. 2) is a long-lived tree commonly reaching 200 years if undisturbed; maximum age may exceed 450 years. It has a remarkable rate of growth compared to other pine and hardwood species within its range (20). Trees 102 cm (40 in) in d.b.h. and 46 m (150 ft) tall were common in the virgin forests of Pennsylvania, Michigan, and New England *(71)*. In the "National Register of Big Trees" *(54)*, there are two champion white pines: one in Michigan is 168 cm (66 in) in diameter and 48.2 m (158 ft) tall, and the other in Maine is 173 cm (68 in) in diameter and 44.8 m (147 ft) tall.

Periodic height growth increment of dominant and codominant trees in southern Appalachian natural white pine stands occurs at younger ages on the better sites and tends to decline more rapidly. Height growth of both planted and natural white pine is slow during the first 2 to 3 years. Afterwards, growth accelerates rapidly, peaking at an average annual rate of 1 m (3 ft) between 10 and 15 years on site index 80 (base 50 years) *(6)*. By age 55, the rate of annual growth is about equal on all sites *(9)*. For example, in stands with a site index of 36.6 m (120 ft), maximum growth of 1.0 m (3.4 ft) per year occurred at age 14; whereas, with a site index of 18.3 m (60 ft), maximum growth of 0.5 m (1.5 ft) per year did not occur until age 23. By age 55, however, annual growth for all sites was about 0.3 m (1.0 ft) per year (fig. 3).

Diameter growth may be as rapid as 2.5 cm (1 in) per year or as slow as 2.5 cm (1 in) in 40 years. Dominant trees ordinarily grow at the rate of 1 to 2 rings per 5 mm (5 to 10/in) to an age of 250 years. In fully stocked stands on average sites, the average tree diameter increases at a nearly uniform rate of 2.5 cm (1 in) every 5 to 6 years *(71)*.

Generally, rates of growth in basal area, cubic volume, and sawtimber volume in natural southern

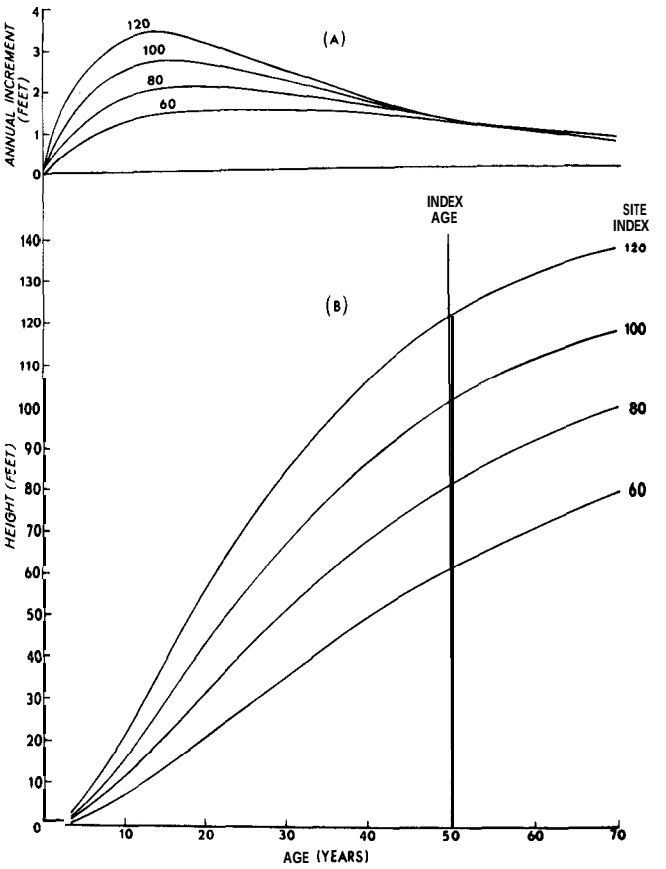

Figure 3—*Curves of annual increment (A) and cumulative height (B) for selected site indices. These curves show the changing pattern of growth with level of site index* (9).

Appalachian stands tend to be slower than those in old-field plantations. For example, maximum mean annual increment in cubic volume occurs at 60 to 70 years in natural stands and at about 25 years in plantations. Similarly, sawtimber volume in natural stands is still increasing at 100 years, though very slowly. In New England stands, mean annual increment in cubic volume occurs at age 40 to 50 (8). Sustained cubic volume growth extends from about age 30 to 90. Mean annual growth peaks at 8.6 m^3/ha (615.0 fbm/acre). In New England, a stocking guide for white pine has been prepared (55) (fig. 4). The A curve represents 80 percent stocking, and stands above it are considered overstocked. The B curve represents minimum stocking for full site utilization and stands that fall below are considered understocked. Stands between the A and B curves are considered adequately stocked. Where a particular stand might fall in the guide is based on basal area per acre, number of trees per acre, and mean d.b.h. for trees in the main canopy. Tables have been prepared for different stand ages, site and stocking percent, and cubic and sawtimber yield (table 1) (43). Yields of about 504 m^3/ha (36,000 fbm/acre) at 50 years in nearly fully stocked managed stands are entirely possible. The average white pine stand in New England grows from 4.2 to 11.2 m^3/ha (300 to 800 fbm/acre) per year depending on age, site index, and stocking *(41).* Site index for eastern white pine is determined from the average height of dominant trees at age 50 years.

For more detailed information, refer to publications on the growth and yield of white pine in natural stands and plantations prepared specifically for the various parts of the range *(6,10,41,49,55,57).*

Rooting Habit-The form and distribution of the white pine root system vary with the soil characteristics. The normal root system has just a vestige of a taproot. Usually three to five large roots spread outward and downward in the soil, giving the tree a firm anchor under most conditions. In deep, coarse-textured soils, sinker roots that branch from the laterals and grow straight down seem to be fairly common, but they are seldom found in other soils. A concentration of fine roots within the H, A, and B horizons seems to be greatest where the soil is fine textured, with good structure and consistency, and a relatively high moisture equivalent *(71).* A high total exchange capacity and a relatively high content of exchangeable bases, total nitrogen, and organic matter also favor the concentration of roots.

Much root grafting occurs in white pine stands *(12).* Regardless of either stand age, soil characteristics, or drainage class, root grafting occurred in 30 to 67 percent of dye-injected trees in five white

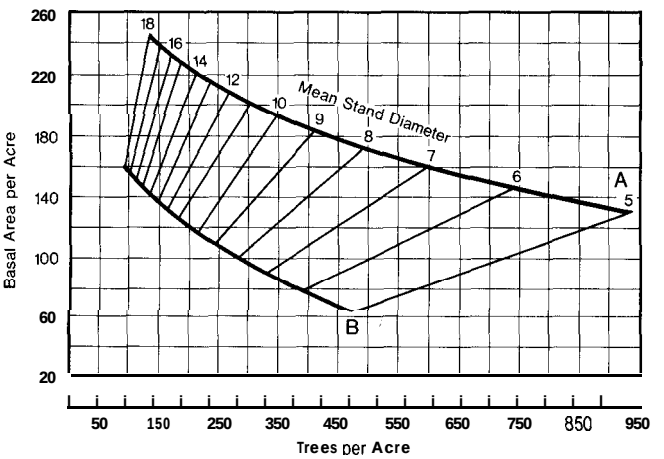

Figure 4—*Stocking guide for nearly pure even-aged white pine stands, showing basal area per acre, number of trees per acre, and mean d.b.h. for trees in the main crown canopy (55).*

Table l-Yields from fully stocked, natural stands of eastern white pine in New England *(41)*

Stand age (yr)	Site index at base age 50 years: 15 m or 50 ft	21 m or 70 ft	27 m or 90 ft
		m^3/ha	
Sawtimber[1]			
40	108	209	405
60	236	456	—
80	349	674	—
100	440	852	—
Pulpwood[2]			
20	100	137	187
40	247	339	464
60	334	458	628
80	388	533	731
100	425	583	800
		fbm/acre	
Sawtimber			
40	7,729	14,948	28,909
60	16,858	32,604	—
80	24,898	48,152	—
100	31,460	60,845	—
		ft^3/acre	
Pulpwood			
20	1,423	1,952	2,677
40	3,526	4,836	6,632
60	4,771	6,543	8,974
80	5,550	7,611	10,439
100	6,077	8,334	11,431

[1]Volume to a 15 cm (6.0 in) diameter top outside bark-fbm measured using the International 0.25-in log rule.
[2]Volume to an 8 cm (3.0 in) diameter top inside bark.

pine stands in New Hampshire, Maine, and Vermont. Exposure of the root systems indicated that often several trees, rather than two or three, were united by root grafts. Root grafting indicates that competition may be a factor in white pine growth for the first 5 to 10 years of a stand. Thereafter, root grafts begin to form, and the stand may function as a union of grafted trees interspersed with individual trees.

Reaction to Competition-White pine is intermediate in shade tolerance, and vegetative competition is a major problem *(60)*. Although it will tolerate up to 80 percent shade, tree growth increases as shade is reduced (6). It can achieve maximum height growth in as little as 45 percent full sunlight *(60)*. In competition with light-foliaged species such as the birches and pitch pine, white pine usually gains dominance in the stand. It can grow successfully in competition with black walnut ***(15).*** Against the stronger competition of species such as the aspens, oaks, and maples, however, white pine usually fails to gain a place in the upper canopy and eventually dies ***(71).*** Pure stands of white pine seldom stagnate because of inherent variations in vigor. This characteristic is more pronounced on better sites and in natural stands than in plantations *(6)*.

In Ontario, on upland sites white pine and its associates are rated in decreasing order of shade tolerance as follows: balsam fir *(Abies balsamea)*, sugar maple *(Acer **saccharum**)*, American beech *(Fagus grandifolia)*, eastern hemlock *(Tsuga **canadensis**)*, white spruce *(Picea glauca)*, yellow birch, white pine, black spruce *(Picea mariana)*, gray birch *(Betula **populifolia**)*, red oak *(Quercus **rubra**)*, red maple *(Acer rubrum)*, red pine *(Pinus **resinosa**)*, jack pine, trembling aspen, bigtooth aspen, and pin cherry *(Prunus **pensylvanica**)* ***(71).***

In the seedling stage, white pine is very susceptible to competition because its height growth is slow compared to most of its associates. If white pine survives to the sapling stage, its ability to compete is greatly improved ***(71).***

At either stage, the response to release depends primarily on 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 respond well, but response declines proportionately with increasing age and decreasing crown length.

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 species on the drier, sandier soils. It may function as a long-lived successional species, and it may be a component of climax forests throughout its range. In Canada, however, it is considered that many of the present white pine stands are edaphic or pyric relicts and that present climatic conditions are against its maintenance as a major species ***(71).***

Pure natural stands of white pine almost never stagnate (fig. 5). Because of differences in vigor, age, and site, differentiation into crown and diameter classes usually occurs. Dominance is more pronounced on the better sites, at the greater stand densities, and in natural stands as compared to plantations ***(71).***

White pine has been regenerated successfully by a wide variety of methods including clearcutting, seed tree, shelterwood, and group selection (44). If there is abundant advanced reproduction, overstory removal is all that is necessary. Clearcutting during or just after heavy seed crops often results in well stocked stands on light soils. Clearcutting in small patches or stands with seed dispersed from adjacent stands is also possible. Because of competition from

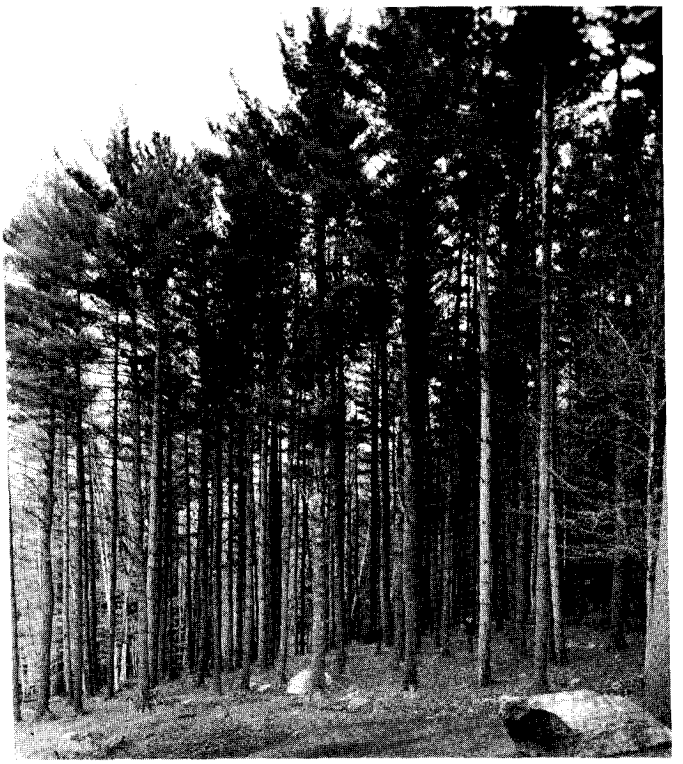

Figure 5-A *stand of pure eastern white pine; such stands* **are** *now rare.*

other vegetation and poor seed crops, mechanical site preparation and planting may be necessary sometimes in conjunction with clearcutting.

Where esthetic considerations are important, group selection may have merit. Probably the most versatile reproduction method is the shelterwood method. By control of overstory density with a series of shelterwood cuts, seedbed conditions may be improved; an accumulation of advanced seedlings is obtained over a period of years; protection of seedlings on hot, dry aspects is afforded; weevil attacks are reduced; and competition from herbaceous and hardwood sprout vegetation is suppressed. Two, three, or more cuts spread over a number of years may be used, but usually white pine can be regenerated successfully with a two-cut shelterwood system. Seed cuts should be timed to take advantage of good seed crops, but timing of the final cut is not critical.

Trees in pure second-growth stands of white pine are noted for their limbiness. The limbs live for about 15 years and persist on the trunk for more than 25 years after they die. In the first log of these stands, there is an average of about 60 limbs *(71)*. Pruning has been recommended to increase quality production. If possible, pruning should begin early when branches are less than 5 cm (2 in) in diameter but not before dominance is expressed. At least 25 percent of the live crown and up to 50 percent in closed stands can be pruned without losses in height growth. To realize full benefits of pruning, only potential crop trees should be pruned and stands should be thinned to maximize growth (24). In Canada, pruning is recommended on fast-growing trees in stands 35 to 80 years old because of the inefficiency of pruning smaller trees and the lengthened rotation and probable growth reduction in older stands (34). This recommendation assumes that the highest returns will accrue if the trees are allowed to grow for another 40 years before harvest.

Damaging Agents-There are a total of 277 insects and 110 disease organisms known to attack white pine. Only 16 insects and 7 diseases cause sufficient injury or mortality to be of concern. The three most important are white pine weevil *(Pissodes strobi)*, white pine blister rust *(Cronartium ribicola)*, and *Armillaria mellea* (63). The white pine weevil kills the terminal shoot, which may include the last 2 or 3 years of growth. The tree is seldom killed unless it is very small; lateral branches from the highest live whorl turn upward to produce new terminal shoots. Bole crook and loss of stem length result from this injury *(71)*. There is evidence that white pine provenances differ in resistance to weevils but even the lowest levels of injury are unacceptable *(25)*.

Among other insect enemies are white pine aphid *(Cinara strobi)*, which causes damage to twigs and branches of large trees and sometimes kills small trees; white pine sawfly *(Neodiprion pinetum)*, which feeds on old and new foliage; Zimmerman pine moth *(Dioryctria zimmermani)*; the Allegheny mound ant *(Formica exsectoides)*, which injects formic acid into the tree tissue; pales weevil *(Hylobius pales)*, which feeds on bark of young twigs and seedlings; pine root collar weevil *(H. radicis)*; European pine shoot moth *(Rhyacionia buoliana)*, which feeds on buds and twigs causing crooked trunks and branches; eastern pine shoot borer *(Eucosma gloriola)*, which attacks terminal needle sheaths, often causing bushiness after repeated attacks; introduced pine sawfly *(Diprion similis)*, which feeds on foliage and may defoliate an entire tree in one season; and white pine cone borer *(Eucosma tocullionana)*, which feeds on white pine cones and is a potentially serious pest (5).

White pine blister rust *(Cronartium ribicola)* is highly virulent throughout the range of white pine. Trees are susceptible from the seedling stage through maturity. Blister rust can cause high losses both in regeneration and in immature timber stands *(71)*.

Red ring rot caused by *Phellinus pini* is the most important heart rot of white pine. The fungus enters through wounds, dead limbs, or tips killed by weevils. Losses are greater in older trees but do not build up rapidly. *Haematostereum sanguinolentum,* a wound parasite, is probably the third most destructive fungus associated with white pine. It usually enters through pruning wounds *(71).*

Phaeolus schweinitzii causes one of the most common and destructive root rots. A root rot caused by *Heterobasidion annosum* is found particularly on white pines growing on poorly aerated soils. Thinnings appear to increase the incidence of this disease *(71). Armillaria mellea* destroys much of the white pine seedling and sapling reproduction for distances up to 9 m (30 ft) from hardwood stumps. The fungus radiates and girdles pines at the root collar and causes resinosis (33). Other root rots that attack white pine are *Inonotus tomentosus* and *Scytinostroma galactinium.* Many fungi invade white pine foliage. The most serious damage is caused by *Bifusella linearis,* which attacks first-year needles; *Scirrhia acicola,* which can cause spring shedding of all needles; and *Capnodium pini,* which causes surface sooty mold on aphid secretions on needles.

Three categories of nursery diseases are preemergence and postemergence damping off, most commonly caused by *Rhizoctonia solani, Fusarium* spp., *Pythium debaryanum, l? ultimum,* and *Phytophthora cinnamomi;* damping off and root collar rot caused by the preceding fungi and *Cylindrocladium scoparium* and *Diplodia pinea;* and foliage and succulent stem blights caused by *Cylindrocladium scoparium, Diplodia pinea, Phacidium infestans,* and *Rhizina undulata.* In the field, seedlings may be attacked by *Armillaria mellea* and by most of the fungi observed in the nursery. In 3- to lo-year-old plantations in Pennsylvania, *Verticicladiella procera* was identified *(65).*

The bark on exposed roots and the stem in second-growth white pine stands is thin, and fire resistance is low. Losses invariably are heavy after a fire, with mortality continuing for several years. Also, fire injury is probably responsible for introducing disease agents. If fires occurred more frequently than once in 10 years, white pine reproduction might be eliminated (53). Old trees have thicker bark and are at least moderately resistant to fire.

The species is relatively windfirm if permitted full development, but in dense stands, wind damage may be expected from an occasional severe storm, particularly after a recent partial cutting *(71).* Wind-deformed trees are subject to later compression failures in the bole. Also, white pine is damaged by deer browsing; ice and snow, which often cause limb and stem breakage; sulfur dioxide in stack gases resulting from large scale burning of coal and oil refining; fluorine gas from brick kilns; atmospheric ozone; and sea-salt spray *(11,26,33,58).*

Special Uses

Although the genus *Pinus* is used by wildlife for food and cover, few specific observations of eastern white pine have been noted. Some species of songbirds that consume seeds of white pine are the yellow-bellied sapsucker, black-capped chickadee, white-breasted nuthatch, pine warbler, pine grosbeak, and the red crossbill. Some mammals that eat seeds, bark, and foliage of white pine are beaver, snowshoe hares, New England cottontails, porcupine, red and gray squirrels, mice, and white-tailed deer (48).

White pines are useful in urban plantings. Trees grown from seeds obtained in Prince Edward Island, Nova Scotia, or in adjacent regions of New Brunswick, Maine, and New Hampshire may be more suitable than trees obtained from other regions (27). They usually have more compact crowns and are more resistant to snowbreak; they grow more slowly, have darker blue-green color, and seem to be more resistant to air pollutants than trees from other origins.

White pine has been used extensively for stabilizing strip-mine spoils. In the anthracite region of Pennsylvania, white pine survived well on spoils that fell within the pH range 5.1 to 6.5, and growth was better on lower slopes of the spoils than on upper slopes *(18).* On bituminous spoils in West Virginia, white pine survived best on spoils having a pH greater than 4.0 *(13).* Growth on the spoils was slow for the first 5 years, but total height exceeded that of Scotch pine *(P. sylvestris),* and red pine at 10 years.

The bark of white pine is used as an astringent and an expectorant, and the wood has been used to produce white pine tar, which is used as an antiseptic, expectorant, and protective (38). White pine wood has medium strength, is easily worked, and stains and finishes well. It is used for furniture, patterns, matches, and many other items. White pine is also planted for Christmas trees. The foliage has a good color and responds well to shearing *(19).*

Genetics

Population Differences

Early provenance tests by the USDA Forest Service and by Genys showed that trees from the southern Appalachians grew more rapidly at a number of test locations. In a followup test, Wright and

others collected 177 seedlots from the southern Appalachians. After 12 years, the trees from Georgia and parts of North Carolina and Tennessee grew most rapidly and trees from West Virginia and Maryland grew most slowly wherever they were tested. There are geographic differences in air pollution sensitivity, flower production, winter injury, and susceptibility to blister rust *(4,27,35,73)*. White pine varies greatly in appearance in different parts of its range, suggesting that unidentified ecological or geographical races may exist (32). Likewise, trees immune to white pine blister rust and weevil occur, suggesting the feasibility of selection propagation and breeding of resistant varieties (72).

Races and Hybrids

Eastern white pine is represented in the United States by the typical variety, *Pinus strobus* var. *strobus.* Chiapas white pine, *P. strobus* var. *chiapensis,* is native in the mountains of southern Mexico and Guatemala. Four horticultural varieties have been recognized in Connecticut (68).

Eastern white pine crosses readily with western white pine *(Pinus monticola),* Balkan pine *(P. peuce),* blue pine *(P. griffithii),* and Japanese white pine *(P. parviflora).* It can also be crossed with limber pine *(P. flexilis)* and Mexican white pine *(P. ayacahuite) (21).* The cross *P. strobus x griffthii* is more vigorous than *P. strobus* in Northern Ohio and more winter hardy than *P. griffithii (37).*

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