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FOREST PLANTATIONS IN THE LAKE STATES
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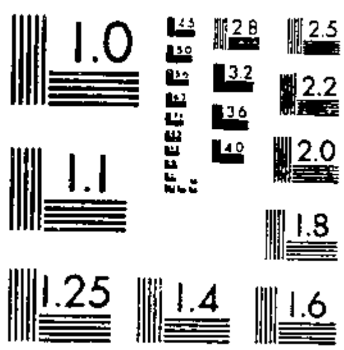

MICROCOPY RESOLUTION TEST CHART
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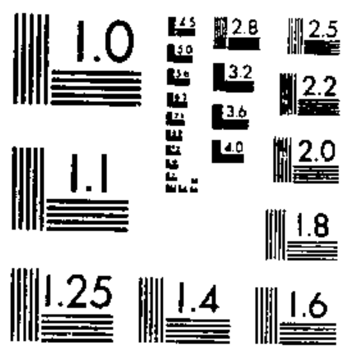

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TECHNICAL BULLETIN No. 1010 • AUGUST 1950

Forest Plantations in the Lake States

By

PAUL O. RUDOLF, Forester
Lake States Forest Experiment Station
Forest Service

UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

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UNITED STATES
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WASHINGTON, D. C.

Forest Plantations in the Lake States[1]

By PAUL O. RUDOLF,[2] *forester*

Lake States Forest Experiment Station, Forest Service[3]

WHY REFORESTATION IS NEEDED

For almost 100 years the forests of the Lake States region, which embraces the States of Minnesota, Wisconsin, and Michigan, have contributed vitally to the building up and prosperity of that and neighboring regions. These forests, one of the richest natural resources of the region, were used in prodigal fashion. Today, out of the 56 million acres of land better suited to growing forests than to any other purpose, there are some 20 million acres[4] that because of repeated logging, burning, or both, now bear very sparse or no valuable forest growth. In addition there are some 17 million acres[4] of young stands whose productivity is greatly impaired by understocking.

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[1] Submitted for publication February 14, 1950.

[2] The author wishes to express his appreciation to those who aided in the preparation of this bulletin, especially the following: R. A. Farrington, W. A. Kluender, E. J. Lott, and N. C. Tuttle, former assistants, who aided in the basic field studies; R. K. LeBarron, J. H. Stoeckeler, and P. J. Zehngraff, colleagues at Lake States Forest Experiment Station, who made some of the basic studies; G. S. McIntire, Michigan Conservation Department, R. Clement, Minnesota Conservation Department, F. G. Wilson, Wisconsin Conservation Department, Prof. P. W. Robbins, Michigan State College, Prof. T. Schantz-Hansen, University of Minnesota, and Prof. L. J. Young, University of Michigan, for review of the entire manuscript; Dr. Clyde M. Christensen, University of Minnesota, Dr. Dow V. Baxter, University of Michigan, Dr. A. J. Riker, University of Wisconsin, and Dr. J. R. Hansbrough, Bureau of Plant Industry, Soils and Agricultural Engineering, for review of the section on diseases; Dr. H. J. MacAloney and Dr. Charles B. Eaton, Bureau of Entomology and Plant Quarantine, Dr. A. C. Hodson, University of Minnesota, and Dr. R. D. Shenefelt, University of Wisconsin, for review of the section on insect pests; S. E. Aldous of the U. S. Fish and Wildlife Service for review of the sections on animals; and Dr. N. W. Hosley and L. W. Krefting, U. S. Fish and Wildlife Service, and Prof. W. H. Marshall, University of Minnesota, for helpful suggestions.

[3] Maintained by the U. S. Department of Agriculture at University Farm, St. Paul 1, Minn., in cooperation with the University of Minnesota.

[4] Based on estimates of the U. S. Forest Service as of January 1, 1945, which indicate 14 million acres of denuded and poorly restocking forest land, and 6 million acres of off-site aspen, i. e., aspen growing on former pine sites where it will not develop merchantable stands. In addition, there are 13 million acres of only medium-stocked seedling stands, and 4 million acres of poorly stocked pole stands.

If protected from forest fires long enough, much of this land would restock with trees naturally, although chiefly with less valuable kinds. Such a process of natural restocking, however, would be so slow that it would be against public interest in many cases to allow these lands to lie unproductive for so many years. Hence a large part of this 37 million acres must be restored to valuable forest growth by planting (fig. 1). Probably 12½ million acres are in need of planting now, and warrant first attention because they are sufficiently needed for timber production and are near to markets.

This enormous area, comprising about one-fourth of the total forest land of the region, in itself is a strong argument for reforestation. There are, however, other more cogent arguments. At present much of the large quantity of wood used in the homes, the factories, and the mines, and on the farms is shipped in from the far West or the South. If all the forest land of the region were restored to a high state of productivity, much of this wood could be produced locally, with a saving in freight and a longer life for local wood industries.

Although increased production of wood is the chief reason for reforesting the land, there are other important reasons. In some areas the planted trees would protect the watershed and prevent loss of the best soil through erosion. Along streams, lakes, roads, or other areas reforestation would enhance recreational values; and trees and shrubs should be planted in some places to provide shelter and food for wildlife. In general, the various uses of forest land can be carried on simultaneously in a given area through judicious management.

That the need for reforestation in the Lake States had long been recognized is evidenced by regular annual planting programs of various State and Federal agencies as early as the 1920's. However, even under the greatly expanded program between 1933 and 1942, when Civilian Conservation Corps and other emergency labor contributed to the work, the rate of reforestation was not great enough to replant the required area in less than several centuries.

Although past estimates have shown the area in need of reforestation in the Lake States to be anywhere from 1 to 20 million acres (*47, 90*),[5] the most recent estimate, based on statistics brought up to January 1, 1945, is 12½ million acres. Federal agencies own 1.4 million acres; State agencies, 1.8 million acres; county and municipal agencies, 2 million acres; and private agencies, 7.3 million acres (4.1 million acres on farms). This planting job will require about 1¼ million man-months of work. Later, release and other care will require at least ¾ million man-months of work. Thus, reforestation of the Lake States provides a backlog of useful, constructive work that ought to be considered in any plans for postwar emergency works programs. Few projects offer the same opportunity for sound investment of public funds. *But beyond its value as an emergency employment measure, reforestation ought to be carried out by regular annual programs until the land is again restored to full productivity.*

Before any large-scale program of reforestation can be undertaken there must be a background of knowledge and experience. According to the Land Committee of the National Resources Planning Board (*47, p. 116*) —

[5] Italic numbers in parentheses refer to Literature Cited, p. 159.

FIGURE 2.—A, [illegible] pine timber was cut and the land burned over; land was [illegible], unsuited for agriculture, and impaired in productivity. B, Reforestation is restoring such lands.

Forest planting is a technical job, not merely growing small trees or seedlings and setting them in holes in the ground. It involves technical knowledge of site quality of areas to be planted—the factors of moisture, temperature, soil, etc.; the existing or prospective cover, such as grass, weeds, or brush, and its probable effect in competition with planted trees; the choice of species suited to the area and yielding the most desirable products; source of seed; how to produce the best planting stock; planting technics; and finally planting itself, which may involve site preparation and measures to protect the plantations.

Obviously in any reforestation program the best methods are necessary to insure the greatest return on the forest planting investment. In 1924 and 1925 the Lake States Forest Experiment Station made a survey of plantations throughout the region in order to formulate and make available the best practices. On the basis of that survey and other information, the first comprehensive work on reforestation in the region was prepared (*37*). Since that time the area planted in the Lake States has increased almost ninefold, many planting experiments have been carried on (especially on the national forests of lower Michigan), the plantations measured in 1924–25 have been reexamined, and new experience has been gained. As a result, much of the earlier information is outmoded. For that reason the present bulletin, based primarily on the research and experience of the Forest Service and supplemented by that of other public and private agencies, has been prepared to provide the best general guide for the large-scale forest planting program required in the Lake States.

BACKGROUND FOR REFORESTATION PRACTICE

The Region and Its Physical Characteristics

The land in need of reforestation to which this bulletin applies lies largely in the northern two-thirds of Michigan, Wisconsin, and Minnesota. Broadly, it includes the area north of a line from Saginaw Bay in Michigan westward through Sheboygan, Wis., thence northwestward through St. Croix Falls, Wis., to Wadena, Minn., and northward to Thief River Falls and the Canadian boundary. This is the region from which the famous white pine lumber of the Lake States came, and which is now producing a large quantity of sugar maple, eastern hemlock, basswood, yellow birch, elm, spruce, balsam fir, aspen, and jack pine. It corresponds approximately to the area in which the natural forest vegetation is spruce-fir, beech-maple-basswood-yellow birch-hemlock, jack pine-red pine-white pine, and aspen [6] (fig. 2).

Generally the area to which this publication applies does not include the southern, predominately agricultural part of the three States, where oaks, hickories, and maples are the characteristic trees usually found as small woodland areas. Although the planting problems of the south [7] are not the same as those of the north, there are localized areas with comparable characteristics and problems, particularly in

[6] A list of common and scientific names of trees and shrubs mentioned in this publication appears in the appendix, p. 164.

[7] Planting problems of the southern area of the three States to which this publication applies have been covered to some extent in several published reports (*4, 5, 8, 13, 14, 30, 31, 32, 35, 62, 71, 72, 79, 80, 81, 82, 101*).

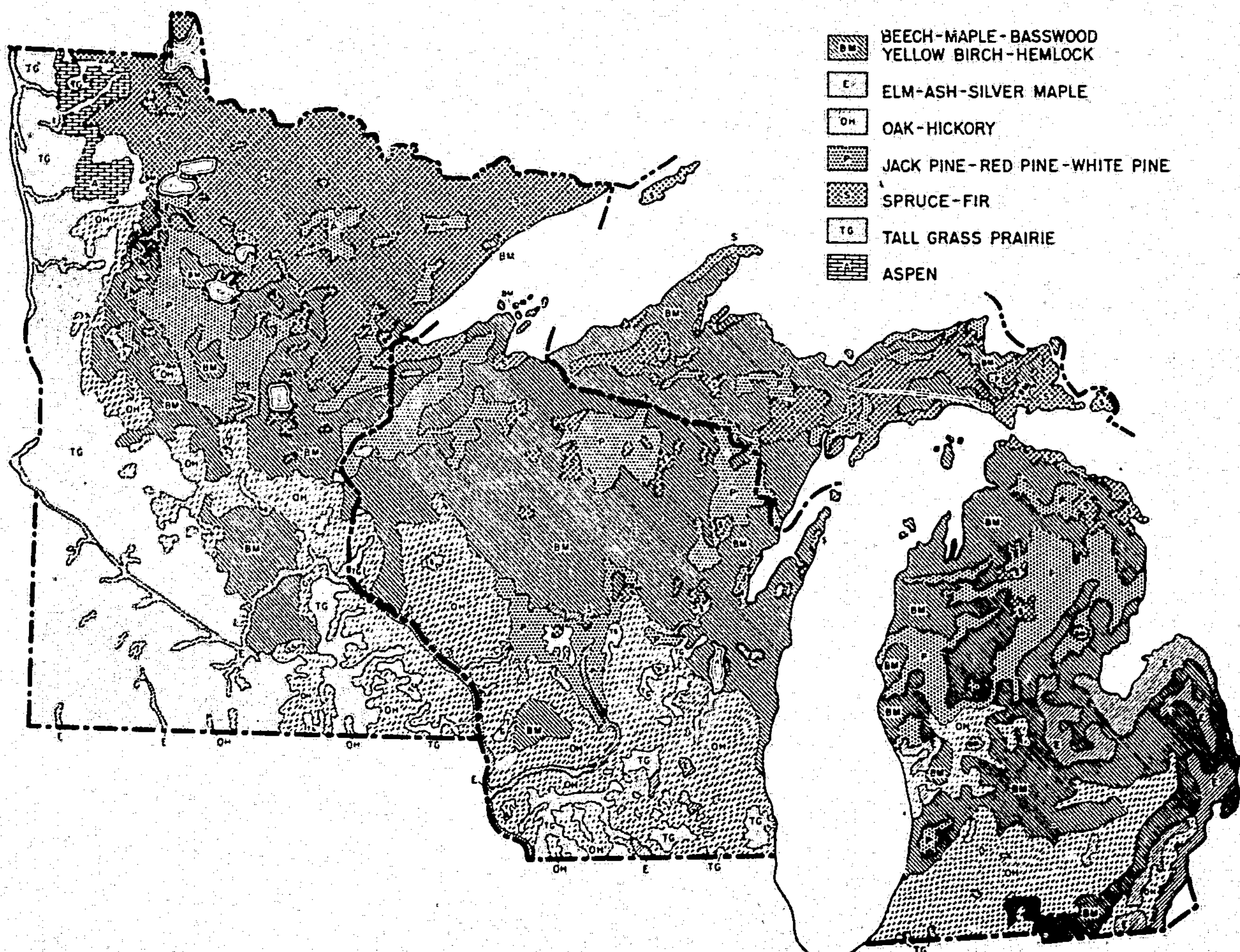

FIGURE 2.—Forest types of the Lake States.

central Wisconsin, which can be handled in the same way. The climate, topography, and soil vary locally, but are comparatively uniform for the region as a whole.

PRECIPITATION AND TEMPERATURE [4]

Total annual precipitation ranges from about 20 inches in parts of northwestern Minnesota to 35 inches in parts of lower Michigan. For most of the region it averages about 30 inches, of which about 56 percent falls during the warm months, May through September.

Snowfall increases northward, is noticeably heavier, and remains on the ground longer around Lake Superior and in northern Minnesota than elsewhere in the region. For example, the average annual snowfall is more than 100 inches along the Lake Superior shore of upper Michigan and less than 50 inches in central lower Michigan.

Irregular drought periods of 10 to 30 days, with little or no rain, are characteristic during the growing season. The distribution of rainfall, particularly during the growing season, is a more important factor in forest planting in this region than the total annual or seasonal precipitation.

The mean annual temperature for the Lake States region is about 44° F. In general, temperatures tend to decrease from the southeastern toward the northwestern part of the region. The annual average at Warroad, Minn., is 32°, compared with 47° at Saginaw, Mich.

Maxima of 90° to 100° F. are recorded throughout the region almost every summer, and they have gone as high as 111°. Minima below 0° are recorded every winter and have gone as low as −59° in northern Minnesota.

The growing season, generally between the middle of May and the latter part of September, averages about 130 days. Within the forest region it varies from 181 days, at Sheboygan on the Lake Michigan shore of Wisconsin, to 50 days, at Humboldt in northwestern upper Michigan. As a rule it is longest near Lake Michigan and shortest in the northern inland areas.

The mean summer temperature (June to September, inclusive) varies from 57° F., on the north shore of Lake Superior at the extreme northeastern tip of Minnesota, to 67°, in central lower Michigan and central Wisconsin.

The mean temperature for January, ordinarily the coldest month of the year, increases rather regularly from the northwestern to the southeastern part of the region. The range is from 0.9° F. in Roseau County, Minn., to 24.2° in Mason County, Mich.

TOPOGRAPHY

The topography of the region varies locally, but is typically gently rolling. The triangular area in northeastern Minnesota, where in many places the bedrock is exposed or is covered with only a thin layer of soil, and the Porcupine Mountain section of the Upper Peninsula of Michigan are more rugged than other parts of the Lake States. The rest of the region is overlaid by comparatively thick glacial deposits that form the confusing array of hills and valleys, plains, ridges,

[4] Climatic maps of the Lake States region appear in the appendix, pp. 169 to 171.

swamps, and lakes characteristic of the region. These glacial deposits have much to do with the character of the soil.

Elevations above sea level range from 580 feet, the level of Lake Huron and Lake Michigan, to 2,230 feet in the Misquah Hills of Cook County, Minn.

SOILS

The soils of the Lake States vary widely, from the droughty dune, beach, and outwash sands to the clays of the old lake beds and the mucks and peats of the swamps. Most of the soils of the area in need of reforestation are sandy or loamy and often also rocky or gravelly.

Although some 400 soil types have been recognized in soil surveys throughout the region, they have been differentiated in more detail than is necessary in discussing forest planting. For forest management purposes these soils need be classed only into broad groups based on texture and moisture relationships. These range from the dry, sandy soils occupied naturally by jack pine or oaks, at one extreme, to the loamy soils, with their better conditions of moisture and fertility, at the other. The heavier soils are or have been characterized by natural growth of eastern white pine, sugar maple, basswood, yellow birch, beech, eastern hemlock, white spruce, or aspen. The swamps, with their natural growth of black spruce, tamarack, northern white-cedar, and other species, form a separate soil division of the region. As little planting has been or is likely to be done in the swamps, however, they offer no foundation for a discussion of planting. More detailed soil classifications will be useful in special cases and where more intensive forest management is to be practiced.

Soil distinctions are important in any reforestation policy, not only because they influence the success or failure of the trees planted and the choice of trees to be planted, but also because they determine primarily the uses to which the land will be put. The better soils, especially when they are reasonably free from rocks and large stumps and are suitably located in respect to markets, are generally best suited for agricultural use. However, only a relatively small part of the several million acres of denuded land in the northern Lake States falls into this class.

The role of soils in reforestation practice is discussed further on pages 20 to 24.

History of Reforestation in the Region

AREAS PLANTED

The first white men coming to the Lake States found a great forest covering nearly 104 million acres. Today, exploitation and fires have reduced this to 56 million acres, of which about one-fourth is barren or not restocking itself with valuable forest growth.

The first step toward the restoration of the denuded forest land took place in 1876, when, as a memorial on the centennial of American independence, an eastern white pine plantation was set out on the Walter Ware farm, near Hancock, Wis. (52). In Michigan the first forest plantations were established in 1888 at Grayling and Oscoda by the Michigan Agricultural College. In 1894 St. Johns University initiated forest planting in Minnesota at Collegeville. A few private companies and individuals did a little planting in the region in 1903, 1904, and 1905. Some planting was done on the Higgins Lake State Forest in Michigan as early as 1904.

The Federal Government began planting operations on the national forests in Michigan in 1910 and in Minnesota in 1911, at which time the State of Wisconsin made a similar beginning. In the same year, Michigan expanded its planting program. The rate of planting did not accelerate very greatly until after 1915, however. During World War I forest planting decreased. In 1926 the Nekoosa-Edwards Paper Co. initiated industrial planting in Wisconsin. Wisconsin now leads the other Lake States in this respect.

After World War I, the area planted annually in the Lake States increased. In 1923, 4,000 acres were planted; in 1924 the total exceeded 10,000 acres; in 1926, 15,000 acres were planted; in 1934 the total reached 92,000 acres; and in 1936 a peak of 144,000 acres was reached. During the decade 1933-42, a little over 1,000,000 acres were planted in the Lake States, almost all of it by Civilian Conservation Corps and Work Projects Administration labor. The increased rate of planting brought about corresponding expansion in the total area planted.

The total area planted at the end of 1926 in the three Lake States, including 80,000 acres in the prairie region of southern and western Minnesota, was about 155,000 acres. By the close of 1933 (first year of the CCC), this total had risen to 112,000 acres. At the end of 1944 about 1,400,000 acres had been planted. Of this total, 55 percent has been planted by the Federal Government, 21 percent by the States, 6 percent by counties and municipalities, and 18 percent by private owners. About one-quarter of the area had been replanted one or more times. Plantings on about two-thirds of the area are considered successful. Details as to area planted by the close of specified years, 1926-44, are given in table 1. By the end of 1948 the total area planted was about 1,500,000 acres.

KINDS OF TREES PLANTED

The three native pines, red, white, and jack, are the species that have been planted most commonly in the northern Lake States. At the close of 1944 the percentages for the various kinds of trees planted were as follows: Red pine, 43.0; jack pine, 40.7; eastern white pine, 9.2; other pines, 0.3; white spruce, 4.1; other spruces, 1.4; other conifers, 0.4; and hardwoods, 0.9. Details as to kinds of trees planted by agencies, and periods, are given in table 2.

Jack pine, red pine, white pine, and white spruce will continue to predominate in future plantings, but perhaps not so strongly. Other conifers, making up about 2 percent of the area planted, include such species as Scotch pine, Austrian pine, ponderosa pine, pitch pine, lodgepole pine, Norway spruce, western white spruce, blue spruce, black spruce, European larch, tamarack, northern white-cedar, eastern redcedar, balsam fir, and eastern hemlock. Among those only black spruce and tamarack are likely to be used more extensively for regular forest planting. Scotch pine and possibly Norway spruce of suitable seed origins (northern European or Siberian) will probably continue in more or less regular use for special purposes. Northern white-cedar may be planted more widely for wildlife browse. The other species are not likely to continue in use to any appreciable extent.

Hardwoods have been planted on but 1 percent of the area reforested in the Lake States. This is primarily due to three facts: (1) The typical northern hardwood forest has a dense understory of reproduction that regenerates the stand without planting. (2) Forest fires are less common in hardwood than in coniferous forests and consequently have denuded less hardwood land. Furthermore, when hardwoods are burned they are able to sprout and thus produce a new stand naturally. (3) Hardwood stands on the lighter soils, which have been badly burned ouver, cannot be restored to valuable hardwood species because of the destruction of the organic matter in the soil. They must be replanted with conifers. It seems likely that reforestation with hardwood species will increase as knowledge of their handling develops. Such species as northern red oak, white ash, sugar maple, yellow birch, basswood, rock elm, and eastern cottonwood seem promising for such use.

TABLE 1. —*Total area planted in the Lake States by public and private agencies, 1926–44*

Agency and year	Minnesota	Wisconsin	Michigan	Total
	Acres	*Acres*	*Acres*	*Acres*
Federal:				
1926	[1] 7,500	0	[1] 20,000	27,500
1933	23,794	21,305	95,461	140,560
1939	79,646	177,842	406,249	663,737
1944	100,997	199,898	467,719	768,614
State:				
1926	2,667	2,703	31,612	36,982
1933	3,252	15,779	140,052	159,083
1939	24,124	26,146	202,202	252,472
1944	37,147	30,257	217,473	284,877
County, municipal, and other public:				
1926	353	0	595	948
1933	[2] 500	2,471	995	3,966
1939	[2] 1,500	33,539	5,813	40,852
1944	1,955	74,586	10,503	87,044
Farmers and other small owners:				
1926	[2] 81,000	[1] 2,414	[2] 2,000	85,414
1933	[2] 82,000	[1] 8,852	[2] 8,000	98,852
1939	84,804	38,697	25,608	149,109
1944	84,944	55,618	41,989	182,551
Industrial organizations:				
1926	[2] 400	[2] 1,500	[2] 600	2,500
1933	[2] 1,000	6,204	2,163	9,367
1939	[2] 3,000	15,629	4,952	23,581
1944	3,056	38,742	28,065	69,863
Total, all agencies:				
1926	91,920	6,617	54,807	153,344
1933	110,546	54,611	246,671	411,828
1939	193,074	291,853	644,824	1,129,751
1944	228,099	399,101	765,749	1,392,949

[1] Estimated on basis of partial data. [2] Estimated; no data.

TABLE 2.—*Cumulative number of trees planted to the end of specified years, by species, in the Lake States, 1926–44* [1]

FEDERAL AGENCIES

Species	Minnesota				Wisconsin				Michigan			
	1926	1933	1939	1944	1926	1933	1939	1944	1926	1933	1939	1944
	1,000 trees	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*
Jack pine	0	0	34, 089	44, 246	0	0	62, 236	75, 954	0	0	160, 159	199, 388
			(0)	(3. 4)			(0)	(0. 7)			(0)	(0. 1)
Red pine	[2] 9, 280	15, 189	36, 226	43, 697	0	[2] 11, 000	68. 631	79, 032	[2] 16, 003	54, 649	177, 726	209, 328
	(0)	(0)	(25. 8)	(37. 9)		(0)	(16. 8)	(26. 8)	([3])	([3])	(12. 0)	(14. 4)
Eastern white pine	[2] 7	201	11, 923	12, 987	0	[2] 4, 000	12, 168	13, 586	[2] 500	1, 023	20, 567	24, 909
	(0)	(0)	(27. 8)	(33. 2)		(0)	(8. 0)	(17. 6)	(0)	(1. 6)	(27. 0)	(36. 3)
White spruce	93	404	3, 782	6, 087	0	[2] 1, 300	14, 977	18, 131	0	[2] 1, 400	6, 098	14, 867
	(0)	(0)	(53. 3)	(71. 1)		(0)	(28. 0)	(40. 1)		(0)	(29. 9)	(65. 1)
Other conifers	0	[2] 63	237	311	0	[2] 4, 111	10, 176	10, 274	[2] 500	1, 200	2, 999	3, 180
		(0)	(43. 8)	(56. 0)		(0)	(2. 7)	(3. 0)	(0)	(0)	(22. 0)	(22. 9)
Hardwoods	0	0	0	0	0	2	[2] 260	530	0	0	[2] 600	1, 098
						(0)	(0)	(0)			(0)	(0)
Total	9, 380	15, 857	86, 257	107, 328	0	20, 413	168, 448	197, 507	17, 003	58, 272	368, 149	452, 770
	(0)	(0)	(17. 1)	(25. 0)		(0)	(10. 1)	(16. 1)	([3])	([3])	(8. 0)	(11. 0)

State Agencies

Jack pine	0	160	[2] 5,000	10,036	110	4,289	13,058	16,199	11,440	41,840	69,100	76,427
		(0)	(0)	(14.7)	(32.8)	(0.8)	(1.5)	(1.2)	(0)	(0)	(0)	(0)
Red pine	764	[2] 1,120	[2] 10,000	16,918	1,502	8,832	15,363	18,243	19,800	50,200	81,930	88,935
	(32.5)	(28.6)	(29.0)	(24.7)	(27.3)	(4.6)	(3.1)	(5.7)	(0)	(0)	(0)	(0.3)
Eastern white pine	599	[2] 695	[2] 3,750	6,146	688	2,159	4,140	4,829	11,000	27,600	31,110	31,958
	(32.6)	(28.8)	(29.4)	(31.2)	(4.8)	(1.5)	(3.3)	(6.3)	(0)	(0)	(0)	(0.6)
White spruce	862	[2] 1,105	[2] 3,750	5,810	0	0	283	491	0	0	0	0
	(11.6)	(27.2)	(33.3)	(48.1)			(10.6)	(13.8)				
Other conifers	95	[2] 110	[2] 2,300	462	628	2,087	3,016	2,269	1,760	1,760	1,760	1,760
	(100.0)	(100.0)	(47.8)	(55.4)	(9.9)	(3.0)	(5.7)	(19.2)	(0)	(0)	(0)	(0)
Hardwoods	90	[2] 110	[2] 200	98	0	0	2	68	0	0	6,040	7,571
	(0)	(0)	(0)	(0)			(0)	(19.1)			(0.7)	(2.6)
Total	2,410	3,300	25,000	39,470	2,928	17,367	35,862	42,099	44,000	120,800	189,940	206,651
	(26.5)	(28.2)	(25.4)	(26.9)	(18.5)	(3.1)	(2.8)	(4.9)	(0)	(0)	([3])	(0.3)

County, Municipal, and Other Public

Jack pine	0	0	[2] 400	512	0	1,534	20,248	46,751	59	100	799	1,296
			(0)	(0.2)		(0)	(0)	(0)	(0)	(0)	(0)	(0)
Red pine	150	[2] 200	[2] 305	412	0	1,676	19,636	34,065	351	587	4,710	7,469
	(94.5)	(90.0)	(91.7)	(42.0)		(0)	(3.0)	(7.8)	(0)	(0)	(0)	(0)
Eastern white pine	14	[2] 22	[2] 26	86	0	36	6,151	8,143	185	308	2,438	3,506
	(35.7)	(31.8)	(34.6)	(81.4)		(0)	(8.2)	(19.9)	(0)	(0)	(0)	(0)
White spruce	140	[2] 180	[2] 200	292	0	0	773	1,551	0	0	0	0
	(100.0)	(100.0)	(100.0)	(100.0)			(10.0)	(23.4)				
Other conifers	0	0	0	40	0	0	3,758	6,347	5	5	10	10
				(37.5)			(7.1)	(19.3)	(0)	(0)	(0)	(0)
Hardwoods	49	[2] 64	[2] 66	66	0	0	256	314	0	0	0	265
	(0)	(0)	(0)	(0)			(0)	(0)				(0)
Total	353	466	997	1,408	0	3,246	50,822	97,171	600	1,000	7,957	12,646
	(81.2)	(78.7)	(49.0)	(39.1)		(0)	(2.8)	(6.1)	(0)	(0)	(0)	(0)

See footnotes at end of table.

TABLE 2.—*Cumulative number of trees planted to the end of specified years, by species, in the Lake States, 1926–44* [1]—Con.

ALL PUBLIC AGENCIES

Species	Minnesota				Wisconsin				Michigan			
	1926	1933	1939	1944	1926	1933	1939	1944	1926	1933	1939	1944
	1,000 trees	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*
Jack pine	0	160 (0)	39,489 (0)	54,794 (5.5)	110 (32.8)	5,823 (0.6)	95,542 (0.2)	138,904 (0.5)	11,499 (0)	41,940 (0)	230,058 (0)	277,111 (0.1)
Red pine	10,194 (3.8)	16,509 (3.0)	46,531 (26.9)	61,027 (34.3)	1,502 (27.3)	21,508 (1.9)	103,630 (12.2)	131,340 (19.0)	36,154 ([3])	105,436 ([3])	264,366 (8.1)	305,732 (9.9)
Eastern white pine	620 (32.2)	918 (22.6)	15,699 (28.2)	19,219 (32.8)	688 (4.8)	6,195 (0.5)	22,459 (7.2)	26,558 (16.3)	11,685 (0)	28,331 (0.1)	54,115 (10.2)	60,473 (15.2)
White spruce	1,095 (21.9)	1,689 (28.4)	7,732 (44.8)	12,189 (60.8)	0	1,300 (0)	16,033 (26.7)	20,173 (38.2)	0	1,400 (0)	6,098 (29.9)	14,867 (65.1)
Other conifers	95 (100.0)	173 (63.5)	2,537 (47.5)	813 (54.7)	628 (9.9)	6,198 (1.0)	16,950 (4.2)	18,890 (10.4)	2,265 (0)	2,965 (0)	4,769 (13.9)	4,950 (14.7)
Hardwoods	139 (0)	174 (0)	266 (0)	164 (0)	0	2 (0)	518 (0)	912 (1.4)	0	0	6,640 (0.6)	8,934 (2.2)
Total	12,143 (7.6)	19,623 (6.6)	112,254 (19.3)	148,206 (25.6)	2,928 (18.5)	41,026 (1.3)	255,132 (7.6)	336,777 (11.8)	61,603 ([3])	180,072 ([3])	566,046 (5.2)	672,067 (7.5)

[1] Figures in parentheses=percent of total number of trees that were transplants.
[2] Estimated on basis of partial data.
[3] Less than 0.05 percent.

About 35 percent of all trees planted in the Lake States plantations before 1920 were still living at an average age of 23 years. The average percentage of trees still living varied according to species as follows: Red pine (130 plantations), 32 percent; eastern white pine (123 plantations), 31 percent; jack pine (64 plantations), 41 percent; Scotch pine (40 plantations), 52 percent. Assuming an original planting of 1,200 trees per acre, the percent of trees still living should have been nearly twice as great. Survival was low because of improper selection of species and classes of stock for the sites, lack of release, and failure to control snowshoe hares. With the widespread use of improved reforestation practices, better plantation survivals can be attained.

THE JOB AHEAD

To reforest from 8 to 12 million acres is a big job. If completed over a 20-year period, it would involve planting about 400,000 to 600,000 acres per year, a rate from three to four times that achieved at the peak of CCC planting in the Lake States, and it would cost about $120 million to $180 million at prewar prices. Present costs would be considerably higher unless increased labor costs could be offset by technological improvements. An undertaking of this scope should be carefully planned and executed, and cooperation of both public and private landowners would be necessary.

As a starting point from which more detailed plans can be built, estimates have been made as to the areas in need of complete and partial planting, by units of each of the three Lake States (tables 3 and 4, and fig. 3).

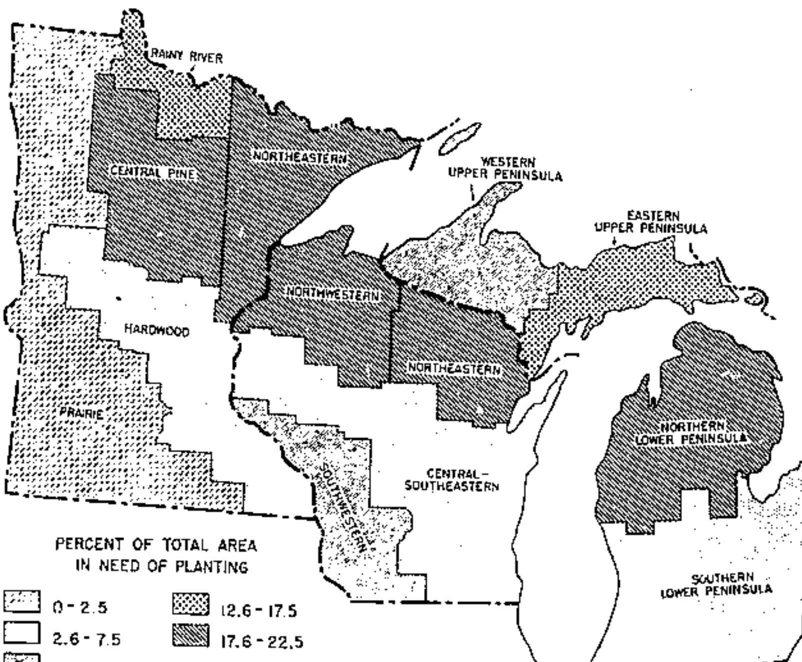

FIGURE 3.—Area in need of reforestation in the Lake States by units.

TABLE 3.—*Estimated deforested plus off-site aspen [1] land in immediate need of planting in the Lake States by ownership classes and species suitable for planting*

[Thousand acres, i. e., 000 omitted]

State and unit [2]	Total deforested plus off-site aspen	Ownership					Species suitable for planting					
		Federal	State	County and municipal	Farmers	Other private	Eastern white pine	Red pine	Jack pine	White spruce	Northern hardwoods	Northern red oak
Minnesota:												
Northeastern	885	156	128	298	118	185	146	269	311	159	-------	-------
Central pine	1, 165	162	233	384	270	116	192	395	447	131	-------	-------
Rainy River	244	10	144	31	18	41	46	85	66	47	-------	-------
Hardwood	336	0	0	4	332	0	44	100	97	54	20	21
Prairie	206	0	7	7	145	47	26	66	61	28	11	14
Total	2, 836	328	512	724	883	389	454	915	982	419	31	35
Wisconsin:												
Northeastern	780	123	39	208	155	255	138	245	211	114	29	43
Northwestern	954	138	18	364	197	237	153	274	288	148	42	49
Central	1, 034	1	7	101	707	218	138	310	369	115	42	60
Southwestern	323	6	11	47	244	15	33	119	125	13	5	28
Total	3, 091	268	75	720	1, 303	725	462	948	993	390	118	180
Michigan:												
Eastern Upper Peninsula	421	110	140	1	60	110	64	124	155	67	11	-------
Western Upper Peninsula	411	37	86	2	52	234	73	142	102	70	13	11
Northern Lower Peninsula	1, 611	84	332	5	510	680	257	472	626	140	49	67
Southern Lower Peninsula	355	2	11	1	292	49	69	146	22	57	22	39
Total	2, 798	233	569	9	914	1, 073	463	884	905	334	95	117
Total, Lake States	8, 725	829	1, 156	1, 453	3, 100	2, 187	1, 379	2, 747	2, 880	1, 143	244	332

[1] Aspen growing on former pine sites where it will not develop merchantable stands. About one-half the area of this land is included in this table as in immediate need of planting.

[2] The Economic Units used by the Forest Survey.

TABLE 4.—*Estimated understocked seedling and sapling and pole areas in the Lake States in need of partial planting, by ownership classes, species suitable for planting, and cover type*

[Thousand acres, i. e., 000 omitted]

State and unit [1]	Total seedling and sapling and pole areas	Ownership					Species suitable for planting						Cover type				
		Federal	State	County and municipal	Farmers	Other private	Eastern white pine	Red pine	Jack pine	White spruce	Northern hardwoods	Northern red oak	Eastern white pine	Red pine	Jack pine	Oak	Spruce-fir
Minnesota:																	
Northeastern	479	159	56	149	35	80	86	175	55	163	0	0	21	17	174	4	263
Central pine	400	70	95	104	54	77	48	201	72	79	0	0	21	31	212	21	115
Rainy River	194	14	121	18	15	26	42	56	16	80	0	0	8	12	43	0	131
Hardwood	128	1	0	7	117	3	24	42	14	25	0	23	4	3	3	117	1
Prairie	80	1	11	14	37	17	16	23	7	18	1	15	1	1	(2)	73	5
Total	1, 281	245	283	292	258	203	216	497	164	365	1	38	55	64	432	215	515
Wisconsin:																	
Northeastern	305	60	19	62	50	114	49	98	24	93	31	10	25	28	44	53	155
Northwestern	355	67	10	106	62	110	43	142	46	87	30	7	22	24	123	37	149
Central	338	1	3	25	202	107	48	144	51	51	3	41	17	8	94	206	13
Southwestern	328	8	11	32	262	15	62	107	36	62	0	61	6	4	12	306	0
Total	1, 326	136	43	225	576	346	202	491	157	293	64	119	70	64	273	602	317
Michigan:																	
Eastern Upper Peninsula	293	67	98	1	13	114	37	112	34	80	30	0	18	29	94	0	152
Western Upper Peninsula	210	58	55	1	10	86	35	57	11	77	30	0	22	13	27	0	148
Northern Lower Peninsula	467	72	144	2	50	199	43	242	89	59	1[illegible]	20	19	49	230	98	71
Southern Lower Peninsula	127	2	7	(2)	64	54	25	41	12	26	0	23	10	0	0	116	1
Total	1, 097	199	304	4	137	453	140	452	146	242	74	43	69	91	351	214	372
Total, Lake States	3, 704	580	630	521	971	1, 002	558	1, 440	467	900	139	200	194	219	1, 056	1, 031	1, 204

[1] These are the Economic Units used by the Forest Survey.
[2] Less than 0.5.

Based on the best statistics available as of January 1, 1945 (*60*), these units have been broken down to show the estimated plantable area by broad ownership classes—Federal, State, county and municipal, farmers, and other private owners.

Also shown in tables 3 and 4 is the estimated area suitable for planting to jack pine, red pine, eastern white pine, white spruce, northern hardwoods, and northern red oak. These are the main species likely to be planted, although changes or substitutions may be made as the result of more detailed planning. For instance, some of the area suitable for eastern white pine may be planted to red pine, white spruce, or other species because of local difficulties in white pine blister rust control; some of the areas suitable for northern hardwoods might be planted with white spruce; some of the white spruce areas might be planted with black spruce, tamarack, or even Norway spruce; or some of the northern red oak areas might be planted to red pine. In the main, however, the areas set up are indicative of the extent to which the principal species should be planted. The number of trees required to plant the estimated areas is shown in table 5.

TABLE 5.—*Trees required for complete and partial planting in the Lake States, by species*

Species	Complete planting	Partial planting	Total	Annual requirements, 20-year program
	1,000 trees	*1,000 trees*	*1,000 trees*	*1,000 trees*
Eastern white pine	1, 379, 000	223, 200	1, 602, 200	80, 110
Red pine	2, 747, 000	576, 000	3, 323, 000	166, 150
Jack pine	2, 880, 000	186, 800	3, 066, 800	153, 340
White spruce	1, 143, 000	360, 000	1, 503, 000	75, 150
Northern hardwoods [1]	244, 000	55, 600	299, 600	14, 980
Northern red oak	332, 000	80, 000	412, 000	20, 600
Total	8, 725, 000	1, 481, 600	10, 206, 600	510, 330

[1] Includes sugar maple, yellow birch, basswood, white ash, and rock elm.

The 1947 capacity of all public nurseries in the three Lake States was 143 million trees per year. It would take more than 70 years to plant all areas in need of complete and partial planting with trees from existing nurseries; to plant the total area in 20 years, present nursery capacity would have to be increased to more than 3½ times.

Estimates indicate that in the three Lake States there are more than 5½ million acres of deforested land, more than 3 million acres of off-site aspen, and about 3¾ million acres of understocked seedling, sapling, and pole stands now in need of reforestation.[9] Responsi-

[9] An estimate of the reforestation job in Wisconsin, made in 1944 by the Wisconsin Conservation Department (*28*), shows 1,004,000 acres of deforested and understocked area in need of complete or partial planting in 19 northern Wisconsin counties, as compared to 1,673,000 acres on the basis used for estimating in this bulletin.

bility for reforesting the 12½ million acres is estimated on the basis of landownership as follows: Federal agencies, 11 percent; State agencies, 14 percent; county and municipal agencies, 16 percent; farmers, 33 percent; and other private owners, 26 percent.

DIRECT SEEDING

Reforestation by means of sowing seed directly on a planting site has been attempted rather universally ever since planting has been done. There has always been the hope that areas could be reforested more cheaply by direct seeding than by planting, and that trees grown from seed directly on the planting site could develop normal root systems and therefore avoid a possible detrimental effect of planting.

Reforestation by means of direct sowing was begun in the Lake States about the time the earlier plantings were made, and has been thoroughly tested. The earliest direct sowing tests involved red, eastern white, and Scotch pines, and northern red oak. The first extensive tests, however, were made on the Huron National Forest in Michigan between 1910 and 1912, and involved the sowing of red pine, jack pine, and Austrian pine on about 100 acres. Because of early failures, this method fell into disfavor.

Between 1926 and 1936 the Lake States Forest Experiment Station began a series of direct seeding experiments, using 20 distinct methods and 18 species on some 310 acres widely scattered over the national forests of Minnesota, Wisconsin, and Michigan (*65*). Up to July 1948 the national forests had seeded about 4,200 acres, of which about 3,500 acres were considered successful. In recent years foresters for various State and private agencies have also tried direct seeding, with varying success (*34*). The following species have been used in recent tests: Balsam fir, jack pine, red pine, eastern white pine, ponderosa pine, Scotch pine, white spruce, Norway spruce, European larch, northern white-cedar, tamarack, northern red oak, bur oak, basswood, white ash, black locust, butternut, sugar maple, and yellow birch.

Methods Used

Two general methods of direct seeding are used—broadcast sowing and seed-spotting. There are various refinements and modifications of each general method.

Broadcast sowing is done by scattering seed rather uniformly over an area, and may be carried on without mechanical ground preparation after burning over the area, or after stirring up the soil by disking, furrowing, or dragging logs or large slash over the ground. As a rule, the ground is prepared prior to sowing, but some tests that involved disking after sowing have been made. Broadcast sowing with conifer seed usually requires from 1 to 2 pounds of seed per acre to insure adequate stocking.

Seed-spotting generally involves more labor than broadcast sowing, but it more economical of seed (fig. 4). Although seed-spotting may be done on unprepared soil or on disked areas, it is usually done in scalped spots or in furrows. Small quantities of seed (10 to 20) are placed in spots spaced about 6 feet apart and worked into the surface soil by stepping on them, or by raking or hoeing; or they may be sown in small grooves about 1/4 inch deep made in the soil with a finger or a stick and then covered over. However, in the Lake States, sowing by means of a garden drill in furrows has been found to be the cheapest and most promising method of direct seeding (*65*). By this method, approximately 4 ounces of conifer seed will sow an acre. There are possibilities that pelleted seed and seed guns or walking-

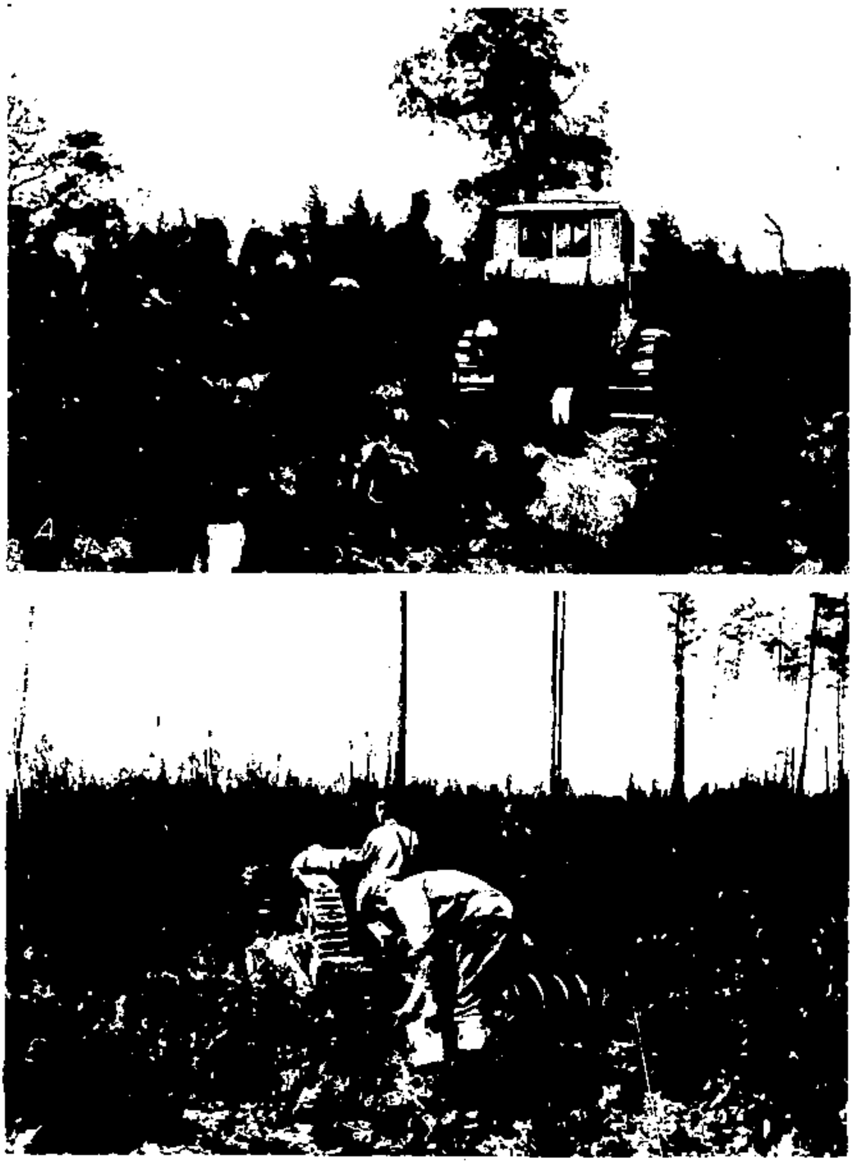

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FIGURE 4.—*A*, Direct seeding jack pine in drills in plowed furrow, near Nekoosa, Wis.; *B*, direct seeding red pine behind disk, Chippewa National Forest, Minn.

stick planters may prove useful, but they have not been tested adequately in the Lake States.

Results in the Lake States

Direct seeding is not a satisfactory substitute for planting in the Lake States except under especially favorable conditions. Although jack pine, northern red oak, and bur oak have been successfully seeded on sites free from aggressive, competing vegetation and seed-eating rodents, when the first two seasons were favorable, other species largely have failed.

An example of successful direct seeding after forest fires is found in a tract of nearly 300 acres on the Superior National Forest, Minn., that was severely burned in 1936. In 1937 the ground surface was torn up with a toothed harrow and broadcast sown with 2.5 pounds of jack-pine seed per acre. On a considerable part of the area the resulting stand was so dense—over 15,000 trees per acre—that it needed a heavy thinning when only 5 years old. Because an excessive quantity of seed was used, the cost of the operation was at least as great as planting would have been (*19*).

In 1942, over 900 acres of furrowed area were seeded to jack pine by means of a mechanical drill on the Chippewa National Forest, Minn. Results of this large-scale seeding are only fair.

Such direct seeding as is done should be confined to the finer-textured soils or to sandy soils only where the permanent water table is high enough (2 to 5 feet below ground level) to keep the surface soil moist and relatively cool (*74*, *75*).

Although rodents (*3*), birds, fungi, and insects have contributed to the failure of direct seeding, high temperatures have been the major cause of mortality in the Lake States. On open sandy sites in this region, temperatures of 120° F. at the soil surface are to be expected almost every summer. If they endure for 1 hour or more they are lethal to young seedlings. In 1933 and 1936 this soil-surface temperature was exceeded several times in both severity and duration.

The first cost of direct seeding may be only one-third to one-half that for planting. However, this advantage is offset by costs for care during the first 2 years and for replacing losses, both of which are likely to be somewhat greater than in planting. The conclusion, therefore, is that in the Lake States direct seeding is not a substitute for planting, but may supplement it under very favorable conditions.

PLANTING

Where to Plant

The first important step in forest planting is to determine what areas need reforestation. This decision must be based on an accurate evaluation of soil quality, kind and extent of cover, and economic conditions. Since the latter factor, which includes such items as stumpage values, distance to market, types of products, and transportation facilities, cannot be accurately measured or predicted and must be appraised currently, it will be briefly discussed. Only those factors that influence the survival, growth, or development of trees will be considered in any detail. The other two factors (cover and soil), which in the long run are the product of climate, are so intimately entwined not only with themselves but with the entire question of species selection, that the discussion of one must include some consideration of the other. Therefore, there is some overlapping in the following two sections.

CHARACTER OF SOIL AND COVER

Differences in soil are chiefly responsible for the need to consider where to plant and what to plant in the northern Lake States. Variations within areas as small as 20 to 40 acres may be so marked as to require the use of two or more species, planting methods, or types of ground preparation. However, the kind and vigor of natural tree and plant growth on the different soils are so closely related to the soil conditions that, when considered in connection with the original forest growth on the same area, they usually offer a more convenient means of deciding on a planting plan than would a detailed examination of the soil (fig. 5). Sometimes, of course, deterioration of a site because of fires may not be evident from the present and past forest cover.

Seven broad soil groups, based on texture and moisture relations, occur in this region. These, with their characteristic cover, are listed as an aid in determining planting sites.

1. *Poor sandy lands* consist of deep sands or gravelly sands, usually coarse to medium in texture and with excessive drainage, typically in the form of outwash plains or morainic ridges. They are characterized by sparse ground cover of sweetfern, sand cherry, huckleberry, blueberry, sedge, and beardgrass, and will produce only poor jack pine and scrubby oak (fig. 6).

2. *Better sand plains*, which are generally of finer texture, often have a more accessible water table and are more productive. The original growth was red and white pines with some hardwoods. The better sand plains have a more luxuriant ground cover and are suitable for jack pine, red pine, and possibly northern red, black, and northern pin oaks (the latter not likely to be planted).

3. *Sandy loams* are heavier in texture, more retentive of moisture, and consequently more productive. The original forest was red pine-white pine, white pine and hardwoods, or pure hardwoods. In the northern part of the region white spruce and balsam fir supplanted the hardwoods. The present dominant cover is aspen and paper birch, with considerable areas, particularly in lower Michigan, in small second-growth oaks. The ground cover contains many species. There is usually good reproduction of tree species but not always those of high value. Such soils when covered with aspen or birch may be converted to conifers if adequate release work is done after planting. Eastern white pine is probably the most suitable species for such conversion (where Ribes bushes are not too abundant), but jack pine must also be considered because of its rapid growth and consequent lower release cost.

4. *Loams* are finer than soils of the preceding group, and moisture conditions are optimum. They occur on rolling plains, on broad ridge tops, and on slopes of ridges. The original cover was dominantly hardwoods, or in the north spruce and balsam fir. White pine,

[illegible]

[illegible] A, [illegible] on former eastern white pine [illegible] Michigan. [illegible] common over much of the [illegible] Lake States. B, Dense brush of aspen, pin cherry, raspberry, and [illegible] northern hardwood land in northern Wisconsin [illegible] planted.

[illegible] *B*, [illegible] Lake [illegible] where present, grew as scattered individuals. The present growth is largely aspen and paper birch, with an understory of better hardwoods (sugar maple, basswood, northern red oak, American elm, and white ash) and conifers (hemlock, balsam fir, white spruce, and eastern white pine). The ground cover, which is very luxuriant, is composed of such species as wild leek, wild spikenard, blue cohosh, hepatica, bloodroot, and trillium. These soils often show a pronounced development of the gray horizon. Generally they are satisfactorily stocked with reproduction of the valuable hardwoods or with good-quality aspen and do not require planting. Where planting is needed, white spruce or northern hardwoods are probably the best species to use.

5. *Heavy loams* are fine-textured soils usually occurring in the form of till plains or in glacial lake beds. They are very wet at certain times of the year. The natural cover is much the same as on the loams. White spruce or northern hardwoods are also recommended where planting is necessary on these soils, although broad experience in planting on them is lacking.

6. *Poorly drained mineral soils* generally occur along the margins of swamps, lakes, and rivers, or as wet plains. The original cover varied from hardwood swamp to the spruce-balsam fir transition type. Much of the present cover is aspen. Very little planting is likely to be done on these soils because of the difficulties involved and their relatively small extent.

7. *Poorly drained organic soils* are composed chiefly of peat and muck. Productivity varies greatly, ranging upward from the brown peats to the black peats and mucks. The original cover was made up largely of black spruce, tamarack, elm, oak, yellow birch, balsam poplar, red maple, black ash, northern white-cedar, and balsam fir. Often only one or two of these species occur in individual stands. Little if any planting is likely to be done on these soils, because of the difficulties involved, the low productivity of some of them, and the higher priority given to upland areas.

Several attempts have been made to determine the suitability of various soils for given species on the basis of one or two easily measured factors, such as soil acidity (*94*) and percentage of fine material (*95*). Although there are certain limits of soil acidity within which various species grow best, in general this one factor is not enough for assigning species to planting sites. For instance, a study of 5,000 planted jack and red pines on the sand plains of the Huron National Forest in Michigan in 1936 showed no relation between the degree of soil acidity and survival or growth.

If there should be any question, however, as to the suitability of a site for a given species from the soil-acidity standpoint, pH tests should be made. Suitable pH ranges for the species most likely to be planted in the northern Lake States are as follows (*96, pp. 137–146*): Eastern white pine, 4.8 to 7.3; red pine and jack pine, 5.0 to 6.5; Scotch pine, 4.0 to 6.5; white spruce and Norway spruce, 4.7 to 6.8; tamarack, 3.7 to 6.8; northern white-cedar, 4.0 to 8.0; sugar maple and basswood, 5.5 to 7.3; yellow birch, 4.7 to 6.0; white ash, American elm, black locust, and eastern cottonwood, 5.5 to 8.0.

A method that combines soil acidity and percentage of fine material,[10] in determining the suitability of a site for a given species, has been used widely on the national forests of the Lake States since 1935. This method has proved useful, but it cannot be applied directly in all cases. Modifications for local use have been made.

A later method combines percentage of fine material and percentage of organic matter (*97*) for determining what species to plant on given sites. County foresters in Wisconsin regularly use a combination of soil texture, acidity, and organic-matter content for selecting species to be planted.[11] They report satisfaction with the method.

Another very useful guide developed for use on the national forests of Wisconsin is based on a combination of density of cover (both overstory and ground cover), presence or absence of beneficial water table, and soil texture (*76*).

GROUND COVER AS AN INDICATOR OF PLANTING SITES

There is an indirect way to determine the forest cover for a given site, and hence the right species to plant. As ground cover or undervegetation is composed largely of annuals and other plants with a rapid reproductive cycle, it can readjust itself more rapidly after it has been disturbed by logging and fire than can the longer-lived forest trees. Therefore, if a correlation can be worked out between the plants and forest cover, it will be of value in indicating the types to be restored to the large areas now covered by brush and grass. Also, it may indicate the species to favor in the conversion of aspen which, judging from the work of other investigators, appears to have no characteristic vegetation of its own.

On the basis of an analysis of the vegetation on some 600 plots throughout the Lake States (*51*), lists of indicator plants were determined for the pine (red and jack pine combined), white spruce, balsam fir, oak, northern hardwood, bottom-land hardwood, and coniferous swamp types. None characteristic of aspen, eastern white pine, or red pine was found. Table 6 lists the plant indicators.

In addition to serving as a site indicator, the cover, composed of natural tree or other growth already on the area, directly affects the success of planting and must be considered in this light in the selection of a planting site. At one extreme are the cleared and cultivated lands upon which the planted trees face but little competition. With increasing amounts of cover, the plan for planting must be modified so that trees best adapted to meet the competition will be planted. Ordinarily, an area with more than 50 percent natural tree growth requires a different plan than that which has less than 50 percent. Where planting is done under cover that takes up more than 50 percent of an area, frequently called underplanting, the trees should be planted in openings wherever possible, and not close under the crowns of the larger trees. They still need release, however, if they are to be established successfully.

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[10] The method was developed by Dr. S. A. Wilde of the University of Wisconsin. The determinations can be made in the field with a kit containing a hydrometer, a Cenco soil-texture outfit for determining the percent of fine material, and a Truog soil reaction tester for determining pH.

[11] Organic matter is determined by a Cenco-Wilde rapid colorimetric test. Kits that contain this instrument, along with those for determining soil texture and acidity, are available.

TABLE 6.—*Plant indicators of forest types in the Lake States*

Common name	Scientific name	Constant and exclusive [1]	Constant but not exclusive [2]	Exclusive but not constant [3]
Pine, jack and red (basis, 290 plots):				
Common yarrow	*Achillea millefolium*			X
Big bluestem	*Andropogon furcatus*			X
Canada pussytoes	*Antennaria canadensis*	X		
Smaller pussytoes	*A. neodioica*			X
Bearberry	*Arctostaphylos uva-ursi*			X
Smooth aster	*Aster laevis*			X
Bluebell	*Campanula rotundifolia*			X
Sweetfern	*Comptonia peregrina*	X		
Danthonia	*Danthonia* spp			X
Checkerberry wintergreen	*Gaultheria procumbens*			X
Rough alumroot	*Heuchera hispida*			X
Hoary gromwell	*Lithospermum canescens*			X
Narrowleaf cowwheat	*Melampyrum lineare*			X
Shorthorn ricegrass	*Oryzopsis pungens*			X
Sand cherry	*Prunus pumila*			X
Bracken	*Pteridium aquilinum*		X	
Prairie willow	*Salix humilis*			X
Canada blueberry	*Vaccinium canadense*			X
Oak (basis, 48 plots):				
Jerseytea ceanothus	*Ceanothus americanus*	X		
Largeflower tickclover	*Desmodium acuminatum*	X		
Barestem tickclover	*D. nudiflorum*			X
Black huckleberry	*Gaylussacia baccata*		X	
Spotted geranium	*Geranium maculatum*		X	
Thinleaf sunflower	*Helianthus decapetalus*			X
Divaricate sunflower	*H. divaricatus*			X
Fourleaf loosestrife	*Lysimachia quadrifolia*			X
Oldfield cinquefoil	*Potentilla canadensis*			X
Carolina rose	*Rosa carolina*	X		
Little merrybells	*Uvularia sessilifolia*		X	
Northern hardwood (basis, 53 plots):				
Mountain maple	*Acer spicatum*			X
American maidenhair	*Adiantum pedatum*			X
Wild leek	*Allium tricoccum*			X
Wild-sarsaparilla	*Aralia nudicaulis*			X
American spikenard	*A. racemosa*			X
Whitebear sedge	*Carex albursina*			X
Blue cohosh	*Caulophyllum thalictroides*	X		
Toothed woodfern	*Dryopteris spinulosa*			X
Sharplobe hepatica	*Hepatica acutiloba*			X
American fly honeysuckle	*Lonicera canadensis*			X
Shining clubmoss	*Lycopodium lucidulum*			X
American lopseed	*Phryma leptostachya*			X
Blackberry	*Rubus* sp		X	
American red raspberry	*Rubus idaeus strigosus*	X		
Scarlet elder	*Sambucus pubens*			X
Bloodroot	*Sanguinaria canadensis*			X
Feather Solomonplume	*Smilacina racemosa*			X
Canada yew	*Taxus canadensis*			X
Snow trillium	*Trillium grandiflorum*			X
White spruce-balsam fir (basis, 10 plots):				
Canada wildginger	*Asarum canadense*		X	
Ladyfern	*Athyrium filixfemina*		X	
Sedge	*Carex arctata*			X

See footnotes at end of table.

TABLE 6.—*Plant indicators of forest types in the Lake States*—Con.

Common name	Scientific name	Constant and exclusive [1]	Constant but not exclusive [2]	Exclusive but not constant [3]
White spruce-balsam fir (basis, 10 plots)—Continued				
Sedge	*C. intumescens*	X		
Drooping woodreed	*Cinna latifolia*			X
Alpine circaea	*Circaea alpina*	X		
Redosier dogwood	*Cornus stolonifera*		X	
Field horsetail	*Equisetum arvense*		X	
Hairy honeysuckle	*Lonicera hirsuta*		X	
Woodrush	*Luzula* spp		X	
Bristly clubmoss	*Lycopodium annotinum*			X
Naked miterwort	*Mitella nuda*	X		
Palmate butterbur	*Petasites palmata*	X		
White rattlesnakeroot	*Prenanthes alba*	X		
Alder buckthorn	*Rhamnus alnifolia*	X		
Skunk currant	*Ribes glandulosum*	X		
American red currant	*R. triste*	X		
Nodding trillium	*Trillium cernuum*			X
American cranberrybush viburnum.	*Viburnum trilobum*		X	
Sweet white violet	*Viola blanda*		X	
Bottom-land hardwoods (basis, 7 plots):				
Agrimony	*Agrimonia* spp			X
Common marshmarigold	*Caltha palustris*	X		
Honewort	*Cryptotaenia canadensis*			X
Bluestem joepyeweed	*Eupatorium purpureum*			X
Sensitivefern	*Onoclea sensibilis*	X		
Cutleaf coneflower	*Rudbeckia laciniata*			X
Skullcap	*Scutellaria* sp			X
Nettle	*Urtica* sp			X
Coniferous swamp (basis, 45 plots):				
Downy andromeda	*Andromeda glaucophylla*			X
Resindot birch	*Betula glandulifera*			X
Leatherleaf	*Chamaedaphne calyculata*	X		
Creeping pearlberry	*Chiogenes hispidula*	X		
Reindeermoss	*Cladonia* spp	X		
Showy lady's slipper	*Cypripedium reginae*			X
Cottonsedge	*Eriophorum* spp			X
Hypnum moss	*Hypnum* sp	X		
Blueflag iris	*Iris versicolor*			X
Bog kalmia	*Kalmia polifolia*			X
Labradortea ledum	*Ledum groenlandicum*	X		
Haircapmoss	*Polytrichum* sp	X		
Common pitcherplant	*Sarracenia purpurea*			X
Sphagnum	*Sphagnum* spp		X	
Small cranberry	*Vaccinium oxycoccos*	X		

[1] Constant and exclusive species=those growing on more than 40 percent of the plots in any one forest type and on less than 5 percent of the plots in not more than two other types (aspen excluded).

[2] Constant but not exclusive species=those growing on more than 40 percent of the plots in any one forest type and on less than 5 percent of the plots in more than two other types.

[3] Exclusive but not constant species=those growing on less than 40 percent of the plots in any one forest type and on less than 5 percent of the plots in not more than two other types.

What Species to Plant

Lacking specific experimental evidence, the safest rule in choosing the kind of trees to plant is to select those that are thriving naturally or have been planted successfully on the same site. For individual localities, however, examples are often lacking and in some cases the present cover may offer a misleading clue. Therefore, a generalized summary of the soil and cover conditions under which to plant various species is given in table 7, and the principal species recommended for planting are given in table 8.

Important as it is to select the right species in planting, it is of equal or even greater importance to use only stock grown from the right source of seed. It seems neither logical nor efficient to spend great sums in planting huge acreages of trees of wrong seed source. Such trees can never utilize the site to its full capacity and, in fact, may have to be eradicated at even greater cost to keep them from hybridizing with local trees and producing inferior strains. Until there is significant experimental evidence to the contrary, only time-tested local varieties should be used in plantings except for certain special uses. It will be safest to consider local collections those made within 100 miles of the planting site,[12] until seed collection zones can be worked out.

Unfortunately there are not enough plantations in the Lake States of sufficient age and development to afford any striking examples of the use of seed from improper sources. The importance of this factor, however, is clearly shown by European investigations. Experiments, conducted chiefly in Germany, Switzerland, and the Scandinavian countries, have shown such striking differences in survival, form, rate of growth, and susceptibility to injury in trees of the same species but grown from seed collected in different localities that many European countries now have stringent laws governing the use of forest tree seed in other than home localities. Tests in the western United States have also brought out striking differences in survival, growth, and form of ponderosa pine (*92*) and Douglas-fir (*46*) of diverse origins. Differences in yield and disease resistance of loblolly pine, associated with seed origin, have also been illustrated by experimental plantings in the South (*89*).

The Lake States Forest Experiment Station has under way a test (field planting begun in 1931) in which red pine from more than 150 seed sources throughout its range and Scotch pine of some 30 sources are being tested on the Superior and Chippewa National Forests. Obviously the experiment is too young to yield any final results, but even in the nursery distinct differences can be noted in length of needles, color of foliage, size, and rate of growth of Scotch pine from different sources (fig. 7). Although the differences are not so pronounced in red pine, there is a distinct tendency for seed from the southern and eastern parts of the range to produce larger stock than that from the northern regions. Some differences in survival, growth, and resistance to winter damage have appeared in the first 20 years. For instance, on the Superior National Forest in northern Minnesota red pines grown from seed of northeastern Minnesota origin were

[12] See U. S. Department of Agriculture Tree Seed Policy, appendix, p. 167.

TABLE 7.—*Species and class of stock*[1] *suitable for planting under various site conditions in the Lake States*[2]

Density of overstory	Presence or absence of beneficial water table[3]	Density of ground cover[4]	Sands (0–15[5] percent silt+clay)	Loamy sands (15–20 percent silt+clay)	Light sandy loams (20–30 percent silt+clay)	Good sandy loams and loams (30–50 percent silt+clay)	Heavy soils (50+ percent silt+clay)
Open, 80–100 percent of light reaching ground.	Absent	Heavy[6]	1–1 JP, (2–1 SP).	1–1 JP, 2–2 RP, (2–1 SP).	2–1 RP,[7] 1–1 JP, (2–1 SP).	2–1 RP, 1–0 RO, RO seed.	([8])
		Medium	1–1 or 2–0 JP[9] (2–1 SP).	2–0 JP, 2–2 RP, (2–1 SP).	2–1 RP, 2–0 JP, (2–1 SP).	2–1 RP, 1–0 RO, RO seed.	([8])
		Light	2–0 JP, (2–1 SP).	2–0 JP, 2–1 RP, (2–1 SP).	2–1 RP, 2–0 RP, 2–0 JP, (1–1 SP).	2–0 RP, 1–0 RO or RO seed.	([8])
	Present	Heavy	1–0, 2–0 JP, or JP seed (1–1 SP).	1–0 JP, JP seed, 2–0 RP, (2–0 SP), (1–1 T), (2–1 BS).	2–0 RP, (2–2 NS), (1–1 T), (2–1 BS).	2–0 RP or 2–2 WS, (2–1 BS).	([10])
		Medium	do.	do.	do.	do.	([10])
		Light	1–0, 2–0 JP, or JP seed (1–1 SP) C.[11]	do.	do.	do.	([10])
Partial cover, 50–80 percent of light reaching ground.	Absent	Heavy	2–0 JP, 2–1 RP, (2–1 SP).	2–1 RP, 2–0 JP, (2–1 SP).	2–1 WP, 2–1 RP.	2–1 WP, RO seed, 1–0 RO, (2–2 NS), (1–0 A), hardwoods.	Hardwoods or 2–2 WS.
		Medium	do.	do.	do.	2–1 or 2–0 WP, 2–2 WS, 1–0 RO or seed, (1–0 A), hardwoods, (2–2 NS).	Do.
		Light	2–0 JP, 2–1 RP, 2–2 RP, (2–1 SP).	2–0 RP, 2–1 RP, 2–0 JP, (2–0 SP).	2–1 WP, 2–1 RP, 2–0 WP, 2–0 RP.	do.	Do.
	Present	Heavy	2–0 JP, JP seed, (2–1 SP).	2–0 RP, 2–1 RP, 1–0 JP, JP seed, (2–1 SP).	2–0 or 2–1 WP, 2–0 or 2–1 RP, (2–2 NS).	2–2 WS, 2–1 WP, (2–2 NS), (2–1 BS).	2–2 WS or hardwoods.
		Medium	2–0 JP, 1–0 JP, JP seed, (1–1 SP).	2–0 RP, 2–0 WP, JP seed, (2–0 SP), (1–1 T) (2–1 BS).	2–0 WP, 2–0 RP (2–2 NS), (1–1 T), (2–1 BS).	2–2 or 3–0 WS, 2–0 WP, (2–2 or 3–0 NS), hardwoods, (2–1 BS).	Do.
		Light	1–0 JP, 2–0 JP, JP seed, (2–0 SP), C.	do.	do.	do.	Do.

Medium to dense cover, 0–50 percent of light reaching ground.[6]	Absent	Heavy	2–1 or 2–2 RP, 2–0 JP, (2–1 SP).	2–1 or 2–2 RP, (2–1 SP).	2–1 or 2–2 WP, (2–2 NS).	2–1 or 2–2 WP, 2–2 WS, (2–2 NS), (1–0 A).	Hardwoods or 2–2 WS.
		Medium	2–1 RP, 2–0 JP, (2–1 SP).	2–1 RP, (2–1 SP).	2–1 WP, 2–1 RP, (2–2 NS).	2–1 WP, 2–2 WS, (2–2 NS), (1–0 A).	Do.
		Light	do.	2–1 or 2–0 RP, (2–0 or 2–1 SP).	2–1 or 2–0 WP, 2–1 or 2–0 RP, (2–2 NS).	do.	Do.
	Present	Heavy	2–1 WP, 2–1 RP, 2–0 JP, (2–1 SP).	2–1 WP, 2–2 WS, 2–1 RP, (2–2 NS).	2–2 WS, 2–1 WP, 2–1 RP, (2–2 NS).	2–2 WS, hardwoods, (2–2 NS), (1–0 A).	2–2 WS or hardwoods.
		Medium	2–1 WP, 2–1 RP, 2–0 JP, (2–0 SP).	do.	2–2 WS, 2–1 or 2–0 WP, 2–1 or 2–0 RP, (2–2 NS), (2–1 BS).	2–2 WS, hardwoods, (1–0 A), 3–0 WS, (2–2 NS), (2–1 BS).	Do.
		Light	do.	2–1 or 2–0 WP, 2–2 WS, 2–1 RP, (2–2 NS), (2–1 BS).	do.	do.	Do.

[1] Species and classes of stock listed in order of preference for each site. JP=jack pine; RP=red pine; WP=eastern white pine; SP=Scotch pine; WS=white spruce; BS=black spruce; NS=Norway spruce; T=tamarack; RO=northern red oak; C=cottonwood; A=green or white ash; hardwoods=northern hardwoods (sugar maple, basswood, yellow birch, rock elm, and white elm). Class of stock is indicated by figures, i. e., 1–2=1-year seedlings transplanted at end of first year and grown 2 years in transplant beds; 2–0=2-year-old seedlings. (See footnote 13, p. 40 for further discussion of class of stock.)

Parentheses indicate stock recommended for special purposes only, or stock not tested sufficiently to warrant unqualified approval.

[2] Recommendations in this table are made on the assumption that proper ground preparation and adequate after-care, discussed on pp. 48 and 134, will be provided.

[3] Beneficial water tables are considered to be those 3 to 6 feet below surface in midsummer. Deeper or shallower water tables are not beneficial.

[4] Using 1.0 as full cover, density is divided into 3 classes: Heavy=0.7–1.0; medium=0.3–0.7; light=0.05–0.3.

[5] On soils with less than 10 percent silt+clay and without beneficial water table, plant jack pine exclusively.

[6] Planting should not be done under heavy competition unless it is planned to give the tree enough release to establish itself.

[7] Wherever 2–1 red pine is listed, 1–2 red pine can be used interchangeably.

[8] Information not available on these sites. Indications are that aspen will eventually take over. Thereafter northern hardwoods may be planted.

[9] Since 2–0 jack pine may be top-heavy, it frequently can be improved by top-pruning in the nursery; another alternative is to use 1½–0 stock.

[10] These sites are rare.

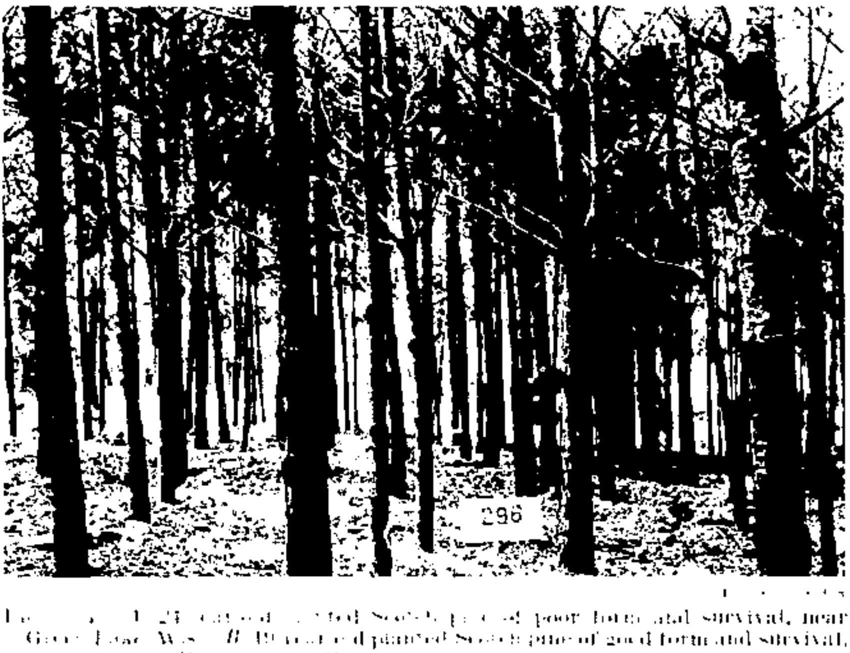
[11] With cottonwood or other poplars, use 1–0 stock, rooted cuttings, or good wildlings.

TABLE 8.—*Principal species recommended for planting in the Lake States, by usual type of stand, planting site, and chief use*

Species	Native range	Usual type of stand in Lake States or in native range of exotic species	General sites on which to plant [1]	Size of mature trees [2]			Uses in Lake States	Relative growth rate
				Total height	Diameter breast high			
					Average run	Range		
				Feet	*Inches*	*Inches*		
Jack pine	Nova Scotia west to Canadian Rockies, south to Minnesota and northern New England.	Pure, even-aged; also in mixture with red pine or oak; occasionally with black spruce or aspen.	Poor sandy lands and open areas on better sand plains and sandy loams.	55–65	8–10	4–14	Pulpwood, box lumber, fuel, railway ties, mine timbers, slack cooperage, cabin logs, and posts; dune and sand-blow control, Christmas trees locally, windbreaks.	Rapid.
Red pine	Nova Scotia west to Manitoba, south to Minnesota and West Virginia.	Mixture with white pine, oak, jack pine, or aspen; sometimes pure.	Better sand plains or sandy loams with overstory up to 30-percent density.	70–85	10–12	6–18	Lumber, piling, poles, cabin logs, railway ties, posts, mine timbers, and fuel; dune and sand-blow control; snowbreaks; windbreaks.	Medium.
Eastern white pine	Newfoundland west to Manitoba, south to Iowa and mountains of northern Georgia.	Mixture with red pine, northern hardwoods, oak, spruce, or aspen.	Sandy loams or loams with overstory of 15- to 40-percent density, free or freed of Ribes plants.	75–90	12–14	6–22	Lumber, to some extent for matchwood; windbreaks.	Do.
White spruce	Newfoundland west to Bering Strait, south to Minnesota and New York.	Mixture with balsam fir, white pine, white birch, northern hardwoods, or aspen.	Loams and heavy loams with overstory of 15- to 60-percent density.	65–75	8–10	4–16	Pulpwood, lumber; Christmas trees; windbreaks.	Do.
Black spruce	Newfoundland to Alaska, south to Minnesota and mountains of West Virginia (usually in swampy areas).	Usually pure, or in mixture with tamarack, and sometimes northern white-cedar.	Loams, heavy loams, or peats with overstory of 10- to 40-percent density.	40–60	5–7	2–12	Pulpwood, Christmas trees	Slow, medium slow to medium on upland sites.
Tamarack	do	Pure, even-aged; or in mixture with black spruce.	Loams, heavy loams, peats, or muck with less than 20-percent density of overstory.	60–70	10–12	6–17	Pulpwood, lumber, railway ties, mine timbers, fuel, posts, and poles.	Rapid.
Eastern cottonwood.	Quebec west to North Dakota, south to eastern Texas and Florida, omitting mountain areas.	Pure, even-aged; or in mixture with willow, elm, black ash, hackberry, etc.	Well-drained bottom lands	70–80	12–16	8–22	Lumber, veneer, pulpwood, excelsior, and fuel.	Do.

White ash	Nova Scotia west to southern Minnesota, south to eastern Texas and Florida.	Mixture with northern hardwoods or aspen.	Loams and heavy loams with 10- to 40-percent density of overstory.	60-70	10-12	5-17	Handles, cooperage, furniture, motor vehicle parts.	Medium.
Northern red oak	Nova Scotia west to Ontario, south to Arkansas and mountains of Georgia and Alabama.	Mixture with other oaks, pines, or sometimes northern hardwoods or aspen.	Sandy loams or loams with light or no overstory.	70-80	12-16	8-22	Lumber, railway ties, fuel wood, cooperage, and mine timbers.	Do.
Rock elm	Quebec west to Minnesota, south to Nebraska and Tennessee.	Mixture with northern hardwoods, or sometimes oak.	Loams and heavy loams in the open or under overstory up to medium density.	60-70	12-14	8-20	Lumber, veneer, slack cooperage, furniture, vehicle parts.	Do.
Sugar maple	Southern Newfoundland west to Minnesota, south to eastern Texas and northern Georgia.	Mixture with other northern hardwoods, hemlock, and occasionally white pine, spruce, and balsam fir.	do	70-90	14-16	5-28	Lumber, distillation, veneer, railway ties, fuel, and pulpwood.	Slow.
Basswood	Maine west to North Dakota, south to eastern Texas and Florida.	do	do	70-90	14-16	8-26	Lumber, veneer, cooperage, excelsior, and pulpwood.	Medium fast.
Yellow birch	Newfoundland west to Manitoba, south to Indiana and Georgia.	do	do	70-90	14-16	10-26	Lumber, veneer, distillation, railway ties, and fuel.	Medium.
Scotch pine	Northern and Central Europe, and Siberia.	Pure, even-aged; also in mixture with oak or sometimes Norway spruce.	Poor sandy lands, better sand plains and sandy loams with little or no overstory; sand blows, or eroding stream banks.	60-70	10-12	6-16	Dune and sand-blow control; snowbreaks; windbreaks; Christmas trees, fuel, and pulpwood.	Medium fast.
Norway spruce	Northern and central Europe	Pure or in mixture with silver fir, beech, or sometimes oak or Scotch pine	Sandy loams, loams, or heavy loams with overstory of 15- to 50-percent density.	60-70	8-10	4-16	Pulpwood, Christmas trees, windbreaks.	Medium slow.

[1] Greater detail given in table 7.
[2] Average size at harvesting age of mature trees in well-stocked stands on medium sites in the Lake States, except for exotic species; trees average smaller on poorer sites and larger on better sites.
[3] In approximate order of importance.



[illegible]

[illegible] A, 24-[illegible] Scotch pine of poor form and survival, near Green Lake, Wis. B, 19-[illegible] planted Scotch pine of good form and survival, [illegible] Rusk County, Wis.

better in growth and survival than those from lower Michigan and New England (*58*), and Scotch pines from colder climates showed much less winter injury in 1948 than those from milder climates (*77*).

Mixed Plantings

Mixed plantings of two or more species are supposed to have the following advantages over pure plantings, chiefly according to European experience:

1. In general, they provide greater use of the productive capacity of the site and yield more higher-quality products that are subject to a wider variety of use and market.
2. If insects or disease attack the plantations and become epidemic, serious damage to more than one kind of tree is unlikely, and damage to the more susceptible tree is less than it would be if the tree were in a pure plantation. Even if one species is completely destroyed, the others remain to provide a forest crop on the area. A good example of this is a natural stand on a moist but upland site on the Superior National Forest in Minnesota, which consisted originally of mixed tamarack, black spruce, and jack pine. Although the larch sawfly wiped out the tamarack, the other species have closed up the openings so that little evidence of any injury to the stand remains. Many older swamps bear testimony on how the stand would appear today had it been pure tamarack.
3. Different kinds of trees have different capacities for obtaining from the soil the water and other materials they need. For example, the roots of two or more kinds of trees planted in mixture make different demands upon different layers of the soil, and each tree is able to fill its needs more completely than it could if its neighbors were of its own kind. European experience has shown that mixed stands of pine and spruce, pine and beech, and oak and beech produce higher yields, sometimes as much as one-third higher, than either kind by itself (*37*).
4. The hardwoods are desirable in mixtures because their presence decreases the risk of loss by fire, particularly by fires that might otherwise burn and spread through the crowns of the trees. The green foliage in summer and the bare branches in winter will not carry a fire. Application of this principle in the northern Lake States is limited; the dry sandy soils where the fire hazard is greatest are not suitable for the planting of hardwoods, and on the heavier soils a certain number of hardwoods are usually growing naturally, so that there is little need for planting them. In release operations, however, it is important to remember the value of natural hardwoods and refrain from removing them completely—especially on sandy soils.
5. Another reason for mixed plantings is that tree species vary in their effectiveness in building up soil fertility. As soil builders, the hardwoods, such as maple, ash, and oak, are more effective than the pines and spruces. Some species may even have detrimental effects. In Germany, for instance, pure Norway spruce plantations have created soil conditions so unfavorable that the growth of the trees has been greatly reduced. This condition is avoided if other species, such as beech, are planted in mixture with the spruce (*37*).

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Over one-third of the area reforested in the three Lake States through 1944 has been planted to mixtures of two or more species (table 9). On the State forests of Michigan nearly three-fourths the total area reforested is in mixed plantings. If the volunteer growth—often of such species as aspen or oak—is considered, probably 80 percent of the established plantations are mixed stands.

Mixed plantings may be arranged and carried out in several ways. The different kinds of trees may be planted in alternate rows, or alternately in each row, or in two or more rows of one kind alternating with two or more of the other, or in groups of four or more trees of one kind to a group. Where there is considerable variation in soil and cover conditions, two or more species may be planted, each under the conditions best suited to it (*42*). This provides the most natural type of mixture.

Planting in alternate rows or strips requires only that half the planters have one kind of tree and the other half the other kind, and that they are started right at the beginning of each row so as to give the desired alternate or strip arrangement. Alternating the kinds in each row is usually done by having two planters work the same row. One goes ahead and plants his trees 10, 12, or 16 feet apart, and the other follows him, putting in the other trees midway. These schemes do not greatly increase the cost over that of planting a single kind. Group planting, however, requires more care and increases the cost.

TABLE 9.—*Area planted to mixtures of two or more species, in the Lake States, by public agencies, specified years, 1926–44* [1]

Agency and year	Minnesota	Wisconsin	Michigan	Total
	Acres	*Acres*	*Acres*	*Acres*
Federal:				
1926	[2] 200	0	0	[2] 200
1933	2,964	[2] 4,132	[2] 3,006	10,102
1939	16,273	39,644	80,440	136,357
1944	[2] 22,410	[2] 44,450	90,400	157,260
State:				
1926	[3] 100	1,167	25,090	26,357
1933	[3] 150	8,351	129,105	137,606
1939	[3] 400	14,360	187,698	202,458
1944	[3] 616	[2] 16,630	205,934	223,180
County, municipal, and other public:				
1926	0	0	[3] 100	100
1933	[3] 100	1,047	[3] 400	1,547
1939	[3] 300	11,832	[3] 2,500	14,632
1944	[3] 400	[2] 26,720	5,000	32,120

[1] Data not available for such planting by farmers, other small owners, and industrial organizations.
[2] Estimated on basis of partial data.
[3] Estimated; no data.

Alternate rows or alternate trees in the row give the most intimate mixture and result in the most severe competition, so that if one species lags behind it is likely to be seriously suppressed or killed. This danger is partly avoided and at the same time many of the advantages of mixed plantings are obtained by planting three or more rows of one kind alternated with three or more of the other. Until more is known about the development of mixed plantings this plan is safest.

Another method of planting mixtures is to plant first the slower-growing kind or the one to which it is desired to give a start, and a few years later to fill in with other species. This plan would be applicable to mixed planting of red and jack pine, in which the red pine needs a start of 3 to 5 years, but it would almost double the cost of the planting because it would mean covering the same area twice. The later planting of a more rapidly growing tree has practical importance, however, in replanting the fail places in a plantation. Replanting with some other suitable kind of tree of faster growth than that originally planted serves not only to fill up the holes but also to obtain the benefits of a mixed planting.

A variation of the latter method has been used on the Chippewa National Forest where brushy sites with better soils are planted. Narrow strips (about 5 rows) are planted to species best adapted to the soil—usually red pine, white pine, or white spruce—and these are separated by wider strips (about 15 rows) planted to jack pine. The fast-growing jack pine can be brought through by one or two releases; the slower-growing better species probably will require additional releases. This method reduces the cost of release. The theory behind the method is that the better species will be able to reseed the jack pine strips when they are cut clean at maturity.

Forest planting in the Lake States is too young to prove conclusively the advantages of specific mixtures of species. However, some information on the development of mixed plantings averaging about 20 years in age was revealed by a study of older plantations in Minnesota, Wisconsin, and Michigan conducted by the Lake States Forest Experiment Station in 1935 and 1936. It was discovered that, with the exception of those planted on old fields, most of the pure plantations in this region have become mixed stands through the invasion of volunteer trees.

COMPOSITION OF MIXED PLANTATIONS

Most of the older mixed plantations in the Lake States region are composed of two species; progressively fewer plantations are composed of three, four, or five species. Nearly all of the mixture has been effected by planting alternate rows to different species or alternating two species within the rows. In a few cases groups of rows have been alternated by species. Other methods of mixing the older plantations were rare.

The mixed plantations were originally planted with an average of 1,760 trees per acre (approximately 5- by 5-foot spacing) and included the following species: Eastern white pine, 23 percent; red pine, 30 percent; Scotch pine, 10 percent; jack pine, 32 percent; Norway spruce, 2 percent; white spruce, 1 percent; European larch, 1 percent; and ponderosa pine, 1 percent. The most common mixtures were red pine-white pine and red pine-jack pine. It is interesting to note that main reliance was placed on the native pines.

At the end of 1936 the plantations had an average stand per acre of 750 planted trees and 270 volunteer trees (mostly hardwood species). The relative abundance of the planted trees had not changed very greatly, but the average stand contained about 26 percent volunteer trees.

COMPARISON OF PURE AND MIXED PLANTATIONS

The description of mixed plantations just given is of interest and value as a record of what has been done in this field within the region. However, a matter of more moment is a comparison of mixed and pure plantations to see how they differ in growth and development, how well various species get along in mixture as compared with pure stands, and what, if any, advantages are apparent from mixed planting.

Comparisons of injury in table 10, and comparisons of growth and survival of pure stands and mixed stands in the following paragraphs, by species, are based on observations in plantations with no overstory or very little overstory so as to eliminate the obscuring effect of overstory competition.

Jack Pine

There was no significant difference in growth of jack pine in pure stands and jack pine in mixture with eastern white pine, red pine, or Scotch pine. From the standpoint of injury the behavior of jack pine in pure and in jack-Scotch pine plantations was much the same, but somewhat different from that in jack-white and jack-red pine plantations. Pure jack pine and that in mixture with Scotch pine had greater weevil and borer damage, whereas that in mixture with red or white pine showed greater tip moth and budworm damage.

Compared with its associates in mixed pine plantations, jack pine grows more rapidly in height than any of them. Jack pine has better growth both in diameter and height, and slightly better survival than the red or eastern white pine associated with it; it has slightly better growth and slightly poorer survival than the Scotch pine in mixture with it. From the standpoint of injury, jack pine is bothered less by rabbits, more by tip moth and through mechanical injury (except for Scotch pine), and more by borers and pine-oak gall rust than any of the species associated with it.

Eastern White Pine

White pine survives and grows as well in pure plantations as it does in mixture with red pine (fig. 8). However, white pine grown in mixture with jack pine has significantly poorer growth than that grown in pure plantations. This difference cannot be attributed entirely to interaction of the two species, although that may be a factor, because the soil of the white-jack pine plantations is of significantly coarser texture than that of the pure plantations.

In general, pure-planted white pine has about the same proportion of injury from various causes as it does in mixture with red pine. However, pure-planted white pine shows a greater tendency toward budworm injury and less tendency toward mechanical injury, pine-oak rust infection, and borer damage. White pine grown in mixture with jack pine is attacked more by rabbits, pine needle scale, and bark aphids, and less by weevils and budworms than pure white pine. Some entomological studies, however, have indicated that white pine suffers the heaviest budworm damage when it occurs under jack pine.

TABLE 10.—*Percentage of trees injured in comparable stands of pure and mixed composition, by cause of injury*

Species composition	Key species in mixture	Trees injured [1] by—										Basis, trees
		Hare and rabbit	White pine weevil	Spruce budworm	Tip moth	Pine needle scale	Bark aphid	Flathead and roundhead [2] borers	Mechanical injury	Pine-oak gall rust	Total [3]	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*
Pure jack pine	100	1	24	1	22	0	0	24	19	16	107	429
Jack-Scotch pine	48	1	15	0	26	0	0	30	16	10	98	372
Jack-white pine	54	0	9	7	48	0	0	10	20	11	105	484
Jack-red pine	51	2	2	3	49	0	0	16	16	11	99	882
Pure white pine	100	9	42	10	0	1	4	0	9	0	75	1,889
White-red pine	57	10	46	0	0	3	5	7	15	3	89	347
White-jack pine	46	36	24	4	0	10	10	0	9	0	93	419
Pure red pine	100	10	5	1	2	0	0	0	5	0	23	3,102
Red-white pine	43	10	4	0	0	0	0	2	5	0	21	259
Red-jack pine	49	10	3	0	1	0	0	0	10	0	24	845
Red-Scotch pine	50	1	0	0	2	0	0	0	9	0	12	109
Pure Scotch pine	100	2	16	21	33	0	0	1	9	9	91	954
Scotch-jack pine	52	3	14	0	33	0	0	3	24	2	79	410
Scotch-red pine	50	0	71	0	12	0	0	0	17	5	105	109

[1] Figures on injury refer only to first-named species in mixture.
[2] These insects normally attack trees only after they have been seriously weakened by some other cause.
[3] In some cases a single tree received more than one type of injury. Therefore, the total may be more than 100 percent.

FIGURE 8.—*A*, 20-year-old mixed red and white pine plantation near Millston, Wis.; *B*, interior view of same plantation 31 years after planting.

White pine has a lower growth rate and somewhat poorer survival than does red or jack pine growing in mixture with it. This difference is greater in the case of jack pine.

In general, white pine shows more injury than does red pine growing in mixture with it, especially from weevils. White pine also suffers more injury than the jack pine associated with it, if injuries from tip moths, mechanical breakage, pine-oak rust, and borers are excepted.

Red Pine

Pure-planted red pine does not differ significantly in growth, survival, or development from red pine planted in mixture with eastern white or Scotch pine. It does differ significantly in growth from that planted in mixture with jack pine. Since there is no real difference in soil, the poorer growth apparently reflects some aspect of the interaction of the two species.

Red pine on the whole shows relatively little injury whether in pure or mixed plantations. It suffers slightly less injury, especially from rabbits, in mixture with Scotch pine than in any other type of planting.

Red pine exhibits somewhat better growth and survival than eastern white pine, and poorer growth and survival than Scotch pine (slightly) and jack pine (considerably) grown in mixture with it.

Scotch Pine

In pure plantations, Scotch pine shows no significant difference in growth, development, or survival from that planted in mixture with red or jack pines, with one exception: grown in mixture with jack pine, it does have significantly poorer height growth.

Scotch pine grown in pure stands is very similar to that grown in mixture with jack pine in degree and type of injury, although pure-planted Scotch pine has noticeably more spruce-budworm damage and less mechanical injury. In mixture with red pine, Scotch pine exhibits decidedly heavier weevil damage and less tip moth injury.

In comparison with its associates, Scotch pine has slightly better survival than either red or jack pine, slightly better growth than red pine, and slightly poorer growth than jack pine. From the injury standpoint, Scotch pine suffers considerably more damage than associated red pine, particularly from weevil. It is attacked in much the same manner as associated jack pine, the main difference being the markedly heavier borer damage of the latter.

General

At the present stage of development, the various species show little difference in growth, survival, or injury, whether they be grown pure or in mixture, with the one exception that jack pine seems to have a detrimental effect on the growth of red, eastern white, or Scotch pine associated with it. This may be due to the fact that much of the planting has been done on sites better suited to jack pine than to the other three species. There is some evidence that Scotch pine is good "bait" to plant with red pine, since the Scotch pine showed the highest degree of injury and red pine the lowest when the two species were planted in mixture with each other.

The value of mixed planting may be expected to show up more definitely later on in the life of the stand. Studies are needed covering more species and a greater variety of conditions to bring out more clearly the advantages or disadvantages of mixed planting. Until more conclusive experience is available, the greatest assurance of success in producing mixed plantations can be had by following Nature's guidance. Table 7, p. 28, can be used to select species for mixed as well as pure plantations.

Size and Age of Trees to Plant

After it has been determined what kind or kinds of trees are to be planted on any given site, the size and age of planting stock[13] best suited to the conditions should be decided. The considerable variation in dimensions of several kinds of stock is brought out in table 11.

The marked variations that can be produced in the size and development of different kinds of stock within the same species make it possible to meet highly varied field conditions—from the most favorable to the most severe—fairly economically. Recommendations of the classes of stock to use under conditions typical in the Lake States are given for several species in table 7, p. 28.

SEEDLING AND TRANSPARENT STOCK COMPARED

Generally, under Lake States conditions transplant stock does better than seedling stock (fig. 9). Among older plantations averaging 23 years in age the seedling stock most commonly used, 2–0, had an average survival of 31 percent, whereas the best represented transplanted stock, 2–2, had an average survival of 60 percent. Experiments conducted by the Lake States Forest Experiment Station over a period of 10 years on the Huron National Forest have shown a consistent superiority of transplant over seedling stock for red, eastern white, and Scotch pines. When a favorable season follows planting, the differences between the classes of stock in survival are slight, usually not over 5 or 10 percent, but when droughts and high temperatures occur the differences become much greater. This point is illustrated in the tabulation that follows, in which first-year survivals on the Huron National Forest, Mich., are given.

	First-year survival (percent)	
	End of 1933[1]	*End of 1935*[2]
Red pine:		
2–0	27	85
2–1	45	91
White pine:		
2–0	20	86
2–1	54	95
Scotch pine:		
2–0	35	97
2–1	60	95

[1] Unfavorable year with severe drought and high temperatures.
[2] Favorable year.

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[13] Trees available for planting from nurseries may be from 1 to 5 years old, or older. Usually they are grown in seedbeds for 1, 2, or 3 years, and then, if not used at once for field planting, are transplanted in the nursery and allowed to grow 1 or 2 years longer before being set out. This transplanting makes sturdier trees with compact, bushy root systems, which are more desirable for planting; it also increases the cost of the stock. Forest nursery stock is known and will be referred to in this publication by a numerical system, the first figure representing number of years in the seedbeds and the second, number of years transplanted. Thus, 2-year-old seedlings are called 2–0 stock, and 1-year seedlings transplanted at the end of the first year and grown 2 years in the transplant beds are known as 1–2 stock.

TABLE 11.—*Average dimensions of planting stock grown in Forest Service nurseries in the Lake States, by species*

Species and class of stock	Average length		Average green weight		Top-root ratio [3]	Average dry weight		Top-root ratio [3]	Diameter at base of stem		Basis, trees
	Top [1]	Root [2]	Top	Root		Top	Root				
	Inches	*Inches*	*Grams*	*Grams*		*Grams*	*Grams*		*1/1000 inch*	*1/64 inch*	*Number*
Jack pine:											
1-0	3. 1	9. 0	1. 48	0. 57	2. 6	0. 41	0. 17	2. 4	81	5	1, 060
1½-0	4. 4	10. 0	2. 31	. 48	4. 8	. 70	. 17	4. 1	88	6	200
2-0	5. 8	8. 7	4. 70	. 88	5. 3	1. 63	. 32	5. 1	122	8	3, 479
1-1	5. 0	11. 5	9. 88	3. 40	2. 9	------	------	------	156	10	80
1-2	10. 4	14. 7	17. 58	4. 10	4. 3	------	------	------	202	13	100
Red pine:											
1-0	1. 1	5. 6	. 28	. 09	3. 1	. 13	. 04	3. 2	40	3	853
2-0	2. 7	9. 1	2. 47	. 69	3. 6	. 94	. 26	3. 6	87	6	2, 304
3-0	7. 5	8. 3	9. 15	1. 33	6. 9	2. 99	. 46	6. 5	150	10	610
1-1	2. 0	11. 2	2. 17	. 94	2. 3	1. 10	. 44	2. 5	91	6	1, 321
1-2	5. 1	13. 6	10. 17	2. 25	4. 5	5. 11	1. 10	4. 6	156	10	154
2-1	4. 0	13. 1	5. 73	2. 13	2. 7	2. 54	. 89	2. 9	131	8	1, 909
2-2	7. 1	14. 9	16. 57	3. 91	4. 2	7. 86	1. 92	4. 1	195	12	636
3-1	7. 6	13. 1	8. 68	3. 91	2. 2	4. 13	1. 29	3. 2	166	11	40
Eastern white pine:											
2-0	2. 4	9. 7	1. 31	. 64	2. 0	. 54	. 25	2. 2	83	5	1, 750
3-0	6. 4	8. 8	4. 72	1. 32	3. 6	1. 41	. 41	3. 4	117	7	430
1-1	2. 0	11. 3	1. 34	. 96	1. 4	. 62	. 44	1. 4	86	6	814
1-2	5. 0	15. 9	5. 29	3. 52	1. 5	2. 14	1. 04	2. 1	125	8	140
1-3	11. 5	14. 0	18. 59	8. 50	2. 2	6. 49	2. 59	2. 5	230	15	40
2-1	3. 8	13. 2	3. 41	2. 05	1. 7	1. 40	. 82	1. 7	118	8	1, 001
2-2	6. 9	15. 9	8. 75	3. 56	2. 5	3. 49	1. 40	2. 5	162	10	265
2-3	15. 3	14. 7	38. 57	16. 80	2. 3	11. 05	4. 16	2. 7	292	19	30
3-1	7. 1	14. 7	5. 87	4. 38	1. 3	1. 68	. 92	1. 8	152	10	30

See footnotes at end of table.

TABLE 11.—*Average dimensions of planting stock grown in Forest Service nurseries in the Lake States, by species*—Continued

Species and class of stock	Average length		Average green weight		Top-root ratio [3]	Average dry weight		Top-root ratio [3]	Diameter at base of stem		Basis, trees
	Top [1]	Root [2]	Top	Root		Top	Root				
	Inches	*Inches*	*Grams*	*Grams*		*Grams*	*Grams*		*1/1000 inch*	*1/64 inch*	*Number*
Scotch pine:											
2–0	2.9	8.8	1.76	.56	3.1	.79	.24	3.3	95	6	558
1–1	3.2	11.4	2.67	1.30	2.1	1.09	.51	2.1	114	7	358
2–1	4.3	12.0	3.91	1.80	2.2	1.86	.87	2.1	125	8	367
White spruce:											
2–0	3.5	7.8	1.58	.44	3.6	.76	.19	4.0	98	6	150
3–0	5.0	9.3	2.35	.88	2.7	.87	.25	3.5	113	7	990
2–1	4.5	9.4	3.09	1.24	2.5	.94	.29	3.2	117	7	150
2–2	6.6	13.1	10.00	4.05	2.5				197	13	80
3–1	6.1	11.9	4.04	2.48	1.6	1.70	.88	1.9	138	9	300
3–2	8.6	9.6	19.62	9.15	2.2	3.18	3.00	1.1	268	17	60
Norway spruce:											
2–0	2.6	7.8	.92	.32	2.9	.48	.13	3.7	97	6	100
3–0	8.3	10.5	8.28	1.93	4.3	3.02	.83	3.6	150	10	100
2–4	11.6	7.5	32.03	8.41	3.8				275	18	30
3–1	6.1	14.1	5.09	3.70	1.4	2.16	1.27	1.7	142	9	250
3–2	6.0	12.4	17.00	5.13	3.3				162	10	30
Black spruce:											
2–0	6.7	5.8	6.44	2.63	2.4				144	9	20
2–1	10.4	9.3	13.06	7.06	1.8				227	15	30
Northern white-cedar:											
2–0	3.0	2.7	7.75	1.90	4.1				48	3	20
3–2	7.3	10.9	18.79	6.38	2.9				209	13	30

Eastern hemlock:											
3-1	6.1	7.4	4.01	2.85	1.4				116	7	40
Sugar maple:											
1-0	2.9	6.4	1.85	1.61	1.1				100	6	30
3-0	8.7	13.4	2.36	5.54	.4				202	13	280
Rock elm:											
2½-0	7.9	9.0	6.09	10.68	.6				186	12	30
Basswood:											
2-0	4.8	7.7	1.54	5.04	.3				283	18	30
Northern red oak:											
1-0	5.5	10.7	1.00	5.30	.2				183	12	60
Yellow birch:											
1-0	3.8	5.1	1.53	.60	2.6				100	6	80
2-0	10.2	9.0	2.34	2.34	1.0				188	12	50
3-0	19.4	12.7	8.35	5.91	1.4				260	17	260
White ash:											
1-0	4.6	9.0	2.40	1.22	2.0				106	7	80
2-0	9.7	10.8	4.95	5.97	.8				186	12	30
Black locust:											
1-0	10.8	9.2	8.18	2.51	3.3				173	11	30

[1] Length to tip of terminal bud.
[2] Based on roots of stock unavoidably modified by standard nursery lifting practice.
[3] This value is obtained by dividing the weight of the top (part above ground) of the tree by that of the root. It provides an index of stock balance.

Another striking illustration of the differences in survival of various classes of stock was furnished by experimental plantings on the Huron National Forest. At the close of 1936, the most severe drought year on record in that locality, red pine planted in the fall of 1935 showed the following survivals: 1-0 stock, 5 percent; 2-0, 14 percent; 1-1, 18 percent; 2-1, 39 percent; and 2-2, 58 percent.

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FIGURE 9.—Nine years after planting near Tomahawk, Wis., 2-2 red pine (left) showed 95-percent survival and an average height of 12 to 14 feet. 2-0 red pine (right) showed 60- to 70-percent survival and an average height of 4 to 7 feet.

Although the main advantage of transplants lies in better survival, they also make more rapid growth than seedlings during the early years following planting. A study of experimental plantations on the Huron National Forest showed that 3 years after planting, 2-1 red pine had grown significantly more than 2-0 red pine planted on the same areas (*57*). Heights of different classes of red pine stock on the Huron National Forest 5 years after planting were: 15 inches for 1-0 seedlings, 20 inches for 2-0, 21 inches for 1-1 transplants, and 27 inches for 2-1. Fifteen years after planting, however, there were no significant differences in height between the different classes of stock.

Despite the fact that the differences in height between classes of stock may become of little moment after 10 or 15 years, the greater initial height and more rapid rate of growth for the first few years after planting of the transplants gives them a considerable advantage where there is danger of smothering from hardwood leaf litter or overtopping of low competing vegetation. The advantage of the transplant stock over seedling stock lies not only in greater height growth, but also in greater root growth, as shown by studies made on the Nicolet National Forest in Wisconsin (*75*).

Under other site conditions, however, the transplant stock has continued to have an advantage over the seedling stock for many years. In experiments with planting stock of different classes at the Cloquet

Station in northern Minnesota (*36*) 2–2 stock of eastern white and red pine had higher percentages of the trees alive than other classes. The growth of the 2–2 stock was also greatest, and the superiority in both growth and survival was maintained for the first 10 years after planting. This transplant stock (2–2) of eastern white and red pine gave better results when planted (1) under stands of jack pine of different sizes and densities, (2) on cut-over barren sites, (3) where sweetfern formed the predominating cover, and (4) in the thick brush. In another series of experiments (*27*), observed 5 years after planting, the survival of transplants was slightly better than that of seedlings and the growth was markedly greater.

Although there is abundant evidence that under Lake States conditions transplant stock gives better survival and better initial growth than seedling stock, the factor of cost must be considered before definite recommendations are made. For instance, 2–1 stock generally costs from three to five times as much as 2–0 stock. If favorable conditions of climate and competition could be assured, then ordinary seedling stock could be used successfully. Such assurance is impossible, of course. In the decade 1927–36, extremely unfavorable climatic conditions prevailed during several years. At the end of the third year after establishment, experimental planting on the Huron National Forest lead to the conclusion that under the more difficult conditions existing in the lower Michigan sand plains, results with 2–1 red pine were sufficiently superior to those obtained with 2–0 red pine to justify its cost (*57*).

STOCK SPECIFICATIONS

Different classes of stock grown in a single season in a given nursery bear a certain size relation to each other, that is, 2–1 red pine may be expected to have a thicker, taller stem, a longer, more fibrous root, and greater weight than 2–0 red pine. However, there is a great deal of variation in the same kind of stock produced from nursery to nursery and from year to year (fig. 10). It is necessary, therefore, to set

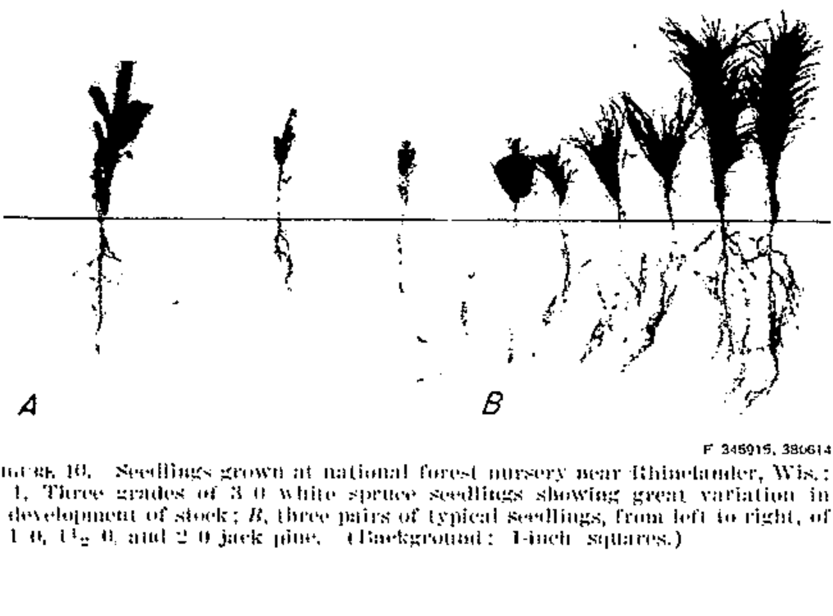

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FIGURE 10.—Seedlings grown at national forest nursery near Rhinelander, Wis.: *A*, Three grades of 3–0 white spruce seedlings showing great variation in development of stock; *B*, three pairs of typical seedlings, from left to right, of 1–0, 1½–0, and 2–0 jack pine. (Background: 1-inch squares.)

up certain standards or specifications for grading nursery stock according to size and development in order that recommendations may be more specific and accurate.

While many tests comparing classes of stock have been made in the Lake States, very few tests of different stock grades have been made. The Lake States Forest Experiment Station made tests on the Superior National Forest in Minnesota and the Nicolet National Forest in Wisconsin in which 2–0 red pine was graded into large, medium, and small classes. These tests showed that there was little difference in first-year survival between the large and medium classes, and that first-year survival for the small class was definitely poorer. Similar results were obtained for several species—especially marked in jack pine—in tests made on the Chippewa National Forest in Minnesota.

Although there is not yet sufficient experimental evidence to provide a conclusive basis for stock grading in the Lake States, a start has been made for most of the classes of stock included in table 7. On the basis of available tests and experience, the Lake States Forest Experiment Station has developed a set of standards for planting stock to be used in the Lake States (table 12). This is a goal nursery

TABLE 12.—*Suggested grading specifications for coniferous planting stock in the Lake States, by species and class of stock*

Species and class of stock	Acceptable grade [1]			Premium grade [1]		
	Stem diameter	Length		Stem diameter	Length	
		Top [2]	Root		Top [2]	Root
	1/64 inch	*Inches*	*Inches*	*1/64 inch*	*Inches*	*Inches*
Jack pine:						
1–0	5	2½	8	7	4	10
2–0	7	3½	8	10	6	10
Red pine:						
2–0	5	2½	8	8	4	10
3–0	6	4	8	9	6	10
2–1	6	3	8	8	6	10
1–2	8	4	8	10	7	10
2–2	10	5	8	12	8	10
Eastern white pine:						
2–0	5	2½	8	7	4	10
3–0	6	4	8	8	6	10
2–1	7	3	8	9	6	10
1–2	8	4	8	10	6	10
2–2	8	6	8	11	8	10
White spruce:						
2–2	7	6	8	9	8	10
Norway spruce:						
2–2	7	6	8	9	8	10

[1] Minimum values for the grade are given. Trees not meeting the acceptable standards should be culled. If desired, the premium grade need not be sorted out, but ordinarily trees falling into the premium grade can be used in place of acceptable trees of the next highest class for a given species. It is understood, of course, that any trees used for planting must not only meet the above specifications for size, but must also be thrifty, sound, and dormant or nearly so.

[2] Length to tip of terminal bud.

managers should strive to attain. A modification of those standards is in use at the national forest nurseries of the region.

Trees with 12- to 15-inch tops are preferred for machine planting.

USE OF WILDLINGS

Successful plantations of red and eastern white pine have been established by digging natural seedlings and resetting them on the planting site. Experiments with wild stock at the Cloquet Station gave reasonably good results, although not as good as with nursery stock. Ordinarily the wild seedlings are not easy to find in large quantities. Moreover, they have a sparser root system and are less likely to succeed than those grown in nurseries. Unless they can be dug in spare time or without incurring special cost for labor, they are usually more expensive than stock purchased from the State nurseries. If wild seedlings are used, they should not be over 8 inches high; larger ones are less likely to survive transplanting.

How to Plant

CARE AND HANDLING OF PLANTING STOCK

Since planting has little chance of success if stock in poor condition is used, the importance of proper care and handling of stock from the time it is lifted in the nursery until it is set out in the field can scarcely be overemphasized. The planter should have assurance that the trees he received have not been allowed to dry out in the lifting and packing processes, and that undersized, injured, or unthrifty stock has been culled out. Since these are properly nursery practices they are not discussed in further detail in this publication.

Transportation

Because it is necessary to get trees to the planting site before they dry out, they should be shipped by some rapid means, such as truck or express; freight ordinarily is too slow. Where trucks are used it is often possible to haul stock directly from the nursery to the planting site without any intermediate handling.

If stock is shipped by express, the following requirements must be met: (1) Stock containers must be sufficiently substantial to withstand ordinary handling; (2) crates or bales must not be wet on the outside and no ends of wires, which might tear the covering of other shipments, should project; (3) shipments must be marked "perishable"; (4) nursery inspection tags must be attached to shipments consigned to any State requiring such inspection. Information on inspection requirements is given on page 166 in the appendix.

Care of Stock in the Field

When stock is received in the field, whether it be at a planting camp or at the planting site, it should be stored in a cool, shaded spot and kept well moistened. Ordinarily, a temporary shelter covered with canvas, burlap, or brush is satisfactory for such short-time storage. The bales or crates should be so stacked that air can circulate freely between them.

It is necessary to protect trees not only from drying but also from freezing. For this purpose, and also to aid in retarding growth late in the spring, it is advisable at planting camps to have cheaply constructed underground cellars in which good air circulation is possible and in which temperatures between 32° and 45° F. may be maintained.

As far as possible, planting stock should be delivered from the nursery at frequent enough intervals so that none of it need be stored in the field for more than a few days. However, unforeseen circumstances, such as dry periods, unseasonable freezes, forest fires, etc., occasionally make it necessary to interrupt the planting operation for several days, weeks, or even until the following season. In such cases the trees must be heeled in. This process should be handled very carefully, as follows:

1. In moist, easily worked soil exposed neither to full sunlight nor to excessive cold, dig a shallow trench 1 to 1½ feet deep, depending on the size of the stock, with one side sloping about 20° to 40°. If natural shelter is lacking, some sort of temporary brush, canvas, or burlap shelter should be provided.

2. Place the trees against the sloping side of the trench with their tops projecting above ground slightly less than when they stood in the nursery. Care must be taken to place them neither too high nor too low. To prevent heating, the trees should be in a layer not more than 2 inches thick. The longer it is expected to keep the trees heeled in, the thinner should be the layer. If the trees are to remain in this condition more than a week, it is best to place them in a layer the thickness of a single tree.

3. A layer of moist soil 3 or 4 inches thick should be packed against the roots. Another row of trees is then placed against the new soil surface and the process repeated as many times as is necessary to accommodate the available stock. If only one layer of stock is to be heeled in, a layer of earth 6 inches or more thick should be packed against the roots.

4. The heeling-in beds should be kept moderately moist.

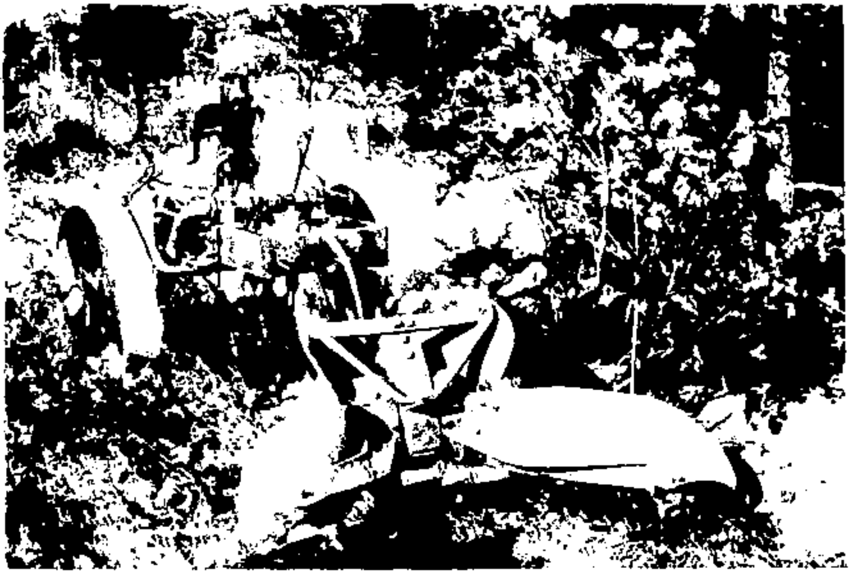
5. The soil of the beds should be kept from freezing by mulching it lightly with leaves or straw. Heavy mulching is apt to favor heating and molding of the trees and should be avoided.

PREPARING THE GROUND FOR PLANTING

In parts of the Southern and Central States it is possible to plant successfully without preparing the soil in advance. In the Lake States, however, early trial-and-error observations proved that field planting without some sort of ground preparation usually is wasted effort. As a rule, it is necessary to allow at least 2 or 3 years for the planted trees to establish their own roots well enough to compete successfully with lower vegetation such as grasses, herbaceous plants, and low shrubs. Furrowing and scalping are commonly used for this purpose, and there is some promise that new heavy types of plows will permit satisfactory furrowing in comparatively heavy brush (fig. 11). In this region plowed furrows generally have given much more satisfactory results than hand-made scalps. Recent evidence indicates that disking the soil has certain advantages over both furrowing and scalping.

The relative advantages of scalping, furrowing, and disking may be brought out by comparing them.

Scalping.—(1) It can be done by hand labor with hand tools; no special machinery or heavy equipment is needed. (2) It can be [illegible] that are strewn with rocks, stumps, or down logs and [illegible] where plowing or disking is difficult or impractical. (3) It [illegible] where the cover is too dense to permit furrowing or [illegible]. (4) It [illegible] where the topography is too rough for [illegible]. [illegible] Scalps are not nearly so subject to erosion [illegible] furrows. [illegible] Natural reproduction is largely saved [illegible] scalped areas, which is [illegible] destroyed by furrowing or [illegible].



[illegible]

[illegible] 22. [illegible] drawn by a 35-horsepower crawler-type [illegible] forests in the Lake States.

[illegible] (1) It usually is more effective than scalping in re[illegible] vegetative competition. (2) Where practical, it can be done at [illegible] one-third the cost of scalping (*[illegible]*) and at a lower cost [illegible] disking. (3) The planting job is simplified because [illegible] for planters to follow furrows than rows of scalps or to [illegible] proper spacing [illegible] disked areas. Furrows are also easier to fol[illegible] operations. (4) Furrowing requires much less man[illegible] scalping.

[illegible] (1) It eliminates competition more effectively than fur[illegible] or scalping. (2) It promotes faster initial growth by keep[illegible] topsoil [illegible] the zone where the roots are placed in plant[illegible]. (3) It avoids furrows or ridges that make logging, travel, and [illegible] difficult. (4) It can be used in areas having too much [illegible] and windfalls for satisfactory furrowing or scalp[illegible]. (5) It requires [illegible] less manpower than scalping.

Scalping

[illegible] prepared for planting by scalping usually where rough [illegible] rocks, stumps, windfalls, or heavy cover make furrow[illegible] impractical. [illegible] Scalps are made with mattocks, grub

[illegible]

hoes, or Finn hoes; even spades and shovels can be used, but they are not very efficient. The scalps should be 18 to 24 inches wide, either circular or rectangular in shape. On areas with heavy cover they should be made wider than where the cover is more sparse. The scalps should be deep enough to remove the surface roots of competing vegetation. However, if they are made too deep they are likely to collect water or leaves, or other debris to the detriment of the planted trees.

Ordinarily scalps are made at some predetermined spacing such as 4 by 6, 6 by 6, or 6 by 8 feet. In placing scalps, however, such spacings should not be followed blindly, but good judgment should prevail. For instance, scalps should not be made on bedrock or rock clumps, on stumps or old down logs, in dense thickets, in or adjacent to thrifty reproduction of valuable species, or beneath the crowns of trees unless it is known that such trees will be removed before they can seriously suppress planted trees.

Ten to fifteen men under an experienced straw boss or subforeman make an effective scalping crew. A good foreman can supervise two or three such crews. A practical method for keeping the crew in good alinement is to have a lead-off man who can follow a previous row of scalps, a fire lane, a row of stakes, or some other good guide. This man should keep one scalp ahead of the second man, the second man one scalp ahead of the third man, and so on; that is, the crew should proceed in an echelon formation. By this method each man has a guide to follow. It is well to have marked strips at intervals of 200 to 300 feet so that this alinement may be checked at frequent intervals.

Furrowing

On the basis of past experience in the Lake States, planting sites should be prepared by furrowing wherever feasible. Probably the majority of the sites that should be planted are reasonable furrowing chances, with the equipment available today. Generally speaking, areas that have too dense a cover to permit furrowing have too dense a cover for planting, except perhaps in small natural openings.

Furrowing in the Lake States has been done by means of light horse-drawn walking or sulky plows and by progressively heavier tractor-drawn plows. The ordinary plows developed for agricultural use are suited only for furrowing relatively open sites. Within the past few years heavy plows have been developed especially for forestry use.

The old plows produced furrows about 1 foot wide and were limited to use in areas with little or no cover. The large Killefer, Baldwin, Mesaba, or Wagler plows[14] now used by the United States Forest Service produce furrows 18 inches wide or wider and are able to cope with moderately dense brush or sapling growth. The old plows threw the furrow slice in one direction only; the Killefer, Baldwin, Mesaba, and Wagler plows are the middlebuster type, throwing the slice on both sides of the furrow. Because they make a wider furrow and throw the slice on both sides, the new plows are more effective in keeping down competition the first few years after furrowing. Ordinarily, furrows are plowed 6 to 8 feet apart in the Lake States, depending upon the spacing at which the trees are to be planted.

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[14] See appendix for sources of information on this and other special equipment mentioned in this publication.

Good furrowing practice should meet the following requirements:

1. Furrows should be deep enough to remove sod and surface roots, but no deeper. Deep furrows are subject to excessive fill-in, and also give the planted trees less chance to get their roots into the nutritious layer of organic matter in the soil. In addition, they have brought serious objection from sportsmen because of the difficulty of hunting across such areas, and they make access to the area difficult for logging, fire protection, and other purposes. Plow operators should be taught that an occasional break in the furrow is to be preferred to deep plowing. Furrows that are too shallow are not effective in reducing competition. Ordinarily, 3 or 4 inches is the best depth for furrowing.

2. Furrows should lie open for about 2 months before they are planted. There is some filling in of soil after plowing, chiefly from the overturned slice along the side of the furrow. Measurements made over a period of 5 years at various intervals after plowing on the Huron National Forest showed that the bulk of the fill-in during the first year takes place within 2 months after plowing, although the furrows may not be completely stable at the end of 5 years. If furrows remain unplanted too long, of course, vegetation encroaches, and planted trees must face competition from the time of planting. As a general rule, the poorer the site, the longer the furrows remain open.

3. Plowing should be done in such a manner as to reduce water erosion to a minimum. On level areas it is satisfactory to plow straight furrows. On areas of rolling topography, washing can be controlled by plugging the furrows at intervals. Where slopes are steeper, however, plowing should be done on a contour.

On large-scale planting operations it is economical to organize the furrowing job in such a way that four or six plowing units work in close proximity. However, not more than two or three units can ordinarily work in adjacent furrows to advantage.

Disking

Although disking has not yet been widely used to prepare planting sites in the Lake States, it gives promise of being a very effective and useful method, at least on the lighter soils. Where thorough disking has been used on very brushy sites, it has reduced competition very effectively and has had the added advantage of working the more fertile topsoil into the surface layer where the tree roots are to be placed. In a comparison of about 200 acres of disked plantations with a 200-acre area of furrowed plantation on the Chippewa National Forest in Minnesota, 2-2 red pine 2 years after planting showed these differences: On the furrowed area survival was 89 percent and average height 0.80 foot; and on the disked area survival was 96 percent and average height 1.24 feet (*1*).

The best apparatus for disking brushy areas so far developed has been the Athens-type disk plow attached to a 40-horsepower tractor (see p. 79). For satisfactory results, the area must be cross-disked; that is, the disk should be pulled over the ground twice, the second trip in a direction at right angles to the first. It is even better if a third trip in a diagonal direction can be made, although this may make the cost too high. Experience on the Chippewa National Forest indicates that, with a skillful operator, cross-disking can be done at a cost less than 10 percent above that for furrowing even though much of the disked area would have been almost impossible to furrow. If tandem disks work satisfactorily, the cost may be further reduced.

METHODS OF PLANTING

So far there are no comprehensive planting experiments in this region, or so far as the writer is aware, in the United States, sufficiently old to indicate the full effects of the various methods of planting. Several European investigations (*38*, *93*) and some scattered observations in the Northern Rocky Mountain region indicate that the full effects of planting methods may not show up for from 10 to 30 years. With favorable seasons, almost any system that gets the tree roots in the ground will give reasonably good early survivals. However, the poor root distribution resulting from some systems of planting may result in heavy losses when some crisis arises, such as extreme climatic conditions or the severe competition for moisture and mineral nutrients when the tree crowns close in. Among other deficiencies, such root systems also fail to make trees windfirm.

Most of the planting in the Lake States region has been carried out by one or the other of two general methods, the slit and the hole. In line with other measures for obtaining low initial planting costs, the slit method has been favored in many instances.

There are a few general practices that should be observed regardless of the method of planting. These concern (1) location of the individual tree, (2) dimensions of the holes or slits, (3) depth of planting, and (4) removing trees from the planting box.

Trees should be placed about in the middle of the furrow or scalp and, so far as possible, should not be placed near established reproduction of desirable species nor competing brush or other vegetation.

The planting holes or slits should be deep enough to permit the roots to hang straight down without looping or curling at the bottom, and wide enough (at least 4 inches) to permit some spreading of the roots.

The trees should be planted at the same level, or not more than one-half inch deeper than they grew in the nursery. The location of the root collar (ground line) is usually marked by a change from the darker stem color to the lighter root color and a very slight swelling of the stem, but where this is not distinct, care must be taken in planting to cover all roots with soil and to have all living leaves above ground.

When trees are removed from the planting box, care should be taken that the roots are not stripped and also that the roots of the trees that remain are kept covered with moss or burlap and not exposed to drying. A very satisfactory planting box for small stock can be made from wooden cartridge boxes, measuring about 10 to 12 inches wide, 20 to 24 inches long, and 5 to 7 inches deep, by simply fastening a loop of No. 9 or No. 12 wire lengthwise across the box to serve as a handle.[15] For large stock it is best to have one end of the box sloping. Such a box, used by the United States Forest Service, has the following dimensions: 20 inches long across the top and 15 inches long across the base, 10 inches wide, and 6 inches deep.

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[15] Pails, baskets, bags, or boxes may be used to carry planting stock, but experience in the Lake States favors the planting box. Planting boxes have been made of steel; although they are less subject to breakage than wooden boxes, their weight is a disadvantage. They weigh 8 to 9 pounds as compared with 4 to 5 pounds for similar wooden boxes.

Comparison of Hand Methods

The advantages, disadvantages, and techniques of each of the following methods of planting, which are used in the Lake States, are discussed in order: Slit (bar and mattock), center-hole, side-hole, mound, and wedge.

The Slit Method (Bar and Mattock).—The slit method of planting is the most rapid and cheapest practiced in this region. Using the bar-slit method, well-trained crews of local planters on the Huron National Forest have consistently planted from 1,000 to 3,000 trees per man-day of 8 hours, with an average of nearly 1,500 trees per man-day. Crews of CCC enrollees, which seldom accumulated more than 2 years' planting experience, rarely exceeded 1,500 trees per man-day, and averaged nearly 1,000 trees per man-day of 6 hours. This is roughly equivalent to 1 acre per day per man. Survey of older plantations in the Lake States showed that 87 percent had been established by the slit method, and it is probably true that 75 percent of all the plantings in this region have been so planted. Since 1938, when larger stock came into more prominent use, the slit method has been less widely used.

The advantages of the slit method are that it is rapid; it is easy for planters to learn and to execute; and it makes for low-cost planting. On the other hand, the slit method has some rather definite disadvantages: It is not well suited for use with large planting stock, and ordinarily should not be used with any but 1-0 or 2-0 seedlings; the planters cannot observe root placement and, as a result, looped or curled roots are difficult to avoid, and the entire root system is cramped into a single plane. This factor is probably the greatest indictment of the method.

Studies in Russia (*38*) and Sweden (*93*) have indicated that slit-planted trees that appeared perfectly healthy showed sudden losses when the crowns closed and competition became keen. These losses were attributed chiefly to deficient root development as a result of the method of planting. Large-scale studies of such advanced plantations are not possible in the Lake States. However, a study made in 1936 on the Huron National Forest (*54*, *55*), which involved the excavation of 5,000 planted 2- to 3-year-old jack pine and 3- to 13-year-old red pine, showed that the root systems of about 65 percent of all the trees were cramped into a single plane. The study also revealed that the cramping had reduced the trees' survival 20 to 30 percent and their growth about 20 percent. Jack pine showed better ability to overcome such root deformity than did red pine.

The bar-slit method is commonly used on sandy lands with few rocks or roots and where furrows or scalps have been prepared. The best tool for use with this method is the Michigan bar [18] (fig. 12), although other types of bars or good sturdy spades and shovels can also be used.

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[18] The Michigan bar consists of a good-quality steel, straight blade 12 inches long and 3½ to 4 inches wide; it is about ½-inch thick at the top, tapers down to $^{3}/_{16}$ inch, and is sharp at the base. This blade is welded to a handle about 30 inches long made of ¾- or 1-inch iron pipe.

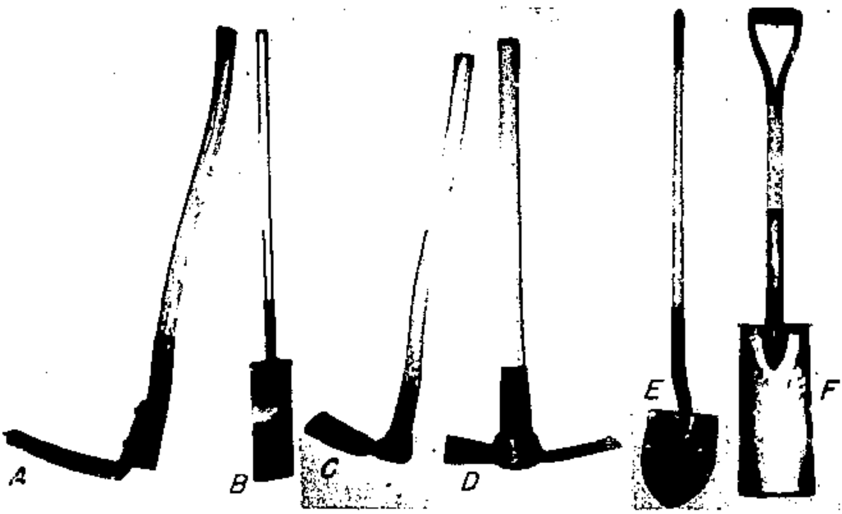

FIGURE 12.—Planting tools commonly used in the Lake States: *A*, Baldwin hoe; *B*, Michigan bar; *C*, hazel hoe; *D*, mattock; *E*, long-handled shovel; *F*, No. 2 spade.

The bar-slit method is carried out as follows:

1. With the right foot on the ground and the left foot reaching forward, thrust the bar (held in the right hand) perpendicularly into the ground for the full length of the blade.

2. As the left foot strikes the ground, push the bar forward, with a stiff arm, to an angle of about 35 degrees, and at the same time place the planting box (held in the left hand) to the left and slightly ahead of the spot to be planted.

3. Slide the right hand halfway down the handle, and force the blade 2 or 3 inches into the soil before bringing the bar back into a perpendicular position again. By this procedure a rectangular hole 3 to 4 inches wide and 8 to 12 inches deep is produced.

4. With the left hand, select a tree from the planting box. Holding the tree between the first and second fingers, at or just above the root collar, flip the roots into the hole so that all the roots are hanging straight down. If the roots are inclined to hang to the side, use the bar to guide them into position. The back of the hand should rest on the ground at the left side of the hole.

5. While in this position, and holding the tree erect and at the proper height, remove the bar and thrust it perpendicularly into the soil 3 or 4 inches back of the tree.

6. Pull the bar handle back about 6 inches to close the bottom of the hole, and then push it forward with the weight of the body until the hole is tightly closed. Test the tree for tightness by a gentle pull on three or four needles.

7. Pick up the planting box and, in moving forward, thrust the right foot forward to close the hole created by the packing movement. Firm the tree slightly with the foot, but do not stamp. Proceed to the next planting spot and repeat the process.

The mattock-slit method ordinarily is used where the soil is too heavy, rocky, or full or roots for satisfactory use of the bar. Mattocks, grub hoes, or planting hoes (fig. 12) are the usual tools for planting by this method. The procedure is as follows:

1. Set the planting box to the left and slightly ahead of the place where the slit is to be made.
2. Sink the mattock blade to its full depth, as nearly perpendicular as possible, so that at the end of the stroke the end of the handle is nearly flush with the ground.
3. Open a slit by pulling the handle up about 3 inches off the ground and then straight back.
4. Drop to the right knee with the right hand grasping the mattock handle near the blade.
5. Take a tree out of the planting box, holding it between the thumb and forefinger of the left hand at the root collar; insert the roots in the slit and push them well down so that the root tips are at the bottom of the slit.
6. Raise the tree until the root collar is at ground level, and with the right hand remove the mattock and permit some loose soil to fall into the slit; then place the mattock to the right of the slit.
7. Close the slit partially by firm tamping with the right fist. Then grasp the mattock in the right hand; straighten up; sink the mattock about 3 inches behind the tree; pull up on the handle to close the slit; withdraw the mattock and close the second slit with a vigorous thrust of the right heel applied in a downward and forward direction.
8. Test the tree for firmness with the left hand by a gentle pull on three or four needles; then grasping the mattock in the right hand and the planting box in the left, proceed to the next planting spot and repeat the process.

The Center-hole Method.—Probably one of the oldest methods of planting trees is the center-hole method. It has the following advantages: (1) It is well suited for use with large stock. (2) It can be used wherever planting can be done. The presence of rocks and roots does not make the method impractical. (3) It is thorough and gives the planter a chance to see that the roots are straight and well distributed. (4) It gives good results. A study of older plantations in Michigan showed that those planted by the hole method had an average survival of 60 percent at the end of 23 years, while those planted by the slit method had an average survival of only 42 percent. (5) It can be done without previous ground preparation. (6) It results in breaking up tight soils and gets away from puddling, which frequently occurs when the slit method is used.

On the other hand, the principal disadvantage of the center-hole method is that it is slow and consequently costly. An average of 200 to 300 trees per man-day is about all a crew can be expected to plant with this method.

Mattocks or grub hoes are ordinarily used in center-hole planting although planting hoes and even spades or shovels can be used. The procedure is as follows:

1. Set the planting box down to the left and slightly ahead of the point where the hole is to be made.

2. If the ground needs preparation, scalp off the sod and litter over a space at least 18- to 24-inches square with 3 to 5 strokes of the mattock, removing as little soil as possible with the sod.

3. Sink the mattock blade perpendicularly to its full depth near the center of the prepared spot in such a way that the handle is nearly flush with the ground.

4. Lift up and pull back and slightly to the right on the handle, depositing the soil near the right-rear edge of the hole.

5. Repeat steps 3 and 4 if it is necessary to enlarge the hole or to take out roots or rocks. One or two strokes and not more than four should be sufficient to make a hole 8 to 12 inches deep and 6 to 8 inches wide.

6. At the completion of the last stroke, drop the mattock to the right of the hole with the handle toward the rear and drop to the right knee.

7. With the thumb and forefinger of the left hand take a tree from the planting box, using the right hand to hold the remaining trees in the box.

8. Grasping the tree just above the root collar, hold it in the center of the hole so that the root collar will come just below the soil level and spread the roots with the right hand.

9. With the right hand scoop in a few handfuls of soil (avoid leaves and trash) and place it quickly and carefully about the roots in the bottom of the hole.

10. Tamp the soil gently from three to five times with the fist (wooden tampers have been used on the Superior National Forest, but hand tamping ordinarily is more satisfactory).

11. Scoop in more soil to fill the hole.

12. Holding lightly to the top of the stem or needles, come to a semierect position, place both feet on the filled soil, and pack it firmly about the roots.

13. Test the tree for firmness by a gentle pull on three or four needles, pick up the mattock in the right hand and the planting box in the left, proceed to the next planting spot, and repeat the process.

The Side-hole Method.—This is a variation of the center-hole method; it makes for more rapid planting, but has some of the disadvantages of the slit method in that one side of the root system is compressed against firm soil. Well-trained crews can plant 700 to 800 trees per man-day by this method and should average 600.

The same tools (usually mattocks or grub hoes) are used as in the center-hole method and the procedure is the same, except for steps 8 and 9 which are as follows:

8. Grasping the tree just above the root collar, hold it against one side of the hole so that the root collar will come just below the soil level and the roots hang down freely.

9. With the right arm held stiff and crooked at the elbow, scoop in about half the soil (avoid leaves and trash).

The Mound Method.—The mound method is essentially a refinement of the center-hole method. Its principal advantage is that it provides the best root distribution of any method of planting. Its principal disadvantage lies in its slowness (slower than the center-hole method) and consequently its high cost.

The mound method can be done with several tools, but the mattock, grub hoe, or planting hoe are usually best. The procedure is as follows:

Follow steps 1 through 6 as described under the center-hole method.

7. With the right hand scoop soil into the hole and pat it into a cone-shaped mound with both hands.

8. With the thumb and forefinger of the left hand, take a tree from the planting box, using the right hand to hold the remaining trees in the box.

9. Grasping the tree just above the root collar, hold it over the center of the mound so that the root collar will come just below the soil level, and spread the roots on all sides of the mound with the right hand.

10. With the right hand scoop enough soil into the hole to cover the roots, and pat it down firmly.

From this point, carry on steps 11 through 13 as described under center-hole planting, p. 56.

The Wedge Method.—The wedge method, which is also known as the inverted-vee, W, or saddle method, has long been used in Europe. However, it has been used in the Lake States only since the late 1920's, and not until 1936 was it employed on a large scale.

The wedge method has several advantages: (1) It is suitable for use with large stock and (2) it is rather fast and therefore moderately cheap. In experimental work, planting by this method has been done at half the speed of the bar-slit method. Techniques for large-scale use have only recently been worked out, but some well-trained crews have averaged 600 trees per man per day. On the average, it seems likely that crews can plant 500 trees per man per day by this method. (3) It is thorough and gives the planter a chance to see that the roots are straight and well distributed.

The disadvantages of the wedge method are: (1) It cannot be carried out efficiently in soils that are rocky or heavily rooted; (2) it is more expensive than the slit method; (3) if not supervised closely planters tend to get the holes too shallow, thus bringing the bulk of the roots too close to the ground surface; (4) planters may injure the roots in separating them to place over the wedge.

A planting hoe, called the Baldwin hoe [17] (fig. 12), developed on the Manistee National Forest, is the most convenient tool for use with the wedge method, but mattocks, hazel hoes, Finn hoes, spades, or shovels can also be used. The method of planting is carried out as follows:

1. Set the planting box down to the left and slightly ahead of the point where the hole is to be made.

2. Drive the hoe blade perpendicularly to its full depth near the center of the furrow or scalp so that the end of the handle is nearly flush with the ground at the end of the stroke.

3. Lift up and pull back and slightly to the right on the handle, depositing the soil near the right-rear edge of the hole.

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[17] The Baldwin planting hoe consists of a good-quality steel, slightly curved blade 3½ inches wide and 10½ inches long, fastened to an ordinary carpenter's adz handle by means of two 3½-inch carriage bolts.

4. Quickly drive the hoe again in the same manner at a point about 2 inches ahead of where it was first driven and remove the soil in the same manner. If the hole must be wider to accommodate the stock, repeat steps 3 and 4 alongside of the hole just made. The hole should be 10 or 12 inches deep and slope up at the side near the planter at an angle of about 45 degrees.

5. Drive the blade to its full depth at an angle of about 45 degrees just below the near crest of the hole.

6. Pull the soil back and to the right. Repeat this step to widen or deepen the second part of the hole. The entire hole is now shaped like a W with a wedge-shaped mound of soil in the center, and should be large enough to allow the roots to hang down on either side of the wedge without curling or bending in the bottom.

7. Drop to the knees and with the thumb and forefinger of the left hand take a tree from the planting box.

8. Holding the tree just above the root collar, center it over the wedge so that the root collar will come just below the soil level, and with the right hand divide the roots and spread about half of the root system on each side of the wedge.

9. With the right arm held stiff and crooked at the elbow scoop in about half the soil.

10. Tamp the soil over the roots gently with the fist of the right hand.

11. Repeat step 9 to scoop the rest of the soil into the hole.

12. Holding lightly to the top of the stem or needles, come to a semierect position, place both feet on the filled soil, and pack it firmly (do not stamp heavily or use the heels).

13. Test the tree for firmness by a gentle pull on three or four needles, pick up the hoe in the right hand and the planting box in the left, proceed to the next planting spot and repeat the process.

The class of stock best suited for planting by the methods just described and for machine planting described later, and the average number of trees that can be expected to be planted by each method per man-day, are given in table 13.

Machine Planting

In the Lake States from one-third to one-half the cost of forest planting usually goes into hand labor. Mechanization of the operation should result not only in a lower planting cost but also in the planting of large acreages by small crews. Thus, fuller advantage would be taken of the rather short planting season and a limited labor supply.

Machines Developed in Other Regions.—Several tree-planting machines have been developed and used to some extent in the United States. Although they differ in detail, most of the machines have these features: A coulter to cut the sod and small roots, a trencher to open a slit, packing wheels to close the slit, and a container for the planting stock. Many also include a plow to turn a furrow. One or two planters ride the machine and insert the tree roots in the slit just ahead of the packing wheels. Most of the machines are tractor drawn. In the Northeast two machines (the Simplex and Duplex), differing chiefly in size, were developed several years ago (*84*) and have been used rather extensively. Recently a tree planting sled, the TreeP, has been developed for planting hilly land in New York State.

Table 13.—*Methods of planting, with class of stock best suited, and average number of trees that can be expected to be planted per man-day*

Method of planting	Recommended tool	Class of stock best suited to method	Expected average number of trees planted per man-day [1]	Ground preparation and soil condition best suited to method
Bar-slit	Michigan planting bar	1-0 or 2-0 seedlings	1,500	Furrows or scalps in light soils with few roots or rocks.
Mattock-slit	Mattock	1-0 or 2-0 seedlings or stock with short taproot.	700	Furrows or scalps in heavy, rocky, or thickly rooted soils.
Center-hole	do	Large well-rooted transplants (2-1, 1-2, or 2-2).	250	Heavy, rocky, or thickly rooted soils with or without ground preparation.
Side-hole	do	do	600	Do.
Mound	do	do	200	Do.
Wedge	Planting hoe	do	500	Furrows, disked areas, or scalps in sandy or light loam soils with few roots or rocks.
Machine	Wisconsin, Michigan, Minnesota, or similar planting machine.	2-0, 2-1, 1-2, or 2-2 stock	[2] 2,200-3,500	Fairly level, light soils with few roots, stumps, or stones.

[1] 8 hours.
[2] 3-man crew (tractor driver and 2 planters) can average triple this number.

During the latter years of shelter-belt planting in the plains region by the Prairie States Forestry Project, and in subsequent planting by the Soil Conservation Service, most of the work was done by machines. These machines were adapted only for planting in ground completely prepared as for farm planting. The Naber and Nebraska Tree Planting Machines were developed by the United States Forest Service for planting in the Nebraska sand hills. None of these machines, however, has yet found acceptance in the Lake States. Other machines developed recently include the Lowther Hillside Planter (for use on rough hillsides), and the Purdue, Illinois Central, Lowther Shelterbelt, and Whitfield Planters which operate on the power lift of a wheeled tractor (*67*).

The Lowther Standard Tree Planting Machine.—The Harry A. Lowther Co. designed a tree planter for use in the cut-over lands of the South, where the soil is filled with heavy roots and old stumps. It has since been tested widely throughout the eastern half of the United States.

Briefly, the Lowther tree planter consists of a narrow rectangular frame about 6 feet long. The front end is mounted on sturdy wheels equipped with heavy duty 6.00 by 16 tires, and the rear end on two 16-inch pneumatic tired wheels that serve as packing wheels. A seat for the operator is mounted above and immediately behind these wheels. Suspended within the frame, and hinged to it at the front end, is a trenching and planting unit consisting of a heavy 28-inch disk coulter (capable of cutting through roots 2½ inches in diameter) and a special plow into which planting guides are built. This unit floats freely from the front suspension and may be raised and lowered by means of a fast-acting hydraulic ram activated by a hand pump located within easy reach of the operator (fig. 13).

The tree planter can be readily handled under all conditions by a tractor of 30 or more horsepower. It can be drawn by any type of farm tractor, and it has been drawn by a jeep under favorable conditions. In operation, when the hydraulic lift is released, the coulter and plow settle into the soil because of their weight and the natural suction of the plow. The plow is hung to operate at a uniform depth of 8 inches at all times, and the coulter—set close to the plow point—cuts a track 1 inch deeper. The plow at a depth of 8 inches, following in the 9-inch cut of the coulter, opens a narrow furrow, not by compressing the earth outward or turning the soil over as in conventional plowing, but rather by lifting the entire section of soil upward and slightly outward. The soil is then held in that position by the planting guides until planting is accomplished. The planting guides are parallel wings of heavy sheet metal built into the rear of the plow and spaced 2 inches apart. The operator sits astraddle the narrow frame and plants the tree by placing its roots within the planting guides and then moving the plant back slightly.

The Lowther machine is very rugged and has worked well under a variety of soil and cover conditions and on slopes up to 30 percent. One trial in northern Wisconsin showed that this machine could operate in fairly heavy brush or young aspen. As used so far, this machine does not throw a furrow. This may be a drawback in the

Lake States because of the extra competition given the planting stock by survival of brush or sod close to it. To overcome this objection the company has added a sod-furrowing shoe, which is a slit share, left and right, operating on either side of the coulter blade at a depth of 3 inches.

FIGURE 13.—The Lowther tree planter. (Photo courtesy of Harry A. Lowther Co.)

Production for this machine is about the same as for the Wisconsin or Michigan machines. It has averaged about 10,000 trees per day in the South.

Lake States Machines.—Tree planting machines have been developed by State agencies in Wisconsin (85), Michigan, and Minnesota with which a crew of a tractor driver and 1 or 2 planters can set out 1,200 to 2,000 trees per hour. The Minnesota and Michigan machines have not yet been given a thorough trial, but the Wisconsin machines have been used extensively since their development in 1943.

Because of their comparatively wide use, the machines developed in Wisconsin are described in some detail. Not only have these machines been used by farmers and State and county agencies, but also by some of the pulp and paper companies.

Two types of tree-planting machines were developed for establishing forest plantations on land free from stones and large stumps. One is designed for use by farmers on old fields, principally on sandy soil types, and the other is designed for use on cut-over sandy areas where some stumps and brush may occur.[18]

The farm-type tree planting machine (fig. 14), designed by the Wisconsin Agricultural Experiment Station, is built around the modern, single-bottom, heavy-duty tractor plow. The standard plow bottom

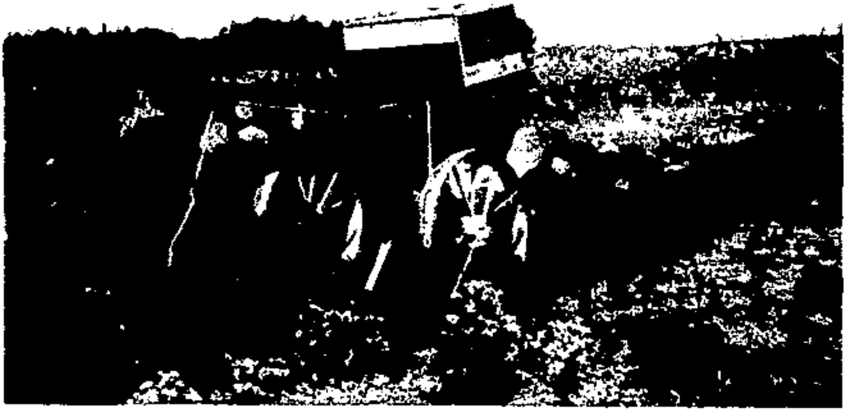

FIGURE 14.—The Wisconsin farm-type tree planting machine, built on a John Deere subsoil chassis, with the shoe hoisted out of the ground. The operator's seat is in the rear and under it are the press wheels that tamp the soil around the tree roots. This is not a commercial model. (Photo courtesy of Extension Forester, University of Wisconsin.)

is replaced with a middlebreaker plow, under which is attached a box shoe about 4 inches wide, 8 inches deep, and 3 feet long. On the front of the shoe is a chisel snout that serves the double purpose of holding the shoe in the ground, and elevating the soil out of the planting trench instead of merely prying apart a slit in the soil. A rear assembly with press wheels provides a place for the operator to sit as he sets the trees (carried in one or two boxes just ahead of the planter) in the trench shoe. The press wheels pack the soil around the tree roots after a pair of plates, or berms, flow loose soil into the trench. Trees up to 4 years of age may be planted easily in the 4- by 8-inch trench, but in general 3-year-old stock has proved most satisfactory except for jack pine; 2-year-old stock is standard for that species.

The second model, designed by the Wisconsin Conservation Department, is generally similar to the farm model, but is built around a middlebreaker fire plow. Because of its extremely heavy construction it will operate in land too stony or stumpy for the lighter, farm-type planting machine. The ordinary farm tractor will operate the lighter machine, while a moderately heavy crawler-type tractor is required for the operation of the heavy machine.

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[18] Based on a statement furnished by Wisconsin's Extension Forester, Fred B. Trenk, who played an important part in the development of these machines. Cost figures were supplied by Mr. Trenk, F. N. Fixmer of the Mosinee Paper Mills Co., and R. C. Dosen of the Nekoosa-Edwards Paper Co.

The tree planting parts may be made so that they are detachable from either of the two models, thus permitting the use of the plows during the balance of the year for other purposes. Tree-planting attachments for the farm tractor plow will cost from $60 to $70 (prewar), while those for the fire plow may cost about $5 more per unit. These costs may be liquidated easily in one season's planting. Commercial models of the Wisconsin machine, called the Badger Tree Planter, are available.

A 3-man crew consisting of a tractor driver, planter, and stock man (who loosens the trees and hands them to the planter) can plant from 13,000 to 16,000 trees per 8-hour day with either machine, but under actual operating conditions the daily production usually runs from 6,500 to 11,000 trees.

The economy of planting with these machines may be illustrated by records obtained from operations of four machines in 1944 and 1945 (table 14). If the trees had been planted by hand, any comparable costs for hand planting the sites would have to include the costs of furrowing, assuming that furrowing would have been necessary.

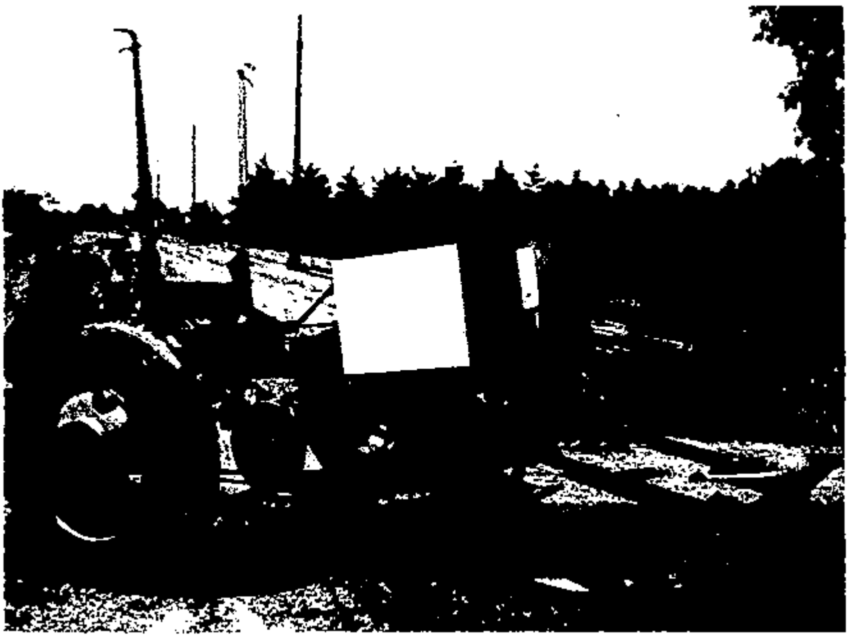

FIGURE 15.—The Michigan State Reforestator with trencher resting on the soil surface. (Photo courtesy of Forestry Department, Michigan State College.)

A tree-planting machine called the Michigan State Reforestator (*72*), which combines some of the features of the Wisconsin and plains shelter-belt machines, has been developed at Michigan State College (fig. 15). Mounted on a standard farm-implement unicarrier with power lifts, as is the shelter-belt machine, it is otherwise similar to the Wisconsin machine. It differs principally in these respects: The plow can be raised up for use on prepared ground, and through the use of the uni-carrier, the plow is easily adjusted to

TABLE 14.—*Costs of planting with two types of Wisconsin tree-planting machines, 1944–45*

Machine	Area planted	Trees per acre	Time per acre		Costs per acre			Costs per thousand trees planted
			Labor	Machine	Wages	Other [1]	Total [2]	
	Acres	*Number*	*Man-hours*	*Hours*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Farm type: [3]								
Machine 1	145	1, 490	4. 55	1. 23	2. 40	1. 73	4. 13	2. 77
Machine 2	100	1, 360	5. 40	1. 58	2. 70	2. 21	4. 91	3. 61
Conservation type: [4]								
Machine 1	232	1, 110	3. 22	[5] 1. 07	1. 36	2. 67	4. 03	3. 63
Machine 2	230	1, 800	[5] 4. 09	[5] 1. 17	[5] 2. 71	[5] 2. 82	5. 53	3. 07

[1] Includes tractor hire, fuel, repairs, depreciation on machines, etc.
[2] Exclusive of costs of stock which would add about $2 per thousand trees planted if jack pine seedlings were used, or $5 per thousand trees for red pine transplants.
[3] Light machine used chiefly on old field.
[4] Heavy type used chiefly on land never before cultivated.
[5] Derived from data supplied in another form, not from records of operation.

varying depths; by lowering one wheel and raising the other, contour planting can be done on slopes up to 30 percent.

Although the standard trencher on this machine makes an opening 4 inches wide and 8 inches deep (as does the Wisconsin machine), it is removable and may be replaced with a trencher that will make an opening to accommodate larger planting stock.

The reforestator can be pulled by an ordinary farm tractor, although wheel-type tractors are not satisfactory when planting on loose sands or steep slopes. It is easily transported as a trailing unit behind a tractor or automobile, since truck wheels have been substituted for the standard uni-carrier wheels. Under normal conditions a 2-man crew (tractor driver and planter) can set out 10,000 trees in an 8-hour day with the reforestator.

The Forestry Division of the Minnesota Conservation Department has developed a machine for planting trees on open sand plains (fig. 16). This machine differs from the Wisconsin and Michigan machines in that no plow is used. The ground is broken by a trenching shoe. Fairly extensive trials during 1945 indicated that a 3-man crew (2 planters and a tractor driver) could plant an average of 1,500 trees per hour or better. After minor adjustments, it is planned to use this machine extensively for planting State and county lands in the sand plains.

Advantages and Disadvantages of Machine Planting.—The main advantages of tree-planting machines are that planting can be done more rapidly and with less labor, and at a cost of about 30 to 50 percent less than for hand planting comparable sites; ground preparation and planting are accomplished in one operation. Under comparable conditions, stock survival seems to be about the same for both machine and hand planting.

On the other hand, there are some disadvantages in machine planting: (1) Areas with much rock, stumps, brush or other cover, or heavy soil cannot be planted; (2) roots over 8 inches long may be looped, and other disadvantages of the slit method may develop; (3) only generally level areas can be planted; and (4) larger trees are required than for hand planting. Machine planting is a promising innovation in reforestation; it merits wider trial to explore its full possibilities. Planting machines are being improved constantly to make them more rugged, safer to operate, and adaptable to more difficult planting conditions.

Spacing or Number of Trees per Acre

Natural forest stands usually begin with a dense stocking of young trees and then gradually thin themselves with increasing age. For instance, fully stocked, even-aged stands of the native pines in the Lake States at an age of 30 years range from 1,400 to 3,000 trees per acre, depending on species and site quality (*11*). Younger stands are much denser. It is not feasible, of course, to plant trees as densely as they occur in young natural stands. However, it is desirable to plant enough trees per acre to produce a well-stocked stand in which the crowns will close by the age of 20 years, and in which good-quality products will grow. The density at which the trees should be planted varies with the species, quality of the site, product to be grown, the probable mortality, the abundance of natural seedlings of

FIGURE 16.—*A*, Minnesota tree-planting machine. Note that there is no plow; the trenching shoe prepares the ground. *B*, The machine in operation on open sand plain. (Photo courtesy of Forestry Division, Minnesota Conservation Department.)

desirable species already present, and the probable opportunity to dispose of material cut out at an early age.

If too many trees per acre are planted, not only is the cost of planting increased, but also one or more thinnings may be necessary before the trees reach merchantable size, thus increasing the cost of establishment even more. If the trees are planted moderately dense, necessary thinnings may be deferred until some merchantable products, such as pulpwood, can be realized, thus reducing the cost of thinning. Later thinnings usually produce a net return and help to liquidate the planting cost. On the other hand, if too few trees are planted per acre, even though thinnings may not be necessary and the trees are large in diameter, they will have numerous large branches that cause knotty, low-quality lumber.

An example of the effects of density of stocking is provided by the comparison of two 35-year-old jack pine stands growing side by side under the same site conditions near Tomahawk, Wis. The denser stand probably started with a spacing of about 5 by 5 or 4 by 6 feet, whereas the more open stand had an original spacing of about 10 by 10 feet. The two stands are compared in table 15.

The following conclusions may be drawn from this comparison:

1. *Wide spacing represents an enormous waste of space.*—While the dense stand produced 4.24 cubic feet of wood for every 100 square feet of ground area (1,847 cubic feet per acre), the poorly stocked stand produced only 1.19 cubic feet. The wood production of the area occupied by the poorly stocked jack pine, therefore, was only 28 percent efficient.

2. *Wide spacing lowers the efficiency of growth.*—In the dense stand each square foot of basal area at breast height supported $\frac{1,847}{85.6}$ or 21.6 cubic feet of wood, while in the poorly stocked stand 1 square foot of basal area supported only 16.4 cubic feet of wood, or 24 percent less.

3. *Under poor density of stocking, brush, grass, and other vegetation occupy more ground space than the trees themselves.*—The dense stand showed that on the average about 42 square feet of ground area was occupied by one tree. The space per tree in poorly stocked pine was 140 square feet. In normal stands where the crown canopy is closed, about 39 square feet of ground area is needed per tree. The dense stand approached this condition, but the poorly stocked stand wasted almost 100 square feet of ground per tree. This waste area was occupied by brush and other vegetation.

4. *No thinning is possible under poor densities of stocking.*—The poorly stocked stand contained only 5 cords of wood in trees just large enough for pulpwood. If these merchantable trees had been cut, the stand would have been completely ruined, and the area largely occupied by brush. In the dense stand, on the other hand, it would have been possible to remove as many as 10 cords per acre without converting the area to brush. In addition, such cutting would have improved the growth of the remaining trees.

5. *The quality of wood in the poorly stocked stand was very low.*—Large, bushy crowns, heavy limbs, etc., on some trees made the wood practically worthless for pulpwood. The analysis in table 15 does

TABLE 15.—*Growth comparisons, per acre, for well-stocked and poorly stocked stands of 35-year-old jack pine growing on the same site, by diameter classes* [1]

Diameter breast high (inches)	Good stocking					Poor stocking				
	Trees	Basal area	Total volume	Merchantable volume	Height	Trees	Basal area	Total volume	Merchantable volume	Height
	Number	*Square feet*	*Cubic feet*	*Cords*	*Feet*	*Number*	*Square feet*	*Cubic feet*	*Cords*	*Feet*
1	106	0. 6	6		13	57	0. 3	2		9
2	187	4. 1	64		23	32	. 7	7		15
3	248	12. 2	208		31	32	1. 6	18		22
4	240	20. 9	418	4. 8	38	69	6. 0	81	0. 7	27
5	127	17. 3	392	3. 8	44	47	6. 4	103	. 9	32
6	85	16. 7	406	4. 2	48	49	9. 6	170	2. 0	36
7	32	8. 5	211	1. 9	50	18	4. 8	91	. 9	39
8	10	3. 5	91	. 8	52	5	1. 7	36	. 4	42
9	3	1. 3	36	. 3	54	1	. 4	9	. 1	43
10	1	. 5	15	. 1	55					
Total	1, 039	85. 6	1, 847	15. 9		310	31. 5	517	5. 0	

[1] This table was prepared by S. R. Gevorkiantz of the Lake States Forest Experiment Station.

not consider this important loss of volume. Had it been considered, the comparison between the two stands would have been even more striking.

Plantings have been made with spacing between the trees varying from 3 by 3 to 10 by 10 feet. The latter spacing, which requires only 435 trees to the acre, is too wide. Prior to 1933 a large proportion of the planting on the national forests was done with 700 to 800 trees to the acre, which is the equivalent of a spacing of about 7 by 8 feet. Since 1933 the national forest plantings have averaged close to a 6 by 6-foot spacing, or 1,210 trees per acre. The Wisconsin and Minnesota State Forest Services in their recommendations to private owners have usually suggested 6 by 6-foot spacing. On the State forests in Michigan, close spacing of 3 by 3 or 4 by 4 feet was used in some of the earliest plantings, but the density has averaged about 800 trees per acre spaced about 7 by 7 feet for the bulk of the State plantings. On the average plantation in the Lake States there are from 100 to 200 trees to the acre of natural jack pine, oak, aspen, or other species, in addition to the planted trees.

As a good general average, a spacing of 6 by 6 feet can be recommended. At this rate the branches of the trees come together when they are from 10 to 20 years old. The lower branches of the pines begin to die from shading between the ages of 15 and 25 years, when they are not more than 0.75 inch in diameter and average only about 0.5 inch. By the time the trees are 25 years old, the branches will be dead 10 to 15 feet from the ground. At 25 to 30 years, when the trees are 4 to 5 inches in diameter, some thinning will be necessary (*37*) to maintain rapid growth and thrift. Thinning at this age sometimes is the first opportunity to obtain income from the plantation and thus reduce the rapidly mounting investment.

The standard spacings adopted by the Forest Service for tree planting in the Lake States are as follows, and may be used as a guide:

Species:	*Site quality*	*Spacing (feet)*	*Trees per acre (number)*
Eastern white pine Red pine White spruce	Good to medium	6 by 8	908
Jack pine	do	6 by 6	1, 210
Eastern white pine Red pine White spruce	Medium to poor	6 by 6	1, 210
Jack pine	do	4 by 6	1, 815
Hardwoods	Good to medium	6 by 6	1, 210
Hardwoods	Medium to poor	4 by 6	1, 815

For special purposes, such as erosion planting or where spruce is planted with the idea of removing part of the stand for Christmas trees, denser plantings up to 4 by 4 feet (2,722 trees per acre) may be justified. There is a possibility that hardwoods should be planted closer than recommended in order to avoid excessive limb development.

Organization of the Planting Operation

The planting operation should be planned in advance, taking into consideration the area to be planted, the number of trees that will be planted per man per day, and the number of men required to do the job in the time available in one or more planting seasons. The camp or camps, if needed, should be carefully located as near to the planting site as possible, and yet accessible to a road or trail by which equipment and stock can be brought in (37).

Local men, farmers, and settlers in the vicinity usually make the best planters. They are likely to be available in successive years, and their accumulated experience will make their help increasingly valuable. Such men take more interest in the work at the time and are more interested in the plantations after they are established.

Foremen, straw bosses, and others supervising the planting operation should be thoroughly versed in the techniques and procedures to be employed. New planters should be trained for a day or two in handling the tools to be used. After that has been mastered, they should be allowed to plant for another 2 or 3 days in a training crew, where the main emphasis will be on the technique of planting. When their abilities are definitely evident the planters should be sorted into fast, medium, or slow crews, so that each man can plant with others of similar abilities.

Ordinarily, one foreman cannot adequately supervise a crew of more than 15 men. However, if he is given 2 experienced subforemen or straw bosses, he can handle 2 such crews. The main efforts of supervision should go into: (1) Checking each planter several times a day to see that he is planting correctly at the desired spacing and keeping his trees well covered with moist sphagnum moss or burlap; (2) keeping the crew properly lined out and held together; (3) seeing that stock and water is distributed as needed; and (4) seeing that each man accomplishes a proper day's work.

Each crew should have a stock man who will see that the bales or crates are kept moist and shaded; that the unused stock within them is kept well packed; that the planters' boxes are well packed with moist moss each time their stock of trees is replenished; that stock is used in the proper order, i. e., stock out of the nursery longest is used first; and that the foreman is informed of the amount of stock on hand at the close of each day.

Crew members should proceed, as nearly as possible, abreast of each other when planting furrowed areas. To plant scalped or unprepared areas, it is best to have the crew operate in a diagonal line or echelon. On unprepared areas some sort of guide, such as flags, poles, etc., should be provided to insure reasonably straight rows and to make certain that no part of the area is missed.

A new method of crew organization, which is reported to increase planting efficiency, has recently been used in Oregon.[19] Known as the unit-planting system, this method provides for each planter to work alone in an area selected by the foreman as representing about a day's work for one man. In the morning each man carries in enough trees to last him for the day, his own water bag, and his lunch. This eliminates the need for stock men and water carriers. Since he is on his own, each planter knows that his production as well as any excellencies or deficiencies of his planting can be attributed directly to him by the foreman. This has a tendency to keep each man hewing to the line at the pace best suited to himself. As applied by its originator,

[19] Described by Ross J. Bowles, chief forester, C. D. Johnson Lumber Corp., Toledo, Oreg., in letter dated September 8, 1945. [On file Lake States Forest Experiment Station.]

this method of crew organization has increased the number of trees planted per man-day and reduced overhead. Although developed with crews of 15- to 17-year-old boys, the unit-planting system should be effective with certain other classes of labor.

Large-scale planting, covering a series of years, requires the services of a trained man to make plans, prepare maps, organize crews, and supervise the work. More detailed discussion of such operations can be found in United States Department of Agriculture Bulletin 475 (*80*).

When to Plant

Success is most likely to attend reforestation if the trees are planted in a dormant or near-dormant state, in moist soil, during cool days. Cloudy days with high humidities and low wind velocities are particularly favorable for planting. In the Lake States good planting days may occur almost any time from April to December, but they are most apt to occur in the spring or fall; consequently the great bulk of the planting is done during those two seasons.

SPRING VERSUS FALL

Experience indicates that better initial survival results from spring planting in the Lake States. This is particularly true on the loams and heavier soils where fall planting usually results in serious losses caused by frost-heaving. These points are well illustrated in the following tabulation of the results of an experiment carried out in eight different localities on the Superior National Forest in Minnesota (*30*).

	First-year survival of 2-0 red pine	
	Planted spring of 1936 (percent)	*Planted fall of 1935 (percent)*
Soil class:		
Light	56	33
Medium	70	36
Heavy	96	17
Average, all classes	66	33

These findings attain added significance when it is realized that the fall of 1935 was favorable, followed by a good winter, and that the spring of 1936 was rather dry and unfavorable for planting in that locality.

A survey of older plantations in Minnesota, Wisconsin, and Michigan, most of them on the lighter soils, showed that 20 years after planting, those established in the spring had on the average a survival 8 percent higher than those established in the fall. Furthermore, a recent analysis of 1- to 3-year-old national forest plantations in the same States showed that in the case of jack pine, eastern white pine, and white spruce, the survival of trees planted in the spring was from 9 to 27 percent greater than for those planted in the fall. In addition, in an experiment on the Huron National Forest, 2-0 jack pine planted in the spring of 1937 showed from 8 to 17 percent greater survival at the end of the first year than did the same kind of stock planted on the same site in the fall of 1936.

Not all of the extra mortality associated with fall planting is due to frost-heaving. Even on the lighter soils, where frost-heaving is not a problem, spring plantings survive better than fall plantings. Undoubtedly an important cause of fall losses is excess transpiration, particularly in stock with comparatively long, succulent tops. That this factor causes heavy losses—up to 75 percent mortality—in such stock, usually within a few weeks after fall planting and before snows or severe winter temperatures have set in, has been noted over a period of several years in experimental plantations on the Huron National Forest. The roots of the fall-planted trees are dormant and cannot supply any moisture demands of the tops until the following spring, whereas the roots of spring-planted trees are usually in growing condition and can establish intimate contacts with the soil almost immediately.

Despite the abundant evidence that better results are obtained with spring planting than with fall planting, there are some advantages in fall planting: (1) The planting season is apt to be longer and is more certain once it has started; there are less apt to be unseasonable dry or warm spells in the fall than in the spring. (2) On the lighter sandy soils results are apt to be nearly as good with fall planting as with spring planting. (3) The planting stock is not likely to break dormancy during the planting season. (4) Where rural labor must be depended on, fall coincides better with periods of slack work than does spring.

The safest and most general rule is to plant the trees as soon as the ground can be worked after the frost goes out in the spring, and before the tree buds have opened and new growth is started. It is therefore desirable to obtain the trees from a nursery as near to the planting site as possible. Trees for spring planting should be ordered in the winter and for fall planting not later than the preceding spring. The beginning of the spring planting season is between April 1 and 10 in the warmer sections such as lower Michigan, and about April 15 to May 1 in the northern part of the region. With favorable weather, planting can be continued until early in June, although the later plantings are likely to prove less successful than the earlier ones (*37*).

Planting should not be undertaken when there has been more than a week of dry weather, if it can be avoided. It is best to heel in the trees where they can be watered, and wait until rain comes before continuing. However, on large jobs where many men are employed such a plan may not be feasible (*37*).

Fall planting may begin with the first good rains in September and continue through October and sometimes November. Planting too late in the fall is undesirable. Hardwoods should not be moved and planted in the fall until they have dropped their leaves. Species that start their growth very early in the spring, such as European larch, are more likely to succeed when planted in the fall. Drought periods should be avoided in planting. In general, the fall is likely to be a little drier than the spring (*37*).

Spring planting can be begun several days earlier, and often before plowing is possible, if furrows have been plowed the previous fall, because furrows thaw out before the adjacent sod. In the fall, planting in furrows previously plowed may begin immediately after the first good rain. It would often be impossible to plow and plant immediately at that time because the soil below the surface would still be too dry. Plowing the furrows well in advance of planting, therefore, increases the length of the planting season both in spring and fall.

Under favorable conditions, successful planting can also be done in the summer (*91, 57*). The results of several small exploratory tests conducted in lower Michigan over the past 20 years have shown that summer plantings ocasionally may be superior to spring or fall plantings. However, this anomaly occurred only when the conditions surrounding the summer plantings were more favorable (good soil moisture and cloudy, cool weather) than those surrounding the compared spring or fall plantings. Since it is only in exceptional cases that summer conditions are more suitable for planting than spring or fall, planting between June 1 and September 15 cannot be recommended as a general rule. Aside from the unlikelihood of favorable planting conditions, the greatest objections to summer planting stem from the difficulty of caring for large amounts of stock between the nursery and the planting site, and the rapidity with which weather conditions may change.

EXTENDING THE PLANTING SEASON

Because the spring planting season is the most favorable one and yet the most uncertain, efforts have been made to extend it by artificial means. Since conditions at the planting site cannot be controlled, these efforts have gone into lifting the stock in the nursery before the tips have begun to grow and holding it in cold storage (in a dormant state) until conditions at the planting site are favorable for its use.

Observations near Roscommon and on the Manistee National Forest in lower Michigan show that jack pine, red pine, eastern white pine, and white spruce planted after the shoots have grown noticeably lose those succulent shoots by the end of the season. Whether this drying up of the tips is more serious than the loss of height growth for the year through cold storage cannot be said definitely. It seems logical, however, to assume that trees planted after the shoots have grown are weakened somewhat and that avenues for the entrance of injurious fungi are provided by the dead tips.

Stock storage facilities are now available at several of the Forest Service nurseries in the Lake States, and tests are under way to determine the best storage practices for various kinds of stock. The first year's results of one such comprehensive storage test conducted near Rhinelander, Wis., showed that cold storage for periods of 1, 2, 3, 4, and 5 weeks at 50° F. had no adverse effect whatever on nursery survival—the stock was transplanted in lieu of field planting—of jack pine, red pine, or eastern white pine. The longest period of storage (5 weeks) did, however, cause a considerable dropping off in size of the stock when measured the following fall. This indicates that if spring transplanting is done in Lake States nurseries the stock should certainly be in the ground before the end of May.

The 5-week storage period at 50° F. caused a significant drop in survival of 2-2 white spruce transplanted in the nursery. This indicated, as had been suspected, that white spruce is more sensitive to storage than other species. Its nursery survival for the 0-, 1-, 2-, 3-, 4-, and 5-week storage periods was 99, 100, 96, 96, 93, and 81 percent, respectively. This species showed the same general tendency to drop off in size with the lengthening of the storage period—the 5-week storage lot had the smallest stock in the fall. This can be attributed very simply to the reduction in length of the growing season, because of prolonged storage.

Planting Aspen and Brush Lands: A Special Problem

Within the northern Lake States there are some 6 million acres of commercial forest land covered with low-quality aspen and up to 4 million additional acres covered with brush.[29] Much of this land formerly bore valuable coniferous forests, but, as a result of logging and subsequent fires, it has been reclaimed by brush and defective aspen of little or no value as wood crops. An estimate of the area of off-site aspen lands in need of planting to convert them to valuable forests is given in table 16.

Observations within the region indicate that only under the most favorable conditions will aspen or brush be converted to valuable conifers and hardwoods by natural processes within 100 years. In most cases it will take much longer than that. In view of these circumstances it becomes of considerable importance to replace the low-value aspen and brush with valuable conifers and hardwoods by artificial means; that is, through reforestation, where wood products are to be the main objective of management. A considerable portion of the aspen and brush lands may be enough higher in value for wildlife or other purposes to warrant keeping it as it is.

About one-half of the off-site or low-quality aspen stands are either young enough or close enough to maturity to be plantable under the suggested conversion methods. The other half will become plantable as they reach maturity in the next 20 to 30 years.

Although there has been a natural predilection for easy planting chances, considerable planting of pine and spruce has been done in the Lake States under aspen and brush for the purpose of converting such stands to the more valuable species. Unfortunately, much of this planting was waste effort, chiefly because of faith in the nurse crop theory, which assumes that without any further aid from man the overstory will protect the planted trees during early life, and then obligingly open up at the proper time and allow them to pass through and grow unmolested. Experience has proved this theory a delusion. Actually such underplanting can be successful only if constant attention is given to the removal of competing vegetation. With the pines the overstory removal must begin early; with spruces it may be delayed somewhat longer.

Tests carried out by the Lake States Forest Experiment Station, chiefly on the Chippewa National Forest, during the past 10 years have

[29] The brush type (included in estimated totals, table 3, p. 11) is made up of a variety of species, prominent among which are American and beaked filbert, *mountain maple, various dogwoods, and speckled alder.* The aspen type is characterized by the following species: Quaking aspen, bigtooth aspen, balsam poplar, and paper birch.

TABLE 16.—*Estimated off-site aspen land in need of planting in the Lake States, by ownership classes and species suitable for planting*

[Thousand acres, i. e., 000 omitted]

State and unit [1]	Aspen type [2]	Upland off-site aspen [3]	Ownership: Federal	Ownership: State	Ownership: County and municipal	Ownership: Farmers	Ownership: Other private	Species suitable for planting: Eastern white pine	Species suitable for planting: Red pine	Species suitable for planting: Jack pine	Species suitable for planting: White spruce	Species suitable for planting: Northern red oak
Minnesota:												
Northeastern	2, 305	639	183	83	200	53	120	100	275	255	9	----
Central pine	2, 322	1, 120	172	250	320	200	178	200	507	403	10	----
Rainy River	956	202	13	122	21	15	31	40	88	68	6	----
Hardwood	276	31	(4)	0	1	29	1	7	12	8	2	2
Prairie	153	(4)	(4)	0	0	0	0	----	(4)	(4)	----	----
Total	6, 012	1, 992	368	455	542	297	330	347	882	734	27	2
Wisconsin:												
Northeastern	1, 542	741	130	40	154	134	283	160	285	228	11	57
Northwestern	2, 139	702	107	17	215	141	222	153	270	216	9	54
Central	834	419	1	3	33	279	103	92	161	129	5	32
Southwestern	95	2	(4)	(4)	(4)	2	(4)	0	1	1	0	0
Total	4, 610	1, 864	238	60	402	556	608	405	717	574	25	143
Michigan:												
Eastern Upper Peninsula	1, 006	301	58	93	1	22	127	60	139	93	9	----
Western Upper Peninsula	1, 061	413	62	83	2	25	241	85	179	127	10	12
Northern Lower Peninsula	2, 602	1, 526	148	415	5	288	670	348	586	510	5	77
Southern Lower Peninsula	302	103	1	5	(4)	71	26	24	50	21	----	8
Total	4, 971	2, 343	269	596	8	406	1, 064	517	954	751	24	97
Total, Lake States	15, 593	6, 199	875	1, 111	952	1, 259	2, 002	1, 269	2, 553	2, 059	76	242

[1] These are the Economic Units used by the Forest Survey. [2] Exclusive of deforested area. [3] On former pine types. [4] Less than 500 acres.

brought to light certain essential requirements for successful conversion practice (*66*). Briefly, these requirements are as follows:

1. Areas cut or burned within the past 15 years, particularly on the better soils, should be first choice for conversion. Aspen more than 10 feet in height growing on good soil should be allowed to reach maturity before converting it to conifers. Aspen on poor soil may be converted at any age, but the task becomes very expensive if undertaken in stands more than 15 feet in height.

2. Planting should be confined to the following species: jack pine, red pine, eastern white pine, white spruce, and possibly Norway spruce. The choice of species should be governed by the soil. (See recommendations in table 7.)

3. Only thrifty, stocky, high-quality planting stock with a minimum height of 6 inches should be used. Classes of stock recommended are: jack pine 1-1; red pine 2-1, 1-2, or 2-2; eastern white pine 2-2; white spruce and Norway spruce 2-2 or 2-3.

4. To permit satisfactory growth of the plantation, the aspen overstory should be thinned enough to allow at least 50-percent light to penetrate it. However, each planted tree should receive some shade for part of the day. Not only must the overstory be thinned, but to insure satisfactory survival it is also imperative that competition from shrubs and other lower vegetation, such as bracken fern, bush honeysuckle, and large-leaved aster, be removed. Early trials indicated that both operations could be accomplished at one time by use of the Olympic plow (fig. 17).[21] However, sprouting of aspen and brush was so prolific in the cleared strips that subsequent release needs were almost prohibitive. The Minnesota-type pusher plow, which is a heavy planting plow mounted in front of a tractor, is more satisfactory. Probably the most effective ground preparation and reduction of competition can be accomplished with the Athens-type disk plow, although this may result in almost complete and immediate elimination of the overstory.

5. The soil must be prepared thoroughly in advance of planting. Well-made scalps are satisfactory but furrowing or disking is usually cheaper and more effective in reducing competition. To carry out conversion practices at a reasonable cost, it is desirable to use special heavy equipment that makes it possible to perform the thinning, removal of undergrowth, and ground preparation in one or, at most, two operations. Furrows should be spaced as closely as is feasible.

6. Trees should be planted closely, about 4 feet apart, in the furrows, or 4 by 6 feet in scalps, to permit early closing of the crowns with attendant early reduction of competition. The wedge or center-hole methods of planting should be used. Planting should be done only in the spring on heavy soils. Either spring or fall planting may be done on the sandy soils.

7. From one to three annual weedings should be made to enable the planted conifers to gain ascendancy over the competing undergrowth. Care must be taken to prevent the establishment of a sod around the trees, which may result from too many weedings.

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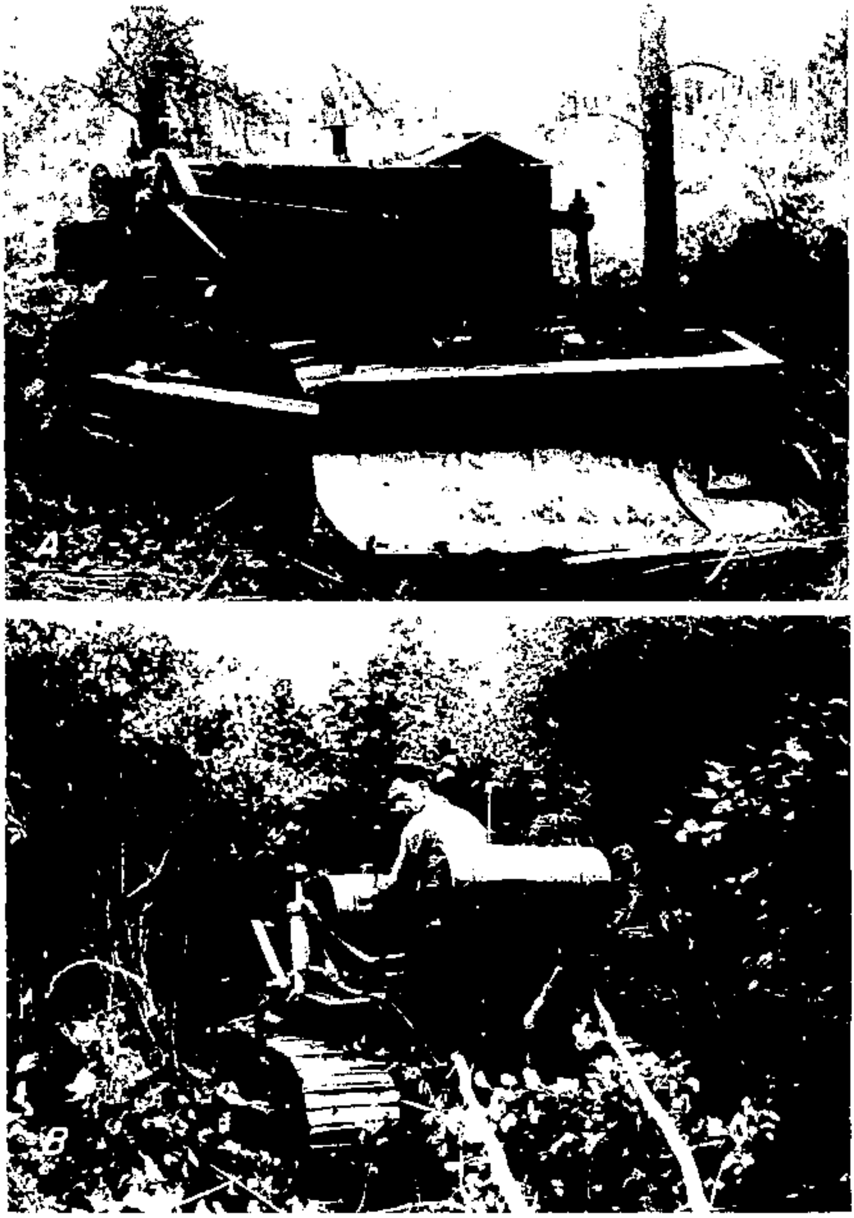
[21] The Olympic plow is a modified bulldozer having a heavy V-shaped share built of welded grader blades, beneath which is attached a heavy shoe to prevent undue digging. The bulldozer frame with blade is mounted on a 35-horsepower armored tractor. It clears a strip about 5 feet wide free of brush and small aspen.



[illegible]

[illegible] caterpillar tractor, Chippewa [illegible] M[illegible] B [illegible] plow shown starting through [illegible] way through dense brush or aspen [illegible]

8. After the planted trees have reached a height of 4 to 5 feet the final removal of the overstory should be started (fig. 18). It is desirable that the removal be done in more than one operation so as to give the conifers time to close their canopies before they are completely exposed. If the overstory trees have no commercial value they can be removed by girdling.

F-443271

FIGURE 18.—View in 1937 of Jack pine planted in the fall of 1934. Three weedings have been made and the remaining aspen trees just girdled.

9. The plantations must be protected from fire indefinitely, and from the depredations of snowshoe hares, rabbits, and deer until the trees have reached sufficient size to be immune from such damage.

Using the heavy equipment now available, heavy planting plow or heavy disk plow (fig. 19), aspen or brushlands can be converted to conifers at a probable average prewar cost of $20 to $35 per acre. This cost includes preparation of site, rabbit control, planting stock, planting, and four weedings. Although it is high, it is not out of reason, and is quite low when compared with the $30 to $100 per acre required when heavy equipment is not used (*66*).

Large-scale projects of converting aspen and brushlands to conifers cannot be recommended until administrative experience in such work has been accumulated. However, small-scale conversion projects should be carried on under several conditions throughout the region to provide such experience (69). After experience has been gained, the conversion of aspen and brushlands may be given high rank among useful conservation projects to be undertaken during slack periods of employment.

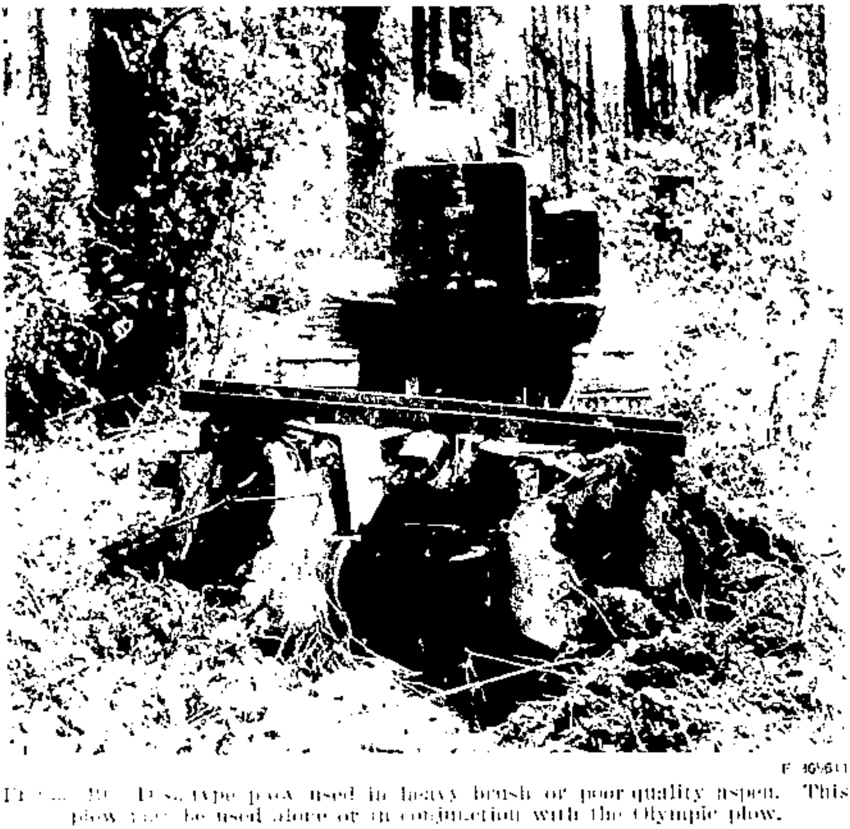


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FIGURE 30.—Disk-type plow used in heavy brush or poor-quality aspen. This plow may be used alone or in conjunction with the Olympic plow.

Planting Food and Shelter for Wildlife

One of the increasingly valuable products of the forest, chiefly for recreational purposes, is wildlife. The game birds, fur bearers, and other fauna that make up the forest wildlife have certain requirements that must be met if they are to thrive in desired numbers. In general, they need a variety of plants to provide food throughout the year, occasional openings in the forest, and occasional dense coverts for shelter. These requirements should be taken into consideration when planning any large-scale planting program.

Because of variations in soil, kind and density of forest cover, moisture conditions, and other physical and biological factors, conditions in this region ordinarily should be favorable for wildlife species, at least on forests that are given some semblance of management. Locally, moreover, large-scale successful planting and effective fire protection may produce extensive areas of dense forest growth predominantly of one or two species. Where such conditions prevail, some measures will have to be taken if wildlife species are to be maintained in relative abundance. Openings of ½ to 2 acres, to make up at least 10 percent of the area, should be provided, and if browse, berry, and edible-seed plants are lacking, they should be planted therein (fig. 20). One authority (*24*) recommends that out of each quarter section in the planting area, a 40-acre patch be omitted from the regular program and planted with some game-food species.

F-45009

FIGURE 20.—Favorable cover conditions for deer. Small opening filled with western thimbleberry, common red raspberry, and mountain maple. The surrounding forest is chiefly black spruce, northern white-cedar, and balsam fir. (Photo courtesy of Fish and Wildlife Service.)

Over 100 species of trees and shrubs, which are hardy in the Lake States, are known to provide wildlife foods (*3*, *36*). The majority of these plants also provide cover for animals. Special planting of trees and shrubs for wildlife purposes ordinarily, however, should be limited to species that furnish food during the seasons when it normally is scarce. The most useful wildlife-food plants, hardy in the Lake States, are as follows (*33*):

Plants:	*Preferred use*
Apples	Fruit and browse.
Balsam fir	Browse.
Bearberry	Fruit.
Beech	Do.
Birches	Browse.
Blackberries	Fruit.
Blueberries	Fruit and browse.
Black cherry	Do.
Chokeberries	Browse.
Virginia creeper	Fruit.
Dogwoods	Fruit and browse.
Filberts	Browse.

Plants—Continued	*Preferred use*
Wild grapes	Fruit.
Hawthorns	Do.
Hemlock	Browse.
Huckleberries	Fruit and browse.
Oldfield common juniper	Browse.
Maples	Do.
Oaks	Fruit and browse.
Poplars	Browse.
Sumacs	Fruit and browse.
Viburnum	Fruit.
Northern white-cedar	Browse.
Winterberry	Fruit.
Checkerberry wintergreen	Browse.

The following list includes the trees and shrubs that are important food sources for several important wildlife species in the Lake States (*33*).

Bird:	*Important food plants*
Bobwhite	Apples, American bittersweet, wild grapes, oaks, shining sumac, and common winterberry.
Wild ducks	Dogwoods, wild grapes, and oaks.
Pinnated grouse	Birches, chokeberries, filberts, and poplars.
Ruffed grouse	Birches, American beech, blackberries, blueberries, cherries, dogwoods, filberts, wild grapes, hawthorns, eastern hophornbeam, huckleberries, oaks, poplars, sumacs, and viburnum.
Sharp-tailed grouse	Alders, birches, blueberries, cherries, huckleberries, junipers, poplars, wild roses, and willows.
Ring-necked pheasants.	Dogwoods, wild grapes, hawthorns, wild roses, sumacs, and American cranberrybush viburnum.
Nongame birds	Blackberries, blueberries, cherries, Virginia creeper, dogwoods, wild grapes, greenbriers, hawthorns, huckleberries, oaks, raspberries, wild roses, serviceberries, and sumacs.
Animal:	
Beaver	Alders, birches, poplars, and willows.
Black bear	Apples, bearberry, American beech, blackberries, blueberries, huckleberries, oaks, and raspberries.
Cottontail	Apples, basswood, American elm, eastern hophornbeam, American hornbeam, black locust, red oak, red maple, and sumacs.
White-tailed deer	Apples, white ash, American beech, black birch, paper birch, yellow birch, black cherry, chokecherry, balsam fir, eastern hemlock, oldfield common juniper, red maple, striped maple, sugar maple, red oak, sumacs, northern white-cedar, witch-hazel, and Canada yew.
Elk	Ashes, basswood, American beech, birches, and maples.
Gray fox	Apples and wild grapes.
Red fox	Apples, blueberries, black cherries, and wild grapes.
Snowshoe hare	Speckled alder, birches, balsam fir, pines, spruces, tamarack, northern white-cedar, and willows.
Moose	Birches, balsam fir, striped maple, mountain-ashes, poplars, and willows.
Raccoon	Apples, American beech, black cherry, Virginia creeper, wild grapes, oaks, and viburnums.
Eastern skunk	Blackberries, cherries, dogwoods, plums, and raspberries.
Gray and fox squirrels.	American beech, cherries, filberts, and oaks.

Many of the species in the list have had little or no place in past reforestation work consequently, their use involves the solution of a

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host of new problems by the nurserymen and planters. Since most of these problems are still largely unsolved and since planting for wildlife purposes is very new, only general directions for such work can be given. A fact to bear in mind is that many of these species also provide food for certain beetles, the adults of the white grubs. A large supply of such plants might lead to severe grub infestation in nearby coniferous plantations. Another point to consider is that wild currants or gooseberries are alternate hosts for white pine blister rust, and chokecherry is suspected of harboring a peach disease. Actually some 70 species have been grown in Lake States nurseries for wildlife purposes, but the tendency now is to simplify both nursery and field planting problems by settling on a list of 10 to 15 species for this purpose.

Much of the rather limited planting for wildlife purposes so far done in this region has been a failure, chiefly for two reasons: (1) Selection of species poorly adapted to the site, and (2) browsing of the planted stock before it could establish itself. The trend among wildlife specialists now is toward providing wildlife food and cover chiefly through management of natural growth, and to resort to planting only in special cases.

The correlation of regular reforestation work with wildlife requirements can contribute a great deal to maintaining favorable conditions for wildlife. This can be accomplished by such practices as: (1) Avoiding the planting of areas of high value for wildlife as they are; (2) preserving as much as possible of any natural vegetation valuable for wildlife purposes in the course of ground preparation, planting, or subsequent release work; (3) establishing mixtures of conifers and hardwoods; (4) block planting; and (5) occasionally opening an edge.[22] Such matters should be taken into consideration in drawing up reforestation plans.

In the light of present sketchy knowledge, the following practices are recommended:

1. Use good, sturdy stock with a top length of at least 6 inches and a well-developed root system. For conifers this will usually mean 2-2 or larger stock, and for hardwoods 1-0 or 2-0. For species that can be propagated by cuttings, only well-rooted cuttings should be used. Although the transplanting of wildlings may be successful, nursery-grown stock should be given preference.

2. Use a method of planting that will give good root distribution. Except for stock that is predominantly taprooted (suitable for slit planting), the wedge or center-hole methods should be used.

3. Although furrowing ordinarily will not be feasible for wildlife plantings, since planting is usually done in patches, ground preparation should be thorough. Scalps should be large (24 inches square) and well made.

4. Species should be planted only on sites to which they are well adapted.

5. The planted trees or shrubs should be given adequate release and protection until they are able to maintain themselves. Obviously wildlife plantings should be made only where there is sufficient population control to prevent overbrowsing.

[22] In wildlife management, an edge is a boundary between food or cover types.

Planting for Erosion Control

Soil erosion is not especially serious in the northern Lake States because the topography is in general relatively flat and because the great bulk of the area is covered with vegetation of some sort. Some soil erosion, however, does take place almost wherever the soil is cultivated, and locally it may present a serious problem. In the southern part of the Lake States, especially in the nonglaciated areas, soil erosion has assumed serious proportions.

Nature controlled erosion with vegetation, and man has found no better means of preventing soil wastage. Terraces and other mechanical or artificial structures minimize soil losses on cultivated fields, but a complete job can be done only with the use of plant cover (*70*). All kinds of plants help to control erosion, but trees and shrubs usually produce a more permanent and valuable cover.

Since eroded areas usually have been denuded of the fertile topsoil, they must be reclaimed by plants capable of pioneering on barren, low-quality soils. Among plants having such characteristics, first choice should be those that have far-reaching root systems or those that have the habit of making dense growth. The ability to produce valuable crops must be considered as subordinate to the first two characteristics.

Among the trees suitable for erosion planting in the Lake States may be listed:

1. Black locust, a favorite tree for erosion planting. However, it is not well suited to poor, sandy soils and is not particularly thrifty in the northern Lake States.
2. Eastern cottonwood, a hardy, rapid-growing tree suitable for planting in the bottoms of gullies or in other situations where it can obtain a fair amount of moisture.
3. The willows, useful under the same conditions as cottonwood.
4. Scotch and Austrian pines, useful for planting on sand dunes and blows in lower Michigan. Scotch pine has also shown value for reclaiming eroding stream banks in the same locality.
5. Red pine and jack pine which have shown considerable merit for planting on "blow" sand.
6. Common juniper, eastern redcedar, oaks, American elm, Siberian elm, American plum, Siberian peashrub, boxelder, Russian-olive, and green ash.

Shrubs suitable for erosion planting include: Sweetfern, filbert, red mulberry, hawthorns, serviceberry, blackberry, raspberry, wild rose, sumac, American bittersweet, bristly greenbrier, Jerseytea ceanothus, wild grapes, Virginia creeper, dogwoods, bearberry, blueberry, huckleberry, elders, American cranberrybush viburnum, arrowwood viburnum, blackhaw, snowberry, and Tatarian honeysuckle (*41*). Most of these plants are useful for wildlife purposes also.

Methods of reclaiming gullies by planting have been worked out in the South (*43*) and elsewhere, but are not discussed in this publication since gully erosion is of minor occurrence in the northern Lake States.

The control of stream bank erosion is a problem in localized areas. Small eroded patches can be controlled by planting cuttings of willow or cottonwood near enough the water's edge so that they will remain moist until the roots have become established. Long cuttings placed in trenches with the lower end extending into moist soil have been effective in some instances. Scotch pine and jack pine are probably the best species to plant on the drier, eroded parts. Larger eroded patches most likely will require some mechanical adjuncts, such as deflector logs, suitably placed to turn the force of the stream away from the eroded spot; this will prevent undercutting of the bank and allow the planting to become effective.

Wind erosion is much more serious than water erosion in some parts of the northern Lake States, particularly in certain parts of lower Michigan where sand blows and dunes are familiar features of the landscape. Small blows often can be controlled simply by planting trees around the borders. They can be controlled more quickly by covering the exposed area with brush and planting it with trees either before or after brushing, or by planting it with beachgrass (*Ammophila*). The beachgrass, of course, does not give promise of a useful crop as do tree plantations.

Large blows and dune areas can be controlled similarly by a combination of broadcast brushing and tree planting. Where there is much sand movement, as on dunes, good success has been obtained by spreading brush over the exposed area during the late fall or winter and then planting trees in the brush-covered area the second spring following, when the sand has become somewhat stabilized. On large sand blows it has been found satisfactory to spread the brush soon after the trees have been planted.

Conifers are preferred for this work, since they are particularly effective in reducing wind velocities during the late fall, winter, and early spring, when most of the soil blowing takes place. Jack pine and Scotch pine, because of their hardiness and rapid growth, are preferred (fig. 21). Red pine also does quite well, but its effect is less immediate because of its slower growth.

Cost of Planting

There are three distinct elements in the cost of reforestation—establishment, maintenance and protection, and taxes on the land.

ESTABLISHMENT

The cost of establishment includes such items as nursery stock (or seed, in the case of direct seeding), ground preparation, and the actual planting or seeding operation. Each of these items may vary a great deal according to conditions.

In the case of nursery stock, for instance, transplants usually cost two to five times as much as seedlings of the same species. Because of variations in such factors as nursery losses and cost of seed, the price of the same kind of stock for a given nursery may also differ considerably from year to year.

The cost of stock varies according to whether the operator grows it himself, purchases it from a public nursery,[23] or purchases it from

[23] Stock for forest planting can be purchased from State nurseries in Michigan and Wisconsin, and since 1947 in Minnesota where it is produced in cooperation with the Federal Government under Section 4 of the Clarke-McNary law. See page 166 in appendix for further information concerning private purchase of planting stock from State nurseries. Forest Service nurseries are operated primarily for the production of planting stock for use on the national forests. Such stock cannot be sold or given away except as surplus to the national forest requirements.

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FIGURE 21.—*A*, Jack pine 1-1 planted on open sand blow. Without broadcast brush between the rows, slow growth is to be expected. *B*, Same area after 7 growing seasons. In row to left, along brush windrow, trees are 1 to 7 feet tall; in other rows they are 1 to 5 feet tall. *C*, Part of same area covered with broadcast brush at time of planting; the trees are 7 to 10 feet tall.

a commercial nursery. An operator who expects to plant on a large scale over a long period of years may find it cheaper and more expedient to grow his own stock, especially where he cannot obtain it from public nurseries. Smaller operators will find it more economical to buy stock from public nurseries that sell at prices close to the cost of production. Ordinarily commercial nurseries are engaged chiefly in producing stock for ornamental and orchard purposes in small numbers and large sizes; hence, for forest planting purposes their prices, which include a fair profit on the cost of production, are likely to be higher. Accordingly, suitable planting stock may cost anywhere from $1 to $20 per thousand trees, prewar rates.

The cost of ground preparation depends, first of all, on whether or not furrowing, disking, or scalping is used. It depends also on the type of equipment used, the density and kind of cover, the relative amount of rocks, stumps, and other physical obstacles, the topography, and the kind and condition of the soil. On large-scale planting operations in the Lake States region, prewar costs for scalping ordinarily ranged from $4 to $10, furrowing from $2 to $4, and disking from $3 to $10 per acre.

The planting operation itself varies in cost according to the spacing or number of trees planted per acre, the method of planting, physical obstacles to planting (such as brush, rocks, and soil texture and condition), type of labor, and wage rates. On large-scale planting operations before World War II, the cost usually averaged between $3 and $7 per acre. Machine planting—including ground preparation—has cost from $4 to $5 per acre on sizable operations in Wisconsin.

In this region the cost of the entire establishment operation usually ranged from $10 to $20 per acre and averaged close to $15 per acre before the war. Under very favorable conditions costs have gone as low as $3 per acre and at the other extreme as high as $80 per acre.

MAINTENANCE AND PROTECTION

Plantation maintenance includes weeding, release cuttings, thinnings, and other cultural measures necessary to maintain a thrifty, well-stocked plantation after establishment. Protection consists primarily of preventing damage or destruction by forest fires, but cash outlay may also be required to protect plantations from insects, diseases, birds, mammals, and other enemies.

The cost of maintenance necessary during the early life of a plantation is difficult to estimate but probably will average $10 to $15 per acre at prewar wage rates. The annual cost for fire protection by public agencies averages about 3½ cents per acre in the Lake States, and it has been estimated that complete fire protection would require an expenditure of about 5 cents per acre each year. The cost of fire protection has to be borne whether an area is planted or not. As a matter of fact, open grassy areas are among the worst fire hazards.

TAXES ON THE SOIL

In the Lake States taxes on cut-over and denuded lands, such as usually are considered for forest planting, range from about 4 to 50 cents per acre. Generally speaking, they are low on the sandy lands of lower Michigan where the frequent failure of attempts at farming over a period of years has proved the land's low value, and they are higher in the developing parts of northern Wisconsin and Minnesota. Variations in tax rate may mean the difference between a profit and a loss in the results of the planting operation. Rates much above 15 cents per acre are apt to preclude profitable planting.

Some efforts have been made to alleviate the tax burden on forest lands through the passage of special forest tax laws in each of the three Lake States, but despite frequent amendments these laws have failed to attain any widespread application (*20*). In general, the laws provide for a reduced annual tax on forest land registered under them and an additional payment based on a specified percentage of the value of products when they are removed from the forest. During the period of reduced taxation the State pays local governmental units a specified sum per acre in lieu of the reduced taxes.

Private landowners planning a reforestation program should investigate their State laws (Forest Crop Law in Wisconsin, Commercial Forest Reserve Act in Michigan, and Auxiliary Forest Law in Minnesota) so that they may decide for themselves whether it is more advantageous to pay the regular taxes or to come under the special provisions of these laws. A Michigan law that limits taxes to 15 mills on land valued at $10 per acre or less has reduced taxes on forest lands so that they are often less than they would be if the lands were placed under the provisions of the Commercial Forest Reserve Act.

HOW TO MAINTAIN FOREST PLANTATIONS

Plantation Enemies and Their Control

The success of planting is limited by various causes of damage or failure (fig. 22). Many of these can often be eliminated or reduced by taking the right preventive measures in time, but for others there is little prospect of control. In the Lake States the most common causes of loss or injury to plantations have been found to be climatic conditions (including heat, drought, freezing, snow and ice damage, and flooding); competition; poor stock and careless planting; fire; animals (such as snowshoe hares and rabbits, cattle, and deer); insects; and diseases.

SOME DIFFICULTIES IN DIAGNOSIS

Although some agents of mortality leave such unmistakable imprints that it is very easy to determine what they were, the great majority of them do not. Another difficulty in diagnosis is that mortality often is induced by several factors acting in conjunction. Often the separate roles of each factor cannot be determined. Unless it is known what has happened in the locality, and unless examinations are made reasonably soon after death has occurred, accurate diagnosis cannot be made.

Physiological causes of loss are particularly hard to diagnose. Trees killed by drought, heat, freezing, excess transpiration, and such causes usually do not differ sufficiently in appearance to distinguish which factor brought about death. Consequently, it is necessary to know what has happened in the locality and then to make logical deductions in order to classify the cause of loss. In the case of fall-planted trees examined the following spring, losses due to physiological factors would be attributed to some form of winter damage, since neither heat nor drought could have been the cause. If the examination were not made until fall, however, all three factors might have played a part; the only possibility of distinguishing between them then lies in the greater deterioration of foliage (and to some extent a difference in its color) of the trees killed earlier, which probably are winter-killed trees.

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FIGURE 22.—A, Tamarack girdled by porcupine in northern Minnesota. (Photo courtesy of U. S. Fish and Wildlife Service.) B, Planted red pine killed by drought in lower Michigan sand plains. Poor root distribution that resulted from the bar-slit method of planting probably predisposed the tree to injury.

Biotic factors present similar difficulties. For instance, trampling injury looks little different whether caused by cattle, horses, or deer, and nipping damage caused by various rodents or ruminants is very similar in gross appearance.

CLIMATIC CONDITIONS

During the first few years following planting, while the trees are establishing themselves in their new environment, climatic conditions—in the absence of abnormal biotic conditions—are probably the most important factor determining success or failure of planting. In experimental plantations in lower Michigan, for instance, from 32 to 92 percent of the first-year losses, depending upon the severity of the season, have been caused by weather conditions. Throughout the life of the stand, of course, climatic factors play an important part, but their role is usually more critical during the early years.

Although high temperatures, very low temperatures, droughts, unseasonable frosts, heavy snow and sleet, strong winds, floods, and other climatic factors cause considerable damage to plantations, in general not very much can be done about it. There are, however, a few measures that can be used to reduce such losses. Stock of greater hardiness than is commonly planted can be used, and on open areas regular spacings can be varied to take advantage of the cool shade of the trees and bushes. In the future it may be possible to predict drought cycles by analyzing long-time weather records and to adjust planting plans accordingly. It may also be possible to delimit areas of high-drought frequency and either eliminate them from planting plans or give them special treatment.

Heat

Commonly in this region, prolonged periods during the summer with deficient precipitation (known as droughts) are also characterized by periods of excessively high temperatures. So drought and heat losses frequently occur together and ordinarily no distinction is made between them. However, some heat losses do occur during years when there are no droughts. For instance, the mortality record of drought and nondrought years for experimental plantings on the Huron National Forest was as follows:

	Percent of mortality in drought years		*Percent of mortality in nondrought years*	
	1933	*1936*	*1934*	*1935*
Cause of mortality:				
Deficient soil moisture	26	17	3	0
Heat	65	68	19	24

If any great time elapses after injury, it is next to impossible to distinguish between drought and heat damage. However, if the trees are examined within a month or two after injury, there are usually some symptoms that indicate heat damage. It has been noted that even under very severe conditions on the lower Michigan sand plains, trees with a diameter of more than one-half inch at the root collar are seldom killed outright by heat, although larger trees up to 4 inches in diameter at the root collar often are injured. On these smaller trees heat injury is made evident by a discolored ring of cooked cambium, usually within 1 inch of the soil surface. Shortly after such injury, there is a tendency for the bark to stick over the injured part, although it will peel easily both above and below. The wood at the point of injury becomes brownish in color. As disintegration proceeds, a dark growth of mold begins near the ground line, which can prove confusing.

In addition to the trees that are killed in drought years, there is usually a considerable number of generally larger trees that are injured but still remain alive. For example, in a 9-year-old natural stand of jack pine on the Huron National Forest, 28 percent of the trees were killed by heat and drought during the summer of

1936 and an additional 20 percent were injured, chiefly by heat. Such injured trees usually develop lesions near the ground line on the south to west side of the stem. It is only on very thin-barked trees, however, that the bark actually breaks open so that the lesions can be seen immediately. Usually the presence of lesions is denoted by a swelling of the stem or abnormal roughening of the bark.

That the type of injury and mortality described is actually the result of exposure to high temperature is evidenced by the following points: (1) Laboratory tests show that nursery stock is killed at temperatures of 127° to 136° F. after 2 hours' exposure in dry air; (2) field measurements prove that such temperatures and higher ones occurred at the soil surface in the open for periods of 2 hours or more several times during the summers of 1933 to 1936, and that they were particularly frequent in 1933 and 1936 (table 17); (3) some of the trees killed during drought years still had live roots when excavated, thus precluding drought as the cause of death.

TABLE 17.—*Occurrence of lethally high soil-surface temperatures in the open during comparable 2-week midsummer periods, Huron National Forest, Mich.*

Year	Occurrence of temperatures of—				Maximum duration at—		Maximum temperature
	127+° F. for—		135+° F. for—		127+° F.	135+° F.	
	2+ hours	5+ hours	2+ hours	5+ hours			
	Number	*Number*	*Number*	*Number*	*Hours*	*Hours*	*° F.*
1933	7	3	4	1	6	5	162
1934	5	1	2	0	6	4½	153
1935	3	1	1	1	7	7¼	160
1936	12	9	12	4	9	8½	175

Closely akin to heat damage is damage from sunscald. This injury is generally confined to larger trees and occurs during the winter when warm, sunny days stir the cambium into activity, usually on the southwest side of the stem. Such activity causes the tissue to die because water cannot be supplied to it. Sunscald also occurs during the summer when trees are given full release by removing overtopping trees. Sunscald damage, however, is of rare occurrence according to the results of a survey of older plantations in the Lake States. Only a fraction of 1 percent of the trees examined showed sunscald injury.

Drought

Droughts of varying intensity may be expected to occur almost annually in the Lake States. In many years, of course, the droughts may be mild, or they may be severe in restricted localities only. However, between 1921 and 1936, severe drought years of regional significance occurred several times. Accordingly, droughts are one of the foremost causes of injury to forest plantations in this locality.

The question of drought damage was introduced in the preceding discussion of heat damage. In experimental plantations on the Huron National Forest, Mich., drought has been next in importance to heat as a source of damage in young plantations. Over the region as a whole it is probably more important than heat, since it affects larger trees. On the Huron National Forest, for instance, planted red pine may suffer considerable drought damage up to an age of at least 15 years.

Drought injury is not concentrated near the ground line as is heat injury. Trees thus injured usually begin to die from the tips down. The needles of red and jack pines begin to yellow and then become rather a bright rust brown, gradually fading to dull brown. Often only the tops of the trees are thus killed before moisture conditions improve. Many planted red pine trees on the Huron National Forest have been stunted by such injury.

That trees actually died because of insufficient moisture was indicated on the Huron experimental plantations. Measurements of precipitation and soil moisture showed deficiencies sufficient to bring about death. Figure 23 shows the course of soil moisture fluctuations for 2 years; during 1935 there was no drought loss, but during 1936 17 percent of the mortality was caused by drought.

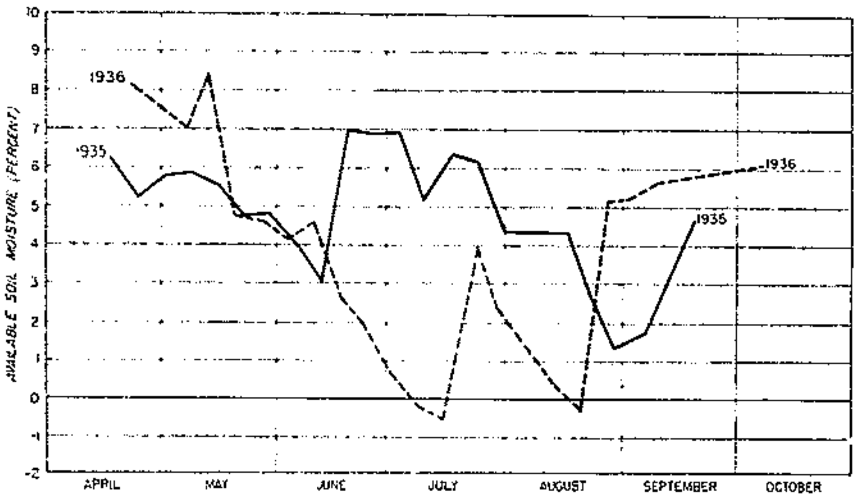

FIGURE 23.—Weekly fluctuation in available soil moisture content (soil moisture percent minus computed wilting coefficient), at a 6-inch depth, during a favorable year (1935) and a drought year (1936), Huron National Forest, Mich.

In the preceding discussion of heat, it was mentioned that drought and heat usually occur together but that there were heat losses in some years when no drought occurred. Conversely, experience on the Nicolet National Forest, Wis., in 1937, where a severe local drought occurred, indicated that heavy drought losses might occur without associated heat losses (75).

Winter Damage

Freezing is not a particularly important type of plantation damage in this region. It usually occurs only where exotic species or alien seed sources are used. For instance, in a Scotch pine source-of-seed plantation on the Superior National Forest, sources of central European origin had their tops frozen back to the snow line in the severe winter of 1935–36, but northern European and Siberian sources suffered no such damage. Similar differences appeared after the winter of 1947–48 (*77*).

The type of winter damage noted most frequently in this region, especially in first-year plantings, is that due to excessive transpiration of fall-planted stock with succulent tops. Such damage usually occurrs within a few weeks after planting, before real winter temperatures occur. Since the tops are not hardened, heavy transpiration often takes place. Because the roots are not yet established and because of slow movement of water under the lower soil temperatures prevailing at that time of the year, the drain is greater than the supply, and death takes place. Fall-planted 2–0 jack pine grown at densities in excess of 55 per square foot in the nursery is particularly subject to such damage. On the Huron National Forest about 80 percent of the total loss with this kind of stock was due to excess transpiration. Other kinds of top-heavy stock, notably 3–0 red pine, have suffered severely from the same cause.

Heavy wet snows, sleet, and ice sometimes cause considerable breakage of branches and tops, but are not especially common causes of death in this region. However, these factors are a source of injury not to be overlooked. In Minnesota, 21 percent of the trees among 55 older plantations suffered from snow breakage. A study (*18*) made in the Upper Peninsula of Michigan showed that as a result of the heavy snowfall of the winter of 1938–39, 10- to 13-year-old plantations were damaged as follows: Red pine, 17.9 percent; eastern white pine, 7.3 percent; white spruce, 2.0 percent; Norway spruce, 1.2 percent; and Scotch pine, 0.9 percent.

Other Weather Factors

Other causes of loss resulting from weather factors are of minor importance, although they may be serious locally on occasion. Unusually heavy rains or sudden melting of snow in the spring may cause pools of water to form around planted trees under certain conditions; if the pools persist long enough, they will drown or suffocate the trees. Heavy downpours of rain sometimes cause sufficient washing of soil in furrows to cover trees, to greater or lesser degree, and thus bring about death from smothering. In open sandy areas, trees are sometimes smothered by shifting sand; others have enough of their root systems exposed by the same action to bring about death. Experimental plantings in lower Michigan have suffered as high as 30 percent of their first-year loss from smothering, although the average is much less.

COMPETITION

As the available open areas are planted or are taken over by brush, planting in the Lake States is being done more and more on areas with considerable cover. Therefore, competition [24] is becoming an increasingly greater cause of mortality and injury among plantations in this region. After the first few years in the field, competition is probably the most common cause of mortality or injury in Lake States plantations.

Good ground preparation gives young plantations a short respite from competition, but soon the young trees must compete with grasses and other low vegetation. Later they enter into active competition with taller shrubs, adjacent trees, and each other. In severe cases death results, but more commonly competition brings about reduced growth and loss of vigor. Unfortunately, competition from other plants is usually most severe on the best-quality sites.

In older plantations examined throughout the Lake States, there was a 16-percent reduction in average survival between the ages of 12 and 23 years. Most of the mortality was attributable to competition. Competition may also be a serious enemy of young plantations; 14 percent of the first-year mortality in experimental plantations on the Manistee National Forest, Mich., was attributed to this cause in 1938.

There are differences in the ability to withstand competition among the species commonly planted in the Lake States. Jack pine is least able to withstand overstory competition. Red and Scotch pines survive better than jack pine but usually not satisfactorily for more than about 10 years. Eastern white pine, white spruce, and Norway spruce survive well in competition with trees and high shrubs that shade them, but their growth is comparatively slow.

The kind and density of the competing natural tree growth are also factors in competition. Of the common trees occurring naturally on planting areas, the competition of jack pine is more serious than that of aspen, which in turn is more injurious than that of the oaks. The oaks, however, are among the worst from the standpoint of top whipping. In a 15-year-old red pine plantation on the Huron National Forest, Mich., trees that were shaded by oak had an average survival of 73 percent, while those shaded by jack pine had an average survival of 45 percent. The effect of density of overstory upon the height growth of this plantation is illustrated in figure 24.

Sometimes, however, a jack pine overstory may do little harm. In an experiment at Cloquet such a stand did not prevent an eastern white pine underplanting from having a 90-percent survival at 12 years. The influence of density of natural tree growth is indicated by experimental plantings of the Cloquet Forest Experiment Station in Minnesota (27), in which eastern white, red, and Scotch pines were planted under jack pine stands of three different densities. Survivals after 5 years were highest in the 70-year open stand, next in the 35-year dense stand, and poorest in the 15-year dense stand. The eastern white pine had the largest proportion living, with successively smaller percentages of Scotch pine and red pine.

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[24] The term competition is used here to express the effect upon the planted trees of the demands of other closely adjacent trees, brush, or sod for the same space, light, soil moisture, and soil nutrients. Although soil moisture is probably the most important of the elements in the competition, no attempt will be made in this discussion to distinguish between the elements.

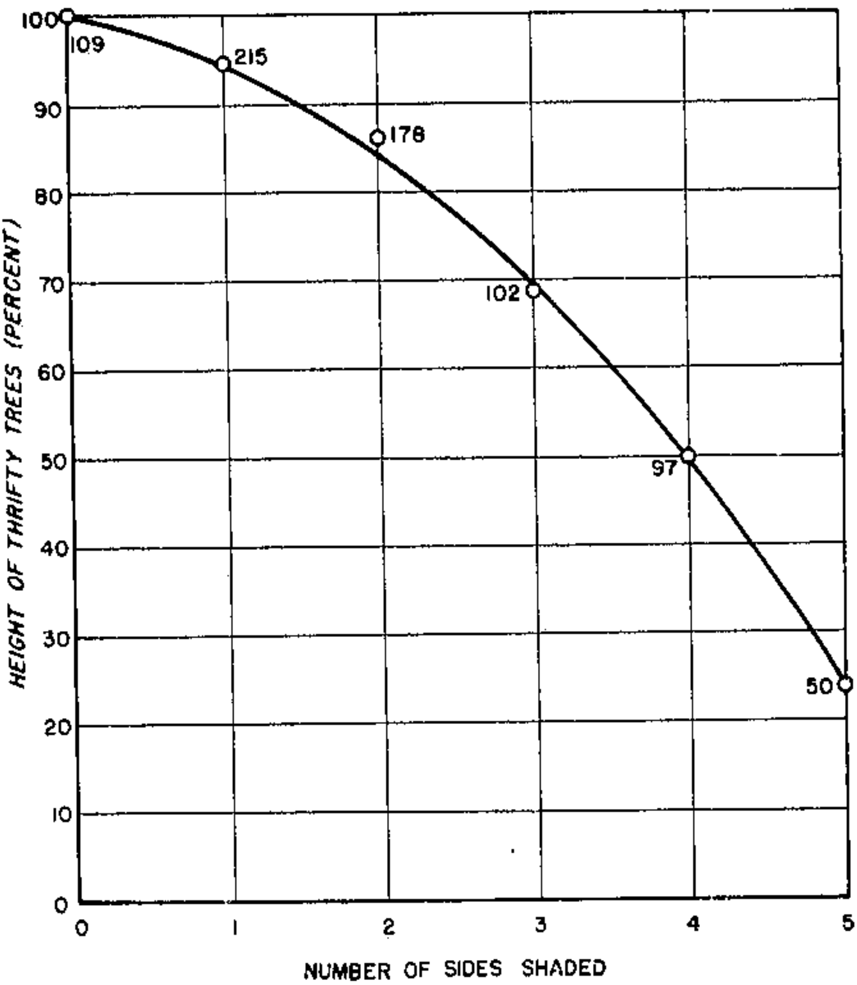

FIGURE 24.—Effect of shading on height growth of planted red pine, Huron National Forest, Mich. (Five-sided shading includes overhead shade. Figures on curve are numbers of trees.)

On the other hand, shading of planted trees by an overstory is not wholly bad. On comparatively open, dry sites that are typical of much of the lower Michigan sand plains, the beneficial effects of shade cast by trees and shrubs are often more than sufficient to offset any injurious effects due to competition during early years. Records show that shade from a single clump of scrub oak reduces the soil-surface temperature as much as 30° F. during the hottest part of the day; this is enough to make the difference between tolerable and lethal temperatures for young trees. One- to thirteen-year-old plantations on the Huron National Forest consistently showed 30 to 40 percent better survival on areas receiving some shade than on those that received none during recent dry years. Extensive natural openings in these plantations are almost completely denuded of planted trees. Even under such conditions, however, the overstory must not be allowed to become too dense after the planted trees have become established.

Smothering by fallen leaves, which, strictly speaking, is not competition but is closely associated with it, is a common cause of mortality wherever small stock is planted under stands of deciduous trees or under shrubs of moderate or greater density.

Man has relatively little chance of reducing loss or injury from climatic factors. He can, however, exercise considerable control over the competition factor by not planting under conditions where serious competition may be expected and by reducing or removing existing competition through weedings, cleanings, thinnings, or release cuttings.

POOR STOCK AND FAULTY PLANTING

Poor planting stock may be a serious source of loss in young plantations; in extreme cases it may result in total failure. Ordinarily the loss due to this factor is much less than from other factors. In experimental plantations on the Huron National Forest from 0 to 33 percent, or an average of 4 percent, of the first-year mortality has been caused by poor stock.

Planting stock may be considered poor because of such faults as (1) small size; (2) succulent, poorly hardened-off tops; (3) poor root development; (4) stripped, cut, or injured roots; (5) becoming dried out as the result of exposure during lifting, packing, or handling on the planting site, or insufficient watering during shipment; and (6) heating or molding during shipment or storage.

Most, if not all, of the loss due to poor stock can be eliminated by careful grading at the nursery, followed by inspection at the time of planting, and, of course, by careful handling of the stock in the nursery, in transit, and at the planting site.

A crew of well-trained planters working under an experienced planting foreman should plant over 90 percent of their trees correctly. In experimental plantings on the Huron National Forest, less than 2 percent of the average first-year loss (varying from 0 to 8 percent for individual years) has been ascribed to faulty planting. In favorable years many poorly planted trees survive, and if there is a succession of favorable years, many of them may overcome the handicap of improper planting. Ordinarily, however, such a succession of faverable years does not occur in this region and many of the poorly planted trees die during the first 5 years after planting. Some of the effects of faulty planting, which lead to deformed root systems, may not affect survival until 15 to 30 years after planting. Therefore, early losses do not reflect all of the disadvantages of poor planting.

The following planting faults are those that seem to be most common in this region: (1) Planting tree too high; (2) planting tree too low; (3) failure to pack loose soil about roots; (4) allowing roots to curl, loop, or bunch; (5) mixing leaves, grass, or other trash into the soil packed about the roots; (6) failure to keep the roots covered and moist in the planting box.

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Mortality or injury resulting from the use of poor stock or faulty planting technique can be almost entirely controlled by man and can be largely eliminated by grading stock and giving planting crews adequate training and supervision.

Fire

Fifteen to 20 years ago fire was probably the most serious enemy of forest plantations in the Lake States. With increasingly improved protection in the region, however, fire now ranks among the lowest in causes of loss. Nevertheless, fire does represent a constant threat to forest plantations. That it is still to be reckoned with is illustrated by the destruction of several thousand acres of plantation by fires on the Huron National Forest in 1937, 1945, and 1946, the loss of the most of the oldest plantations on the Presque Isle State Forest in lower Michigan in a 28,000-acre fire that occurred in 1939, and the injury to plantations on the Manistee National Forest by large fires in the spring of 1945.

A fire that is allowed to run through a young plantation will almost surely kill all of the trees in the area. Protection from fire is peculiarly essential to the success of forest plantations in the northern Lake States, since such plantations must occupy areas where there is more or less grass and brush that is highly flammable during the dry periods of spring and fall.

Fire must be prevented from entering the plantation, and fire that starts within the plantation must be suppressed. The detection of fire is now provided for in much of the forest region of the Lake States by the State or Federal Governments, through a system of lookout towers, telephone lines, radio communication, and observers. As a supplementary measure to this detection system, someone on the ground should be made definitely responsible for keeping fire out of the planted area.

Accessibility of the area to be protected is a necessity in fire protection. Consequently, it is desirable to construct truck trails along land subdivision lines or natural divisions so that all parts of a plantation can be approached reasonably closely by trucks carrying men and equipment for fire fighting. Such truck trails, which are cleared and disked usually to a width of 30 to 35 feet, may also serve as firebreaks to stop small surface fires or provide a base for backfiring.

In the earlier years of reforestation in this region an intensive system of firebreaks and truck trails was customary. These were often about 1 mile apart on the national forests. A large paper company in Wisconsin constructed firebreaks approximately around each quarter section. On the older planted parts of the Michigan State forests, fire lines were established around every 40 acres. However, as fire protection has become more adequate, the emphasis on both national and State forests has shifted to a system of less intensive but better constructed truck trails that permit faster travel. On the State forests of Michigan the present aim is to permit quick access to within 1½ miles of all points in hazardous areas; ordinarily this will require less than 25 percent of the existing drivable trail mileage. The trails are to be so constructed and maintained as to permit comfortable driving at 30 to 35 miles per hour.

Construction cost under the older, intensive system ranged from $25 to $100 per mile for single fire lines, $50 to $200 per mile for double lines, and probably from $75 to $300 per mile for truck trails. Maintenance of such lines ranged from about $3 to $10 per mile per year at prewar costs. Truck trails constructed to present standards cost from $500 to $1,000 and more on the same basis, depending upon the ease of construction.

An intensive system of roads or truck trails is of value not only for fire-protection purposes but also for utilization when the planted trees reach merchantability.

A further important part of fire-protection work is education of the public. This is particularly important in the Lake States where such a large number of fires are man-caused. Fire publicity work is particularly effective among campers, automobile travelers, fishermen, and hunters. Even though the people in a region are in sympathy with the forest fire-protection program and cooperate to the fullest extent, a workable local fire plan that provides for prompt, decisive action is always needed. The owner of a plantation who has an investment at stake can do much to increase the safety of his investment by promoting local sentiment and action for better fire protection.

ANIMALS

Snowshoe Hares and Rabbits

The animal most destructive to forest plantations in the Lake States is the snowshoe or varying hare. During periods of peak population these animals practically preclude planting in certain areas. They are generally numerous in northern Minnesota, parts of Wisconsin, and upper Michigan where there are abundant swamps, bushy areas, and aspen stands. Ordinarily the greatest damage is found in Minnesota and the least in Michigan. Among 55 older plantations in Minnesota, 43 percent of the trees still living showed signs of rabbit injury, but in 239 older Michigan plantations only 10 percent of the living trees had been injured by snowshoe hares. Some species are attacked more severely than others.

Among the older plantations examined in this region, the injury caused by snowshoe hares and rabbits was as follows: European larch, 77 percent; white spruce, 66 percent; eastern white pine, 24 percent; Norway spruce, 15 percent; red pine, 13 percent; Austrian pine, 10 percent; jack pine, 3 percent; Scotch pine, 2 percent. To some extent this trend of injury is probably a reflection of the site on which the various species have been planted, the least injury occurring to those on the more open sites where rabbits or hares are usually least abundant. At any rate, observations on young plantations in northern Wisconsin and upper Michigan indicate quite definitely that where the hares have a choice of several species in the same area, their preferences in descending order are jack pine, Scotch pine, eastern white pine, red pine, Norway spruce, and white spruce. However, any of these species are likely to be badly injured where the hares are abundant.

A recent study in New York showed that eastern white pine, red pine, and white spruce under 4 feet tall were killed outright by hares

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but that intermingled balsam fir and northern white-cedar were untouched (*17*). On the other hand a comprehensive survey in northern and central Wisconsin showed that natural reproduction was damaged by hares as follows: Heavy—northern white-cedar, eastern hemlock, and birches; medium—spruces, American elm, and sugar maple; light—oaks, basswood, aspen, eastern white pine, and balsam fir; very light—ashes, jack pine, and red pine (*78*).

A striking example of the destructive action of these animals is afforded by a plantation in Douglas County, Wis., of 24-year-old mixed white and red pine that had an average height of little more than 1 foot. Almost every tree had been nipped off time and again by hares, so that no increase in height was possible. The cottontail rabbit causes similar damage but is a pest of minor importance in the forest region.

FIGURE 25.—Snowshoe hare damage to a young, planted jack pine on the Nicolet National Forest, Wis. Both the tip and some of the lateral shoots were nipped off. (Photo by courtesy of the U. S. Fish and Wildlife Service.)

Snowshoe hares and rabbits nip off the tops of young trees particularly when green vegetation is scarce. However, observations indicate that they usually do not eat the shoots after they have cut them off. Ordinarily this injury does not cause death directly unless the trees are nipped off within 2 to 3 inches above ground, but it does retard growth severely. Repeated nippings of the terminal shoots will eventually bring about death. Damage may begin immediately after planting and continue as long as trees are within reach of the hares on crusted snow. Species differ in their ability to recover from nippings; red pine is especially poor in this respect. Hare or rabbit nipping can be recognized in that the shoots are cut off cleanly and at a slant (fig. 25). Squirrels make the same type of cut but the tooth marks are smaller.

Apparently the snowshoe hare population fluctuates in cycles of about 10 years. A cycle usually covers a period of from 6 to 12 years. That is, when the hares reach a maximum during a 10-year period, an increase in their natural enemies or some epizootic [23] ordinarily causes them to die off so rapidly that it is another 10 years before they regain their former abundance. Probably the best record of snowshoe hare abundance periods is presented in the 60-year fur returns of the Hudson's Bay Co. which indicate peak years in

[23] Several theories have been advanced as to the cause of the heavy mortality among snowshoe hares when they are at a population peak. It was thought for some time that the cause might be tularemia or some organism introduced into the hares' bodies by wood ticks. According to present knowledge the epidemic that kills the hares is shock disease. It is an ailment of unknown cause affecting the glycogen in the liver and lowering the blood sugar content to a lethal limit.

1853–59, 1865–66, 1877–78, 1887–88, 1896–97, and 1905 (*64 pp. 699–734*). Recent years in which the hares have been reported most abundant in the Lake States are 1901 and 1902, 1908, 1914, 1923 to 1925, 1932 to 1934, and 1943 to 1945. The trend seems to be for population peaks to occur first in upper Michigan and to work westward, reaching Minnesota 2 to 3 years later. During population lows there may be only 1 hare per square mile, whereas there may be 1,000 per square mile when they are abundant, and as many as 10,000 per square mile have been observed (*64*).

A thoroughly satisfactory solution of the snowshoe hare problem has not been worked out. If it is assumed that hares will be sufficiently abundant to do serious damage at 6- to 12-year intervals, it is desirable to do as much planting as possible in the year in which they die off. If this is done, many trees may attain heights of more than 3 feet and so have their tops out of reach before the rabbits are abundant again. Unfortunately, the period is not likely to be sufficiently long to avoid much of the loss, since only a few of the trees in plantations of eastern white or red pine or spruce are more than 3 feet high at 6 or 7 years of age.

Since the hares seem to avoid open country, trees planted in the open, in clearings, or where there is little or no brush, are less likely to be injured. An experiment at the Cloquet station showed damage from hares to be much more severe under dense 15-year-old jack pine than under a moderately dense 35-year stand, or an open 75-year stand. In another experiment hare damage was heavy on a site characterized by a dense growth of alder, willow, and aspen, and negligible on a site with cover of sweetfern (*27*). Experience on the Chippewa and Superior National Forests in Minnesota indicates that showshoe hares can be controlled fairly effectively by opening up the overstory through release cuttings, thus changing cover conditions, and by leaving occasional stubs to provide perches for hawks and owls (*53*).

There is some possibility that snowshoe hare and rabbit damage may be avoided by spraying the trees in the nursery with solutions of repellents. Since the treatment does not affect new growth that develops, repellents so far seem to be effective only during the first year. This is not sufficiently long to guarantee tree establishment in the Lake States region. Some measure of control may be provided by organized hunts but this is an expensive method and has not worked out satisfactorily because sportsmen could not be induced to concentrate their hunting on plantation areas. Snaring, also an expensive method, combined with shooting, worked quite well on the national forests as long as there was abundant manpower available in the CCC camps (*2*). Scattered poison grain has not been very effective and, because of the danger to other animals, is discouraged by Federal agencies, State conservation departments, and sportsmen's organizations.

The most promising control method, developed by the Fish and Wildlife Service, appears to be the use of a poison bait highly selective for hares. The material is painted or sprayed on the bark of felled aspen poles; care must be taken to avoid treating small twigs that might be browsed by deer (*98*). The objective of hare control is not extermination of the species but reduction of their numbers in local areas so that it is possible to bring through enough trees to salvage the planting investment on plantations susceptible to such damage. Since such areas involve only a minor part of the northern Lake States, and the bait is highly selective, objection should not be very great to this method of control. At least one State conservation department in the region issues permits to public or private agencies for the use of this bait.

Rodents

There is some evidence to show that squirrels have done part of the nipping damage attributed to rabbits, but in general squirrels cannot be considered an important enemy of planted trees.

Mice occasionally cause some damage to planted trees by girdling them under the snow. While they may cause serious losses locally, they do not account for any great percentage of the trees that die in plantations over the region as a whole.

Woodchucks and gophers cause slight amounts of loss in plantations, usually by uprooting or covering trees in the process of digging their holes. Occasionally woodchucks gnaw at trees and injure them. Larger trees occasionally are girdled by porcupines. In two plantations studied intensively in Minnesota and Wisconsin, porcupines injured about the same proportion (12 percent) of the trees (*59*). On the whole, the damage caused by rodents in this region is too small to warrant active control measures.

Deer

Throughout the Lake States region, deer probably are not blamed as much as they should be for injury to forest plantations. It is very likely that more nipping damage is done by deer than by hares, especially in open areas where snowshoe hares are never common and during years of low population. Occasionally in lower Michigan or in other areas where deer are unusually abundant, as in Itasca Park, Minn., or around game refuges, they have been responsible for and credited with considerable damage. For instance, near the borders of swamps where deer yarded on the Manistee National Forest, Mich., planted jack pine was nipped off in great quantities during the winter of 1935–36. Deer have caused a great deal of damage to plantations in northern Wisconsin and upper Michigan also. And in Pennsylvania where the deer population is higher than in most parts of the Lake States, these animals have completely destroyed many plantations (*44*). A comprehensive survey in northern and central Wisconsin showed that deer damaged a much greater area than forest fires, and that where deer populations are not controlled they damage reproduction of various tree species as follows (*78*):

Percent of seedlings browsed:	*Tree species*
60–70	Basswood, maples, ashes.
40–59	Oaks, jack pine, eastern white pine.
25–39	Aspen, birches, eastern hemlock, northern white-cedar, elms.
15–24	Balsam fir, red pine.
0–14	Spruces.

Where deer are very numerous, a slight amount of damage to small trees is caused by trampling.

Although deer probably cause much more damage to plantations than they are credited with, they cause relatively little *mortality*, other than in local areas. Less than 1 percent of the average first-year loss on Huron National Forest experimental plantations was caused by deer, and the greatest loss attributable to deer in any one year was 4 percent. Many surviving trees, however, lost part of their growth from nipping. In northern Minnesota, deer damage is particularly costly in plantations recently released. Nipping in such cases sets the trees back enough to nullify the effects of the relatively expensive release operation (fig. 26).

Deer nipping is easily distinguished from rabbit nipping, since it is usually a horizontal cut with a rough surface, more like a break; rabbit nipping is a clean cut.

Deer are a cause of injury to forest plantations only where they are unusually abundant. Thus, the fact that deer damage is fairly common in northern lower Michigan but unusual in upper Michigan seems largely explained; estimated deer population in the former is about 42 per square mile as compared with 16 per square mile in the latter. Deer damage can be held to a low point by maintaining deer populations that will not overtax the carrying capacity of the range, and possibly by planting and maintaining occasional groups of plants that are more acceptable as browse than the valuable forest species. Since control of the deer population is nearly impossible under present conditions, the best method of avoiding deer damage is to refrain from planting in or adjacent to game refuges or other places where deer concentrations may be expected.

Cattle

Locally cattle are an important source of damage to planted trees. This is true on parts of the Manistee National Forest where cattle are fairly abundant and open range exists. On one experimental plot on this forest, where cattle frequently ranged, they accounted for 27 percent of the first-year loss. In addition, many surviving trees were injured. Cattle damage takes the form of trampling, uprooting, and nipping, with the former being the most serious.

Cattle nipping resembles deer nipping so closely that it is almost impossible to distinguish between them unless it is known which of the animals was present on the area.

Where numerous cattle are allowed to graze in the forest, plantations will need protection at least until such time as they are no longer susceptible to trampling injury. Fencing is the only feasible means of giving plantations complete protection against cattle. Although sheep, goats, horses, and hogs have not been a great source of injury to plantations, they are potential sources of injury and should also be fenced out where numerous. Because fencing is costly, careful regulation of number of animals grazed seems a more practical measure.

Birds

On the Huron National Forest ruffed grouse, sharp-tailed grouse, and prairie chickens have caused injury, particularly to planted red pine, by budding the trees early in the spring. This type of injury has not resulted in the death of the trees, but it has reduced their

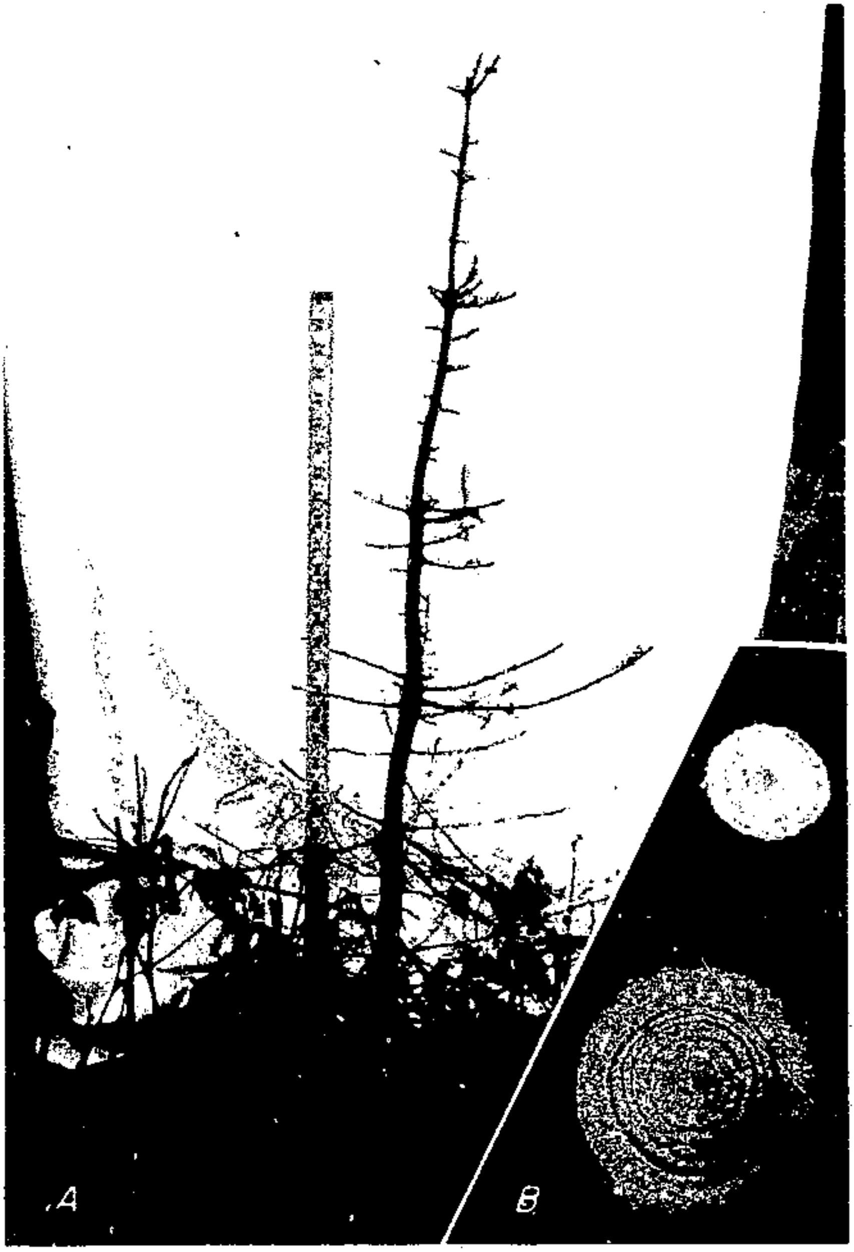

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FIGURE 26.—*A*, Young black spruce in northern Minnesota heavily browsed by deer. *B*, Cross sections of two jack pines of the same age (three-fourths actual size). The larger tree, grown beyond the reach of deer, had begun rapid growth; the smaller, still browsed, showed reduced growth. (Photo courtesy of U. S. Fish and Wildlife Service.)

growth. Grosbeaks have also been known to bud trees and may have caused injury locally (*87*). Injuries from other species of birds have not been noted. In general, little damage has been done by birds, and no control methods are advocated.

INSECTS

Planted trees have many insect enemies. Relatively few insects kill the trees outright, but many species cause injuries that reduce the growth of trees, weaken them, and often cause poor form.

White Grubs

White grubs, chiefly of the genus *Phyllophaga*, frequently kill trees and are sometimes very destructive to forest plantations. In general they are not serious pests in lower Michigan, but in parts of eastern upper Michigan and locally in Wisconsin and Minnesota they have been the most serious biotic cause of plantation mortality. In some places the grubs seem to be most abundant in grassy areas, and in others, as on the Huron National Forest, they are most abundant where there is a dense, low cover of sweetfern, small aspen, and bush-honeysuckle. This variation is probably due to the fact that different species of white grubs are involved. It is known that the adults, which are leaf feeders, have definite host preferences in many cases, and tend to be most numerous where the percentage of favored host is high.

In experimental plantations on the Huron National Forest only about 7 percent of the average first-year loss has been caused by grubs. However, on one area where grubs have been noted in considerable numbers every year since 1931 when observations began, about 20 percent of the average first-year loss is caused by grubs. On this same area where the several species are grown together, eastern white pine and red pine suffer about twice as much grub injury as do jack pine and Scotch pine. In Wisconsin first-year grub damage of more than 30 percent on red pine has been noted (*75*).

The white grubs work beneath the soil surface, apparently going deeper when the soil is dry, and cut off the roots of the young trees. Usually the cut is clean, and several roots of the same plant are all cut off at the same level, much as if a root pruner had been used on them.

Some methods of controlling white grubs in nurseries,[26] where a small, compact area can be treated, have been worked out, but there are no known practical means of controlling these insects in field plantations. The best means of avoiding serious grub injury is to forego planting areas where grubs are known to be abundant, or to plant species that are somewhat resistant to grub damage, such as jack pine, where there are uncertain but possible chances of grub damage. The approximate grub population of an area may be determined by means of a strip survey made during the growing season. Holes 1 foot square and 1 foot deep are dug at regular intervals along

[26] The preferred method in this region is to prepare the area thoroughly with a rotary tilling machine prior to seeding.

the line and the number of grubs in a cubic foot of soil counted. Where there is an average of two or more grubs per hole, planting should be postponed until the grub population declines.

The Pine Chafer

Jack pine on the Manistee National Forest in Michigan has been defoliated in recent years by the pine chafer (*Anomala oblivia* Horn). Although few trees have been killed, height and diameter growth have been seriously retarded in some plantations. The grubs of this insect feed on the roots of grasses and similar plants, while the adults defoliate the trees. Studies by entomologists have shown that the jack pine are injured more in pure than in mixed stands. The only practical method of control therefore seems to be the avoidance of pure stands as far as possible.

The White Pine Weevil

Although it is seldom the cause of fatal injury, the white pine weevil (*Pissodes strobi* (Peck)) repeatedly kills back the tips of trees. This reduces the growth of white pine and other species that are attacked, and results in poor form (fig. 27) and wood of low quality (*69*). In a

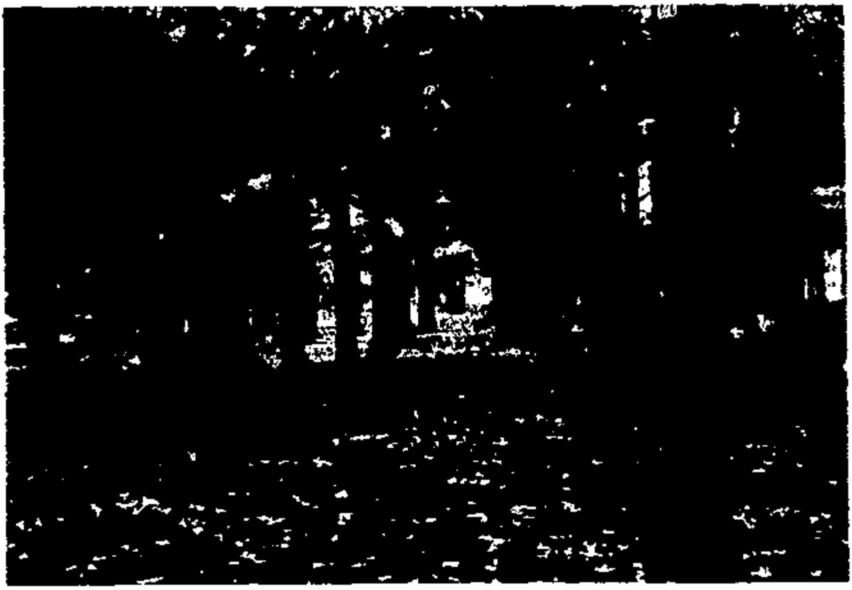

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FIGURE 27.—A thrifty eastern white pine plantation near Eau Claire, Wis., showing evidence (crooks in the stems) of past injury by white pine weevil. The plantation has been pruned.

survey of 400 older plantations (averaging 23 years of age) in the Lake States, 53 percent of all the white pine plantations had been injured by this insect. Approximately 66 percent of all the trees within these plantations had been injured at some time by the white pine weevil, and weeviling was the cause of 34 percent of all the injury suffered by white pine. Evidence from this same survey indicated a tendency to periodicity in weevil attack, with a peak being reached in 1929 in this region.

White pine weevil larvae feed in both the terminal and upper lateral growth. Resinous exudations on last season's growth indicate the presence of eggs. (Attacks on jack pine are very often in the growth of the current season.) Withered, brown, dying leaders in midsummer indicate weevil attack. Trees between 2 and 30 feet in height are most commonly injured, although trees up to 60 feet tall may be attacked.

Although white pine suffers most severely, the weevils also attack several other species of pine and spruce. White pine weevils caused 24 percent of all the damage to Scotch pine and 18 percent of that on ponderosa pine as observed in older plantations. European larch and white spruce were relatively immune, and Norway spruce, jack pine, red pine, and Austrian pine each showed less than 10 percent weevil damage. During recent years, however, the amount of damage to young jack pine has been increasing considerably, chiefly in open-grown trees. The most recent information indicates that white pine and jack pine are severely attacked, Scotch pine and black spruce are attacked occasionally, and white spruce and red pine are rarely attacked (*40*).

Locally the white pine weevil may be controlled by removing and burning the infested shoots before the larvae have left them. This type of control is very expensive and is of strictly limited applicability. Because of dangers of reinfestation, it should be tried only in isolated plantations. Weevil damage often can be corrected by pruning selected, lightly injured trees and freeing them from overtopping badly injured trees. The cost of this is lower than that of direct control (*15*). Recommendations have also been made for control by such silvicultural means as growing dense stands and growing mixed pine-hardwood stands (*22*, *40*, *49*). The latter control methods are capable of widespread application but must be provided for at the time of planting. In this connection release operations must not be too severe lest they expose the planted trees to serious weevil attack.

Pine Tip Moths

The larvae of pine tip moths work on the soft tissue of the new shoots, tunneling through them and later emerging from the buds or shoots. The buds or shoots are killed by this action and the tree's growth consequently reduced. The terminal bud is usually attacked first. There are several native species of *Rhyacionia* that cause such damage. The most common in the Lake States is the Nantucket pine tip moth (*R. frustrana* (Comst.)). In the southern part of Michigan, the European pine shoot moth (*R. buoliana* (Schiff.)) is also present.

Evidence of tip moth work appears in the summer as a small pitch mass or a dead needle at the base of the bud. Later the tips turn brown and will break off easily because they are hollow. In lower Michigan, tip moth work has been noted on red, jack, and Scotch pines. Sometimes red pine is attacked quite severely (even in the case of mature trees). For instance, in a red pine plantation at Roscommon nearly 60 percent of all the living trees were affected by tip moths in 1937. In New England the European pine shoot moth has injured small, isolated red pine plantations so severely that some of the trees have had to be cut out (*21*). However, in the older plantations in the Lake States, tip moth damage represented 35 percent of all damage to jack pine, 24 percent of that to Scotch pine, and only about 1 percent of that to red pine. These insects apparently may attack any 2- or 3-needled pine species ordinarily planted in the Lake States region. The damage has sometimes been attributed to deer or hares by inexperienced field men.

As in the case of most insect pests, the control of the pine tip moths after they are firmly established offers some difficulties. Small-scale infestations may be controlled by cutting off infested tips and badly infested trees and burning them. Spraying with a Penetrol-nicotine combination 3 times at 10-day intervals, beginning the latter half of June, offers some promise of reducing the infestation effectively (*21*). Subzero weather, such as is common in the Lake States in the winter months, is doubtless the most important control factor for both the Nantucket pine tip moth and the European pine shoot moth when infested parts of the trees are above the snow line. DDT sprays have given good control against adult Nantucket pine tip moths.

Since 1942, damage by another shoot moth has been noted on jack pine in the northern Lake States. The larvae of this insect (*Eucosma sonomana* Kearf.) bore through the pith and then girdle the shoot about 2 to 6 inches above the node before emerging (*12*). The shoots often break off at the point of girdling, or they merely droop or tip at an angle. Both terminal and lateral shoots are attacked. The same tree may be attacked repeatedly and may become badly deformed. Planted and natural jack pine have both been damaged heavily. Previously, this insect has been reported only from the West on ponderosa pine and Engelmann spruce. No control methods have yet been worked out.

Pine Pitch Nodule Maker

In the Lake States region the pine pitch nodule maker (*Petrova albicapitana* Busck) confines its work almost entirely to jack pine, although a few instances of its attack on Scotch pine have been noted on the Huron National Forest. The presence of this insect is indicated by pitch balls about ½ to 1 inch in diameter, occurring usually near the base of the present season's growth where two or three branches arise. If the pitch ball is broken open, one larva may be found inside. There may be several such pitch masses on a single limb.

The larva eats the cambium, frequently girdling the stem and causing its death above the point of attack. Even where the stem is not entirely girdled, it frequently is weakened enough so that wind breakage results. The work of this insect results in deformities in the tree and a reduction in growth, but seldom if ever causes death. Although this insect occurs commonly on native jack pine stands, it causes relatively minor damage; no large-scale methods of control have been worked out.

Sawflies

The jack pine sawfly (*Neodiprion banksianae* Roh.) is a defoliator confining its efforts to jack pine. The larvae begin eating the leaves of the previous season's growth late in the spring and continue their work for 4 to 5 weeks. They usually leave the current season's growth untouched. Complete defoliation, of course, means death for conifers, as does repeated partial defoliation. When mature, the jack pine sawfly is about two-thirds of an inch long, has eight pairs of prolegs in addition to three pairs of real legs, is greenish in color with black lines on the back and spots on the side, and has a black head, thorax, and prolegs.

More common in lower Michigan is the red-headed pine sawfly (*Neodiprion lecontei* (Fitch)). Damage caused by this sawfly is more severe than that caused by the jack pine sawfly because both old and new foliage is completely stripped. Jack, red, and Scotch pines appear to be preferred in approximately that order. Damage often is most severe in trees growing under or adjacent to hardwoods. Mature larvae of this sawfly are about an inch long, are red-headed, and pale yellowish-white in color, with rows of triangular black spots along the back and sides. Very similar in appearance and sometimes feeding on the same branch is a "red-headed jack pine sawfly" (*N. dubiosus* Schedl.). This species, however, develops two dark stripes down its back. Somewhat similar in appearance, but with a black head, is the white-pine sawfly (*N. pinetum* Nort), which has also been found in lower Michigan. This insect prefers eastern white pine but also attacks jack and pitch pines.

So far, only the red-headed pine sawfly has caused large-scale epidemics in the Lake States, but with the increasing acreage of jack pine and other susceptible tree species, the possibility of a large-scale epidemic is always present. In the summer of 1938 these insects became sufficiently numerous in young natural and planted stands on the Manistee National Forest to warrant artificial control by means of a lead-arsenate spray; between 1938 and 1940 nearly 12,000 acres were sprayed from the ground. This method is effective if the infestation is small, but is too expensive if widespread attacks occur. Between 1946 and 1949 the red-headed pine sawfly caused enough damage to require the spraying of about 16,000 acres of Forest Service plantations in the Lake States. Airplane spraying with DDT in oil solution at a rate of 1 pound in 1 gallon per acre has proved fairly effective and fairly cheap in controlling infestations on open-grown plantations. In some instances bad mite infestations have developed after plantations have been sprayed with DDT at rates heavier than 1 pound per acre.

The larch sawfly (*Pristiphora erichsonii* Htg.) larvae are gray-green with black heads. This insect has been responsible for the near extinction of mature tamarack in the Lake States. Approximately 20 percent of the damage noted on European larch plantations in this region was attributed to the larch sawfly. Limited outbreaks of this insect may be controlled by means of a lead-arsenate spray applied as soon as the larvae appear (*50*).

The false sawfly is found quite commonly on young planted red pine. Other than killing the foliage near the tip, these insects appear to do little damage, and so control measures are not warranted. Similar infestations on jack or Scotch pine usually are caused by caterpillars of the pine-webbing moth (*Tetralopha robustella* Zell).

Grasshoppers

Grasshoppers will chew the tender young stems in young plantations established in old fields, when grass and other growth dries up prematurely. Locally, grasshoppers may cause heavy damage to young plantations. This was the case in 1935 and 1936 in young planted jack pine on the Manistee National Forest. In 1937, a year in which grasshopper damage was generally slight, 5 percent of the mortality on an experimental plantation in that forest was chargeable to grasshoppers.

Grasshoppers may be controlled by means of sprays, dusts, or poison baits[27] spread over the infested area after most of the eggs have hatched. Effective applications per acre are 1 pound of technical chlordane or 1½ pounds of technical toxaphene as sprays, 1½ pounds of technical chlordane or 2 pounds of technical toxaphene as dusts, 5 pounds of dry bait, or 20 pounds of wet bait (*87*). Bait is more economical than sprays or dusts when vegetation is dry and no longer attractive to grasshoppers as food. If one application does not control the grasshoppers, a second one should be made in 5 days. To be most effective, baits should be spread in the morning between sunrise and 11 o'clock, since this is the time when grasshoppers do most of their feeding (*61*).

***Caution:* The hands should be kept well greased when handling baits. Always keep poison baits out of the reach of children and livestock.**

Pine Tortoise Scale

A tortoise scale (*Toumeyella numismaticum* P. & M.) also known as the Scotch pine scale or Scotch pine Lecanium, is known to attack jack pine, Scotch pine, and Austrian pine in the Lake States. Infestations have been noted from time to time during the past 40 years, the most recent to cause concern being found on young jack pine plantations on the Manistee National Forest during 1942. These sap-sucking insects reduce the vitality of a tree and may kill it in 2 to 5 years. Usually lower branches are attacked first, the infestation gradually spreading to those higher up. Although most infestations have been cleared up naturally before they could cause widespread damage, this insect is a potential threat to jack pine stands, both planted and natural.

The pine tortoise scale insects are found clustered along twigs and at the bases of the needles. The mature females are oval, reddish brown, have an irregular surface, are about one-fourth inch long, and are covered with a thin layer of transparent wax. The males are about one-sixteenth inch long, flat, elongate, and whitish in color. They emerge from under their scales in the fall and fertilize the half-grown females. The latter overwinter in rough, obscure places on the twigs. There is but one generation per year.

Trees severely attacked by the tortoise scale insect appear wilted. They have an abnormal needle fall and the remaining foliage is stunted. The branches and needles have a black, sooty appearance (*6*).

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[27] Several formulas for grasshopper bait are available. They usually include mill-run bran, sawdust, chemicals, and sometimes water (for wet baits) (*87*).

The insects spread mostly from tree to tree so that heavy infestations build up somewhat slowly. On the other hand, the injury is seldom noted until it has become fairly extensive. On a small scale the insect can be controlled by spraying, when the crawlers are moving, with liquid lime-sulfur at a rate of 1 part to 20 parts of water, or 1 part to 15 parts of water if the air temperature is below 85° F. Another method of control is to starve the insects by cutting off infested branches or trees. Care must be taken to remove all signs of infestation, and it may be necessary to go over the area two or three times to do so. Apparently the most effective means of control is by natural predators, such as the ladybird beetles. Several known infestations have been cleared up naturally by this means.

Spittlebugs

For many years the pine spittlebug (*Aphrophora parallela* (Say)), has been observed feeding, both in the nymph (in a mass of spittle) and the adult stage, on planted pines in the Lake States. Damage has been of such a minor nature that control is not warranted.

Much more serious damage, first reported in 1941, is caused by the Saratoga spittlebug (*Aphrophora saratogensis* (Fitch)) to young jack and red pines. More than 200 acres of planted jack pine have been wiped out in northeastern Wisconsin and several thousand more acres in Wisconsin, Michigan, and Minnesota have been injured. Trees up to 15 feet tall have been killed (*63*).

Only the adults of the Saratoga spittlebug feed on the pines, usually from July to October. They puncture the bark and suck out the plant juices. Injury becomes evident the first fall through slight yellowing of the foliage. The bark and wood underneath are covered with small pinholes often sealed by droplets of resin. The following spring, the foliage usually turns a reddish brown and the affected part dies. Death is caused partly by the loss of the sap and partly by the girdling effect produced by resin blocking the conducting tissues. Gradually the whole tree may be killed in this manner (*7*). An associated fungus may also contribute to mortality. (See p. 112.)

Damage is more severe in open-grown plantations with considerable ground cover. The eggs of the spittlebug are laid in dead and living bud scales of the host pines and other trees, such as oaks and maples. The nymphs descend to the ground and develop on the stems of sweetfern, or other low plants, in masses of spittle. Closed plantations or those with an admixture of hardwoods sufficient to shade out the ground cover, are not attacked seriously. This provides the key to prevention of Saratoga spittlebug damage (*63*). Some natural control is provided by late spring frosts since temperatures of 18° F. or below are known to kill the nymphs (*63*). Recently, aerial spraying with DDT before the adults lay their eggs has provided effective control at reasonable cost on more than 10,000 acres of public forest plantations in Wisconsin and Michigan.

Species of fungi capable of killing trees (see p. 112) have been isolated from dead trees that had been attacked by the Saratoga spittlebug. Although the spittlebug alone is capable of killing the trees, the fungi may also contribute to the mortality.

Other Insect Pests

The Zimmerman pine moth (*Dioryctria zimmermani* (Grote)) has damaged planted Scotch pine in lower Michigan and red pine in northern Minnesota; it is probably distributed throughout the region. Farther south in Ohio it is causing serious destruction in Scotch pine plantations. This and the fact that it attacks several species of pine indicate that the Zimmerman pine moth is a threat even though it is still of minor importance as a plantation pest in the Lake States. It attacks trees in two ways: (1) Buds on large trees often are tunneled by the caterpillars, and (2) the more serious injury is a girdling effect on the boles of smaller trees. An infested tree of the latter type can be recognized by large pinkish or brownish pitch masses. Such attacks are likely to occur in thinned or, especially, in pruned stands; they usually originate near a wound, such as a pruning scar or a pine-oak rust gall.

The Spruce budworm (*Archips fumiferana* (Clem.)) attacked 12 percent of the Scotch pine, 5 percent of the Norway spruce, 4 percent of the jack pine, 4 percent of the eastern white pine, and 1 percent of the red pine in older Lake States plantations. It is possible that the form which attacks jack pine may become a serious plantation pest in view of the large acreages of jack pine that have been planted since 1934. This form of the budworm may be controlled most effectively by maintaining closed stands and by removing any wolf trees that bear large quantities of staminate flowers (*23*). As a rule, red pine, white pine, or young jack pine are attacked severely only when they are growing under or very near infested older jack pine.

The eastern spruce gall aphid (*Chermes abietis* L.) injured 38 percent of the Norway spruce in older Lake States plantations. It was not found on other species although it is known to infest white spruce also. Local outbreaks may be controlled by spraying the trees with a dormant miscible oil before the buds open in the spring (*50*); this is seldom practical in plantations, however. It is known that individual trees are practically immune while others are attacked heavily year after year. Some control may be provided by removing the latter "brood" trees.

Minor amounts of injury have been caused in Lake States plantations by root collar weevils, needle scales, flatheaded borers, roundheaded borers, bark aphids, the pine engraver, the jack pine tussock moth, and ants.

If insect damage is found in forest plantations, specimens of the insect and its work should be collected and sent to the representative of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, Milwaukee, Wis. He is prepared to identify the insect and recommend the best known measures for its control. Inquiries can also be sent to the entomologists at the State Agricultural Experiment Stations.

DISEASES

In general, plant diseases have not yet been responsible for much mortality or injury to forest plantations in the Lake States region. Because some of them offer sufficiently serious threat, however, they should be well enough known to be recognized when they are seen in the field.

Vigorous trees, as a rule, are less prone to infection by disease organisms (other than the rusts, for example) than are trees growing under unfavorable conditions. For this reason, an important step in disease prevention is proper selection of species for the planting site (*10, pp. 140–218*), followed by cultural practices such as weedings and thinnings as needed to maintain high vigor.

White Pine Blister Rust

The best known and probably the most dangerous disease found in forest plantations in the Lake States is white pine blister rust (*Cronartium ribicola* A. Fisch.).

Although only 0.2 percent of the eastern white pine in the older white pine plantations examined throughout the region showed signs of white pine blister rust infection in 1935, this disease was more widespread in natural stands. Since then it has been found in plantations and in young natural white pine reproduction in all three Lake States. Where it is not yet present on white pine in plantations, it is usually present on any ribes plants that may be within or near the plantations. The disease represents a definite threat to successful planting with white pine.

The effects and appearance of this disease are too well known to warrant a detailed description here. Briefly the disease works in this manner: Spores of the fungus, which have developed on the undersides of ribes (currant and gooseberry) leaves, are blown by the wind and infect white pine by entering through the needles. As it develops the fungus works through the bark of the branches, producing cankers that girdle and kill the branches. It continues to work down and may eventually reach and girdle the main trunk. Young trees often are killed within a few years; older and larger trees are killed more slowly.

White pine trees may be protected from blister rust by eradicating all currant and gooseberry bushes within 900 feet of the plantation, and all cultivated black currants (*Ribes nigrum* L.) within a mile. Where currants or gooseberries are so abundant as to make eradication too costly, species other than white pine should be planted.

Forest Service planting of white pine in the Lake States is done only where these conditions can be met: (1) Areas of suitable site at least 200 acres in extent are free of ribes or can be made so at a justifiable cost, and (2) no other suitable species can be substituted for white pine. Around the border of swamps, where ribes are numerous and difficult to eradicate, buffer strips of red pine or white spruce are usually planted.

Sweetfern Blister Rust

This disease, caused by *Cronartium comptoniae* Arth., apparently may infect any of the pitch pines (those with 2 or 3 needles in a bundle) and has as its alternate hosts sweetfern and sweet gale. Young trees are often infected near the soil surface where a characteristic fusiform swelling develops. Sometimes cankers are formed, the growth of the tree is reduced, and eventually the tree may be killed (*68*). At the Higgins Lake State Forest in lower Michigan, ponderosa pine, lodgepole pine, and Austrian pine were so severely injured by sweetfern blister rust that the plantations either failed to survive or were destroyed in an attempt to prevent the spread of the disease over the forest. Other planted species in the Lake States region on which this rust has been reported are jack pine, red pine, and Scotch pine.

Although sweetfern blister rust was not noted on the older plantations, it represents a threat, particularly to exotic species, since it is naturally present throughout the region either on sweetfern or jack pine. Apparently the only practical method of control is to refrain from planting the susceptible pines (other than the relatively immune jack and red pines) in areas where sweetfern or sweetgale occur.

Candelabra Disease

Within the past few years a new disease, found chiefly on red pine, has been described. This disease, thought to be caused by a fungus and known as candelabra disease, brings about a retardation in growth of the terminal shoot and an attendant relative lengthening and turning up of the lateral shoots (multiple-leadering). This produces a tree of undesirable form and cuts down useful height growth. It has also been claimed that there is considerable infection by wood-rotting fungi around the bases of the lateral shoots.

Candelabra disease has been reported present in plantations in northern Wisconsin and upper Michigan (particularly in red pine), although none has so far been found in lower Michigan and apparently none in northern Minnesota.

Because of the rather recent discovery of this disease, neither its causal organism nor the danger of widespread injury from it is known. Control measures have not been developed. However, the disease should be watched for so that proper prevention and control methods can be taken if needed, as soon as they are recommended by the pathologists.

Burn Blight

The fungus, *Chilonectria cucurbitula* (Curr.) Sacc., is associated with burn blight of jack pine and red pine (*25*). It is capable of injuring or killing the tree, but it is dependent upon some injury, such as punctures made by spittlebugs, for entry. (See p. 109.)

The spittlebugs feed upon pines in July, August, and September, inoculating the trees with the fungus that kills twigs, branches, and even main stems. The fungus is most active during warm spring weather. The insect alone can cause severe damage, hence the combination of insect and fungus injury presents a serious problem.

Burn blight presents these symptoms. Small twigs at the top of trees turn yellow and then brown. (Diseased branches become chocolate brown rather than tan, as they do from desiccation alone.) The disease continues downward into the branches and finally the main stem. Necrotic spots develop about insect punctures and spread until the stem is girdled. The fungus prefers jack pine over red pine, whereas the spittlebug shows the reverse preference.

Suggested control measures are: (1) Control the Saragota spittlebug by spraying with DDT or other chemicals; (2) plant only on good sites where trees are vigorous and therefore less susceptible to injury by either the insect or the fungus; and (3) mix plantings in groups either by species or age classes.

Other Diseases

A pine-oak gall rust, *Cronartium cerebrum* Hedge. and Long, occurs commonly on jack pine, injuring about 12 percent of the trees examined in older plantations. Occasionally young jack pine are seriously deformed and even killed by it. No control methods seem warranted other than to insure that planting stock is disease free.

On the Higgins Lake State Forest and the Huron National Forest in lower Michigan, a gall rust has infected Scotch pine and caused considerable deformity. The identity of this rust has not been fully established but it is similar to both *Cronartium cerebrum* and to the so-called woodgate rust (the Peridermium stage of an unknown species of *Cronartium*), common and serious on Scotch pine in the East. No control methods have been recommended. Seven percent of the Scotch pine in older plantations was injured by pine-oak or similar gall rust.

Infections of *Armillaria mellea* (Vahl.) Quel. (the shoestring fungus) have been found on Scotch pine in Douglas County, Wis., on planted jack pine on the Presque Isle State Forest (*9*) and the Manistee National Forest in Michigan, and on planted white and Norway spruce in Vilas County, Wis. This disease, which attacks a great many tree species, may prove a serious pest in the forest plantations. No control methods are known. It appears advisable, however, not to plant on land where trees have been killed by this fungus until several years after such killing.

A stem canker, caused by *Tympanis confusa* Nyl., has caused serious losses in a stand of red pine planted in southern Michigan; the stand had stagnated from failure to release by thinning. The same canker appeared widely in the East in planted stands south of the natural range of red pine following a period of excessive drought (*26*). Mixed planting, a spacing of 8 feet, and timely thinning accompanied by pruning of selected crop trees, have been recommended where control is needed.

Stem and branch cankers, caused by several different fungi along with low winter temperatures, have seriously injured and, in some cases, practically destroyed plantations of hybrid poplars (*56*) throughout the Lake States. Until planting stock genetically resistant or immune to these diseases is available, the use of hybrid poplars for reforestation in the Lake States should be greatly restricted.

Many other diseases, not yet found in the Lake States plantations, present serious threats, especially if hardwoods are more widely planted. Among these diseases are the oak wilt, Phloem necrosis, and the Dutch elm disease.

General

A variety of other factors cause death or injury to planted trees, but in general they play a very small part in the total loss and so are not discussed here. A summary of the more important factors that caused mortality in very young stands on the Huron National Forest is given in table 18. Table 19 summarizes the more important factors that caused injury to various species in older Michigan and Minnesota plantations.

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TABLE 18.—*Cause of first-year mortality, and average survival, Huron National Forest, Mich., 1932–39*

Cause of loss	1932	1933	1934	1935	1936	1937	1938	1939	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Heat	—	65	19	24	68	6	16	52	41
Drought	—	26	3	—	17	—	—	22	11
Winter injury [1]	1	—	10	10	7	77	36	1	21
Smothering	14	—	13	30	—	1	4	4	4
Nipping [2]	4	—	—	—	2	—	—	—	1
Trampling [3]	4	—	—	1	—	2	—	1	(4)
Grubs	2	9	6	16	1	5	35	12	10
Poor stock	33	—	3	6	—	4	6	6	4
Poor planting	—	—	1	8	—	3	1	2	1
Other	5	—	—	—	—	1	1	—	(4)
Undetermined	37	—	45	5	5	1	1	—	7
Total	100	100	100	100	100	100	100	100	100
Average survival [5]	94. 1	58. 4	73. 5	83. 9	23. 6	50. 4	71. 8	66. 7	65. 3

Climatic data		1932	1933	1934	1935	1936	1937	1938	1939	Average
Annual rainfall [6]	inches	27. 75	26. 75	19. 78	20. 23	21. 22	18. 50	24. 63	26. 38	23. 2
Summer rainfall [7] (June, July, August)	inches	8. 10	4. 42	4. 80	10. 53	5. 37	5. 16	7. 29	10. 18	7. 0
Maximum air temperature	°F.	96. 0	104. 3	107. 9	95. 3	111. 8	100. 5	101. 8	99. 0	[8] 111. 8
Maximum soil-surface temperature	°F.	—	162. 0	153. 0	155. 0	174. 5	164. 5	150. 0	143. 5	[8] 174. 5

[1] Includes all types of loss associated with low temperatures.
[2] Includes nipping by all animals; chiefly deer, rabbits, grouse, and cattle.
[3] Includes trampling by both cattle and deer.
[4] Less than 0.5 percent.
[5] Each year's average is based on examination of 32,000 trees.
[6] Normal is 28 inches.
[7] Normal is 8.5 inches.
[8] High extreme.

TABLE 19.—*Percent of injury*[1] *to living trees, by cause and species, older Michigan and Minnesota plantations*[2]

Source of injury	Species									All species		
	Eastern white pine	Red pine	Jack pine	Scotch pine	Norway spruce	White spruce	European larch	Austrian pine	Ponderosa pine	Michigan	Minnesota	Combined
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Snowshoe hares and rabbits	24.3	13.0	2.6	2.0	14.6	66.5	76.9	9.9	---	10.1	43.0	14.7
Porcupine girdling	.8	.6	2.3	2.8	.6	---	5.1	1.0	---	1.2	1.2	1.2
Deer nipping	.2	.1	---	---	---	---	---	---	---	.1	.4	.1
Sapsucker	---	---	---	2.4	---	---	---	---	---	.2	.8	.3
White pine weevils	34.3	3.8	8.5	23.6	9.2	---	---	1.9	18.5	17.6	10.2	16.5
Spruce budworm	3.8	.8	4.1	11.6	4.5	---	---	---	---	4.1	.6	3.6
Tip moths	---	1.3	34.6	24.1	---	---	---	---	---	9.8	1.9	8.7
Eastern spruce gall aphid	---	---	---	---	38.0	---	---	---	---	2.3	.8	2.0
Bark aphids	5.5	---	---	---	---	7.8	---	---	---	1.3	4.4	1.8
Larch sawfly	---	---	---	---	---	---	19.2	---	---	.1	---	.1
Flathead borers[3]	.1	.4	10.0	.7	.1	---	2.6	4.5	13.0	2.3	---	2.0
Roundhead borers[3]	---	---	6.2	.4	---	---	---	---	---	1.2	---	1.1
Ips pini[3]	---	.1	---	---	---	---	---	---	---	.1	---	(5)
White pine blister rust	.2	---	---	---	---	---	---	---	---	---	.4	.1
Pine-oak gall rust	---	---	11.8	7.0	---	---	---	---	---	3.1	---	2.7
Needle scales	2.5	.1	.1	---	---	---	---	---	---	1.0	---	.8
Cankers	---	---	---	---	.4	---	---	---	---	(5)	(5)	(5)
Snow breakage	9.9	12.4	10.5	14.0	2.1	---	20.5	---	---	8.9	20.9	10.5
Winter damage	1.2	1.1	.3	---	---	---	---	---	---	.5	2.9	.8
Sunscald	.7	---	.5	---	---	---	3.8	---	---	.1	1.6	.3
Mechanical injury[4]	10.6	6.9	15.6	14.2	10.0	3.5	26.9	1.0	---	10.7	8.3	10.3
Total	94.1	40.6	107.1	102.8	79.5	77.8	155.0	18.3	31.5	74.7	97.4	77.6
Basis, number trees	5,616	5,778	2,916	1,979	942	257	78	314	54	15,452	2,482	17,934

[1] Based on all trees observed for each species. Totals are cumulative and in many cases represent occurrence of more than one kind of injury to the same tree. Severity of injury varies from serious to minor. Many of the factors listed also cause mortality, but such data are not available for older plantations in the Lake States.

[2] Comparable data for Wisconsin are lacking.

[3] This insect usually attacks a tree only after it has been weakened by some other cause.

[4] Includes whipping and several other kinds of mechanical injury.

[5] Less than 0.05 percent.

Maintaining Adequate Stocking

The first criterion of success in forest planting is, of course, adequate survival. When too many of the planted trees die, no matter if the surviving trees make astounding growth, the purposes of planting cannot be fulfilled. Even though survival is necessary for success, it must be supplemented by satisfactory growth and development.

The aim should be to establish and maintain thrifty, well-stocked plantations. Only under such conditions can the forest manager mold a stand so as to obtain the greatest possible yield of high-value products. The intermediate cuts needed to manipulate stand development not only keep the most desirable trees thrifty but also increase the yield while salvaging probable mortality and bringing in early returns on the investment.

As discussed earlier in this publication, survival varies according to species, soil, kind and density of cover, size and age of trees, handling of stock, kind and intensity of ground preparation, season of planting, and methods and carefulness of planting. In addition, survival varies with the age of the plantation: the older the plantation, the lower survival usually is. Ordinarily, the heaviest losses are to be expected the first 2 years after planting when the trees are in the process of establishing themselves in their new environment, although comparatively heavy losses may occur up to 10 years in age. After 10 years the drop in survival normally shows a decreasing trend.

Survival may be considered from two aspects: (1) The percentage of trees planted that remain alive, and (2) the number of living trees per acre. The first method is a measure of the success of the planting operation, while the second is a measure of the success of producing a plantation. The two measures are not always synonymous. For instance, if one man plants 100 trees to the acre and 75 of them are alive at the end of 20 years, he has done an excellent job of planting, but so far as producing a plantation goes, his efforts have been a failure. On the other hand, another man who plants 1,000 trees to the acre and has 500 of them alive at the end of 20 years has done a good job of planting and has had fair success in establishing a plantation. In other words, density of stocking is the important thing, and the percentage of trees surviving is unimportant except when translated into number of trees per unit of area.

A basis for classifying Lake States plantations according to survival percentage and number of trees per acre is given in figure 28. The curves in this figure are based on results from some 500 Lake States plantations ranging in age from 1 to 40 years, and the trends in later years are strengthened through comparison with the development of natural stands. The curves, therefore, represent an average for the region. For individual species or specific localities or conditions, the placement of the curves would probably vary somewhat but the trends would be similar.

These curves may be used not only to compare the success of one plantation with that of another, but as a basis of judging whether or not replacements should be made. Ordinarily, plantations classed as average or better do not need replacement of dead trees. For those classed as fair, replacement is advisable, and for those classed as poor, it is necessary if stand conditions are to develop. Of course, the application of these curves must be tempered by sound judgment. For instance, a plantation may average enough trees per acre to be classed as good or average but still have such patchy stocking that a considerable part of the area is badly understocked. In such cases, the understocked area should be replanted. On the other hand, parts of fair or poor plantations may be sufficiently stocked. Obviously, replanting of such parts would not be necessary.

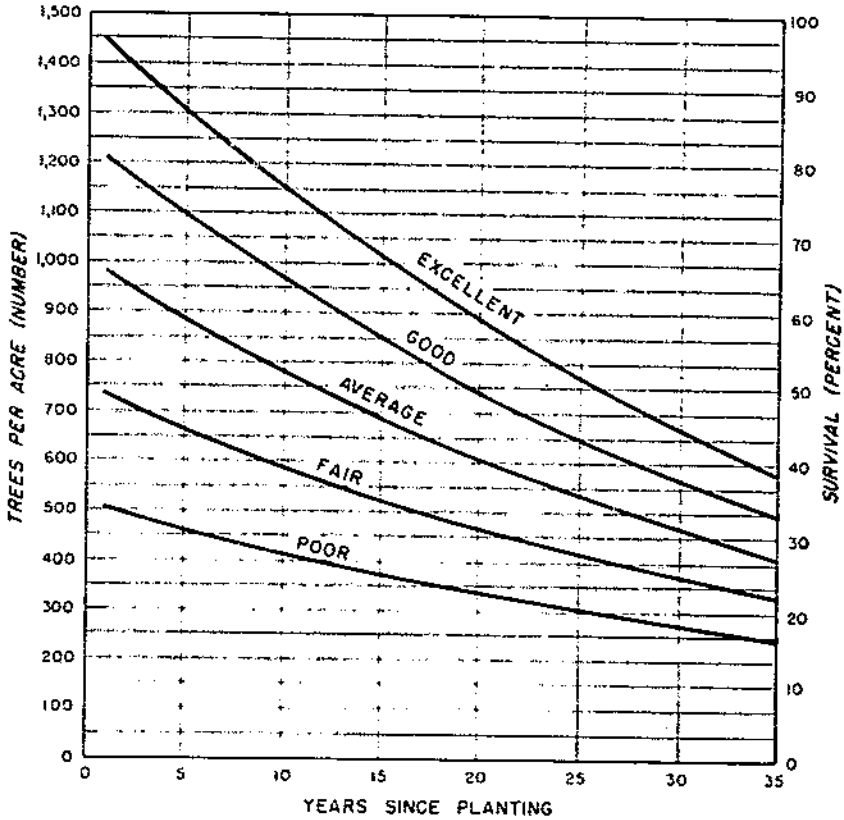

FIGURE 18.—Stocking standards for Lake States plantations.

Another point, too, is that most plantations have a certain amount of volunteer growth (about 200 trees per acre on the average in 20-year-old plantations in the region). If enough of the volunteer growth is of desirable species or of such character that it will help train the planted trees and prevent encroachment of brush and sod on the area, it may also be considered as contributing to the stocking of the stand. Replanting plans should be modified accordingly.

As a rule, any necessary replanting should be done during the first 10 years of a plantation's existence unless, of course, later losses are very severe. In that event, the replanting becomes essentially a new plantation. During the first 2 or 3 years after planting, necessary replants may be made with the same species but preferably of an older age class. For instance, an area planted with 2-0 or 2-1 red pine.

should be replanted with 2–2 red pine. The larger stock will serve to diminish the size advantage of trees remaining from the original planting. If 5 years or so have elapsed since the original planting, it will be more suitable to use a faster-growing species in the replanting, provided a suitable one can be found. For example, an area originally planted with red pine under such circumstances might better be replanted with jack pine.

Occasionally some catastrophe, such as sleet storms, heavy gales, and floods, causes widespread destruction among planted or natural stands, and it becomes necessary to replenish the stand with desirable trees before brush or low-value species reclaim the area. Where the destruction is complete and natural regeneration is not reasonably certain, a new plantation must be established. In many cases the stands are only partially destroyed, and then the decision must be made as to how much, if any, planting is justified to bring up the stocking of the area. Table 20 is an illustration of such a case. The table was developed by the Lake States Forest Experiment Station to guide replanting work on the Chippewa National Forest following severe sleet and wind storms in 1940.

TABLE 20.—*Standards for underplanting sleet-damaged mixed jack-red pine stands on the Chippewa National Forest*

Average diameter breast high (inches)	Minimum number trees per acre required	Number trees to plant per acre if residual stand is —		
		¾ of minimum	½ of minimum	¼ of minimum
1	1,000	100	300	600
2	800	100	300	600
3	600	100	300	600
4	450	200	350	700
5	350	200	350	700
6	250	200	350	700
7	200	250	400	800
8	150	250	400	800
9	100	250	400	800
10	80	250	400	800

The average survival of various species in the older Lake States plantations (table 21) was revealed by examinations made in 1924–25 and 1935–36. Survival of these older plantations, which averages 34 percent at an average age of 23 years, may be considered fair. By States, Wisconsin is best, with an average of 55 percent; Michigan is second, with an average of 46 percent; and Minnesota is third with an average of 9 percent. These averages reflect the varying conditions within each State, i. e., better soil and relatively little competition in Wisconsin, poorer soil and little competition in Michigan, and severe competition and rabbit damage in Minnesota.

It is interesting to note that the two common European species, Scotch pine and Norway spruce, show better survival than any of our native species. This in itself is not sufficient to recommend their use in preference to the native species, since they have not yet demonstrated their ability to grow to maturity and produce a satisfactory quantity and quality of products in the Lake States, but it does indicate the desirability of giving them continued further trials upon an experimental basis.

TABLE 21.—*Average survival of various species in Lake States plantations given little or no care after planting*

Species	Age	Survival	Age	Survival
	Years	*Percent*	*Years*	*Percent*
Jack pine	8	56. 0±2. 3	20	41. 0±2. 4
Red pine	10	47. 9±2. 2	22	31. 8±2. 3
Eastern white pine	11	51. 0±2. 1	23	31. 3±2. 4
White spruce	14	44. 0±1. 2	26	30. 6±9. 5
Scotch pine	12	62. 0±3. 3	24	51. 9±3. 6
Norway spruce	17	51. 0±6. 0	29	42. 9±6. 8
Ponderosa pine	15	30. 0±1. 8	27	23. 5±6. 6
European larch	8	36. 0±6. 0	20	16. 2±6. 6
Austrian pine	16	54. 0±14. 1	28	15. 5±9. 7
All species	11	50. 0±1. 2	23	33. 6±1. 3

In accordance with the popular notion of their relative hardiness, our native species rank in order of survival as follows: jack pine, red pine, eastern white pine, white spruce.

Although comparative survival of different species, plantations, or other groups can well be expressed in percents, from the practical standpoint it is necessary to know the number of trees per unit of area in order to judge the results of planting. Accordingly the original and present densities of stocking are discussed in average terms.

Originally, there were 1,424 trees per acre in the older Lake States plantations, spaced about 5 by 6 feet apart, with the density averaging greatest in Michigan and least in Minnesota. Red and white pines were planted in spacings averaging 6 by 6 feet, Scotch pine and mixed plantations about 5 by 5 feet, and jack pine about 4 by 5 feet.

By 1936, in addition to the planted trees, averaging 479 per acre, some 258 volunteer trees of various species (mostly hardwoods such as oak and aspen) had come in to the stand, so that the stocking had become 737 trees per acre. Scotch pine showed the best stocking of planted trees (900 per acre) at that time, and was followed by jack pine (816 per acre), other species (ponderosa pine, Norway spruce, etc.) as a group (750 per acre), white pine (370 per acre), and red pine (362 per acre).

Growth of Planted Trees

With survival as the first criterion of success in forest planting, the second criterion is growth. However, both survival and growth must be adequate in order to consider a plantation successful. At first, growth in height alone need be considered. Later, diameter growth assumes importance, and finally the net result of these two factors, volume growth, becomes of chief importance.

HEIGHT GROWTH

Measurements made in older plantations probably afford the best information as to growth of plantations in this region. Growth in height may be represented in two ways: (1) Increase in total height, and (2) current and mean annual height growth. Either way, the records show that height growth has been generally best in Wisconsin and poorest in Michigan, with Minnesota intermediate (table 22).

The average mean annual height growth for all species is 0.55 foot. Jack pine and Scotch pine, respectively, exceed the average, while red pine, eastern white pine, European larch, ponderosa pine, Norway spruce, Austrian pine, and white spruce fall below.

The total average height in feet at the age of 20 years for the species studied varied as follows: jack pine, 15.2; Scotch pine, 12.7; red pine, 10.2; eastern white pine, 9.8; European larch, 8.8; ponderosa pine, 7.5; Norway spruce, 6.3; Austrian pine, 4.7; white spruce, 4.0. On the basis of this study, our native species rate much better from the standpoint of height growth than from that of survival. However, the height growth of Scotch pine was high, and Norway spruce was better than white spruce in this respect.

Height growth varies considerably from year to year and by species, presumably because of differing reactions to climatic conditions by the several species. However, all of the species grew faster during the second decade in the field than in the first. In observations of plantations up to an age of 40 years, red pine, eastern white pine, and Norway spruce had a tendency toward gradual acceleration of height growth. Scotch pine showed a trend toward a decreasing annual growth rate. Data for white spruce, ponderosa pine, and Austrian pine are also available, but they are based on a small number of observations and the trends may not be significant. Since annual whorls are difficult to distinguish in jack pine, no attempt was made in the field to measure annual height growth for this species.

EFFECT OF COMPETITION, SOIL, AND INJURY ON HEIGHT

It is generally known or accepted that height growth is reduced by competition, poor soil, and injury, but specific information as to the degree of such reduction is for the most part lacking. Observations on older plantations in the region indicate that, on the average, competition of the overstory has reduced growth about 30 percent at 20 years of age. Jack pine suffers most from competition, and eastern white pine least among the native pines. Trees planted on soils classed as loams, or on soils finer in texture, have about 30 percent better height development at 20 years than do those planted on sandy soils. Reactions of the various species to soil conditions do not differ greatly, although the pines seem to grow more rapidly on the poorer soils than do the spruces. Whipping out of tops, snow breakage, weevil or other insect attacks, and other factors may cause reductions of 50 percent or more in height growth. Such reductions, however, are not so common on a regionwide basis as are reductions from competition and poor soil.

TABLE 22.—*Height growth at 20 years in Lake States forest plantations, by species and State*

Species and State	Average height all trees at 20 years	Average annual height growth: 20-year period	Average annual height growth: 10th- to 20th-year period	Basis, trees
	Feet	*Feet*	*Feet*	*Number*
Red pine:				
Michigan	8.6	0.43	0.59	1,000
Wisconsin	12.9	.64	.93	548
Minnesota	10.3	.52	.65	575
Average or total	10.2	.51	.69	2,123
Eastern white pine:				
Michigan	7.4	.37	.52	1,063
Wisconsin	14.0	.70	.88	547
Minnesota	11.3	.56	.62	230
Average or total	9.8	.49	.64	1,840
Jack pine:				
Michigan	15.2	.76	.88	1,240
Wisconsin	18.2	.91	.97	20
Average or total	15.2	.76	.88	1,260
Scotch pine:				
Michigan	10.6	.53	.73	402
Wisconsin	17.6	.88	1.22	181
Minnesota	7.4	.37	.64	9
Average or total	12.7	.63	.88	592
Norway spruce:				
Michigan	5.6	.28	.67	189
Wisconsin	8.4	.42	.82	64
Average or total	6.3	.32	.71	253
White spruce:				
Michigan	1.0	.05	.15	20
Wisconsin	13.8	.69	1.02	6
Average or total	4.0	.20	.35	26
Ponderosa pine:				
Michigan	4.0	.20	.42	20
Wisconsin	10.2	.51	.63	26
Average or total	7.5	.38	.54	46
Austrian pine: Michigan	4.7	.24	.39	50
European larch: Michigan	8.8	.44	------	56
All species, average or total	11.1	.55	.72	6,246

EXPECTED HEIGHT DEVELOPMENT ACCORDING TO SPECIES

Although many factors combine to produce great variations in height growth for any one species within a single plantation and from one area to another, guides can be set up for the Lake States region to show what average heights may be expected at various ages for certain species. Such guides are shown in figures 29 to 33. They are based on the growth of plantations in the region up to the 30-year age class and are extended to the 50-year class on the basis of comparison with natural stands.

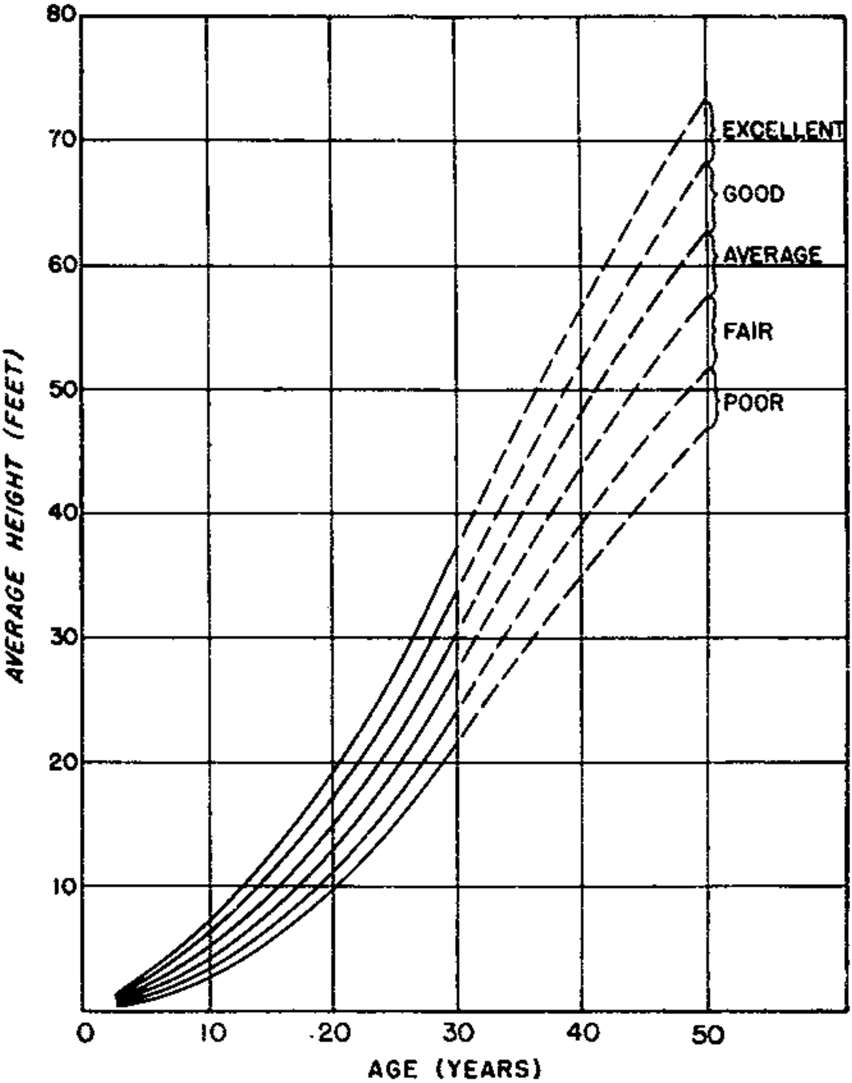

FIGURE 29.—Expected height growth according to age, eastern white pine plantations.

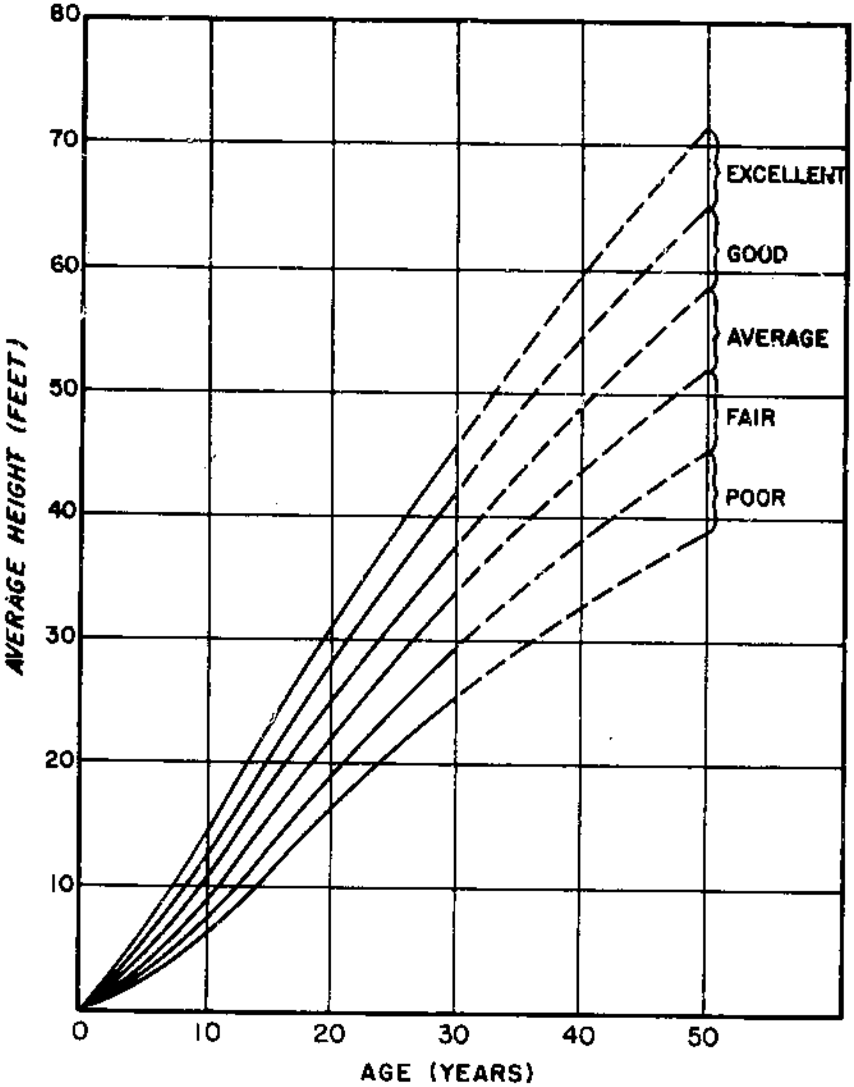

FIGURE 30.—Expected height growth according to age, jack pine plantations.

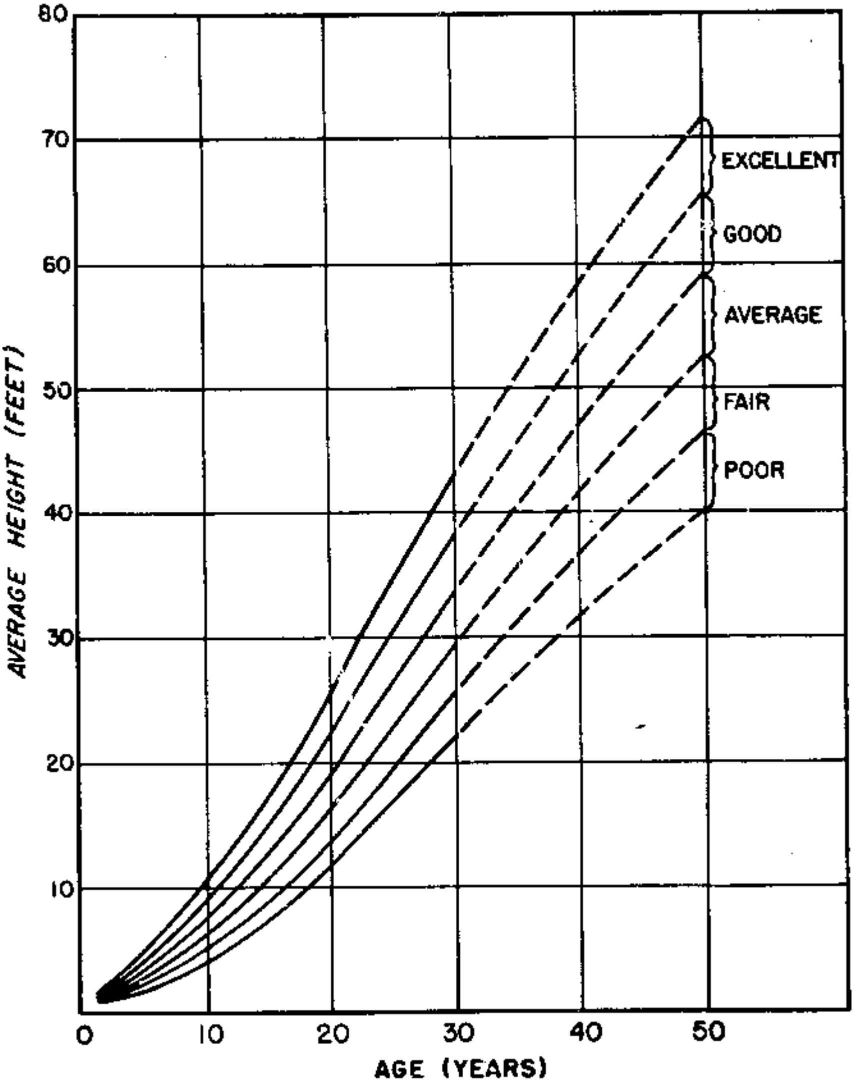

FIGURE 31.—Expected height growth according to age, red pine plantations.

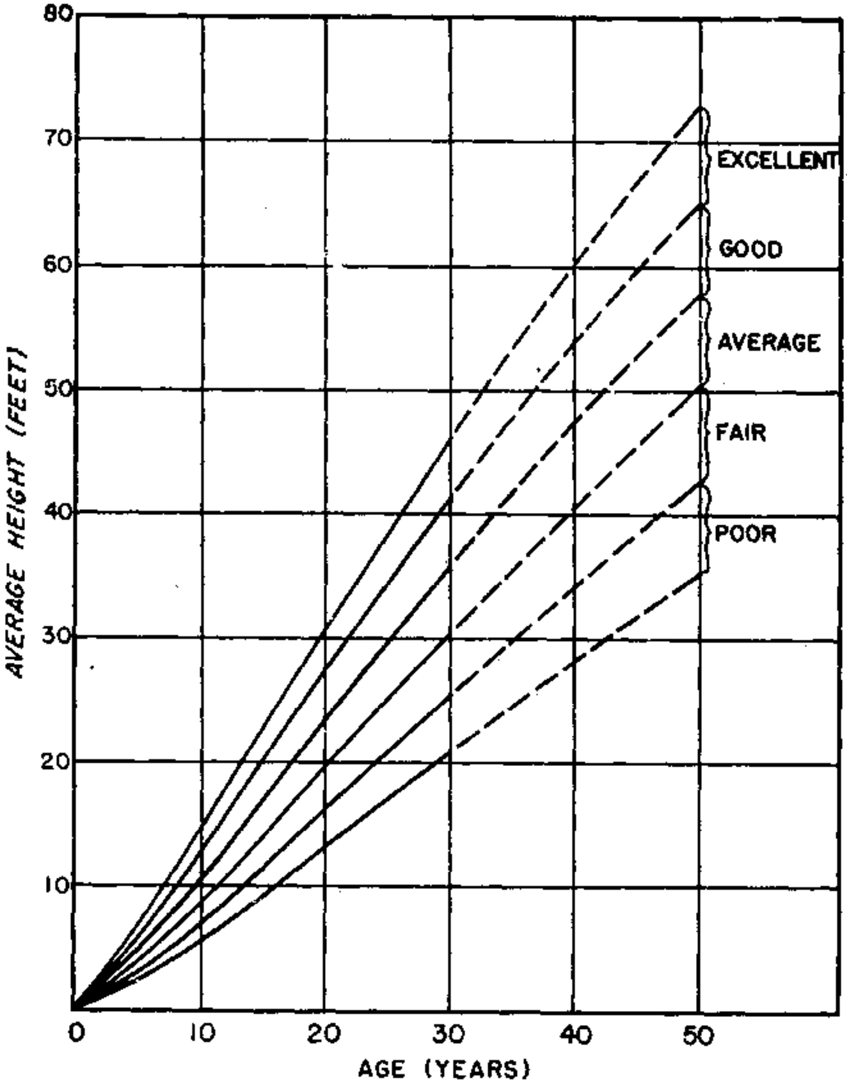

FIGURE 32.—Expected height growth according to age, Scotch pine plantations.

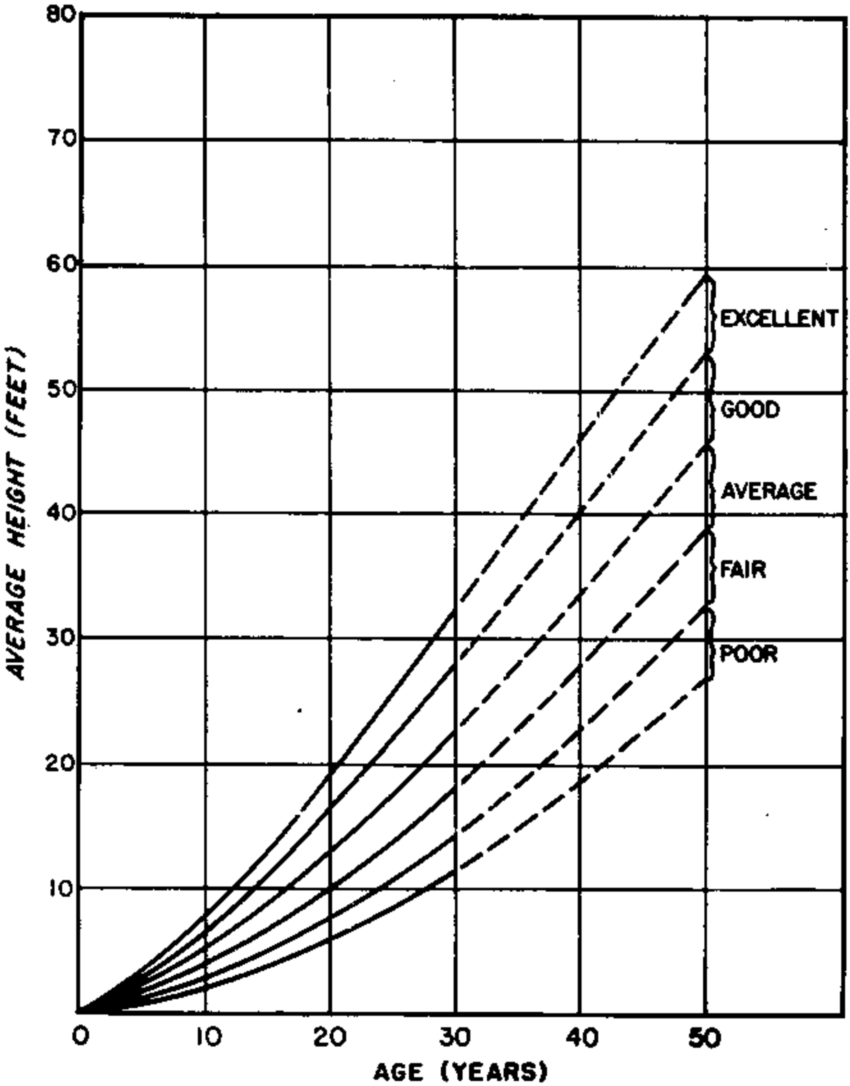

FIGURE 33.—Expected height growth according to age, Norway spruce plantations.

DIAMETER GROWTH

Diameter growth, of course, cannot be measured as early as height growth, since it is the custom to measure diameters at breast height, i. e., at a point 4.5 feet above average ground level. As soon as a tree exceeds this height, however, diameter can be measured and it becomes an important item because of its relation to volume. A study of Lake States plantations revealed that at an age of 20 years the species had average breast-high diameters, in inches, as follows: jack pine, 2.9; Scotch pine, 2.8; red pine, 2.4; eastern white pine, 2.3; ponderosa pine, 2.1; Austrian pine, 1.7; European larch, 1.5; Norway spruce, 1.3.

These diameters are probably somewhat below true average values for the region, because there was such a large number of Michigan plantations, many of which were on the poorer, sandy lands. Diameter growth, like height growth, is greater for all species during the second decade than in the first (table 23). Some of the slower-growing species, of course, scarcely attain breast height—the point at which diameters are measured—during the first 10 years. Annual fluctuations in diameter growth are much less marked than they are in height growth.

TABLE 23.—*Diameter growth at 20 years in Lake States forest plantations, by species and State*

Species and State	Average d. b. h., all trees at 20 years	Average annual diameter growth		Basis, trees
		20-year period	10th- to 20th-year period	
Red pine:	*Inches*	*Inches*	*Inches*	*Number*
Michigan	2. 2	0. 11	0. 15	187
Wisconsin	2. 9	. 14	. 24	63
Minnesota	2. 6	. 13	. 18	98
Average or total	2. 4	. 12	. 17	348
Eastern white pine:				
Michigan	2. 2	. 11	. 17	181
Wisconsin	2. 3	. 12	. 21	26
Minnesota	2. 7	. 14	. 19	39
Average or total	2. 3	. 12	. 18	246
Jack pine:				
Michigan	2. 9	. 14	. 19	245
Scotch pine:				
Michigan	2. 6	. 13	. 16	110
Wisconsin	3. 8	. 19	. 21	21
Minnesota	2. 2	. 11	. 16	7
Average or total	2. 8	. 14	. 17	138
Norway spruce:				
Michigan	1. 3	. 06	. 13	45
Wisconsin	1. 6	. 08	. 16	7
Average or total	1. 3	. 06	. 13	52
Ponderosa pine:				
Michigan	1. 2	. 06	. 06	4
Wisconsin	2. 7	. 14	. 16	6
Average or total	2. 1	. 10	. 12	10
Austrian pine:				
Michigan	1. 7	. 08	. 17	12
European larch:				
Michigan	1. 5	. 08	. 12	6
All species, average or total	2. 5	. 12	. 18	1, 057

EXPECTED DIAMETER DEVELOPMENT ACCORDING TO AGE

Diameter growth, like height growth, is affected by a great many factors that vary according to species and area and even within a rather small plantation, but guides for the region can be set up to show what average diameters may be expected at various ages for certain species. Such guides are shown in figures 34 to 38. They are based on the growth of plantations in the region up to the 30-year age class and extended to the 50-year class on the basis of comparison with natural stands.

COMPARISON WITH NATURAL STANDS

Differences in growth between plantations and well-stocked natural stands are almost entirely a reflection of differences in density of stocking. Plantations in the Lake States start out with about 1,000 trees per acre on the average, and seldom as many as 2,000 trees per acre; well-stocked natural stands begin with many thousand seedlings per acre, and at the age of 30 years have from 900 to 3,000 trees per acre (*11*), depending upon the species and site quality. As a consequence, competition in natural stands becomes intense at an early age and mortality ordinarily is much higher than in plantations of similar ages, up to 80 years or more. At that time, the stocking of natural and planted stands tends to become more comparable.

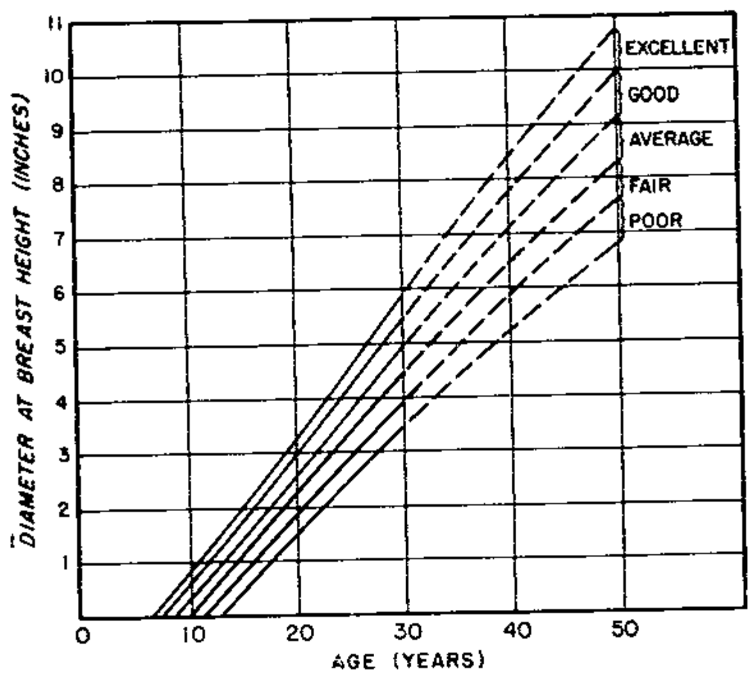

FIGURE 34.—Expected diameter growth according to age, eastern white pine plantations.

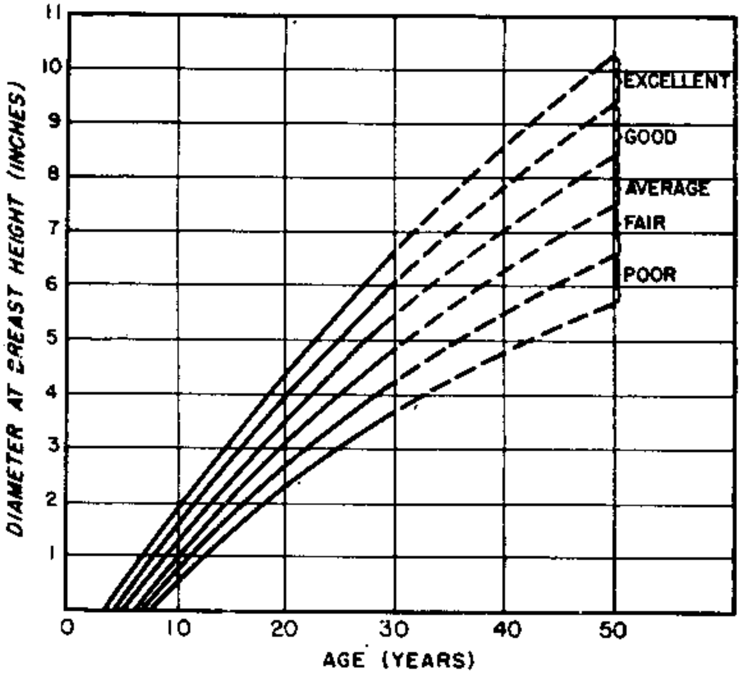

FIGURE 35.—Expected diameter growth according to age, jack pine plantations.

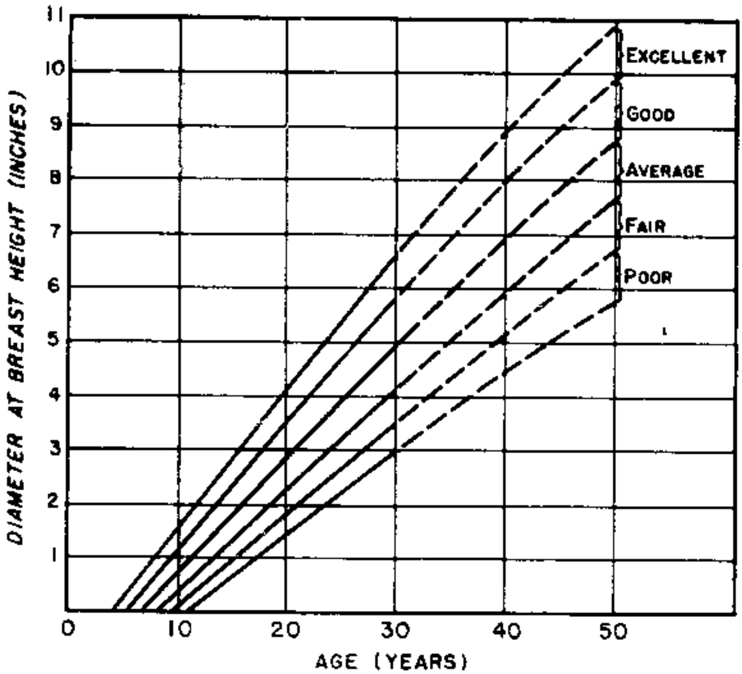

FIGURE 36.—Expected diameter growth according to age, red pine plantations.

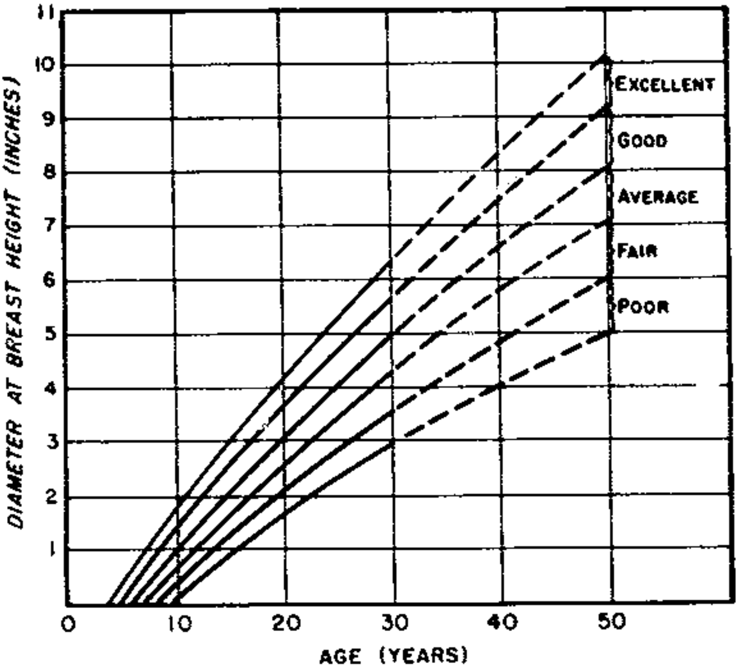

FIGURE 37.—Expected diameter growth according to age, Scotch pine plantations.

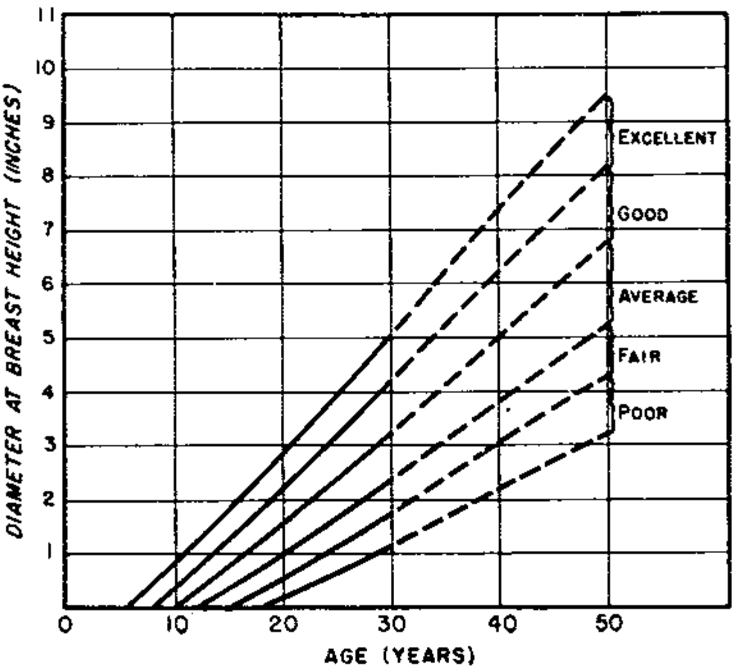

FIGURE 38.—Expected diameter growth according to age, Norway spruce plantations.

Height growth apparently is quite similar in both planted and natural stands in the Lake States (table 24). At given ages, the average heights of planted eastern white pine, red pine, and jack pine compared very closely with those shown in yield tables by Brown and Gevorkiantz (*11*) for the same species and ages, and the same was true for Scotch pine and Norway spruce when compared with Russian yield tables (*83*).

TABLE 24.—*Comparison of growth data for Lake States plantations and natural stands, by species and age*

Species and age (years)	Plantations[1]			Natural stands (medium site, fully stocked)[2]		
	Average height	Average diameter breast high	Trees per acre	Average height	Average diameter breast high	Trees per acre
Eastern white pine:	*Feet*	*Inches*	*Number*	*Feet*	*Inches*	*Number*
19	11.3	2.3	600	12.0	1.6	6,500
21	16.7	3.1	600	14.0	1.8	5,600
24	20.9	4.8	500	19.0	2.4	4,400
28	27.3	3.9	1,850	26.0	3.2	3,200
35	40.1	8.7	250	34.0	5.1	2,900
Red pine:						
10	10.5	1.8	1,550	4.0	.6	10,000+
19	11.9	3.2	300	13.0	1.5	6,000
21	12.7	2.2	500	15.0	1.8	5,200
23	24.2	4.4	650	19.0	2.1	4,300
27	35.2	4.9	1,500	25.0	2.9	3,200
Jack pine:						
13	11.8	2.0	1,200	11.0	1.4	3,000
Norway spruce:						
21	17.5	2.9	250	18.0	1.0	10,000
23	10.7	1.8	150	20.0	1.2	8,200
28	16.0	2.6	600	23.0	1.7	5,400
Scotch pine:						
20	25.1	4.1	1,100	20.0	2.1	2,500
23	26.2	3.6	2,500	24.0	2.5	2,100
23	30.2	5.5	900	24.0	2.5	2,100
24	32.5	5.2	800	25.0	2.6	1,970
25	21.6	3.7	1,900	26.0	2.8	1,870

[1] Values are for individual plantations.
[2] Values are based on averages of many stands, as adapted from normal yield tables.

On the other hand, upon the same basis of comparison, planted trees up to 30 years in age (the limit of data available) tend to be larger in diameter than trees of the same age in well-stocked natural stands (table 24). This indicates that in general planted trees will attain merchantable size somewhat earlier and will be somewhat comparable to trees grown in natural stands that have been thinned.

Judging the Success of Plantations

The success of forest planting, as already pointed out, depends chiefly upon survival and growth. During the first few years after planting, only survival can be measured easily and accurately. Later, usually from 5 years after planting and on, height can be measured readily. After the trees have passed 4.5 feet in height, usually from 5 to 15 years after planting, diameter can be measured. All of these factors, where measurable, should be considered in evaluating the degree of success of any plantation.

In the past, standards set up for judging the success of plantations in the Lake States region have been very crude. The standards used by the United States Forest Service in this region have been set up chiefly for determining the need for replanting plantations not more than 5 years old. They have been based entirely on survival, and the same standards have been applied to all plantations regardless of species, age, or site. A summary of these success classifications is as follows:

		Degree of success		
		Successful	Partial success	Failure
Standard used up to 1934:				
Trees per acre	number	500+	250-499	249−
Standard used 1934-39:				
Trees per acre	do	600+	400-599	399−
Standard adopted in 1939:				
Survival	percent	60+	30-59	29−

Obviously such classifications are inadequate for use in plantations more than 5 years old, and are not complete measures of the entire planting effort even for plantations up to 5 years in age.

A useful success index for young eastern white pine plantations, 3 to 15 years in total age, has been developed in the Northeast (*45*). It is arranged in the form of an alinement chart. To use it, it is necessary to know the total age, average total height, and survival percent of the plantation to be classified. This index is well adapted to measure the success of the planting job in the region for which it was constructed, but because it uses percentage survival rather than actual stocking, it is of less value as an actual measure of plantation success.

Since there have been no adequate standards for determining success of forest plantations in the Lake States, an attempt has been made to set up such standards based on the expected average survival, total height, and diameter at breast height information found on pp. 116 to 131. It is recognized that some plantations are established primarily for such purposes as watershed protection, erosion control, and wildlife habitat improvement, and that different standards should probably be used for judging such plantations. However, since it is believed that most forest plantations in the Lake States have been and will continue to be established for the production of wood, the standards are set up accordingly.

The difficulty of assigning proper weights to stocking, height growth, and diameter growth in order to obtain a single expression of plantation success is best resolved by using volumes per acre. Although volume tables available in the Lake States ordinarily do not contain values for trees as small as those found in plantations under 35 years of age, the approximate unpeeled cubic volume per acre for the conifers commonly planted can be obtained by the formula

$$Vuc = \left(\frac{d}{2}\right)^2 \cdot \frac{h}{100} \cdot N$$

where d = average breast-high stand diameter in inches, h = average height of all trees in feet, and N = the number of living trees per acre. By comparing the approximate volume of a plantation with that which is average for the age and species (table 25) it is easy to determine whether the plantation is better or poorer than normal.

TABLE 25.—*Success indices for average Lake States plantations*

Age (years)	Approximate unpeeled volume per acre [1] for—				
	Eastern white pine	Red pine	Jack pine	Scotch pine	Norway spruce [2]
	Cubic feet	*Cubic feet*	*Cubic feet*	*Cubic feet*	*Cubic feet*
10	0.4	3	25	10	------
15	20	40	115	80	3
20	135	170	380	250	25
25	340	370	690	475	75
30	755	735	1,110	820	170
35	1,290	1,195	1,480	1,150	320

[1] Based on formula:

$$Vuc = \left(\frac{d}{2}\right)^2 \cdot \frac{h}{100} \cdot N$$

where d=average diameter breast high in inches, h=average height of all trees in feet, and N=number of living trees per acre.

[2] Sufficient data were not available to calculate indices for white spruce, but those for Norway spruce can probably be used without too much error.

To use the approximate volume success indices it is necessary to know the total age in years, the average total height in feet, the average diameter breast high, and the number of trees per acre for each plantation to be classified. These values should be obtained through systematic sampling of the plantation. For example, an eastern white pine plantation 21 years in total age, with an average diameter breast high of 3.1 inches, an average total height of 16.7 feet, and a stocking of 600 trees per acre would have a success index of 240, well above average.

For very young plantations refer to figure 28, p. 117, and rate them on the basis of their stocking alone. Plantations from 5 to 10 or 15 years in age should be rated on height growth as well as stocking.

This can be done by using part of the formula given above

$$\left(\frac{h}{100} \cdot N\right)$$

to combine the two factors. Those from 10 or 15 to 35 years in age should be rated according to all three factors, using the approximate volume success indices. Plantations beyond 30 to 35 years old should be classed according to volume, or on the same basis as natural stands.

By means of the curves in figures 29 to 38 and the approximate volume success indices, it is possible to compare plantations with others either of the same or of different ages. As more data become available on the development of older plantations in this region, it may be possible to improve these curves and to develop curves and indices for other species also. The present curves and indices, which are conservative, should serve a useful purpose in the meantime.

Care of Plantations

In the Lake States, ordinarily trees cannot be planted and then left to fend entirely for themselves if successful plantations are to be established. Wherever grassy, herbaceous, or shrubby growth is moderately dense to dense, the trees should be given release from competition in from 1 to 5 years after planting. Later, the planted trees often need release from competing overstory trees. And still later, when the planted trees have gained ascendancy over other vegetation, they may need thinning out to reduce competition among themselves. In planning release operations, increased growth of the planted trees is not the only thing that must be taken into account. Consideration must also be given to such matters as the possibility of reducing insect damage and diseases, chiefly through maintaining mixed stands, and maintaining favorable conditions for wildlife.

PLANTATION RELEASE

As the term is used in the Lake States region, plantation release means any operation that removes or reduces competition affecting planted trees; it is roughly equivalent to a combination of the textbook terms cleaning or weeding, liberation cutting, and improvement cutting.[28] Ordinarily, two classes of release are recognized. (1) High release—removal of all or part of the overstory, and (2) low release—removal of grassy, herbaceous, or shrubby material from around the planted trees. Sometimes, too, the term "sod release" is used. This is merely a form of low release, which, as its name implies, means removal of dense grassy growth or sod, usually on old-field plantations.

Is Release Necessary?

In the Lake States, plantation release was something to read about or at most to test on a small scale prior to 1933. About that time, however, the convincing demonstration of small-scale tests already made, the availability of large amounts of emergency labor for for-

[28] A discussion of release practices recommended for aspen and brushlands will be found on pp. 74–82.

estry purposes, and the great expansion of the planting program all combined to establish release of young plantations on aspen, oak, and brushlands as an accepted practice. By the end of 1948 more than 300,000 acres of plantation had been released on the national forests of the Lake States at an average cost between $4 and $5 per acre.

An apt illustration of the necessity for release is shown by experimental results on the Chippewa National Forest. Paired plots, of which one each was given complete release and the other was left unreleased, show that failure to release meant a reduction, at the end of 5 years, of some 70 percent in survival, more than 90 percent in height growth, and some 99 percent in total dry weight in the case of red pine.

Low Release

The first care required by plantations usually is low release or weeding (figure 39). Such release usually is necessary between the 1st and 5th years after planting, depending upon the kind of ground preparation, the species and class of stock planted, and the density of the competing vegetation.

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FIGURE 39.—CCC crew weeding young planted trees on the Superior National Forest, Minn.

Plantation release may be carried out with axes (usually used in high release), grub hoes, Finn hoes, mattocks, hazel hoes, brush hooks, pruning shears, or machetes. The choice of which tool to use depends on the conditions upon the ground as modified by personal preference for certain tools. Regardless of the tool used, considerable care must be taken to avoid cutting off or injuring either the stems or roots of the trees being released.[29] Where the low growth is dense and the planted trees small, the safest procedure is to remove vegetation for about 6 inches around each tree by hand so that it is not necessary to cut too close to the tree with any tool. Then, using suitable tools, competing vegetation should be removed to a distance of about 18 inches around each tree. This will free the tree of direct competition and at the same time leave some brush between trees to protect them from excessively high temperatures or drying winds. In carrying out such work it has been found advantageous to have one man go down a row and do all of the hand work about each tree, with a second man to follow and do the necessary cutting or grubbing.

Frequency of Release.—Although plantation release is now an established practice on the national forests of the Lake States, little information has been available to show how many releases are needed. Valuable guidance can be derived from experimental plots established by the Lake States Forest Experiment Station on the Chippewa and Superior National Forests. These plots show considerable differences in the response of the various species, and even of age classes and size classes of stock within a species, to different amounts of release. Under moderately dense to dense brush, it is evident already (1) that, to establish the plantation, from one to five low releases are necessary during the first 6 years after planting, depending upon the species and class of stock,[30] and (2) that too many releases may expose the trees too much, permit the entrance of grass and weeds, and be detrimental to both heighth growth and survival. These findings are illustrated by table 26.

It will be noted that the 2-2 stock had considerably better survival and height growth under all conditions than did the 2-0 stock.[31] The transplant stock benefited from an increased number of releases, whereas the seedling stock showed very poor survival with three or four releases, and poor growth accompanied by fairly low survival with only one release. The detrimental effects of frequent release upon the 2-0 stock are due apparently to inability of this stock to stand exposure to drought conditions and additional competition provided by grass and weeds that come in as a result of frequent release. For both kinds of stock, however, releases the 1st and 4th years seem to be best from the standpoint of survival and growth, and economy. The improved results shown by the 2-2 stock with additional releases probably are not sufficient to warrant the extra cost. After the 4th year the 2-2 stock should be able to hold its own without further low release, but the 2-0 stock may need at least one more release, probably about the 6th year. A summary of the recommendations for low release based on these studies is given in table 27.

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[29] In Denmark, where plantation release is an integral part of silvicultural practice, a loss of 1 percent of the planted trees is allowable in any one release operation. If the loss is greater than that, the workman responsible is not given further release jobs. A similar standard of allowable loss in Lake States plantations should be possible of attainment.

[30] Where thrifty stock of the proper age class is planted on a site suitable for the species, not more than three releases should be necessary.

[31] In a similar test using graded 2-0 stock, the large grade showed about 16 percent better survival and about 25 percent better height growth than the small grade.

TABLE 26.—*Effect of low release on survival and height growth of eastern white pine in heavy brush, 6 years after planting*

Years of release after planting	2-2 stock		2-0 stock		Basis, trees each class of stock
	Survival	Height	Survival	Height	
	Percent	*Feet*	*Percent*	*Feet*	*Number*
1st, 2d, 3d, 4th	60.7	4.6	20.8	3.5	800
1st, 3d, 5th	49.9	4.7	26.0	3.1	400
1st, 4th	49.7	4.2	41.9	3.3	400
3d	38.8	3.1	35.1	2.5	400
Average or total	52.0	4.2	28.9	3.2	2,000

TABLE 27.—*Low-release recommendations for Lake States plantations, by species and class of stock*

IN HEAVY BRUSH

Species and class of stock	Release after the—					
	1st year	2d year	3d year	4th year	5th year	6th year
White spruce:						
2-2	X			X		
2-0	X			X		X
Eastern white pine:						
2-2	X			X		
2-0	X			X		X
2-0 [1]	X	X	X	X		X
Red pine:						
2-1	X		X		X	
2-0	X	X	X	X		X
Jack pine:[2]						
2-0	X		X			

IN MODERATE TO LIGHT BRUSH

Species and class of stock	1st year	2d year	3d year	4th year	5th year	6th year
White spruce:						
2-2		X		X		
2-0		X		X		X
Eastern white pine:						
2-2		X		X		
2-0		X		X		X
2-0 [1]	X		X		X	
Red pine:						
2-1	X			X		
2-0	X		X		X	
Jack pine:[2]						
2-0		X		X		

[1] Recommendations for this class of stock are for stock graded as "small". Recommendations for all other classes in the table are for stock not graded as to size.

[2] Studies on the Superior National Forest indicated that 1-0 or 2-0 jack pine stock might be established under moderately dense brush with only one low release made the 1st or 2d year after planting.

Low release, where it is needed, should not be delayed because the trees become spindly and are less able to withstand exposure when left too long under dense shade. Three years under heavy brush produces spindly trees in jack pine.

The Value of Large Stock.—The results from the experimental plots indicate a distinct advantage in the use of large, well-developed stock. In general, good transplant stock has better survival and growth and so can be established with at least one less release operation than seedling stock. The saving in the cost of one such operation, even using wage rates paid relief labor, is at least enough to offset the extra cost of the transplant stock without taking into consideration its better early growth. Good transplant stock should not cost over $5 per acre (prewar prices) more than seedling stock. Other than jack pine, seedling stock should not be used for conversion planting.

High Release

Trees planted under a moderate to heavy overstory will need release sooner or later if reasonable growth and survival are to be obtained. On areas with heavy cover, enough of the overstory should be cut, preferably in advance of planting,[32] to admit about 20 to 25 percent of full sunlight; all, or most, of the remaining overstory should be removed in one or more cuts during the ensuing 5 to 20 years. Because of the dangers of heat and drought damage, heavy sprouting, and encroachment by grass and other low vegetation, too much of the overstory should not be removed at one time either before or after planting. If sprouting takes place, the planted trees may have to be given an extra release from the sprouts. Aspen and red maple are particularly vigorous sprouters. Ordinarily post-planting high release should begin when the planted trees are 4 to 5 feet tall, and preferably should be carried out in two or more operations. Such releases have been made at no cost, or even at a profit, through the sale of aspen overstory for pulpwood. With the expanding use of aspen pulpwood, such opportunities should increase.

Although the initial overstory release can be done most efficiently and economically in advance of planting, many plantations now needing release were established under cover. In such cases release cuttings should be made as soon as possible so that the young planted trees do not become badly suppressed. However, studies made in Minnesota and lower Michigan (*103*) have shown that both red and eastern white pine planted under oak or aspen are able to benefit from release after having been overtopped for 5 to 15 years (fig. *40*). Recently a 29-year-old mixed jack pine-white pine plantation in lower Michigan was released on a commercial sales basis by removing 6.3 cords per acre of jack pine in such a way as to release the eastern white pine and benefit the remaining jack pine.

Although overstory release, in common with all silvicultural operations, must be based upon a thorough understanding of conditions on the ground and varied from place to place even within an acre, table 28 can be used as a guide to such work in the Lake States. It should be kept in mind that the table is only a *guide* and that operations will have to be varied according to local conditions.

[32] The preplanting removal can be done by use of the Athens-type disk or the Minnesota-type pusher plow described on page 76.

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FIGURE 40. — *A*, A 14-year-old red pine plantation on Superior National Forest, Minn., overtopped by aspen; *B*, same plantation 1 year after release; and *C*, 5 years after release when the plantation showed vigorous growth.

TABLE 28.—*Overstory release recommendations for Lake States plantations, by species*

Species	Before planting				1 to 5 years after planting				5 to 10 years after planting				10 to 15 years after planting			
	Full sunlight required	Maximum density overstory retained	Trees to be removed per acre [1]		Full sunlight required	Maximum density overstory retained	Trees to be removed per acre [1]		Full sunlight required	Maximum density overstory retained	Trees to be removed per acre [1]		Full sunlight required	Maximum density overstory retained	Trees to be removed per acre [1]	
			Oak	Aspen			Oak	Aspen			Oak	Aspen			Oak	Aspen
	Percent	*Percent*	*Number*	*Number*	*Percent*	*Percent*	*Number*	*Number*	*Percent*	*Percent*	*Number*	*Number*	*Percent*	*Percent*	*Number*	*Number*
Jack pine	30–35	50	110–230	280–700	60–70	20	110–230	280–700	80–100	0	100–200	250–600	--	--	--	--
Red pine	30–35	50	110–230	280–700	50–60	30	80–160	200–500	70–80	15	60–130	160–400	80–100	0	60–130	160–400
Eastern white pine	25–30	60	90–200	240–600	40–50	40	70–130	160–400	50–70	25	60–120	160–400	75–90	10	60–140	160–400
White spruce [2]	25–30	60	90–200	240–600	40–50	40	70–130	160–400	50–60	30	30–60	80–200	60–70	20	30–60	80–200

[1] Approximate maximum number of trees per acre to be removed, assuming the overstory is well-stocked oak or aspen ranging between 30 and 60 years in age. On the average, the number of trees to be removed per acre probably will not exceed one-half of those given in the table.

[2] 15 to 20 years after planting: not over 15 percent of overstory density to be retained; 70–80 percent of full sunlight required; number of trees to remove per acre—30–70 oak; 80–200 aspen.

Which Plantation to Release

It is not difficult to tell whether individual trees need release. Furthermore, by systematic observations of individual trees, it is not difficult to tell whether a specific plantation needs release. However, the decision as to which plantations to release when there is a choice among several is not always so simple. In each case the following questions should be answered:

1. Does the plantation have sufficient stocking of planted trees to warrant release? Some help in answering this question can be obtained from figure 28; ordinarily the plantation ought to have at least average stocking. It may be desirable to release plantations with less than average stocking if by so doing a fair stand can be produced more cheaply than by replanting, or if the plantation is composed of species poorly able to withstand competition.

2. If high release is involved, can the planted trees be expected to develop into higher quality products than the competing volunteer overstory trees? If the overstory consists of off-site aspen, undoubtedly any native conifer would produce more and better products. However, if the overstory is of sound oak or better hardwoods—a site that probably should not have been underplanted in the first place—the situation must be weighed carefully or money may be spent to destroy trees of equal or higher value than those favored.

3. Even though the plantation is well stocked, are the trees still sufficiently vigorous to respond quickly and well to release? Frequently, planted trees survive quite well for a few or even several years under heavy competition, but they become so badly suppressed (as evidenced by spindly habit, thin foliage, and slow growth) that they are unable to respond to the improved conditions resulting from release. Ordinarily a plantation probably should rate at least fair in growth (check against figures 29 to 38) as well as average or higher in stocking (see figure 28) to be considered for release. Many other factors must also be taken into consideration when only part of the plantations needing release can be treated, such as whether to favor the faster-growing but lower-quality species, whether to favor the 5-year-old plantation over the 2-year-old plantation, and so on. All such decisions should be made on the ground on the basis of local conditions thoroughly understood.

THINNING PLANTATIONS

In the Lake States, plantations on the average will grow and develop so that somewhere between 15 and 40 years of age the crowns of the trees will close and competition will begin to take place. Such competition is beneficial to the extent that it brings about the formation of straight, clean stems and reduces undergrowth, but if it becomes too intense, it will reduce growth and kill some of the trees. Before reduced growth occurs, some of the trees should be cut out so as to provide adequate growing space for those that remain.

It is desirable from a silvicultural standpoint to make frequent light thinnings so as to maintain good, uniform growth of the trees. However, from a practical standpoint it is desirable to delay thinning until merchantable material, usually pulpwood, can be removed in the operation and the cost offset so far as possible by the utilization of such material. As an example, a 27-year-old State plantation in Michigan was thinned on a commercial sales basis, removing 8 cords of pulpwood per acre. A 30-year-old red pine plantation was also thinned at a profit in Wisconsin (*99*). As a rule, with planting done under present standards, it should not be necessary to thin plantations in this region until they produce some merchantable material, and in many cases it probably will not be necessary to thin them at all.

How will the plantation manager know when his trees need thinning? The final decision, of course, will have to be made on the ground for each plantation, taking into consideration all of the silvicultural and economic factors involved, but certain general guides can be set up. Ordinarily, if the density of the plantation approaches or exceeds that of normal, fully stocked, natural stands, thinning could be done advantageously. However, a better guide than number of trees per acre is the percentage of trees in the stand that are found in the dominant and codominant crown classes.[33] If the stand is too open to differentiate crown classes, obviously it needs no thinning. However, even when the canopy is closed, if a relatively high percentage of the trees are in the dominant and codominant classes, no thinning is needed. On the other hand, if a relatively low percentage of trees in the stand are in the upper crown classes, then thinning is definitely needed.

Figure 41 shows the percent of trees in the dominant and codominant crown classes according to average stand diameter in normal stands of the conifers most commonly planted in the Lake States.

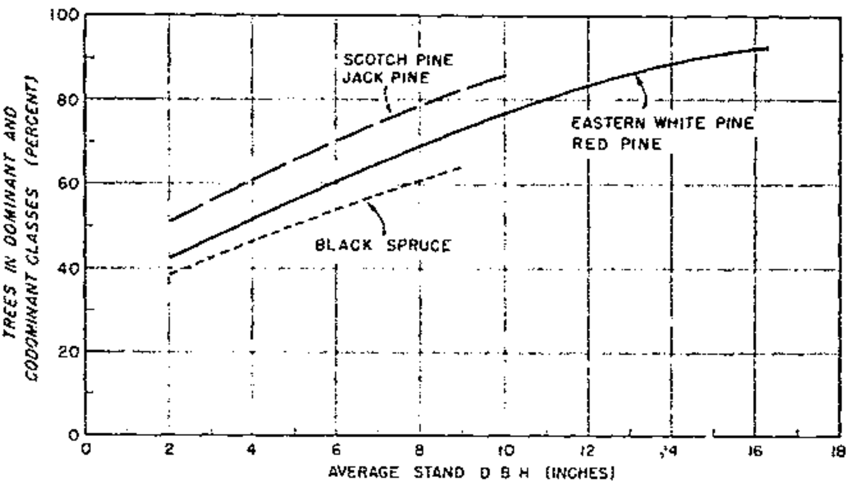

FIGURE 41.—Guide for thinning coniferous stands, based on percent of trees in dominant and codominant crown classes in normal stands in the Lake States.

[33] Crown classes are defined as follows: *Dominant*—trees with crowns extending above the general level of the forest canopy and receiving full light from above and partly from the sides. *Codominant*—trees with crowns forming the general level of the forest canopy and receiving full light from above but comparatively little from the sides. *Intermediate*—trees with crowns below but extending into the forest canopy and receiving a little direct light from above but none from the sides. *Suppressed*—trees with crowns entirely below the forest canopy and receiving no direct light.

In using these curves as a thinning guide, stands falling below the line should be thinned, those falling well above the line do not need thinning, and those falling on or a little above the line would benefit from thinning. In the latter case the decision to thin or not to thin must be made by the owner on the basis of current conditions of market, labor supply, or the like. Sufficient data were not available upon which to base a similar curve for red pine or white spruce. However, use of the eastern white pine and black spruce curves, respectively, will give conservative results.[24]

On the basis of work already done, thinning coniferous stands in the Lake States will require from 1 to 4 man-days per acre, depending on the size, kind, and number of trees per acre and the quality of the labor. It may be done anywhere from a net prewar cost of $15 per acre to a net profit. Ordinarily, lopping and scattering of slash is satisfactory disposal practice except along roads and trails where there is particular danger of fires starting. Plantation owners should obtain the advice of a trained forester in designating trees to be removed in thinning.

PRUNING PLANTATIONS

Even though trees in the oldest coniferous plantations (40 to 60 years old) in this region show very little tendency to shed their lower branches, artificial pruning has been practiced but rarely. Some pruning, confined largely to small private plantations, has been done for aesthetic rather than silvicultural or economic reasons. Recently, the United States Forest Service has done some pruning of planted trees in the Lake States largely for fire protection or experimental purposes.

The old virgin forests of this region, as a result of natural pruning, produced long clean boles that contained high percentages of clear lumber. However, natural pruning does not begin to take place until relatively late in the life of the stand, and in plantations of white and red pines dead branches have been found to persist so long that little or no clear lumber could be expected in rotations of less than 80 years (*18*). Consequently, the owner who wishes to grow his trees to merchantable saw-timber size at the earliest age and at the same time have a good-quality product may find artificial pruning a necessity.

Pruning of eastern white pine in the Northeast has given promise of returns per thousand board feet of $10 to $40 more than for similar unpruned lumber. Based on studies made in that region (*16*, *29*), the following recommendations can be made for pruning coniferous plantations established to produce saw timber:

1. Prune from 150 to 300 good, straight dominant or codominant trees per acre. Only trees that have good prospects of being present at the time of harvest cutting should be treated.

2. Do not undertake pruning until the trees have reached a height equal to the length of the pruned butt log desired (10 to 16 feet), nor until the crown classes can be differentiated.

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[24] A thinning guide based on the average height of dominant and codominant trees has been proposed. It is suggested that the average spacing between trees in a stand should be 1/6 to 1/7 of average height for spruce and fir, 1/5 to 1/6 for eastern white pine, and 1/4 to 1/5 for jack pine (*100*).

3. Pruning may be done at any season, provided that branches 1 inch in diameter and smaller are cut. If larger branches are to be removed, it will be safest to prune during the fall or winter. The cost of pruning can be decreased and the production of clear lumber increased if pruning is done while the branches are less than one-half inch in diameter.

4. Limbs should not be removed, ordinarily, above one-half the tree height or above the point where the highest living branches interlace.

5. Trees should be pruned to one-log height (17 feet) in two or three operations, endeavoring to keep the central knotty core about the same diameter throughout the log. The first pruning can be done up to a height of 6 or 7 feet and following two prunings each can extend another 4 or 5 feet up the stem.

6. Although axes, machetes, billhooks, knives, chisels, shears, clippers, and saws have all been used for pruning, the latter is the most satisfactory tool. Axes or machetes definitely should not be used. For low pruning, a hand pruning saw is recommended; for high pruning, either a hand pruning saw manipulated from a ladder or a pole pruning saw is recommended. In that connection, the Forest Products Laboratory is exploring the possibilities of power-driven pruning saws that may simplify the operation of high pruning considerably.

7. Pruned trees should be favored when thinnings are made.

Although it has been recommended in the Northeast that only saw-timber trees be pruned, it appears now that much of the jack pine planted in the Lake States may have very heavy limb development and that the extra value of knot-free pulpwood may justify the expenditure of several cents per crop tree in pruning. Studies are now under way in this region to determine both the desirability of and the best technique for such pruning. There are some indications that it may be cheaper for pulp companies to rerun the knots in the pulping process than to pay the cost of pruning.

What Records to Keep

As a necessary basis for the satisfactory conduct of a planting program, information as to the establishment, cost, and development of each plantation should be recorded in readily available form. However, where there are a large number of plantations to follow, records of all may present an unreasonable task. In such cases, detailed records on selected plantations should give adequate information. The record of establishment should include the following: location (township, range, section, forty, and further detail if necessary); size (area in acres); species (both common and scientific names preferable); kind of stock (wildling or nursery grown; age, size, quality, or grade); source of seed (State and county in which collected, or more detailed location of seed origin; or, if these are not known, dealer from whom obtained); source of stock (nursery at which grown); dates between which planting was done; ground preparation (method—plowing, disking, or scalping—kind of equipment used, and spacing of furrows or scalps); method of planting (system of planting—slit, wedge, deep hole, or mound—and kind of tool or machine used); and density of stocking (spacing of trees or number per acre).

For each plantation larger than 10 acres, it is advisable to make a map on a scale of 4 inches to the mile or larger. The larger scale is preferred for small plantations. The map should show the boundaries of the plantation, pertinent cultural and natural features—roads or trails, and streams, swamps, etc.—species or species mixtures, areas replanted, dates of planting and replanting.

Accurate cost records are necessary for the most efficient conduct of large planting operations. Such records should include the costs of planting stock; ground preparation; the planting operation, including any replanting; protection against fire, insects, diseases, cattle, rabbits, or other enemies; release cuttings; and thinnings. Any returns from the sale of products harvested from the plantation should also be included.

A record of the development of each plantation should be kept, and it should be started usually at the end of the first growing season after planting. Such records should include survival percentage and number of living trees per acre, average height, and principal injuries (causes and extent). Later, diameter at breast height (4.5 feet above the ground line), crown class or tree classes, and the volumes or quantities of various products should be recorded.

Plantations made at various times and places are subject to weather variations from year to year and differences in such factors as quality of planting stock, species, site characteristics, and kind and quality of ground preparations. Therefore, it is necessary to check the success of any considerable planting program by something more accurate than casual ocular observations. Some systematic method of observing the condition and growth of the planted trees is needed. Several methods of plantation examination that have received rather wide use in this region are as follows:

1. One of the simplest methods is to stake off plots of ¼, ½, or 1 acre in representative parts of each natural unit of the plantation. The main advantage of the method, beyond its simplicity, is that the plots provide an easy means of determining volume of wood per acre in later measurements. Its main disadvantage is that the plots frequently do not provide a representative sample of the entire plantation. Also the stakes decay and need to be replaced as often as every 5 years.

2. The line-plot method, which is based on running diagonal lines across the plantation, provides better sampling of the plantation. According to one variation of this method, the 1st tree in the 1st row, the 2d tree in the 2d row, the 3d tree in the 3d row, and so on, are examined. More frequently this method has been applied by counting 10, 20 or more trees in the 1st row, shifting to the 2d row and counting the next equal number of trees, then shifting to the 3d row and examining the 3d group of trees, and so on. Sometimes two adjacent rows are considered as 1 group, and the shifts are then made 2 rows at a time. This method gives a fairly good sample of the plantation and covers the work of various crew members and crews impartially. The first variation makes it necessary to stake each tree (numbering at least every 10th stake), while the second variation requires the staking of the first and last trees in each group only. Here again stakes need to be replaced periodically.

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3. The cruising method, which now is used commonly by the United States Forest Service in the Lake States, is statistically adequate for plantations of 40 acres or more. As its name suggests, the method is based on timber-cruising procedure. Compass strips are run across the plantation at 5-chain[5] intervals, beginning 2½ chains within the plantation boundary. Counting plots occur at 5-chain intervals along each strip, beginning 2½ chains from the starting point as follows: At each 5-chain interval, shift to the nearest row to the right; examine the first 5 trees directly ahead; then shift to the 1st row on the left and examine the 10 trees directly to the rear; shift back to the first row again and examine 5 trees ahead, bringing the examiner back to the approximate point at which he started the plot. With this method, sixteen 20-tree plots (320 trees) are examined on each forty. The main advantage of this method, beyond its statistical adequacy and the fact that no stakes are needed, is that the examiner can readily make a satisfactory map of the plantation as he traverses it, showing spottiness of stocking and parts that need replanting, release, or other special attention.

At least 200 trees should be observed in each plantation or homogeneous unit of the plantation, in any method of examination employed. More trees should be examined if the plantation is 40 acres or larger. Examinations should be made, 1, 2 or 3, and 5 years after planting to cover the period when mortality usually is greatest and when replanting can be done. It is also desirable to make additional examinations each 10 years after planting. Special counts should be made at other times in the event of severe drought, insect or disease epidemics, or similar serious conditions. Where the planted area is small and the observer experienced, casual ocular observations may provide adequate examination. Otherwise one of the methods described should be employed.

Photographs are a valuable supplement to plantation examination. A series of views taken over a period of years from the same point—preferably with the same size film and camera, oriented in the same way—illustrates plantation development better than either numerical or descriptive data alone can (88). Preferably, each homogeneous unit of plantation should be illustrated by pairs of photographs showing one view from the outside rows of the plantation and one within the plantation. Each camera point should be marked by a stout stake, and the location indicated on the plantation map.

LAYING THE GROUND WORK FOR REFORESTATION PLANNING

The small landowner usually knows, or can readily find, the areas needing reforestation, and he can quickly determine what, when, and how to plant them. Owners of large tracts, however, need some systematic method of reconnaissance to obtain the basic information for planning their reforestation programs several years in advance. There are two phases of reconnaissance, extensive and intensive surveys.

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[5] The chain, a unit commonly used in surveying, is equal to 66 feet, 4 rods, or 1/80 mile.

Extensive Surveys

Specifically, the purpose of extensive surveys is to provide definite knowledge as to the location, size, and character of each area in need of planting. Such information should be compiled by sections and townships and summarized by forties. Ordinarily, it can be obtained by referring to acquisition, timber, or inventory survey reports, or by examining aerial photographs, and little or no additional field work will be required.

Intensive Surveys

The purpose of intensive surveys is to obtain accurate information for each plantable area in order to provide a basis for preparing a detailed planting program for each forest. Such information concerns the species and class of stock to be planted, the methods of ground preparation to be used, and, in fact, all conditions affecting the planting job.

The basic information required for the preparation of detailed planting plans has to do chiefly with soil and cover conditions, and the possibilities of loss or injury on each area. It involves most of the matters discussed in previous sections of this bulletin.

SOIL FACTORS

Fundamental to evaluating sites for planting is the recognition of soil quality. Texture and moisture conditions are highly important and easily determined indices of soil quality. Soil texture can be readily determined in the field by the hydrometer method, or samples can be taken, appropriately labeled, and analyzed later in the office. The soils can be grouped into classes upon the basis of percent of fine material (silt plus clay) as follows: 0–15, sands; 15–20, loamy sands; 20–30, light sandy loams; 30–50, good sandy loams; 50+, heavy soils (silt loams, clays). Soil-moisture conditions are best measured by depth to the water table. If the water table, under normal midsummer conditions, is from 3 to 6 feet below the ground surface, it will exert a beneficial effect upon planted trees. If the water table is deeper, the trees are not apt to benefit from it; if it is shallower, the soils will be too wet for satisfactory growing conditions. The relation of these two soil factors to the selection of species and classes of planting stock is shown in table 7, p. 28.

Soil acidity, pH value, is also rather easily determined in the field. However, in an area such as the northern Lake States forested region, this factor is seldom of critical importance in delimiting the growth and occurrence of the species useful in reforestation. In other words, when the soil texture and moisture conditions are suitable for a given species the pH value almost always is suitable also. However, since pH is easily determined, tests can be run on the samples taken for fine-matter determination and the occasional area of unsuitable reaction eliminated.

COVER CONDITIONS

While the soil largely governs the growth capacity of the site, the kind and amount of vegetative cover largely determines its plantability and future release load. Both the overstory and low or ground cover are important in this respect.

The Overstory.—If there are enough trees of valuable species on the area, there is no need for planting. If, however, the stand is made up of trees of little or no commercial value and there are only remote chances of natural regeneration of the better species, the area ordinarily should be planted sooner or later. As a standard, any such area less than 60 percent stocked (based on a basal area for normal stands as given in yield tables) can be considered plantable, at least on a partial basis. Not only does the overstory govern the plantability of an area, but it also largely determines the difficulty of ground preparation and the amount of release work required.

Plantability of Aspen Stands.—Areas having an overstory of merchantable species are determined to be plantable on the basis of stocking. Aspen, however, must be considered in a special category because it may or may not produce merchantable stands, i. e., stands that will reach a height of at least 60 feet in 50 years. In general, it is known that on good sites aspen can produce merchantable wood crops and that on poor sites it usually becomes decadent before reaching merchantability. Therefore, some method must be found for determining which immature aspen stands are apt to become merchantable and which will fail to do so. There is no infallible method of making such a determination. Probably the best guide for determining potential aspen merchantability is a combination of soil texture, degree of burning, and presence or absence of shallow water table (*73*).

Unmerchantable stands—those considered for planting—will occur on soils with less than 20 percent of silt plus clay or on severely burned areas regardless of soil texture. However, there are exceptions—unburned or lightly burned aspen on soils with 15 to 20 percent silt plus clay and moderately burned aspen on soils with 20 to 30 percent silt plus clay may produce light pulpwood cuts if the permanent water table is within 3 to 7 feet of the surface; on the heavy, red gumbo, clay soils near Lake Superior, aspen does not develop well.

To ascertain the extent of fire damage it is necessary to examine the stand critically for evidence of past fires, to determine present age of stand, time at which fires occurred, and to note the comparative damage done by these fires. It is believed that with some training and sharp observation, field men will be able in most cases to do a reasonably good job of rating degree of burning. However, because of the emphasis placed upon this factor, some explanatory remarks may be helpful.

Evidences of the occurrence and severity of past fires can be obtained from the aspen trees themselves and from such environmental factors as the litter, the understory species, ground vegetation, and stand structure. It is necessary to fell a number of aspen trees in order to obtain a reasonably accurate estimate of the percent of trees injured by fire. Such trees are marked by any of the following: lesions or scars, rot, or discolored wood. On light burns, not over 10 percent of the felled trees show any signs of fire scar. On moderate burns, up to 50 percent of the trees may show scars, rot, or discolored wood. On heavy burns, over 50 percent of the trees are so affected and the stand is often considerably understocked. The site index often is reduced 15 to 25 feet.

Fire-scarred remnants of pine, hardwood, or other members of the previous stand can often be found nearby and are helpful in deciding the dates, number, and severity of fires. Charcoal in the humus or duff layer indicates recent fires. It is important to date fires so as to distinguish between the fire that was responsible for establishing the aspen and subsequent ones that could injure the stand. Fires are especially destructive when the stands are comparatively young.

On light burns only the litter and perhaps part of the duff will have been burned on the area as a whole. There may be a considerable amount of young conifer reproduction present; such would not be the case on moderate or heavy burns.

On moderate burns the fires are hot enough to destroy a considerable part of the duff and humus layer. Any remnants of the previous stand are apt to show telltale fire scars. Moderate and heavy burns cause considerable injury or destruction to the dense mass of shallow roots found in the humus layer.

On heavy burns remnants of the former stand plainly show the intensity of the fire. The occurrence of such burns often is indicated by the existence of two age classes of aspen, normally an even-aged species. Moderate to severe fires may destroy much of a young aspen stand and start another crop of sprouts and root suckers. The survivors of the older stand will retain a size advantage that is most notable in diameter development; the difference in height, after a few years, often is not so marked. The older trees generally have larger limbs and crowns. Any suspicions as to the two-aged character of a stand can be checked quickly by means of a few increment borings.

Low Cover.—The low cover on an area is of importance in determining its planting possibilities from two standpoints: (1) As it may affect ground preparation and the development of the plantation, (2) as it may contain reproduction of tree species.

Depending upon its composition and density, low cover may present a serious obstacle to plowing, may cause serious competition to planted trees, may mat down and smother planted trees over winter, or may protect planted trees from heat damage.

Generally speaking, the density and vigor of low-cover plants are less on the coarser-textured soils than on the finer soils. Consequently, furrowing is usually easier in the sandier areas, there is less need for later release, and furrows remain usable for a longer period in case planting is delayed or replanting is necessary. On the finer-textured soils, however, furrowing stimulates heavy sprouting and suckering of many species, and the furrows may be filled with vegetation in a year or two after plowing, necessitating early and often frequent release.

Low cover frequently contains reproduction of tree species that may range all the way from newly germinated seedlings to those several feet tall. If there are enough seedlings of valuable species to restock the area, planting obviously is not needed.

Using the same standards as for the overstory, any area less than 60 percent stocked with reproduction of valuable species can be considered as plantable. The stocking of the overstory can be determined quite simply by comparison with yield-table values. However, there are no such standards available for determining the stocking of reproduction. Most simply, stocking can be expressed in terms of stocked milacre quadrats. Since seedlings in different stages of development have considerably different survival values, there must be a flexible scale for determining what constitutes a stocked quadrat. The following scale, based on experience, is suggested:

Size class:	*Plants in stocked milacre quadrat*[1] *(number)*
3.1 feet tall to 0.5 inch d. b. h	1
1.0 foot to 3 feet tall	2
0.6 foot to 1 foot tall	4
0.5 foot tall and under	10

[1] Or any combination equivalent to one seedling 3.1 feet tall to 0.5 inch d. b. h., such as one seedling 1 foot to 3 feet tall plus 5 seedlings less than 0.5 foot tall, etc.

Considerable judgment should be used in tallying reproduction. Only seedlings that have survival value at the time should be tallied. For instance, very young seedlings growing on rotten logs or stumps, or on thick litter, should not be tallied because they have only a very slight chance of establishment. Similarly, small seedlings growing close beside vigorous, young to middle-aged trees have little chance of establishment. Another precaution should be observed in tallying sprouts. No matter how many sprouts arise from a single stump or stub, they should not be tallied as more than two plants. More than that seldom carry through to tree size, except perhaps in the case of basswood.

Besides the reproduction on an area, its potentialities for natural reproduction should be weighed. This is particularly true of areas recently burned or logged. If sufficient seed trees are available and soil conditions are suitable—not too many obstructions to seed or young seedlings coming in contact with mineral soil—it is quite possible that natural regeneration will reclaim the area. As a rough guide the following stocking of seed trees should be the minimum adequate for restocking an area:

Diameter breast high (inches):	*Trees per acre (number)*
6	15
7	11
8	9
9	7
10	5
15	3
20	2

Natural regeneration, of course, is rather uncertain, and it may take several years for enough seedlings to become established to restock an area. Exposure of the mineral soil by disking or other means may be necessary for satisfactory establishment of natural reproduction. For this reason, good judgment must be used in classifying areas as to reproduction potentialities. For all practical purposes, areas with a satisfactory reproduction potential but with little or no actual reproduction can be placed in a lower priority group for planting. They should be reexamined before planting to see whether sufficient reproduction of valuable species has taken place.

Ecological Development of Site.—One other point to be considered in observing the cover, both high and low, is the probable ecological development of the site. Such trends can be determined by weighing the present overstory (composition and density), present reproduction (composition and density), and soil conditions as against past cover and soil treatment (burning, logging, etc.), and comparing the results with known ecological successions. The main advantage of considering the ecological status of a site is that it presents further information upon which to assign planting priorities and to judge future release loads.

In the Lake States most upland forested areas are in some stage of development toward either the white spruce-balsam fir or the northern hardwood-hemlock climaxes. The former is the climax of the colder more northerly areas, the latter of the areas of relatively milder climate. In part of the Lake States there is a transition between the two climaxes wherein species of both are represented.

The species ordinarily making up the northern hardwood-hemlock climax are sugar maple, yellow birch, basswood, beech, and hemlock. There is some variation within the region, however. In Minnesota, beech and hemlock are absent. Farther to the east these species come in, and yellow birch becomes somewhat more prominent. Beech does not play a very important part in this climax in the Lake States.

Many factors affect the progress and rate of ecological succession, but probably of most importance are soil conditions. As a general rule, succession may be expected to be farthest advanced and to proceed toward the climax more rapidly on the better (finer-textured) soils. On the poorer sandy lands, however, progress toward the climax will commonly be so slow that it requires less consideration in forest management.

SURVEY METHODS

The information required for the intensive survey will ordinarily be obtained by means of a line-plot survey. The intensity of the survey, to be decided upon by the forester in charge, should be determined by the amount and reliability of information already available, conditions on the ground, and whether or not a complete inventory survey is to be made. Generally the practice will be to run two strips through a forty, taking plots at 2.5, 7.5, and every fifth chain thereafter. Stocking and composition of the overstory (and potential merchantability of aspen) should be taken on a one-tenth-acre plot and of the low cover on a milacre plot. At these points soil samples should be taken and the depth to water table determined by boring with a soil auger down to 6 feet (presence of water table is indicated by saturated soil). Where a white grub count is necessary, holes 1-foot square and 1-foot deep should be dug every 2 chains and the number of grubs counted. The relative abundance of snowshoe hares, deer, or other potential plantation enemies should be noted.

The bulk of the information gathered should be shown on a map (preferred scale, 8 inches=1 mile), which should indicate by appropriate symbols:

1. The boundaries of all plantable areas.
2. Kind and density of overstory and low cover.
3. Physical features, such as roads and trails, drainage, swamps and lakes, ridges.
4. Soil-texture class and depth to water table.
5. The boundaries of areas in which grubs occur in more than 50 percent of the sample holes.
6. The species and age class to be planted.
7. The abundance of ribes, if white pine is recommended for planting.

8. Type of ground preparation and direction of furrows or scalps (size also in case of latter).

9. Areas affected by wind or water erosion.

10. Wildlife and recreational values, including also potential damage from deer, hares, or other animals. Areas to be reserved for wildlife purposes should be outlined on the map.

The technique of making the field survey may vary a little according to local conditions. For instance, either a two-man or three-man crew may be used depending upon whether a complete inventory survey is being made. The distances may be chained out or paced, depending upon the amount of control line available. A staff compass should be used for running the line.

Upon completion of the field survey a report should be prepared that will show for each of the next 4 or 5 years the exact areas to be planted, the acreage, the species and class of stock: method, direction, and spacing of ground preparation; presence or absence of service roads necessary for the distribution of men and trees, and the need for additional roads; and any other special conditions that might affect the planting job. Reasons for the decisions made should be concisely stated. After the initial survey, current surveys should keep the information about 4 years ahead of the planting program.

ANNUAL CHECK SURVEY

Each year a check survey should be made of the areas to be planted the following season so as to determine whether their classification should be changed. In some cases sufficient reproduction may have come in to restock the stand naturally or to make a change necessary in choice of species or class of stock. Sometimes, too, additional research may have been made or experience gained that would make advisable some changes in species, class of stock, or method of ground preparation, or even throw an area into a nonplantable category. A special check should be made of the grub, snowshoe hare, or deer population if the original survey showed a heavy population, or if nearby plantations show serious, recent damage.

A good size-up of the grub population can be obtained by following the plow during furrowing to see how many grubs are turned up. However, since it might be advisable to refrain from furrowing areas badly infested with grubs, some sort of survey should be made in advance on areas where the population appears to be heavy. The most intensive survey will involve digging 1-foot square holes at 1-chain intervals on strips 4 chains apart. At the forester's discretion less intensive surveys may be made. The same criteria in classifying the area will be used as already mentioned; i. e., areas in which more than 50 percent of the test holes contain grubs should not be planted if they are 10 acres or more in extent, or they should be planted with 25 percent more trees than normal if they are less than 10 acres in size.

Briefly, the annual check of the intensive survey should—

1. Check the applicability of the intensive survey and indicate changes needed.

2. Check grub population where necessary.

3. Determine potential damage from snowshoe hares, deer, or other animals.

4. Check effectiveness of any ribes eradication work that may have been done, and note evidences as to abundance of other diseases or insect pests that may cause plantation loss or injury.

5. Stake out, or otherwise plainly mark, wildlife areas either before or after ground preparation.

In a more extensive way, except where detailed grub surveys are needed, the annual check should cover all of the points looked for in the regular intensive survey. An experienced planting man familiar with local conditions could make such checks by merely traveling through each area. A less experienced man would have to run some strips and make some measurements.

Is Forest Planting Profitable?

The profitableness of planting, as of any business transaction, lies in the difference between costs and returns. In the growing of a timber crop there is one distinctive feature, however, and that is the long period over which the costs or investment must be carried before returns are realized. The elements that must be considered in the calculation of profitableness are land value; cost of planting and after-care; annual expense of fire protection, administration, and taxes; number of years to grow the crop; timber yield, and stumpage or wood value. Most of these factors vary with the conditions under which planting is done (*37*). It has already been shown how the cost of planting varies with the species, size, and age of the trees planted; soil and cover conditions; and number of trees planted to the acre. Similarly, the variations in taxes, cost of protection, and cost of after-care have been discussed.

With the exception that public agencies pay no taxes on the lands [36] and that private agencies need pay no direct protection costs, there is no difference in the elements of cost as between public and private planting in the Lake States. However, from the standpoint of evaluating returns, there is considerable difference. Whereas the private operator must reckon his profits almost entirely on the basis of stumpage values or value of the wood produced, occasionally bolstered by some monetary return from sales of recreational privileges, the public agencies must view the profitableness of planting from a much broader angle. Against the cost of planting, public agencies must weigh not only the direct value of wood products produced, but also such items as values of wildlife, recreation, watershed protection, the restoration of a despoiled resource, stabilization of communities, and the general upbuilding of local, regional, and national welfare. Furthermore, it must not be assumed that the cost of planting can or should be "written off" when the first crop is harvested. Consideration must be given to the several rotations, generations, or even centuries that it would take Nature to restore the resource, and to the difference in producivity of the area resulting in the interim from planting or not planting.

A large part of the reforestation job in the Lake States must be a public activity. This is so because of the great area on the poorer sites

[36] The Federal Government pays the counties 25 percent of the income of the national forests in lieu of the taxes they might have derived from private ownership of the land. The State governments also pay the counties fixed sums per acre for State-held land for the same purpose. These payments might be considered as taxes paid by the public agencies.

that needs complete planting. Public agencies can "break even" on such sites; private agencies as a rule cannot.

The accelerating accumulation of compound interest over the long period of years in timber growing is primarily responsible for the comparatively poor economic showing of plantations that start with bare land. However, the planting of lands denuded by logging and fires is not so much a business enterprise as it is the rehabilitation of a resource basic to the welfare of the region. Only public agencies can make large investments now and expect returns—many of which are somewhat intangible—decades, generations, or even centuries in the future. That this fact is becoming recognized is evidenced by the increased holding of public lands (now over 20 million acres) and the expanded public planting program in the Lake States.

There is a further argument for public planting. Whereas the private owner can most profitably grow timber in the shortest period necessary to produce a merchantable crop, the public owner can derive greater profit from growing timber over a longer period of years for the production of higher yields, higher quality, and higher values. It is only under such ownership that this type of product is likely to be produced on any considerable scale in the Lake States.

There are certain conditions under which planting by private owners in the Lake States can be profitable. The private owners who stand to benefit most from forest planting in this region are the pulp and paper companies, particularly those who can use pine pulpwood. They have large investments in their plants and are dependent entirely upon having an adequate wood supply available. Since plantations for pulpwood production can be handled on a relatively short rotation, and the companies can take advantage of thinnings and improvement cuttings to increase the yield and maintain a good growth rate, they can scarcely afford not to plant. Moreover, the pulp companies do not need to make a profit on the stumpage produced since they make their profit on the products of their mills. Just to break even so as to amortize the investment in the plantation is enough.

From the point of view of large companies with a long life, which already own considerable tracts of timber and carry on reforestation chiefly to bring small bare areas and "holes" in the stands into production, forest planting even of the saw-timber species can be profitable. Such operators who obtain an income from the cutting of timber on their own lands can pay the cost of planting by putting part of the value of the timber that is cut back into the forest-producing part of the business.

Small property owners are setting out many small plantations every year, although they do not expect to harvest the crop themselves. The planting may be a matter of personal interest, or an investment for the children, or an improvement of the property and its values. The last two are sound economic motives, for there is no question but that a piece of property with a nice grove of young pine timber has a higher sale value than the same property without the trees. On the other hand, the company that is using timber as a raw product for a manufacturing enterprise and has a supply for only a few years ahead cannot be expected to invest heavily in planting a crop that can make satisfactory returns only when it is too late to prolong the life of the enterprise.

It may be said that forest planting in the Lake States does not promise profit for the small private landowner except under special conditions, but that from the long-time, broad point of view it can be profitable for public agencies and for private owners such as pulp and paper companies dependent upon an adequate supply of wood for their continued operation.

SUMMARY

In the Lake States region, which embraces the States of Minnesota, Wisconsin, and Michigan, there are about 27 million acres of nonrestocking or poorly restocked, cut-over and burned forest land, of which about 9 million acres will have to be reforested if the area is to be restored to valuable forest growth in the reasonably near future. An additional 3½ million acres of understocked young stands could be made much more productive by partial planting.

This bulletin, based primarily on the research and experience of the United States Forest Service and supplemented by that of other public and private agencies in the region, has been prepared to provide the best general guide for the large-scale reforestation program required.

As a background for reforestation practice, there are described briefly the physical characteristics of the region, including (1) the natural vegetation; (2) precipitation, ranging from 20 to 35 inches per year, of which 56 percent falls during the warm months; (3) temperature that averages about 44° F. with recorded extremes of 111° and −59°; (4) the growing season that varies from 50 to 181 days and averages about 130 days between May and September; (5) topography that is generally level to rolling and characteristic of glaciated areas; and (6) soils that vary from droughty sands to stiff clays, and mucks and peats.

Reforestation in the Lake States region began with a planting that was finished in 1876 near Hancock, Wis. Following this there were other intermittent plantings. But regular annual plantings did not begin until about 1910, and then only on a small scale. Thereafter a rather slow but steady increase in planting took place up to 1933 when the CCC and other emergency programs gave reforestation an unprecedented spurt. It reached a climax in 1936 when 144,000 acres were planted. Since then reforestation has suffered a decline, and especially since 1940, but several thousand acres are still planted annually. By the end of 1944 a net area of about 1,400,000 acres had been planted in the region. At that time the percents of various kinds of trees planted were as follows: red pine, 43.0; jack pine, 40.7; eastern white pine, 9.2; other pines, 0.3; white spruce, 4.1; other spruces, 1.4; other conifers, 0.4; and hardwoods, 0.9. Out of all the trees planted through 1944, 88.9 percent were seedlings and 11.1 percent transplants.

The job ahead—reforesting 12½ million acres—is a big one. If done in a 20-year period it would involve planting 600,000 acres per year, four times the peak rate of CCC planting in the Lake States, and a 250 percent increase in nursery capacity. The program would cost 180 million dollars at prewar prices—present costs would be substantially higher—and provide 11¼ million man-months of work. As a basis for planning this job, estimates are presented by broad ownership classes and species as to the areas in need of complete and partial planting for 13 sections of the Lake States.

In the search for a method cheaper than planting, direct seeding has been tried with a variety of species and several methods in the Lake States since about 1910. The conclusion has been that direct seeding should be considered not as a substitute for planting but only to supplement it under very favorable conditions. Such direct seeding as is done should be confined to the finer-textured soils or to sandy soils only where the water table is high enough to prevent the surface soil from drying out.

The first important step in reforestation is to determine where to plant and then what species and class of stock to plant. Recommendations are made according to overstory and ground-cover density, depth to water table, and soil texture, and specifications for suitable planting stock of various species are given. It is important to use not only the right species, but also stock grown from seed of suitable origin, which usually means local origin.

The characteristics, uses, native range, usual type of stand, and general sites on which to plant for the species recommended (jack pine, red pine, eastern white pine, white spruce, black spruce, tamarack, eastern cottonwood, white ash, green ash, Scotch pine, Norway spruce, and a few miscellaneous species) are described briefly.

The advantages and disadvantages of mixed planting of two or more species are listed and results of such plantings as compared to pure plantings in the Lake States are discussed.

The next important step in reforestation is to know how to plant. This involves understanding (1) the proper care and handling of planting stock from the time it is lifted in the nursery to the time it is set out in the field, including such items as packing, transporting, storing, and heeling-in; (2) how to prepare the ground for planting, whether by scalping, disking, or furrowing—usually preferred in the Lake States; (3) what methods of planting to use, whether the slit—bar-slit or mattock-slit—center-hole, side-hole, mound, or wedge; (4) how many trees to plant per acre for different species under varying conditions; and (5) how to organize a planting operation.

When to plant must also be carefully considered. Spring is generally the best season in the Lake States, but fall has certain advantages in some cases. To some extent the spring planting season can be extended by holding dormant stock in cold storage (up to 5 weeks for pine, 4 weeks for white spruce).

The planting of aspen and brushlands to convert them to more valuable coniferous stands presents a special problem in the Lake States. Studies have indicated (1) that conversion should be confined to areas cut or burned within the past 15 years, especially on the better soils, and to aspen not more than 10 feet high on good soils or 15 feet on poorer soils; (2) jack pine, red pine, eastern white pine, white spruce, and possibly Norway spruce, should be used for planting depending on the soil; (3) sturdy high-quality planting stock should be used; (4) prior to planting, the overstory must be opened up and the competition from low vegetation removed; (5) the soil must be thoroughly prepared; (6) trees should be planted closely (4- by 4- or 4- by 6-foot spacing); (7) from 1 to 3 low releases should be given the planted trees; (8) after the planted trees are 4 to 5 feet tall the removal of the overstory should begin, preferably being done in two or more operations.

Where natural conditions do not provide sufficient food and shelter for wildlife, planting may improve conditions. For best results, suitable species of sturdy stock should be planted carefully in well-prepared soil on sites to which they are well adapted. Adequate release and protection should be given the trees and shrubs until they are able to maintain themselves.

Trees and shrubs frequently can be planted to control soil erosion. Good stock of suitable species and careful planting technique should be used.

An important point in deciding on the feasibility of reforestation is the cost involved. While cost will vary widely for individual operations, prewar costs on large planting jobs in the Lake States average $15 per acre for establishment, $10 to $15 per acre for maintenance, probably 5 cents per acre per year for adequate fire protection, and 4 to 50 cents per acre per year for taxes on the land.

Planting machines have been developed by State agencies in Wisconsin, Minnesota, and Michigan, and by private manufacturers. Suitable chiefly for lighter soils without too many obstructions, such as stones, stumps, or large roots, these machines make it possible to plant 6,500 to 11,000 trees per day with 2- or 3-man crews at savings of 30 to 50 percent over hand planting on comparable sites.

After plantations are established, the job has just begun, because they must be maintained until valuable crops are produced. The plantations must be protected from many enemies, chief of which in the Lake States are climatic conditions, fire, animals, insects, and diseases. The occurrence and control of injuries from these factors is discussed, and their relative importance is shown.

Adequate stocking of the plantations must be maintained. Success of planting, however, depends upon a combination of survival, height growth, and diameter growth, or volume. Compared to natural stands, plantations up to 30 years in age (the limit of the data) have poorer stocking, rather similar height development, and better diameter development. To maintain adequate stocking and growth, the plantations usually need periodic release from competition, first from low shrubby or herbaceous growth, later from overtopping trees, and finally from other planted trees when the stand has closed in (thinning). Release and thinning recommendations are made, and the principles of judicious pruning of selected trees are given.

As a necessary basis for the satisfactory conduct of a planting program, careful records—including maps—should be kept concerning the establishment, cost, and development of each plantation. Information on plantation development should be obtained periodically, beginning usually 1 year after planting, on a systematic basis, such as from staked plots, line-plot surveys, or cruising surveys. Photographs are a valuable part of the record.

While the small landowner can quickly determine what areas need planting and decide what, when, and how to plant, owners of large tracts need some systematic method of reconnaissance to obtain the basic information for planning their reforestation programs several years in advance. There are two phases of reconnaissance: (1) Extensive surveys that answer the question, to plant or not to plant; and (2) intensive surveys that answer the questions, what and how to plant. Making these surveys involves an understanding and consideration of most of the information in the previous sections of the bulletin. Details of both types of surveys are given.

The profitableness of planting, which should be weighed before embarking on any large program, lies in the difference between costs and returns. Under Lake States conditions, it is believed that the small private owner cannot consider forest planting a profitable enterprise except under unusually favorable circumstances. He must reckon his profits almost entirely on the basis of stumpage values produced, with occasional additional returns from the sale of recreational privileges, etc.

On the other hand, the pulp and paper companies can well afford to plant because they have large investments in their plants dependent entirely upon having an adequate wood supply available, can handle their plantations on relatively short rotations for pulpwood production and take advantage of thinnings and improvement cuttings to increase the yield and maintain a good growth rate, and do not need to make a profit on the stumpage produced since they make their profits on the products of their mills.

Public agencies must view their return from a much broader angle. They must consider not only the income from the wood products produced, but also such values as wildlife, recreation, watershed protection, the restoration of a despoiled resource, stabilization of communities, and the general upbuilding of local, regional, and national welfare. In addition, they need not "write off" the cost of planting when the first crop is harvested, but can distribute it over several rotations. They can also consider the difference in productivity of the planted area over what it would have been had natural restocking been depended upon. From the public standpoint, reforestation in the Lake States can be a profitable enterprise, and because of conditions, it must be largely a public activity.

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APPENDIX

Common and Scientific Names of Trees and Shrubs Mentioned

Alder, speckled	*Alnus incana* (L.) Moench
Aralia, bristly	*Aralia hispida* Vent.
Ash, green	*Fraxinus pennsylvanica* var. *lanceolata* (Borkh.) Sarg.
Ash, white	*F. americana* L.
Aspen, bigtooth	*Populus grandidentata* Michx.
Aspen, quaking	*P. tremuloides* Michx.
Barberry, European	*Berberis vulgaris* L.
Basswood, American	*Tilia americana* L.
Bearberry	*Arctostaphylos uva-ursi* (L.) Spreng.
Beech, American	*Fagus grandifolia* Ehrh.
Birch, paper	*Betula papyrifera* Marsh.
Birch, resindot	*B. glandulifera* (Reg.) Butler
Birch, yellow	*B. lutea* Michx. f.
Bittersweet, American	*Celastrus scandens* L.
Blackberry	*Rubus* spp.
Blackhaw	*Viburnum prunifolium* L.
Blueberry	*Vaccinium* spp.
Boxelder	*Acer negundo* L.
Bushhoneysuckle, dwarf	*Diervilla lonicera* Mill.
Butternut	*Juglans cinerea* L.
Ceanothus, Jerseytea	*Ceanothus americanus* L.
Cherry, black	*Prunus serotina* Ehrh.
Cherry, pin	*P. pensylvanica* L. f.
Cherry, sand	*P. pumila* L.
Chokeberry	*Aronia* spp.
Chokecherry, common	*Prunus virginiana* L.
Coralberry, Indian-currant	*Symphoricarpos orbiculatus* Moench
Cottonwood, eastern	*Populus deltoides* Bartr.
Crab apple, sweet	*Malus coronaria* (L.) Mill.
Creeper, Virginia	*Parthenocissus quinquefolia* (L.) Planch.
Currants, wild	*Ribes* spp.
Dogwood, bunchberry	*Cornus canadensis* L.
Dogwood, gray	*C. racemosa* Lam.
Dogwood, alternate-leaf	*C. alternifolia* L. f.
Dogwood, redosier	*C. stolonifera* Michx.
Elder, American	*Sambucus canadensis* L.
Elder, scarlet	*S. pubens* Michx.
Elm, American	*Ulmus americana* L.
Elm, rock	*U. thomasi* Sarg.
Elm, Siberian	*U. pumila* L.
Filbert, American	*Corylus americana* Marsh.
Filbert, beaked	*C. cornuta* Marsh.
Fir, balsam	*Abies balsamea* (L.) Mill.
Gooseberries, wild	*Ribes* spp.
Grape, riverbank	*Vitis riparia* Michx.
Greenbrier, bristly	*Smilax hispida* Muhl.
Hackberry	*Celtis occidentalis* L.
Hawthorn	*Crataegus* spp.
Hawthorn, downy	*C. mollis* Scheele
Hemlock, eastern	*Tsuga canadensis* (L.) Carr.
Hickory	*Carya* Nutt.

Honeysuckle	*Lonicera* spp.
Honeysuckle, Tatarian	*L. tatarica* L.
Hophornbeam, eastern	*Ostrya virginiana* (Mill.) K. Koch
Hornbeam, American	*Carpinus caroliniana* Walt.
Huckleberry, black	*Gaylussacia baccata* (Wangenh.) K. Koch
Juniper, common	*Juniperus communis* L.
Juniper, oldfield common	*J. communis* var. *depressa* Pursh
Kalmia, lambkill	*Kalmia angustifolia* L.
Larch, European	*Larix decidua* Mill.
Leatherleaf	*Chamaedaphne calyculata* (L.) Moench
Ledum, Labradortea	*Ledum groenlandicum* Oed.
Locust, black	*Robinia pseudoacacia* L.
Maple, mountain	*Acer spicatum* Lam.
Maple, red	*A. rubrum* L.
Maple, silver	*A. saccharinum* L.
Maple, sugar	*A. saccharum* Marsh.
Mountain-ash, American	*Sorbus americana* Marsh.
Mulberry, red	*Morus rubra* L.
Nannyberry	*Viburnum lentago* L.
Nightshade, bitter	*Solanum dulcamara* L.
Ninebark, common	*Physocarpus opulifolius* (L.) Maxim
Oak, black	*Quercus velutina* Lam.
Oak, bur	*Q. macrocarpa* Michx.
Oak, northern pin	*Q. ellipsoidalis* E. J. Hill
Oak, northern red	*Q. borealis* Michx. f.
Pearlberry, creeping	*Chiogenes hispidula* Torr. & Gray
Peashrub, Siberian	*Caragana arborescens* Lam.
Pine, Austrian	*Pinus nigra* Arnold
Pine, eastern white	*P. strobus* L.
Pine, jack	*P. banksiana* Lamb.
Pine, lodgepole	*P. contorta* var. *latifolia* Engelm.
Pine, ponderosa	*P. ponderosa* Laws.
Pine, red	*P. resinosa* Ait.
Pine, Scotch	*P. sylvestris* L.
Plum, American	*Prunus americana* Marsh.
Plum, Canada	*P. nigra* Ait.
Poplar, balsam	*Populus tacamahaca* Mill.
Poplar, Petrowsky	×*P. petrowskiana* Schneid.
Raspberry, American red	*Rubus idaeus* var. *strigosus* (Michx.) Maxim.
Raspberry, blackcap	*R. occidentalis* L.
Redcedar, eastern	*Juniperus virginiana* L.
Rose, wild	*Rosa* spp.
Russian-olive	*Elaeagnus angustifolia* L.
Sassafras	*Sassafras albidum* (Nutt). Nees
Serviceberry, downy	*Amelanchier arborea* (Michx. f.) Fern.
Snowberry, common	*Symphoricarpos albus* (L.) Blake
Spicebush, common	*Lindera benzoin* (L.) Blume
Spruce, black	*Picea mariana* (Mill.) B. S. P.
Spruce, blue	*P. pungens* Engelm.
Spruce, Engelmann	*P. engelmanni* Parry
Spruce, Norway	*P. abies* (L.) Karst.
Spruce, western white	*P. glauca* var. *albertiana* (S. Brown) Sarg.
Spruce, white	*P. glauca* (Moench) Voss
Sumac, shining	*Rhus copallina* L.
Sumac, smooth	*R. glabra* L.
Sumac, staghorn	*R. typhina* Torner
Sweetfern	*Comptonia peregrina* (L.) Coult.
Sweetgale	*Myrica gale* L.
Tamarack	*Larix laricina* (Du Roi) K. Koch
Thimbleberry, western	*Rubus parviflorus* Nutt.
Viburnum, American cranberrybush	*Viburnum trilobum* Marsh.
Viburnum, arrowwood	*V. dentatum* L.

White-cedar, northern	*Thuja occidentalis* L.
Willow, Bebb	*Salix bebbiana* Sarg.
Willow, peachleaf	*S. amygdaloides* Anderss.
Willow, pussy	*S. discolor* Muhl.
Willow, sandbar	*S. interior* Rowlee
Willow, shining	*S. lucida* Muhl.
Wintergreen, checkerberry	*Gaultheria procumbens* L.
Winterberry, common	*Ilex verticillata* (L.) A. Gray
Witch-hazel	*Hamamelis virginiana* L.
Yew, Canada	*Taxus canadensis* Marsh.

Requirements and Procedures for Nursery Stock Inspection in the Lake States

Each of the three Lake States has laws requiring the inspection of nursery stock before it can be sold or removed from the premises on which it is grown. Although these laws vary somewhat from State to State, they generally include the following rules:

1. Every nursery must be inspected at least once a year by legally appointed inspectors, usually of the State Department of Agriculture, before stock raised in it may be sold or removed from the premises. An established fee is charged.
2. Nurseries that, on inspection, are found free from plant disease and insect pests are granted a certificate of inspection and may ship or sell stock for the remainder of the year without further inspection. Each shipment of stock must bear a tag indicating that it comes from an inspected nursery. If diseases or insect pests are found by the inspector, the infected or infested stock must be given such control measures as the inspector prescribes or it must be destroyed before a certificate will be furnished.
3. Eastern white pine stock will not be certified unless all currant and gooseberry bushes within 900 feet of the nursery have been eradicated.
4. Trees dug from uninspected areas, wildlings or otherwise, must be inspected before they can be moved from the premises.
5. Appropriate penalties are provided for violations of these laws.

Persons contemplating the purchase of nursery stock can obtain copies of the rules and lists of approved nurseries from the following agencies:

(1) State Entomologist, University Farm, St. Paul, Minn.
(2) State Entomologist, Department of Agriculture, State Capitol, Madison, Wis.
(3) Director, Bureau Orchard and Nursery Inspection, Department of Agriculture, Lansing, Mich.

Purchasing Stock for Forest Planting

Nursery stock for farm shelter belts or reforestation purposes may be purchased from State-owned nurseries in Wisconsin and Michigan at nominal prices about equal to the cost of production. A law passed in 1947 makes it possible for Minnesota residents also to purchase forest planting stock from State nurseries.

Purchasers of stock from the State-owned nurseries must meet the following requirements: (1) Make application within specified periods and pay in advance; (2) order at least 500 trees; (3) indicate the exact location at which the trees are to be planted; (4) agree not to resell the trees or to use them for ornamental purposes; (5) agree to protect the plantations and not to cut the trees until they are large enough to produce timber products.

Although the prices vary somewhat from year to year and from nursery to nursery, the species most commonly used for reforestation have been obtainable from the State nurseries at prewar prices per 1,000 trees within the following ranges: seedling conifers, \$2 to \$5; transplant conifers, \$5 to \$16; seedling hardwoods, \$2 to \$10. Recent higher costs will mean increases in these prices. Shipping charges are additional. Inquiries should be addressed to: (1) Wisconsin Conservation Department, Madison, Wis. (2) Division of Forestry, Department of Conservation, Lansing, Mich. (3) Department of Forestry, Michigan State College, East Lansing, Mich. (4) Division of Forestry, Department of Conservation, St. Paul, Minn.

Sources of Information on Specialized Equipment Mentioned [37]

Planting machines:	*For specifications or other details write to:*
Lowther (Standard)	Harry A. Lowther Co., Joliet, Ill.
Michigan (Reforestator)	Forestry Department, Michigan State College, East Lansing, Mich. or L. W. Merriam Co., Elsie, Mich.
Minnesota	Forestry Division, Minnesota Department of Conservation, State Office Building, St. Paul, Minn.
Wisconsin (Badger)	Extension Forester, University of Wisconsin, Madison, Wis. or Wagler Equipment Co., Pewaukee, Wis.
Planting tools:	
Baldwin hoe	U. S. Forest Service, Milwaukee, Wis.
Michigan bar	Do.
Planting box	Do.
Plows:	
Athens disk	Athens Plow Co., Athens, Tenn.
Baldwin	U. S. Forest Service, Milwaukee, Wis.
Killefer	Killefer Manufacturing Corp., Ltd., Los Angeles, Calif., or Peoria, Ill.
Mesaba	U. S. Forest Service, Milwaukee, Wis.
Minnesota pusher	Forestry Division, Minnesota Department of Conservation, St. Paul, Minn.
Olympic	U. S. Forest Service, Portland, Oreg.
Wagler	Wagler Equipment Co., Pewaukee, Wis.

Forest Seed Policy

Recognizing that trees and shrubs, in common with other food and fiber plants, vary in branch habit, rate of growth, strength and stiffness of wood, resistance to cold, drought, insect attack, and disease, and in other attributes which influence their usefulness and local adaptation for forest, shelterbelt, and erosion-control use, and that such differences are largely of a genetic nature, it shall be the policy of the United States Department of Agriculture insofar as practicable to require for all forest, shelterbelt, and erosion-control plantings, stocks propagated from segregated strains or individual clones of proven superiority for the particular locality or objective concerned.

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[37] Mention of specific firms does not constitute an endorsement by the Forest Service or the United States Department of Agriculture.

Furthermore, since the above attributes are associated in part with the climate and to some extent with other factors of environment of the locality of origin, it shall be the policy of the United States Department of Agriculture:

1. To use only seed of known locality of origin and nursery stock grown from such seed.

2. To require from the vendor adequate evidence verifying place and year of origin for all lots of seed or nursery stock purchased, such as bills of lading, receipts for payments to collectors or other evidence indicating that the seed or stock offered is of the source represented. When purchases are made from farmers or other collectors known to operate only locally, a statement capable of verification will be required as needed for proof of origin.

3. To require an accurate record of the origin of all lots of seed and nursery stock used in forest, shelterbelt, and erosion-control planting, such records to include the following minimum standard requirements to be furnished with each shipment:

(1) Lot number.
(2) Year of seed crop.
(3) Species.
(4) Seed origin: State—County—Locality—Range of elevation.
(5) Proof of origin.

4. To use local seed from natural stands whenever available unless it has been demonstrated that seed from another specific source produces desirable plants for the locality and uses involved. Local seed means seed from an area subject to similar climatic influences and may usually be considered as that collected within 100 miles of the planting site and differing from it in elevation by less than 1,000 feet.

5. When local seed is not available, to use seed from a region having as nearly as possible the same length of growing season, the same mean temperature of the growing season, the same frequencies of summer droughts, with other similar environment so far as possible, and the same latitude.

6. To continue experimentation with indigenous and exotic species, races, and clones to determine their possible usefulness, and to delimit as early as practicable climatic zones within which seed or planting stock of species and their strains may be safely used for forest, shelterbelt, and erosion control.

7. To urge that States, counties, cities, corporations, other organizations, and individuals producing and planting trees for forest, shelterbelt, and erosion-control purposes, the expense of which is borne wholly or in part by the Federal Government, adhere to the policy herein outlined.

It is recommended that this memorandum be referred to the Chief of the Forest Service and the Chief of the Soil Conservation Service for their approval before final action by yourself.

Respectfully submitted,

[s] M. A. McCall,
Chairman, Seed Policy Committee.

Approved:

[s] F. A. Silcox, May 29th, 1939.
Chief, Forest Service.

[s] D. S. Myer, June 8, 1939.
Acting Chief,
Soil Conservation Service

[s] H. A. Wallace, June 21, 1939.
Secretary.

Climatic Factors in the Lake States

Figures 42–46 show precipitation, temperature, and frost conditions in the Lake States.

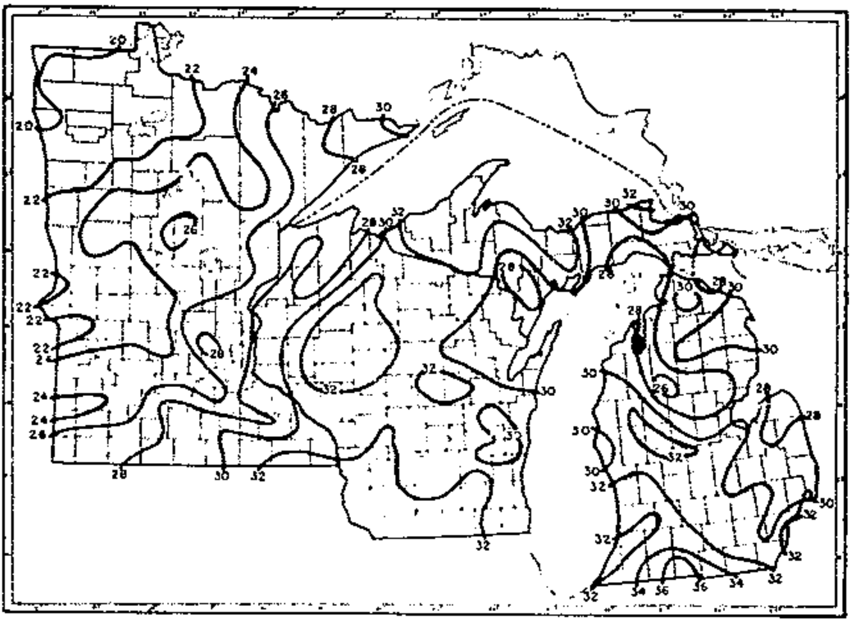

FIGURE 42.—Average annual precipitation, in inches, in the Lake States. (Adapted from 1941 U. S. Dept. Agr. Yearbook, Climate and Man.)

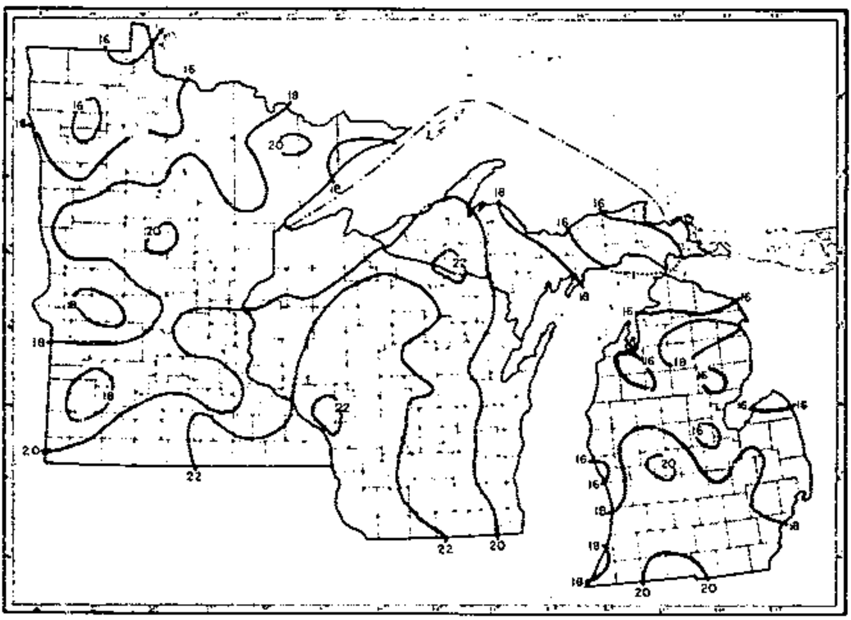

FIGURE 43.—Average warm-season precipitation, in inches, in the Lake States. (Adapted from 1941 U. S. Dept. Agr. Yearbook, Climate and Man.)

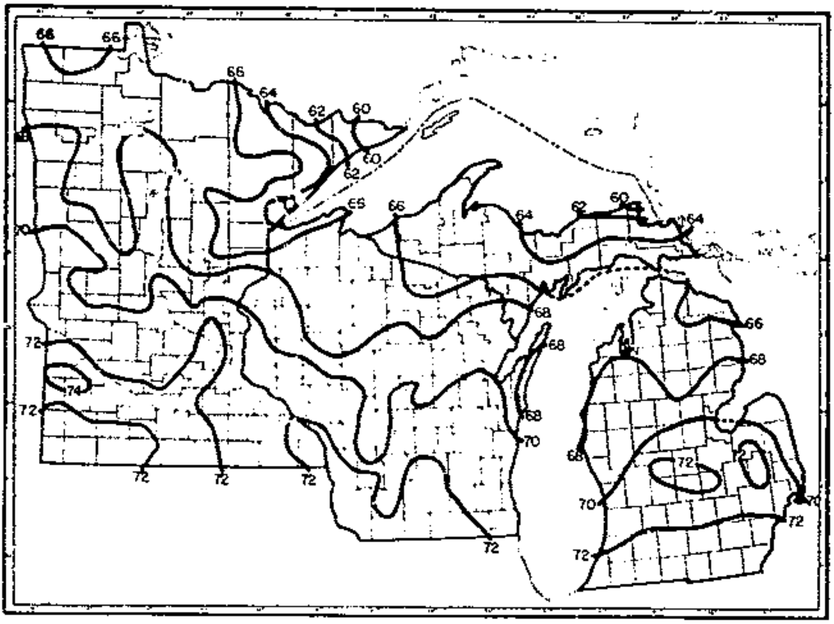

FIGURE 44.—Average July temperature, °F., in the Lake States.

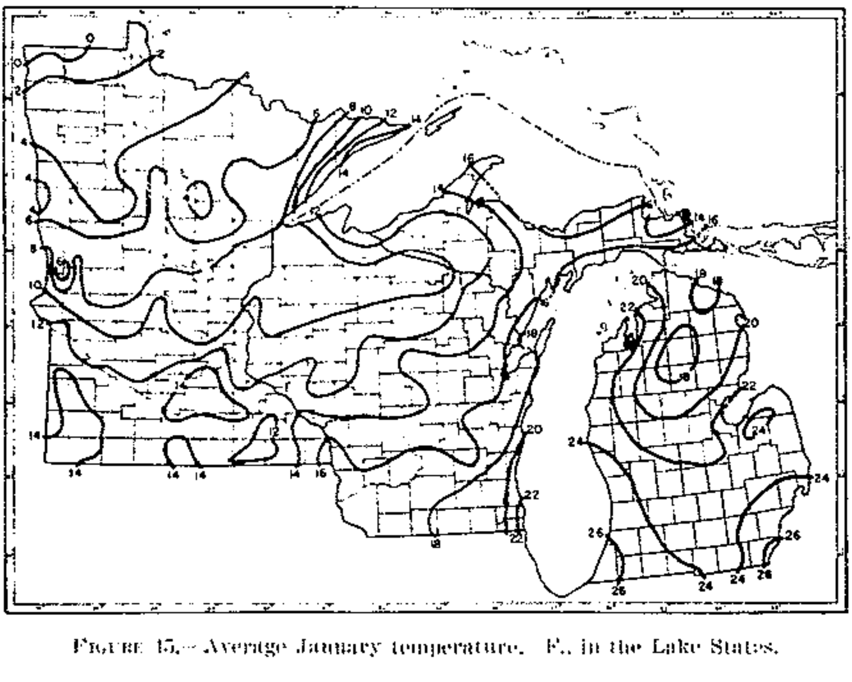

FIGURE 45.—Average January temperature, °F., in the Lake States.

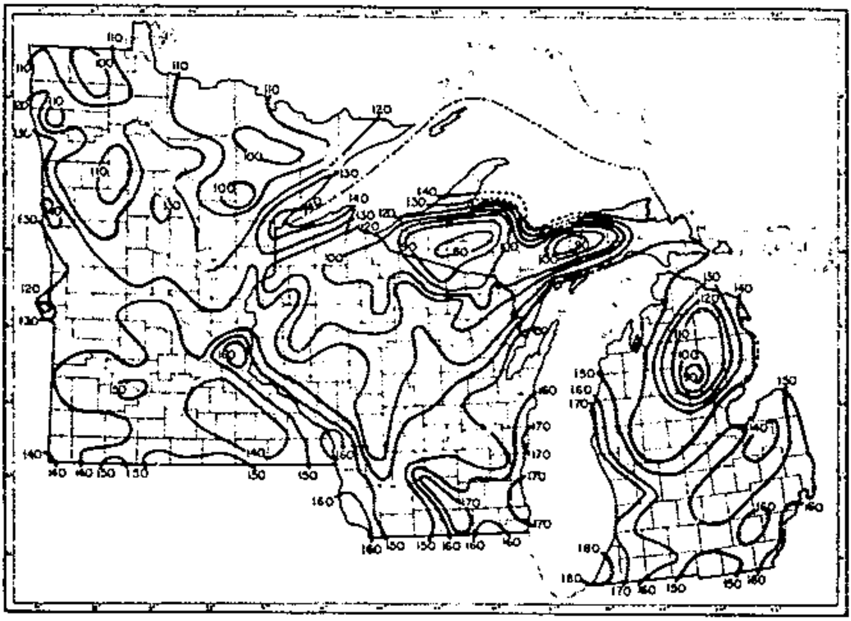

FIGURE 46.—Average frost-free season, in days, in the Lake States.

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