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EUROPEAN LARCH IN THE NORTH-EASTERN UNITED STATES

A Study of Existing Plantations

BY

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INTRODUCTION

DURING the fall of 1926 and the spring of 1927, the writer, assisted by N. W. Hosley of the Harvard Forest staff, examined plantations of European larch (*Larix europaea*, D. C.) at thirty-three widely separated places in the states of Massachusetts, Vermont, Connecticut, and New York. During the winter of 1929–30 the writer undertook a special study of larch plantings located in the east central and southeast sections of New York for the Conservation Department of that state (**14**). The material gathered in the field studies has been supplemented by information from European sources, particularly Gunnar Schotte's complete study of the European larch (**25**), in which he refers to nearly all the literature dealing with this species.

The study was first suggested to the author by A. C. Cline, Assistant Director of the Harvard Forest. To him I am deeply indebted for the inspiration given me during the course of the study, and for valuable suggestions in the revision of the manuscript. To N. W. Hosley of the Harvard Forest I wish to express my thanks for assistance in securing field data and in revising the manuscript. Many pertinent ideas which improved the research were advanced by Professor R. T. Fisher, Director of the Harvard Forest, and by Dr. P. R. Gast. I also wish to thank those who aided in the location of European larch plantations in New England and New York. Among these were H. O. Cook, State Forester of Massachusetts; A. F. Amadon, State Forester of New York; W. O. Filley, Forester of the Connecticut Agricultural Experiment Station; Perry H. Merrill, Forest Commissioner of Vermont; and the late Professor John W. Stephen of the New York State College of Forestry. Miss Helen E. Stockbridge, Librarian of the United States Forest Service, gave

very valuable aid in supplying references. Others who helped to make this study complete were Professor M. O. Lanphear, Agronomist at the Massachusetts Agricultural College; Dr. Perley Spaulding, Pathologist, United States Bureau of Plant Industry; and Dr. H. J. MacAloney, Assistant Entomologist, United States Bureau of Entomology. Those who sent the author material have been mentioned in the footnotes. The author also expresses his appreciation to W. G. Howard, Superintendent of Lands and Forests, Conservation Department, New York, for permission to use data secured during a study of young larch plantations in that state.

DISTRIBUTION OF EUROPEAN LARCH

THE European larch is a deciduous conifer native to central Europe. Although its range has been extended by planting as far as Sweden and Scotland, its natural habitat is limited to a rather small, pear-shaped area in the mountains of south central Europe. This area lies approximately between the fifth and twenty-fifth degrees of longitude and the forty-third and fifty-first degrees of latitude. The southernmost point reached is just north of Nice, France. From there the northern boundary runs through central Switzerland, the northwestern tip of Austria, southeastern Germany, western Czecho-Slovakia, and the Silesian end of Germany. Then the border swings outside of the Carpathian Mountains, reaching its most easterly point at Kronstadt in central Rumania. The southern extension is through north central Yugoslavia and along the southern edge of the Alps (Fig. 1.) (25).

Throughout its natural range European larch reaches higher altitudes than where it has been planted in this country. The highest elevation at which it has been found growing in Europe is in the Dauphine Alps at 8200 feet. Here it exists at the uppermost limits of timber, and is extremely crooked and bushy. Schotte (25) states that on Mt. Blanc it reaches its upper limit at an altitude of 7200 feet; in the central Alps, at 6600–7900 feet; in the Carpathians, at 5200 feet; and in Silesia, at 2800 feet. The lower limit in the Alps is at 1300–2300 feet; in South Tyrol, at 2000–2300 feet; in lower Austria, at 1600 feet; and in Silesia, at 1200 feet. In the northeastern United States plantations have been set out from sea level to 1800 feet.

Larch is most abundant in the central ranges of the Alps, particularly on the eastern branch of the Bavarian Alps, where it often forms pure forests, especially on southern ex-

FIG. 1. NATURAL RANGE OF EUROPEAN LARCH
After Schotte (25)

posures. In other parts of the Alps it forms groups in mixture with beech (*Fagus silvatica*), spruce (*Picea Abies*), Cembric pine (*Pinus Cembra*), and mountain pine (*Pinus montana*).

Variations and Races

There are three fairly well-recognized varieties of European larch which have distinctive habits of growth and different technical properties. The Tyrolean variety is found growing in the Alps, the Silesian variety in the Sudetes Mountains of Moravia and Silesia, and the Scotch variety in Scotland.

From cultivation studies Cieslar (4) concluded that the Silesian variety was distinctly different from the Tyrolean variety in the Alps. He found that the Silesian was superior to the Tyrolean in the following respects:

1. Greater shade tolerance, and therefore greater thrift in dense stands, and better ability to protect the site.
2. Greater height growth, straighter stems, and higher volume production.
3. Thinner bark, more rapid heartwood formation, and heavier wood.

The "Scotch" larch also seems to be a distinct variety, though somewhat similar to the Silesian. Foresters of Europe are quite certain that it originated from a few trees early introduced into Scotland, "The Mothers," or possibly from a few successful plantations. The opinion is advanced that these ancestors of the Scotch variety came from either the Swiss Alps or the Rhine Valley (22). Both of these places have climatic conditions similar to those in Scotland.

Schotte has definitely proved that all of the older stands of European larch in Sweden are direct descendants of the Scotch variety. These stands are very good; while the younger ones, originating from seed or plants from the continent, have bad stem form and reedy heads.

Schotte observed that the Scotch variety has a higher percentage of straight stems than the Tyrolean. Furthermore

he is inclined to believe that the Scotch variety will make more rapid growth, at least during the first ten years. In Scotland it is less damaged by frosts than the Tyrolean, for its needles develop later in the spring and drop earlier in the fall. Mattsson (18) has shown that the Scotch larch has extremely thin bark. For instance, the bark for six-inch stems is about .35 inches thick as compared to .42 inches for the Tyrolean variety.

In view of these important varietal differences, great care should be taken in the selection of seed for use in this country. It should be obtained from Scotland or Silesia. Satisfactory results will undoubtedly be obtained from the use of seed collected from the best plantations now growing in this country. According to Wilson [1] it is likely that the larch planted in New England is of Scotch or English origin.

Introduction into Other Countries

As forestry developed in Europe, foresters saw the desirability of introducing new species to improve the fertility of the soil, to aid regeneration, and to increase yields. Thus the European larch, which originally was limited to a very small portion of Europe, is now distributed over practically the entire continent.

According to old records the English were the first to introduce larch into a new habitat. Nisbet (21) says it was introduced into England in 1629 and into the lowlands of Scotland in 1725. In 1727 it was first planted in the highlands of Scotland by the Duke of Atholl, who obtained his seed from "The Mothers." Subsequently over fourteen million larches were planted on the Atholl estates. By 1829 these plantations and others on nearby estates covered 15,467 acres, of which 9,776 were set out to pure "Scotch" larch. These plantations

[1] E. H. Wilson, late Keeper of the Arnold Aboretum, Harvard University, Jamaica Plain, Massachusetts, in a letter to the author wrote, "I do not know the origin of the stock of European larch so common around New England countrysides, but I strongly suspect it is of Scotch or English origin."

supplied most of the seed used in Great Britain and Sweden until continental seed came in. Nisbet states that in Scotland during the period between 1738 and 1820 twenty-seven million plants were set out.

In Sweden the older plantations were started from seed or plants from England. Peter Kalm in his travels in 1751 obtained larch seeds in England and is considered to be the first to introduce this species into Sweden. About the middle of the nineteenth century a number of German foresters brought larch seed from the continent into Sweden. This seed produced inferior plantations.

Schotte says that the first larch plantations in Germany were started about the year 1700. About 1724 Langen, a German forester, considered the most skilful cultivator of larch in his time, brought it to the Hartz.

Extent of Planting in the United States

European larch has been planted in the United States since the middle of the nineteenth century. In Illinois, Iowa, Minnesota, and the Dakotas, it was one of the most popular trees for forest planting from 1860 to 1880. During the same period it was planted sporadically in Massachusetts, Connecticut, and Vermont. Nearly all the plantations in Pennsylvania and New York are comparatively young. Pennsylvania commenced using larch in 1909 for reforesting areas within the state forests; and in New York larch planting stock was first offered for sale by the state nurseries two years later.

GROWTH AND YIELD

EUROPEAN larch is noted for its rapid height growth during youth and middle age, and for its straightness of bole. During youth the bole is characterized by rapid taper, but it becomes more nearly cylindrical as the tree approaches maturity. In open stands the crowns are long and pointed (Fig. 2); but where the stocking is denser the crowns are short and thin, allowing a large amount of light to reach the forest floor.

HEIGHT GROWTH

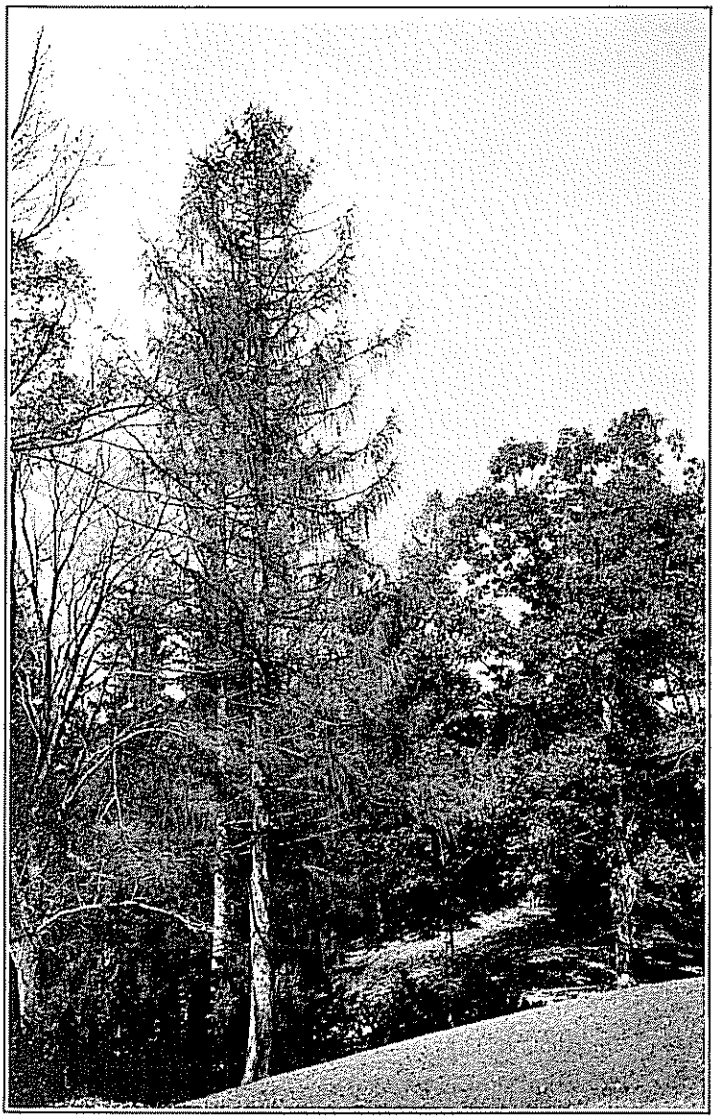
The data on height growth are based on measurements of 612 trees in forty-seven sample plots distributed over New England and New York, and 644 trees in young plantations in New York (14). Ages in the first group ranged from seven to seventy years; and in the second, from four to thirteen years. The data were insufficient to develop site indices on the basis of ten-foot height classes, so the method of Baur (2) was used to make a division into three site classes. Table 1

TABLE 1

HEIGHT GROWTH OF EUROPEAN LARCH FOR THREE SITES

Age in Years	Good Soils Site I	Medium Soils Site II	Poor Soils Site III
	Total height in feet		
5	2.7	2.2	1.6
10	12.1	9.8	7.2
15	26.0	20.9	16.5
20	36.4	29.4	23.5
25	44.5	36.0	28.9
30	51.5	41.5	33.4
35	57.6	46.5	37.3
40	63.0	50.6	40.6
45	67.7	54.5	43.6
50	72.0	58.0	46.5
55	75.9	61.0	48.8
60	79.4	63.7	51.0
65	82.8	66.5	53.3
70	86.0	69.0	55.2

Based on the measurement of 1256 dominant and codominant trees in 119 plots in New England and New York. Faustmann hypsometer used on the taller trees.



Photograph by A. C. Cline

FIG 2. EUROPEAN LARCH SHOWING CHARACTERISTIC FORM

gives heights through the range of ages for the three site classes.

In England height growth of European larch is somewhat slower than that of Japanese (*Larix leptolepis, Gord.*) during early life; but on better sites, growth of the Japanese falls off early while that of the European overtakes it between the ages of twenty and thirty years (17).

Diameter Growth

The rate of diameter growth according to age is shown in Table 2. This is based on the measurement of 441 trees in forty-seven sample plots. Nearly all the plantations examined made their most rapid diameter growth during the first twenty years. After that there was a gradual and often pronounced decrease in the width of the annual rings because of overstocking, thus indicating that thinnings should start early in life.

TABLE 2

DIAMETER GROWTH OF EUROPEAN LARCH FOR THREE SITES
(Unthinned Stands)

Age in Years	Good Soils Site I	Medium Soils Site II	Poor Soils Site III
	Diameter at breast height in inches		
10	2 6	1 7	1 3
15	4 4	3 3	2 7
20	5 8	4 6	3 8
25	6 9	5 6	4 7
30	7 9	6 6	5 5
35	8 8	7 3	6 2
40	9 6	8 0	6 9
45	10 2	8 7	7 4
50	10 8	9 2	7 9
55	11 2	9 6	8 3
60	11 6	10 0	8 6
65	12 0	10 3	9 0
70	12 3	10 6	9 2

Based on the measurement at breast height outside bark of 441 dominant trees in 47 plots. Diameter tape used.

Yield

Portions of thirteen of the plantations studied had sufficient density to be considered fully stocked and suitable for estimating yields. Yield plots were laid out with compass and tape; diameters were measured with a diameter tape, and the total heights and dead lengths with a Faustmann hypsometer. From these measurements the dimensions of the average tree were determined. The form quotient of the average tree for each plot was obtained from Schiffel's Table 16 (24). The volume of the average tree in cubic meters was obtained from Part III, "Form- und Massentafeln." This volume was then converted into cubic feet and multiplied by the number of trees per acre to get the yield. Volumes outside bark were used because, as shown by Mattsson (18), bark volumes are very variable and are not correlated with the characteristics of the stand. It was impracticable to measure bark thickness in the stands studied.

The volumes obtained by the above method were checked by the use of form factors. Those given by Schotte (25) were plotted on height in feet according to site. Then by comparing the height curves of this study with Schotte's, in order to assign his site classification to each yield plot, the appropriate form factors were found. These multiplied by the average height and average basal area of the trees on each plot gave the volumes of the average trees. The volumes thus obtained checked very well with those from Schiffel's tables.

Yields per acre were plotted on age for each site class and a set of three harmonized curves drawn. The number of plots was, of course, small for the purpose; but the scatter was surprisingly small and good trends could be developed from the strong portions of the data for Sites I and III. These trends closely followed those of MacDonald from his studies in England (17). The portion of the curves above forty-five years is a projection closely paralleling MacDonald's data. Yields were read from the curves and are presented in Table 3.

TABLE 3

YIELD OF PURE EUROPEAN LARCH PLANTATIONS IN THE NORTHEAST

(Unthinned Stands)

Age in Years	Site I	Site II	Site III
	Yields per acre in cubic feet outside bark		
10	740	610	510
15	1300	1100	910
20	2030	1700	1400
25	2780	2370	2020
30	3400	2950	2560
35	3920	3450	2980
40	4370	3850	3300
45	4780	4160	3550
50	5120	4410	3760
55	5360	4630	3920
60	5590	4820	4070

Since larch will probably be used as much by the unit piece, that is, as posts, poles, mine props, or railroad ties, as in the form of lumber, statements of yields per acre in cubic or board feet should be supplemented by estimates of the number of trees of a given size that can fully utilize the ground at different ages.

In twenty-six of the plantations studied, the spacing was sufficiently regular to permit tree counts on an area basis. The number of trees per acre was plotted on age, and a curve was drawn through the points which appeared to represent the most desirable stocking. It must be understood that the number of trees shown in Table 4 is merely a rough average for the better sites. Density of stocking in managed stands will of course be regulated according to the kind of product desired, site quality, and other factors. For the time being, however, this table may serve as a guide to thinning in that it shows the approximate number of trees of desirable form and size which can be grown per acre at different ages.

TABLE 4

DESIRABLE STOCKING FOR THE BETTER SITES

Age in Years	Number of Trees per Acre	Approximate Spacing
15	1200	6 × 6
20	800	$7\frac{1}{4}$ × $7\frac{1}{4}$
25	600	$8\frac{1}{2}$ × $8\frac{1}{2}$
30	500	$9\frac{3}{4}$ × $9\frac{3}{4}$
35	420	10 × 10
40	360	11 × 11
45	320	$11\frac{1}{2}$ × $11\frac{1}{2}$
50	280	$12\frac{1}{2}$ × $12\frac{1}{2}$
55	250	13 × 13
60	230	$13\frac{1}{2}$ × $13\frac{1}{2}$
65	210	to
70	200	$14\frac{1}{2}$ × $14\frac{1}{2}$

In the study of European larch conducted for the New York Conservation Department, an attempt was made to estimate the yield of posts in stands from fifteen to forty years of age. The results are shown in Table 5.

TABLE 5

NUMBER OF POSTS * PER TREE FOR A GIVEN AGE, AND AVERAGE SITE

Age in Years	Number of Posts per Tree	
17	1 1	From curve based on standing trees
18	1 7	
19	2 3	
20	2 7	
21	3 1	
22	3 4	
25	4 2	Based on extension of curve and one plantation forty years old
30	5 2	
35	5 8	
40	6 2	

* A post is considered either split or round, seven feet long, with a top diameter inside bark of four to six inches.

SILVICAL CHARACTERS AND THEIR INFLUENCE UPON THE ESTABLISHMENT OF LARCH PLANTATIONS IN THE NORTHEAST

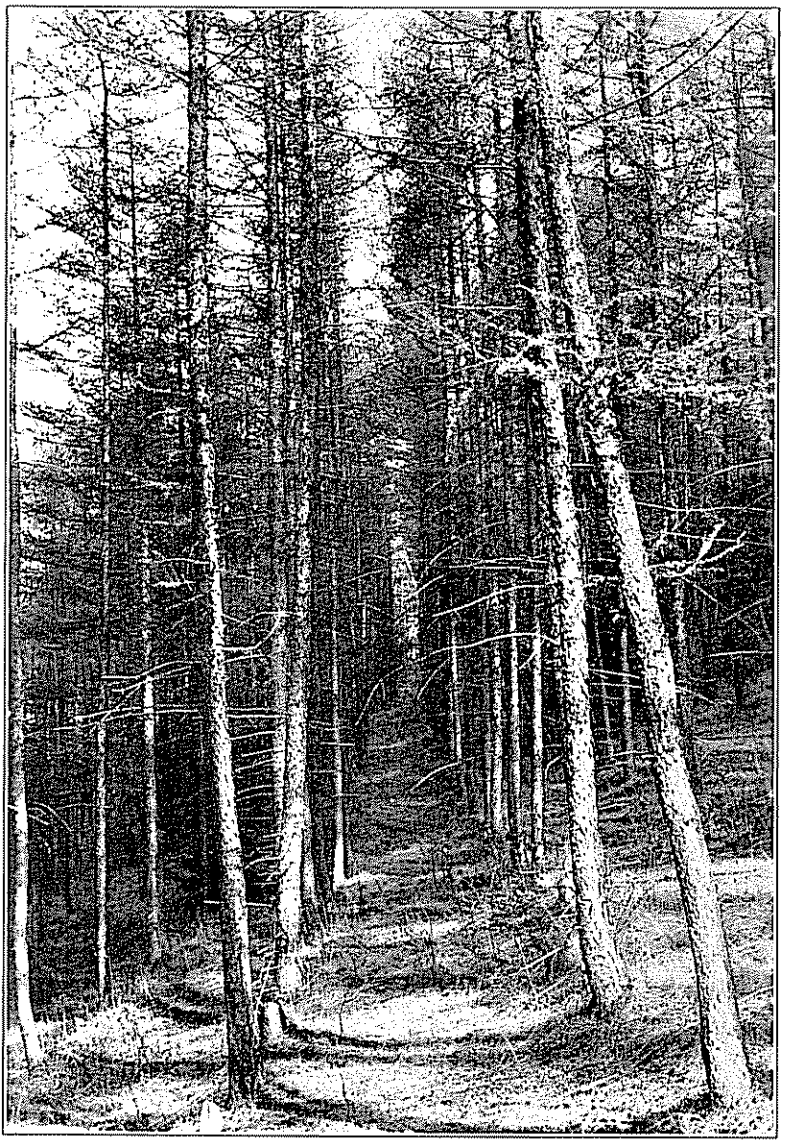
Light

In the development of European larch, light plays an exceedingly important role. For best growth full light is needed on all sides of the crown. Trees planted even in the partial shade of adjoining older stands will show the effects by diminished height growth. European larch should never be used for underplanting. In pure plantations the lower branches commence to die as soon as the crowns close. After differentiation in height becomes pronounced, suppression of the overtopped trees takes place rapidly, and only the dominant or nearly dominant trees survive. As the plantations approach middle age, an herbaceous ground cover is likely to develop, especially where the crown canopy is opened up through thinning or crown friction. Diameter growth commences to fall off soon after the canopy closes, and it is only through timely thinnings that rapid growth and a healthy condition are maintained.

Soil

According to Schotte, many of the older generation of larch experts of Sweden — Kalm, Alstromer, Strom, and others — insisted that European larch could be grown on a soil so poor that no other tree could exist there. However, when plantations repeatedly failed and disease became prevalent, foresters hesitated to recommend planting on the poorer types of soil. Intensive studies were then commenced to learn more about soil requirements, and from these the conclusion was reached that larch was rather exacting.

European larch prefers a deep soil in order to accommodate its long taproot; although on shallow soils it possesses



Photograph by N. W. Hosley

FIG. 3. STAND OF LARCH FORTY-TWO YEARS OLD ON FINE SANDY LOAM SOIL

Billings Estate, Woodstock, Vermont

Average height, dominants and codominants, 54 ft.; average D.B.H., 8.5 in
Total average volume per acre, 2571 cu ft Stand needs thinning

the ability to throw out wide-spreading lateral roots. One fourteen-year-old tree on deep loam soil was found to have a taproot three feet long, with laterals well distributed in the first eighteen inches of soil. In all the plantations visited, not a single larch was seen uprooted by the wind.

The soil was examined to a depth of thirty-six inches, if possible, in each plantation studied, and surface soil samples (down to twelve inches) were taken in all cases to determine whether the physical properties of the soil had any influence upon growth. The soil samples were identified in the field and later verified as to soil class.[1] On the basis of physical properties they were divided into five classes [2] as follows:

Loam: A mixture of sand, silt, and clay particles exhibiting sandy and clayey properties in about equal proportion.

Fine sandy loam: Fine sand particles predominating, the silt and clay particles occupying less than 50% of the soil by weight, but tending to hold the sand together in a plastic mass.

Loamy fine sand: This has a greater proportion of fine sand particles than the above, the silt and clay particles holding the sand grains together. The soil is usually loose and well aerated.

Loamy sand: This is composed of medium or coarse sand particles which predominate over the silt and clay particles.

Fine, medium, and coarse sands: These three soil classes are grouped together for convenience. In all three the silt and clay particles make up less than 20% of the material by weight.

Figure 4 shows the distribution of soil samples taken in the larch plantations according to both soil class and site class.

It is evident that for best development European larch should be planted on the better classes of soil — loams, fine sandy loams, and loamy fine sands. From the data it appears that loamy sand sites are unfavorable for European larch planting, but more complete soil analysis may alter this conclusion. Sandy and gravelly soils, which dry out excessively during the hot summer months, should be avoided

[1] By Professor M. O. Lanphear of the Massachusetts Agricultural College, Amherst, Massachusetts.

[2] The description of soil classes is made up from material given by Lyon and Buckman in The Nature and Properties of Soils, 1929, revised edition, Chapter III.

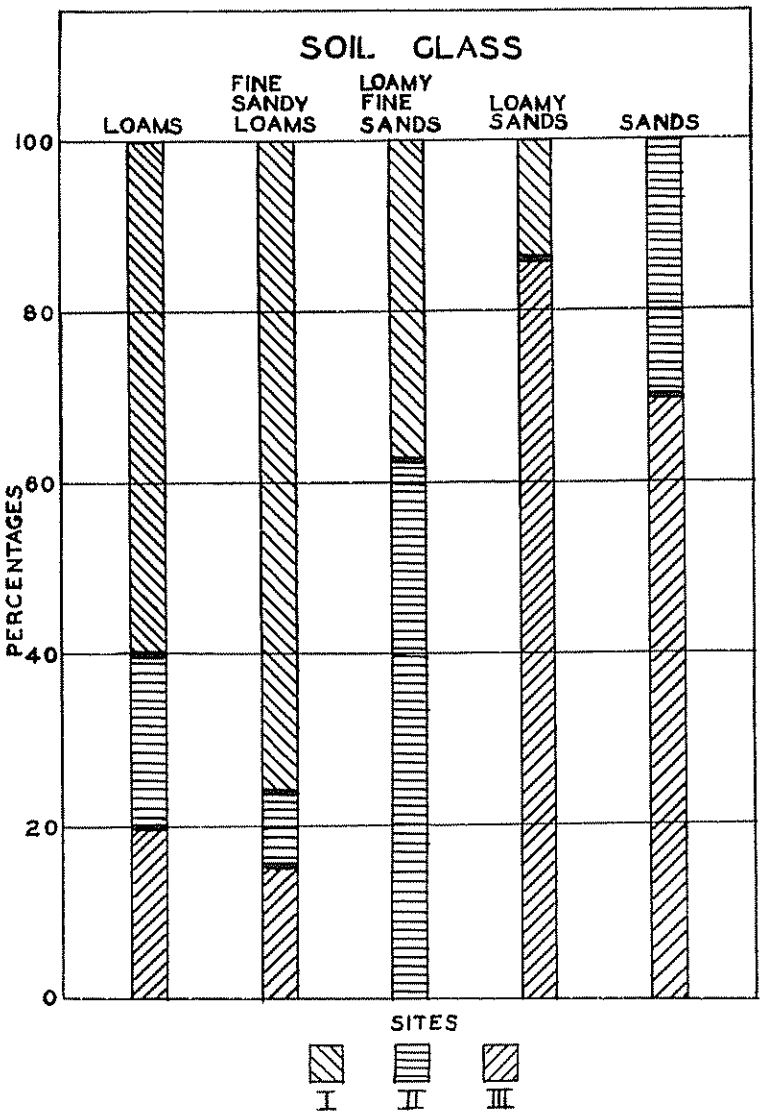


Fig 4 PROPORTION OF SITE CLASSES WITHIN SOIL CLASSES

altogether. The species is not adapted to planting in wet places, where native larch, or tamarack, is often found growing.

The majority of European foresters consider larch a soil improver. In our climate the annual fall of needles and the thin crown which allows an abundance of light to reach the forest floor cause rapid decomposition of the litter which results in the building up of the humus content of the soil. Also Hesselman (**10, 11**) has advanced the opinion that the strong transpiration power of larch may prevent forest soil from becoming swampy.

Temperature and Moisture

In its native habitat the larch is resistant to winter cold, and is not subject to winter killing. During the growing season it prefers continuous and uniform heat, which makes it an ideal tree for an inland climate. Bühler (3) states that in order to make good growth it needs an annual mean temperature of thirty to fifty degrees Fahrenheit, abundant light, and good air circulation. The annual mean temperature for the northeastern United States is from forty to fifty degrees Fahrenheit.

European larch is naturally accustomed to a rest of at least four months during the winter followed by a short spring with a rapid change to summer. In its native mountain habitat there is an abrupt change from winter to spring with no setbacks. This accounts for the fact that in the Northeast it often suffers from the late spring frosts common to the region. Repeated frost injury causes young trees not more than a few feet high to become bushy, but this is overcome with age and no permanent deformity usually results. However, where larch has been planted in frost pockets, there are a number of instances where severe frosts have resulted in death. Hamm (8) pointed out that "at low temperatures it may freeze in a moist climate, but on the other hand may never suffer from the bitterest cold in a dry climate."

Natural Regeneration

Only one example of volunteer reproduction was seen during the course of the present study. This was found near the edge of a forty-year-old stand of larch and spruce. The group of reproduction consisted of eleven trees which were ten years old and about fifteen feet in height. All were growing inside a twelve-foot circle where evidently conditions were just right for germination and survival. In Europe it has been very difficult to obtain natural regeneration.

SUSCEPTIBILITY TO INJURY

Ice and Snow Damage

Twenty-five per cent of the plantations visited had been noticeably injured by ice storms. The branches and leaders of European larch are rather brittle, and this condition is intensified during the winter when the wood is frozen. Ice damage is most severe in wind-swept locations and in plantations of high density which have never been thinned. Too heavy thinning at this point makes the damage worse.

Injuries by Animals

Red Squirrels

The damage done by the red squirrel (*Sciurus hudsonicus*) is best described by Hosley (13) in a study conducted at the Harvard Forest. "The injury in European larch . . . is one of lateral bud eating only. There are two types of work." In one type the squirrel "takes off the small twigs which grow in great numbers from the main stem." In the other type he "takes the tips from the large limbs. . . . A rather long section (average length of 10.9 inches in fifty cuttings) is cut off in either case. . . . The buds are small, and those on new growth are eaten from the tip end. On year-old branches they are usually cut in from the side to remove the contents . . . . Only very severe cases of damage seem appreciably to retard the growth of the trees. . . . Recovery usually seems well under way the first season."

Porcupines

The injury caused by porcupines (*Erethizon dorsatum dorsatum*) is much more serious than that caused by red squirrels. During the winter months when food is scarce, the porcupine eats the inner bark, often girdling the tree. The animal works at any height, but usually girdling occurs where the bark is still smooth and tender, as near the tip. If the

girdling is complete, that portion above the injury dies and in severe cases the entire tree is killed. Where only a small area of bark on one side of the bole is removed, the wound usually heals. The callus tissue formed around the wound seems to be greatly relished and is often repeatedly cut away, thereby enlarging the wound.

Injury by Birds

The only bird observed injuring European larch was the pine grosbeak (*Pinicola enucleator leucora*). In winter it cuts off buds, eats out the inner part, and leaves the snow littered with bud scales. This injury is of minor importance, since, because of the pendulous nature of the branch ends, the birds are able to feed only on the buds of twigs in the inner portion of the crown.

Injury by Fungi

The European Larch Canker

The true European larch canker was first discovered in America in April, 1927, during this study. A serious infection was found at the Harvard Forest's Black Brook Plantations[1] at Hamilton, Massachusetts. Examination by pathologists disclosed an abundance of cankers on the trunks and fructifications on the dead branches. It was conclusively proved that this disease was present on seedlings imported from Scotland in 1904 and 1907. This was the only case of canker found during the study.

In England *Dasyscypha calycina* is almost universal on recently dead branches of larch. Hiley (12) states, "When grow-

[1] A diseased specimen was taken from these plantations to Dr. Perley Spaulding of the Bureau of Plant Industry, who identified the fructifications as *Dasyscypha calycina* as described by a very recent investigator of the European larch canker. Later studies show that what was at first called the single fungus, *D. calycina*, with two forms, one saprophytic and the other parasitic, is really two different fungi. The saprophytic American fungus attacking dead branches of conifers of several species is *D. calycina*, while the parasitic fungus attacking larches is the true European larch canker fungus, which should be called *D. willkommii*.

ing in this way (i. e. saprophytically), it does no damage to the tree. It is only when it begins to live parasitically and to prey on the living tissues that a canker is formed." It was proved by Hiley that the tree is infected by the passage of the mycelium from the dead branches into the living trunk. In regard to the disease at the Black Brook Plantations, Spaulding (26) said, "Every canker started through a dead branch or a short shoot."

The mycelium of the fungus spreads very slowly, killing a wider and wider area of cambium. "In this way a flattened cavity is formed at the point where the cambium has been killed, the dead bark becomes blackened, resin oozes out and streams down the tree, and the whole presents the ugly appearance of a black blister or a running sore. This is the canker" (12). These blisters are often dotted with small fructifications of the fungus, one-eighth of an inch or less in diameter, at first orange red in color but later becoming bleached to a dirty white or yellow.

Control of Larch Canker

By cutting out all diseased trees in the Black Brook Plantations, the outbreak of European larch canker in Massachusetts is apparently now under control. Other plantations of larch on the Black Brook tract have not become infected, and investigation by the United States Bureau of Plant Industry of older larch plantings throughout the Northeast and as far west as Missouri has disclosed no more of the disease.

In England it has been observed that larch in pure plantations is more liable to attack than if mixed sparingly with hardwood. Forbes (5) explains this on the basis of root competition. He states, "When mixed sparingly with deep-rooting or compact-rooting trees, the larch roots can spread without meeting much opposition; while their more rapid stem growth gives them a lead over the other species from the first."

In case of another outbreak, the following suggestion is tentatively advanced by Hiley until experiments prove its worth. Since dead branches are the chief source of infection, in plantations where canker is known to exist, dying branches should be removed at least one year before they become entirely dead. This pruning should be done in early spring when spores are not being liberated in large numbers. The expense should not be excessive if confined to plantations from six to eighteen years of age. If this pruning were delayed until fifteen years of age, suppressed or unhealthy trees could be removed at the same time, thereby decreasing the cost of pruning and increasing the percentage of healthy trees.

Fungi Causing Rot

In Europe, heart rot, caused chiefly by *Fomes annosus*, is serious, especially in the first crop of timber grown on land previously cultivated (12). This fungus, although present in America, is not so serious as many other species. *Polyporus Schweinitzii*, *Poria vaporia*, *Polyporus sulphureus* and *Trametes pini* all cause heart rot of larch. *Armillaria mellea*, the honey or shoestring fungus, is one of the most destructive species on conifers both in Europe and America.

The best method of controlling these fungi is through silviculture. The use of good planting stock on suitable sites, planting in mixtures, thinning to keep stands vigorous, and cutting out any infected trees will reduce fungal damage to a minimum.

During this study several trees at each plantation were bored at stump height with an increment borer, but no evidence of heart rot was found. Neither were any trees seen which showed outward signs of heart rot.

Injury by Insects

Stands of eastern American larch, *Larix laricina*, have been repeatedly injured by insects. Those causing the great-

est amount of damage are European pests. The depredations upon native larch, or tamarack, indicate what may happen if European larch is planted over large areas in unfavorable situations. The most important insect enemies of European larch are the larch sawfly (*Lygaeonematus erichsonii*, Hartig), the larch case bearer (*Coleophora laricella*, Hubn), and two species of aphids (*Adelges viridis*, Ratz and *A. strobilobius*, Kalt).

The Larch Sawfly

The larch sawfly, a native of Europe, has been the most serious pest on eastern American larch. From 1880 to 1890 epidemics of this insect caused great losses in larch throughout the northeastern and Lake states. It was first observed on European larches in this country in 1880 by the late Professor C. S. Sargent, who discovered larvae feeding at the Arnold Arboretum. The sawfly larvae have been observed for a number of seasons in the European larch plantations of the Harvard Forest. Many of the twigs show the characteristic bend where slits were cut for oviposition. European larch planted in the Northeast has thus far survived sawfly attacks, possibly because most of the existing plantations are confined to small areas in favorable situations.

In Europe the larch sawfly generally has not been so destructive as in this country, indicating that European larch is less susceptible to attack than American larch. The value of planting larch in mixture with hardwoods as a means of reducing sawfly infestation has been shown by European experience (6). The grass ground cover which is characteristic of pure larch stands is ideal for pupation, whereas hardwood litter is unfavorable. Underplanting may be resorted to as a means of eliminating the grass.

Graham (7) has found that the insect hibernates only with great difficulty on high ground as compared with swamps, and that large numbers of the pupae are destroyed by fungal parasites and animals. The latter include mice and, to a

lesser degree, shrews. In a fifteen-year-old European larch plantation H. J. MacAloney and the author found hundreds of rifled cocoons and only two normal ones in an area of about one hundred square feet. Hymenopterous parasites also play an important part in keeping down the number of adults maturing.

The Larch Case Bearer

This insect is also of European origin, and Schotte (25) lists it as a dangerous pest in Europe. It defoliated thousands of acres of American larch in Maine during the seasons of 1922 to 1925, and in 1926 the trees commenced to die from the effects of repeated strippings. The larch case bearer has been present on the European larch plantations of the Harvard Forest, and no doubt on other plantations, but the damage has been slight.

Its presence is shown by the appearance of a bleached tan color in the tips of the larch needles. These have been hollowed out by small, brown, black-headed grubs. The needles on the lower limbs are attacked first.

Spruce-Larch Aphids

The two insects, *Adelges strobilobius* and *A. viridis*, are injurious to larch in Europe. Peirson (23) mentions that the former is present in the northeastern United States. Both of these insects alternate between spruce and larch as hosts. In Europe *A. strobilobius* is more harmful to larch, while the opposite is true of *A. viridis* (1).

CULTURE AND MANAGEMENT

Establishment of Stands by Planting

Nursery Practice

On account of the rapid growth of European larch during the first few years, it is undesirable to hold it in the nursery beyond three years of age. Though three-year transplants are large enough for planting, densely grown two-year-old seedlings are too small. On examining twenty-one plantings in New York classed as failures, it was found that approximately 75 per cent were due to the use of too small stock. It is difficult to plant such tiny trees properly, the tendency being to set them too deeply. Furthermore, small seedlings may be suppressed by even a light grass cover (14). In most American nurseries 2–0 seedlings and 2–1 transplants have been grown; but satisfactory stock can also be obtained by transplanting seedlings when one year old, as is commonly done in England. These are left in the transplant beds for two years instead of one and develop into sturdy stock. The best of two-year seedlings grown at low densities on good soil are also large enough for successful field planting.

Season of Planting

In the Northeast fall planting is preferable to spring planting for several reasons. The buds of the larch start swelling during the first warm days of spring and often while the frost still prevents digging the stock. Thus, by the time it is possible to dig and plant the larch, new growth may be well started. If a frost occurs soon after planting, the trees are in poor condition to recover. Plants set out in the early fall as soon as the needles drop are well established when growth commences the following spring, and the uncertainty of planting during the start of growth is avoided. With both spring and fall planting, however, setbacks due to untimely frosts may be expected, especially in frost pockets, but

usually the trees are able to completely outgrow the injury. Active growth is maintained as long as warm weather prevails. Often in middle or late September all the green foliage is still on the plants, and the new wood unlignified. Larch planted as early as this in the fall may be injured by frost, but it is more likely to suffer from inability to draw the necessary moisture from the soil to fulfill its requirements for the remainder of the growing season (14). Not until about October first do the needles begin to turn brown and the stems become lignified.

Data from a study of plantations in New York (14) were analyzed according to the time of planting during the fall and spring. September was considered an early fall planting period and October a late one. During the September period, covering several years, there were three successful plantations (survival over eighty per cent) to nineteen failures (survival under fifty per cent). For the October period there were two successful plantings, four partially successful ones (fifty to seventy-nine per cent survival), and two failures. It appears from these cases that planting in October is preferable. In the case of the spring planting, it was found that the best results were obtained by planting as soon as the stock could be dug. Spring planting, while hazardous, deserves a fair trial before it is entirely abandoned. Early spring growth can be retarded by digging the plants as soon as the frost is out of the nursery and storing them in a cool packing shed until ready for planting.

Pure and Mixed Plantations

On open fields larch should be planted as single trees or in small groups, not exceeding forty feet across, in mixture with other conifers, such as pine or spruce. On cut-over sawtimber lands it may be used to good advantage to supplement desirable natural reproduction, either hardwood or softwood. On cordwood cuttings it may be mixed with other planted conifers; but here, also, it should be planted singly or in

Photograph by N. W. Hosley

FIG. 5. MIXTURE OF EUROPEAN LARCH AND NORWAY SPRUCE FORTY-TWO YEARS OLD

Billings Estate, Woodstock, Vermont

Note the earlier death of larch branches under the more tolerant spruce. The large lower limbs are due to the wide spacing, 12 ft. by 12 ft.

small groups. The larch will outgrow all of the other conifers commonly used in planting except Norway spruce, and will remain in a dominant position during an ordinary rotation. On the best sites larch outgrows Norway spruce up to forty years and will remain in the dominant stand with it to fifty years, after which the larch may fall behind.

Spacing is an important factor in planting larch. On open fields it should be spaced from seven to eight feet in order to allow the development of large, deep crowns, which are needed to promote rapid diameter growth and to keep the stand in a healthy condition. When planted in groupwise mixtures with hardwoods or with other conifers on cut-over lands where young hardwood growth is present, a similar or somewhat wider spacing may be used by taking advantage of weed hardwoods for filler.

Because larch is a tree which will be most commonly used in such products as poles, posts, ties, and dimension lumber, there undoubtedly will be a tendency to minimize quality, and to grow pure stands where quantity production will be large. But, considering all risks, mixed stands unquestionably will be safer and more profitable in the long run.

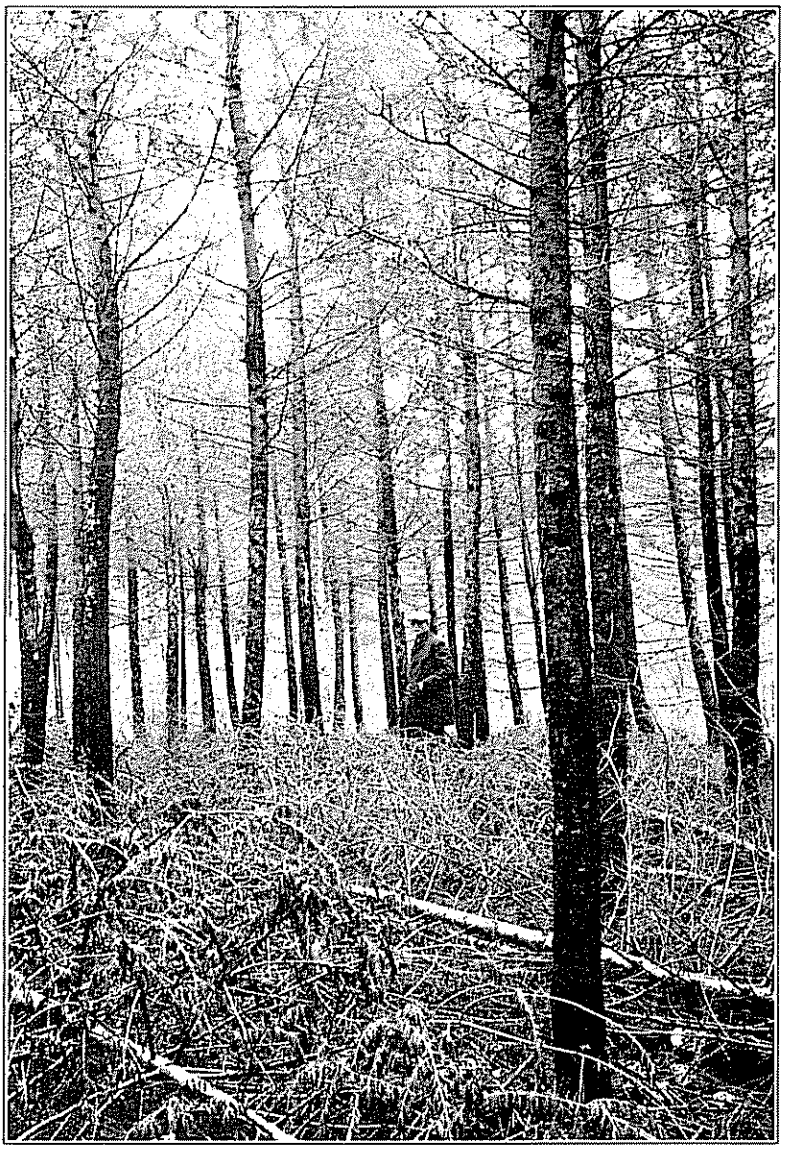
Weeding

All plantations set out on cut-over lands or brushy fields and pastures require more or less weeding during the first ten years in order to keep the planted trees from being overtopped and eventually killed by hardwood weeds. Since larch is very light-demanding, early weeding, in many cases within a year or two after planting, is particularly important. However, the unusually rapid height growth of larch when free to grow should reduce the number of weedings required as compared with that for more slowly growing conifers. Unlike white and Scotch pine and Norway spruce, European larch is not attacked by the white pine weevil, and it is therefore unnecessary to consider the protective value of surrounding hardwoods.

Photograph by N. W. Hosley

FIG. 6 NINETEEN-YEAR-OLD STAND OF EUROPEAN LARCH ON FINE SANDY LOAM SOIL

Harvard Forest Plantation
Stand has been pruned but not thinned



Photograph by N. W. Hosley

FIG. 7. NINETEEN-YEAR-OLD STAND AFTER THINNING

Harvard Forest Plantation

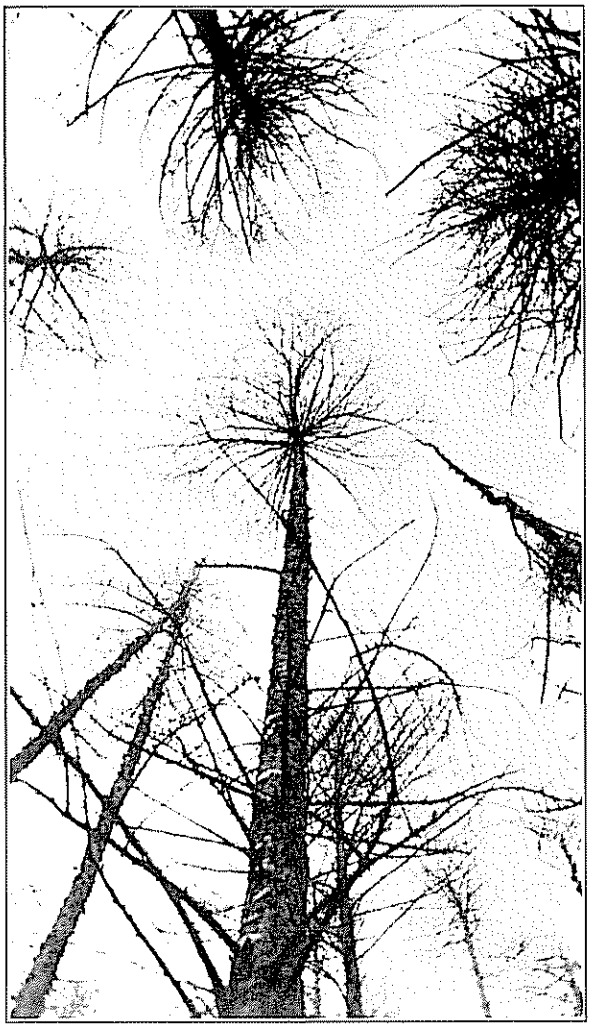
The same stand as in Fig. 6

The thinnings were large enough for fence posts

Thinning

In nearly all of the older stands of European larch in the Northeast lack of thinning has resulted in extreme competition, slow diameter growth, and loss of vigor. All thinnings should aim to give plenty of light to the selected crop trees in order that they may develop large, thrifty crowns. In pure stands or groups the German method of thinning from below seems best adapted. With this method the aim is "to take out the poorest crown class (suppressed) first and then work upward in consecutive order through the better crown classes, increasing the number of classes removed with the severity of the thinning" (9).

Pure stands or groups of larch with spacings not greater than seven feet will require a light thinning when about twenty years of age. With wider spacings, such as eight feet, thinning will not be needed before the age of twenty-five years. Probably two more thinnings will be needed before the end of a fifty-to-sixty year rotation. These should yield merchantable material.



Photograph by N. W. Hosley

FIG 8. FORTY-YEAR-OLD LARCH STAND WITH POOR CROWNS

South Orleans, Cape Cod, Massachusetts

The poor crowns are due to overdensity, resulting in crown friction

PROPERTIES AND USES

SCARCELY any information could be obtained as to the properties of European larch wood grown in America. The older plantations in the northeastern states were made mainly for aesthetic purposes, and only the suppressed and unsightly trees have been removed. These were used for local purposes and very little information could be secured regarding durability, strength, and other qualities. It is necessary to rely on European sources for this information, which is probably applicable with but slight variation to European larch wood grown in this country.

PROPERTIES

The heartwood of European larch is very durable, owing to extremely heavy walled cells. It begins to form early in the life of the tree and constitutes a large part of its volume. Schotte (25) states that on Site I a seventy-year-old stand had a heartwood content of sixty-two per cent of the stem exclusive of bark. European foresters agree that the most durable larch wood is obtained from stands which have grown rather slowly.

The specific gravity of larch, dry weight, varies from 39.8 to 74.7 (15). This is considerably higher than that of pine or spruce.

Larch lumber shrinks more than that of European pine or spruce, but its durability offsets this shortcoming. Thelaus (28) tells of an eight-hundred-year-old building in Switzerland constructed of larch. Lumber from the Silesian variety is superior to that from the Tyrolean.

USES

In Europe more larch timber has been utilized for railroad ties than for any other purpose on account of its durability without impregnation. Many of the railroads of Europe prefer larch ties to those of pine or oak, for they withstand decay

much longer and the rails do not wear into the ties to any extent. There is some complaint, however, that the spikes tend to loosen and creep up. Schotte says that even without impregnation larch ties last twice as long as pine and at least as long as impregnated pine ties. Another common use for larch in Europe is for piling and other construction in water. In England larch mine props are said to command a higher price than impregnated pine. Of late years there has been a big demand for larch for power transmission and telephone poles and a growing demand for larch lumber. The Royal Board of Waterfalls in Sweden buys all the larch poles obtainable and pays high prices because of their durability. Other uses include posts, tools, furniture, boats, oars, and acid containers. For a long time Venetian turpentine was prepared from larch resin.

Experience in Iowa [1] with European larch posts in test fences gives about eight years of life for untreated posts. In the case of posts creosoted by the open tank method, the sapwood took up the creosote very well, but the heartwood was almost impossible to penetrate. After eight or nine years of service, the split posts were showing varying degrees of decay in the heartwood, while the sapwood portions were in fair condition. Creosoted round posts were in sound condition at twelve to fourteen years, with every evidence that they would last twenty years or longer. Therefore, the use of round posts is suggested for creosoting.

[1] Information from I. T. Bode, Extension Forester of Iowa.

SUMMARY

EUROPEAN larch, a native of the high mountains of central Europe, has been successfully planted in the United States since the middle of the nineteenth century.

It makes its best development on the better grades of well drained loamy soils. It will not survive on swampy sites, and will not make good growth on sands and gravels.

In Europe larch is well known for its soil improving qualities. Its deciduous habit and large amount of needle litter rich in food value, combined with the unusually rapid decomposition of the litter, made possible by its thin crown, serve especially to recommend larch for use in coniferous mixtures.

Seed source is very important, since there are three distinct varieties or races which exhibit marked differences in growth and form: the Scottish, the Silesian and the Tyrolean. The Scottish and Silesian are superior to the Tyrolean and seed should be selected accordingly.

European larch makes extremely rapid height growth during the first twenty-five years, outgrowing all native conifers. At forty years of age height ranged from forty feet for the poorest sites studied to sixty-three feet for the best. Stands which have been thinned will produce trees large enough for poles in forty to forty-five years.

The principal enemies of the larch are the larch sawfly and the European larch canker. In the case of these and other enemies of lesser importance, a satisfactory degree of control may be exercised by using larch in mixture with other trees, either as scattered individuals or in small groups, by confining it to favorable situations, and by timely thinnings aimed to promote healthy and vigorous growth.

Three-year-old transplants have given the best satisfaction in establishing plantations in America. Fall planting is preferable to spring planting, because of the impossibility of digging and planting larch stock in the spring before the start of new growth. Late spring frosts find the plants set out in

the spring in a comparatively weak condition, making recovery from frost damage more difficult.

European larch is an excellent tree to use in mixture with other conifers. Although it outgrows most of them, it has a thin foliage which permits the passage of light to a more slowly growing species underneath.

Since it is a light-demanding species, thinnings are essential in order to promote proper development of the crown, rapid diameter growth, and a generally healthy condition.

In Europe the larch has always been noted for its durability in outdoor construction without the use of creosote or other preservatives. It has been in greatest demand for railroad ties, piling, mine props, posts, poles, and dimension lumber. In this country it may prove to be an excellent substitute for the nearly extinct chestnut.

European larch should prove a valuable addition, both silviculturally and economically, to the forests of the Northeast.

TABLE 6

SUMMARY OF DATA FROM EUROPEAN LARCH PLANTATIONS LOCATED IN NEW ENGLAND AND NEW YORK

Location	Altitude	Approximate Area of Plantation (Acres)	Original Spacing	Trees per Acre (1927)	Age from Seed (Years)	Site 50 Yr. Class: Index
Petersham, Mass.	1040	1.5	6 × 6	1200	7	III 40
Sharon, Vermont	..	4.0	4 × 4	2700	9	.. ..
Barneveld, N. Y.	..	0.25	8 × 8	680	13	II 60
Portage, N. Y.	1200	2.0	6 × 10	900	14	I 85
Portage, N. Y.	1300	0.2	6 × 5	1900	14	I 75
Petersham, Mass.	1200	0.7	7 × 7	820	15	I 80
Middlebury, Conn.	900	1.0	6 × 6	1200	15	III 50
Petersham, Mass.	1200	2.0	7 × 7	875	15	I 65
Petersham, Mass.	1000	0.05	6 × 6	1200	16	I 75
Sharon, Vermont	..	5.0	6 × 7	1030	17	I 65
Phoenix, N. Y.	400	.	6 × 6	1200	18	I 80
Phoenix, N. Y.	400	3.0	6 × 6	1630	19	II 60
Phoenix, N. Y.	400	5.0	6 × 6	1130	19	I 75
Hamilton, Mass.	100	.	4 × 4	2700	19	III 45
S. Orleans, Mass.	40	4.0	10 × 10	430	22	III 50
Hamilton, Mass.	100	0.2	2.5 × 4	1777	25	III 50
Hamilton, Mass.	100	..	4 × 4	2700	26	III 50
Hamilton, Mass.	100	..	4 × 5	2170	26	III 50
Hamilton, Mass.	100	0.05	5 × 5	1720	26	II 65
Hamilton, Mass.	100	..	2.5 × 4	3630	28	III 50
Axton, N. Y.	1600	1.0	6 × 6	scattered	29	II 55
Chatham, Mass.	30	0.5	8 × 8	1000	30	III 50
S. Woodstock, Conn.	500	5.0	6 × 6	1260	33	II 55
Woods Hole, Mass.	40	0.75	8 × 8	720	37	III 50
S. Orleans, Mass.	60	0.1	6 × 6	1000	40	III 50
E. Orleans, Mass.	60	1.0	15 × 15	190	40	III 35
Groton, Mass.	300	3.0	15 × 15	190	40	II 60
Pomfret Center, Conn.	500	0.1	15 × 15	190	40	I 75
Fairfield, Conn.	40	1.0	12 × 12	300	40	I 80
Stockbridge, Mass.	880	2.0	6 × 8	300	40	I 75
Amherst, Mass.	200	2.0	6 × 6	800	40	III 45
Fairfield, Conn.	140	20.0	5 × 5	800	41	I 75
Fairfield, Conn.	160	20.0	5 × 5	700	41	II 65
Woodstock, Vermont	800	15.0	12 × 12	50	42	I 70
Woodstock, Vermont	1200	10.0	6 × 12	330	42	II 60
Woodstock, Vermont	1200	10.0	6 × 12	370	42	I 65
Woodstock, Vermont	800	0.25	12 × 12	264	42	I 70
S. Woodstock, Conn.	340	1.5	6 × 6	680	42	I 75
S. Orleans, Mass.	60	1.5	7 × 7	1040	45	III 40
Woods Hole, Mass.	160	.	..	scattered	45	II 60
S. Woodstock, Conn.	320	5.0	12 × 12	300	46	I 70
S. Orleans, Mass.	60	0.75	12 × 12	300	47	II 55
Lunenburg, Mass.	400	1.5	12 × 12	300	50	II 55
W. Cornwall, Conn.	1400	0.25	6 × 6	300	55	III 40
Amherst, Mass.	280	1.0	12 × 12	300	55	II 65
S. Lancaster, Mass.	480	..	15 × 15	190	60	II 55
Woods Hole, Mass.	160	..	..	scattered	70	III 50

TABLE 6

SUMMARY OF DATA FROM EUROPEAN LARCH PLANTATIONS LOCATED IN NEW ENGLAND AND NEW YORK

Average D. B. H. Dominants and Co-dominants (Inches)	Total Height Dominants and Co-dominants (Feet)	Volume per Acre Outside Bark (Cubic Feet)	Dead Length (Feet)	Clear Length (Feet)	Soil to 12″	Subsoil
..	..	..	..	..	Fine sandy loam	
..	..	..	..	..	Sandy loam	
3 3	17 0	..	..	..	Loamy fine sand	Medium sand
4 3	25 9	1159	3 5	..	Loam	Silt and pebbles
3 2	22 7	..	..	..	Sandy loam	Coarse sandy loam
4 2	28 7	1090	3 0	..	Fine sandy loam	Coarse sandy loam
3 0	18 3	..	..	..	Loam	
3 9	23 9	1041	3 0	..	Fine sandy loam	Fine sand
5 0	28 7	..	6 0	..	Fine sandy loam	
4 7	27 6	1649	3 0	5	Fine sandy loam	
9 2	35 5	..	15 0	..	Loamy fine sand	Fine sand
4 3	27 1	2175	10 0	..	Loamy fine sand	Fine sand
5 3	35 1	1988	12 0	..	Loamy fine sand	Fine sand
2 5	21 6	..	..	..	Gravelly sandy silt	Gravelly fine sand
7 2	25 9	..	..	..	Medium sand	
4 1	30 8	2167	22 0	10A	Loamy sand	Gravelly loam
4 6	31 2	..	22 0	..	Gravelly sandy silt	Gravelly fine sand
3 8	30 5	..	20 0	..	Gravelly sand silt	Gravelly fine sand
4 6	35 8	2227	12 0	..	Loamy sand	Gravelly loam
3 6	31 4	..	15 0	..	Loamy sand	Gravelly loam
5 9	37 4	..	14 0	..	Loamy fine sand	Fine sand
5 8	33 5	2640	13 0	10A	Sandy loam	Fine sandy silt
5 4	40 6	3392	20 0	8	Loam	
7 1	38 3	3520	20 0	12	Fine sandy loam	
8 3	41 2	..	25 0	..	Loamy sand	
8 0	32 0	..	25 0	10	Fine sand	
9 4	50 8	..	20 0	10	Fine sand	Medium sand
14 4	66 2	..	20 0	10	Loam	
10 5	68 1	..	45 0	32	Fine sandy loam	
9 8	65 1	..	35 0	25	Loam	
6 5	47 4	..	30 0	15	Loamy sand	Fine sand
8 9	64 9	..	45 0	40	Loam	Gravelly loam
7 9	54 5	..	35 0	30	Loam	Gravelly loam
9 4	60 4	605	30 0	..	Fine sandy loam	
7 9	52 6	2339	..	20	Fine sandy loam	
7 7	55 4	2804	..	20	Fine sandy loam	
11 9	63 6	5691	..	32	Fine sandy loam	Clay 30″
9 8	64 8	..	40 0	25	Loam	
5 2	38 5	3151	25 0	..	Loamy sand	Coarse sand
10 3	58 8	..	40 0	25	Loamy fine sand	
9 5	66 5	..	45 0	35	Loam	
9 9	54 0	..	35 0	..	Loamy fine sand	Medium sand
9 0	56 4	..	25 0	25	Loamy fine sand	Fine sand
8 6	42 2	..	20 0	20	Loam	Fine sandy loam
11 2	67 1	..	27 0	20	Loamy fine sand	Fine sand
8 3	61 1	..	45 0	45	Coarse sand	
9 2	57 4	..	40 0	..	Fine sandy loam	Fine sand

A = Artificially pruned.

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