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NORWAY SPRUCE IN THE NORTH-EASTERN UNITED STATES

A STUDY OF EXISTING PLANTATIONS

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INTRODUCTION

Norway spruce, *Picea Abies* (Linnaeus) Karsten, was one of the first species to be used in forest plantations in the northeastern United States. As early as 1860 small areas were planted with stock imported from Europe. Although the species has come into general use, there seems to be a prejudice against it. Some think it will die before maturing (8, 21); and the general feeling is that it is an unknown quantity. So, in 1926, the present study was undertaken to determine how the plantings, and especially the older ones, had developed. Fifty-seven plantations between the ages of seven and seventy years were studied in the states of Massachusetts, Vermont, Connecticut, and New York.

In the course of the work many people and agencies gave invaluable aid. The State Foresters of Massachusetts, Vermont, New Hampshire, Connecticut, and New York, and Mr. W. O. Filley of the Connecticut Agricultural Experiment Station gave the locations of many plantations. Mr. Stuart S. Hunt and Mrs. N. W. Hosley assisted in the measurement of the plots. The caretakers of several municipal reservoirs gave their time in showing the locations of their plantations. Among these were the caretakers at Little Falls, Glens Falls, Katonah, and Hemlock Lake, New York. Mr. Ludwig Gros, Forester of the Dieterich Estate at Millbrook, New York, gave detailed information on the fine plantations established under his direction. The Division of Lands and Forests, New York State Conservation Department, allowed the use of older sample plot measurements at Millbrook and Norwich, New York. G. Guiney, Librarian of the Imperial Forestry Institute, University of Oxford, Oxford, England, and the late Miss Helen E. Stockbridge, Librarian of the U. S. Forest Service, Washington, D. C., contributed very valuable aid on library references. Professor C. F. Brooks, Director of the Blue Hill Meteorological Observatory, Harvard, Massachusetts, gave the climatological references. The Forest Products Laboratory of the U. S. Forest Service provided data on the wood of the species. Professor R. T. Fisher, Messrs. Ward Shepard and A. C. Cline of the Harvard Forest criticized the manuscript as a whole, and Mr. S. R. Gevorkiantz of the Lake States Forest Experiment Station, U. S. Forest Service, checked the mensuration work. To all of these the author is deeply indebted.

The manuscript of the study was first completed in 1931. It was brought up to date in 1933, but funds were not available for its publication. No attempt has been made to incorporate works published since 1933.

NATURAL RANGE

The natural range of Norway spruce is inferior in area only to that of Scotch pine (Fig. 1), and this range has been greatly extended by planting. At present it is found all over northern and central Europe from latitude 69° north to the southern slopes of the Alps, Cevennes, and Pyrenees. In France it is important only in the higher mountains of the Jura, Vosges, and Alps. In Germany and Switzerland it is the principal tree of all the mountain ranges and hills, often forming large, pure stands at elevations above the broadleaved forests. It forms large forests in Scandinavia, Finland, Lapland, and central and northern Russia. It is seldom found in forest stands in Spain, Italy, Greece, north Germany, Belgium, Holland, or Denmark. The eastern limit is not definite, because there it merges with the Siberian spruce *(Picea obovata)*. It was introduced into England about the middle of the sixteenth century (10, 22).

In Norway and Sweden, Norway spruce is found from sea level to 650 feet in elevation. Farther south both the upper and lower limits are at higher elevations. In the Vosges and Jura mountains, for instance, it does not grow below 2000 to 2600 feet. It is found up to 3300 feet in the Harz Mountains of central Germany; 3500 to 4000 in the Black Forest near the French border; 6000 in the Bavarian Alps; and 6600 in the central Alps. In France it is confined to a zone above the silver fir *(Abies pectinata)* (10, 22).

Norway spruce grows naturally on soils ranging from the strong, friable types of the mountains to sandy loams and drained bogs (10).

While pure stands occur over large areas, it is also found in mixtures with other species. In the northern and eastern parts of its range, Scotch pine is the main species growing with it. In the mountains of eastern France and in central and southern Germany, silver fir and beech are its associates. In the Alps, especially at higher elevations, larch and spruce mixtures are common (10).

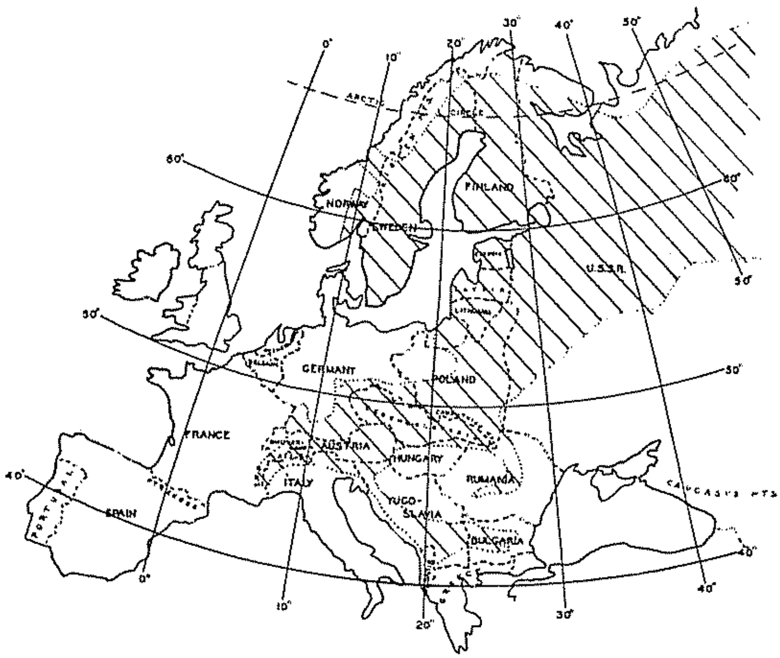

FIGURE 1. NATURAL RANGE OF NORWAY SPRUCE AFTER DENGLER (4).

CHARACTERISTICS OF THE TREE

IN EUROPE Norway spruce reaches large size. It is sometimes 100 to 150 feet tall and upwards of three feet in diameter. The crown is sharply conical, even to great age. The stem is very straight and seldom forked. The distinguishing characters are pendulous branchlets, yellowish green needles one-half to one inch long, and cones which are four to seven inches long and an inch to an inch and a quarter in diameter, with wavy-margined, usually truncate, cone-scales. The cones are light brown at maturity. The root system is shallow, seldom going more than three feet below the surface. The species is one of the most shade tolerant (19, 16, 14, 18). In its native habitat the tree lives to be four to five hundred years old (22). It adapts itself to a wide range of temperature, moisture, and soil conditions.

DEVELOPMENT OF PLANTATIONS

EARLY PLANTINGS IN THE NORTHEAST

INASMUCH as most early American forestry depended upon Europe for guidance, it is not strange that Norway spruce was one of the earliest species used in forest plantations in the northeastern states. Many of the first plantings were made with stock from Germany. The oldest planting found in this study was made about 1860 near Woods Hole, Massachusetts. Other early forest plantings were at Georgetown, Massachusetts (1865), White Lake Corners, New York (1878), Woodstock, Vermont (1880 and 1888) (167), Axton, New York (1894) (203), Groton, New York (1895), and Millbrook, New York (1897).

AMOUNT PLANTED IN THE NORTHEAST

The amount of spruce now growing in the Northeast is difficult to estimate because of the many agencies supplying stock and because of the fact that survival after planting is mostly an unknown quantity. However, the stock distributed by the state nurseries of the region is a good indication. The following table gives the figures supplied by the state departments for the five leading species.

This table shows that of a total of about 450,000 acres planted, 110,000 or twenty-four per cent, were with Norway spruce. If it is assumed that other agencies have produced one-tenth as much as the states, approximately 120,000 acres have been planted with this species in the region. So, for one rotation at least, Norway spruce is destined to be one of our most important planted conifers.

TABLE 1

TREES DISTRIBUTED THROUGH 1932 BY STATE NURSERIES

	White Pine	Norway Spruce	Red Pine	Scotch Pine	White Spruce	Totals
Connecticut [1]	474,836	396,827	2,170,680	332,385	44,091	3,418,819
Maine	11,110,571	1,447,950	2,618,366	93,850	7,633,415	22,904,152
Massachusetts	27,729,990	6,598,068	7,488,040	5,571,411	1,046,631	48,434,140
New Hampshire	9,762,316	481,063	1,325,842	15,450	463,785	12,048,456
New York	90,014,260	73,874,123	60,380,420	35,088,584	15,428,978	274,786,365
Pennsylvania	27,945,576	23,354,333	16,083,752	16,860,133	2,652,652	86,896,446
Vermont	6,087,615	6,931,502	3,876,778	2,822,389	1,039,670	20,757,954
Totals	173,125,164	113,083,866	93,943,878	60,784,202	28,309,222	469,246,332

[1] Planted on State forests only.

DISTRIBUTION OF PLANTATIONS ACCORDING TO ALTITUDE, TEMPERATURE RANGE, AND PRECIPITATION

The species has been planted in the northeastern United States under a wide range of conditions. Plantations are found from thirty feet above sea level to 1700 feet. But, considered alone, this range in elevation has so far had no noticeable effect on growth. All site indexes* are represented even at elevations below 500 feet; and one of the best plantations, sixty-three years old and falling in site index 70, is at an elevation of only 280 feet. Plantations with the 40-foot index occur at elevations up to 1350 feet. Above 1350 feet the indexes range from 50 to 90 feet.

The range in mean annual temperature over the region studied is not great (44° to 48° F.) and has shown no appreciable correlation with growth (42). This agrees with Saxon experience (166).

Precipitation in the region is abundant (forty to fifty inches annual average) and shows no correlation with differences in growth. Comparison with European conditions, however, brings out a striking difference between our region and their lowlands, where the growth of spruce is poor.

LIKELIHOOD OF "SPRUCE SICKNESS" IN THE NORTHEAST

The decreased yields of spruce or "spruce sickness," especially in Saxony, has greatly concerned European foresters for decades. As a result many Americans have come to think of stands where growth has stagnated as the only possibility with repeated crops of spruce. Yet, recent studies have shown that this is not a char-

* Height reached by average dominant and codominant trees at fifty years of age. Poorest growth found was 30 feet and the best 90 feet at fifty years.

acteristic of the species, but rather a result of its mismanagement. Pollen analyses have shown that spruce existed without degradation on certain sites in northern and eastern Europe for thousands of years before man became a factor influencing it. In some cases poor planting has been shown to cause the poor growth (113, 160). New stands properly planted and following directly after those hopelessly "sick" have shown good growth. But the great Saxon sickness, in which stands over thousands of acres have shown a sharp falling off in growth during the same year, is due to a combination of climatic and soil conditions. Repeated clear cuttings followed by pure plantings, inadequate thinnings, and often with continual litter removal as far back as the sixteenth century have led to a compacting of the soil, to raw humus formation and to a physiological shallowness. The spruce roots in these latter stands are so close to the surface that the severe droughts common to the region leave the tree with little available moisture. The result is a strong falling off in growth often lasting many years (166). The present tendency is to plant hardwoods in mixture with the spruce to improve soil conditions.

That we need not expect such conditions here in the Northeast seems to be indicated by our different climate and by the condition of the older stands in the region. Between elevations of 650 and 1950 feet, Saxony has an annual precipitation of about thirty inches, as shown by a fifty-year average (166), compared with thirty-five to fifty inches in the northeastern United States (42). In Saxony during decades of drought, it is not unusual at elevations similar to those in the Northeast to find one out of four of the May-September months with less than 1.57 inches precipitation each. Such dryness is unknown in our region. Records taken at Petersham show that during the eighteen years including 1913 and 1930 the average monthly May-September precipitation was 3.6 inches, the minimum May-September total 10.46 inches, and the maximum 28.23 inches. Only one in nine of the summer months represented had less than 1.57 inches of rain, and in only one case did two of these occur in the same summer, which had a total precipitation of 21.19 inches for this May-September period (41).

In Europe where spruce growth is optimum and the species has maintained itself in pure stands for centuries, conditions for growth are very similar to those in the northeastern United States. The climate is severe; the winters last up to five months; the springs are short; the summers are hot; and autumn lasts till early November. The mean annual temperature is around 6° C. (41° F.); the annual temperature extremes range from 35° C. (95° F.) to —30° C. (—22° F.); and the average annual precipitation is from 29½ to 31½ inches. Maximum precipitation falls in June and July and the most snow comes in February. Geologically this region is made up of eruptive rocks or crystalline primary ones, such as schists, gneisses and quartzites (78).

Raw humus formation with its accompanying podsol profile does not promise such acute trouble here as in Europe during the first rotation of Norway spruce. As shown in Table 18, our Norway spruce plantations do not begin accumulating litter until an age of around 18 years is reached. The youngest stand in which a felting occurred in the humus layer was 32 years old and still had 920 trees per acre. The heaviest litter layers found were two inches deep, and these were observed in only two stands. Considering that many of the stands were badly stagnated in growth, the indications are that the necessary thinnings would produce much better soil conditions. As shown by Dengler (4) in Germany, on the sites which produce the best yields, soil conditions are often very good. The hardwood advance growth which comes in under the more open, old stands in the Northeast will undoubtedly preclude such raw humus formation, if the necessary thinning is done (55). When these stands are cut, the hardwood sprouts will not allow the soil deterioration found so important in Saxony, but will tend to ameliorate any heavy humus layer present (54).

SOILS

New England and New York, with their glaciated topography, present very varied soil conditions. The soils are, in general, complex, a distance of a few hundred feet often separating such radically different physical types as gravels and loams.

One of the most striking relations coming out of the study is that between physical soil type and growth. With one exception the plantings were all made on abandoned agricultural land where the physical make-up of the soil more directly affects growth than it does on forest soils with their organic layer. Before the field work was started, Professor M. O. Lanphear, Agronomist at Massachusetts State College, gave those making the study instruction in classifying typical northeastern soils according to texture by means of "feel" and appearance. Samples of the various classes determined by Lanphear were kept in glass jars for comparison. During the study the soil was examined on each plot as deeply as possible by using a thirty-inch soil auger. A sample of the top foot of soil was classified and kept in a tin container. Some doubtful samples were later verified by screening, and the use of the hydrometer method in the laboratory. A description of each soil profile was made according to depth and condition of litter, humus, surface soil, and subsoil. When the site indexes of the plots were compared with their corresponding soil classes, a very striking correlation resulted, as shown in Table 2. Clays are found in only the lowest site index. The two clay loam plots fall in the two lowest indexes. With one exception the loams occur in all five higher indexes with nearly one-half of the plots in the sixty-foot index. Site index

90 was found only on loam plots. The two fine sand plots show no distinct correlation, probably because of the difficulty of accurately classifying them by the method used. Sands occurred in only the lower three indexes. This shows very conclusively that, to insure good growth, Norway spruce should be planted on soils of the loam or sand loam types.

TABLE 2

RELATION OF SOIL CLASS TO SITE INDEX

Soil Class	Site Indexes (Ft.) Number of Plots 40	50	60	70	80	90	Totals
Clay	2						2
Clay loam	1	1					2
Loam	1	4	12	3	4	5	29
Sand loam	1	5	8	2	3		19
Fine sand	1				1		2
Sand	1	3	3				7
Totals	7	13	23	5	8	5	61

The extremes of soil are often found within a very short distance. In one case on a hillside, a layer of clay was found at varying depths below the surface. Where the clay layer was six inches down, the average height of the nineteen-year-old trees was three feet. About fifty feet away, where this layer was about thirty inches down and the soil above was stony loam, the average height was over thirteen feet. One of the strongest contrasts is shown in Fig. 2. Here two plantings fourteen years old and about five hundred feet apart were made with identical stock and planting methods. One was on a loam with abundant moisture. The average height of the trees here was twenty feet. The other planting was on a glacial dump of stratified gravels and sands with little moisture. The average height was a little over six feet; and where coarse gravel came to the surface, the trees were only stunted bushes less than two feet tall. Knolls of coarse sand often cause complete blanks in otherwise good plantations; and the trees will make an amphitheater effect, their height increasing as the sand grades toward loam.

Spruce will not grow on sites where porous soil and a low water table give little surface moisture. The species is sometimes called "the drunkard of the trees" because of the great amount of moisture needed during the pole stages (4). On the other hand, it can do little more than exist where a high water table or poor drainage caused by an impervious layer close to the surface makes the soil wet. Between these moisture extremes it does well. Since much of the success in plantations depends on selecting soils adapted to the species, no planting of spruce should be made blindly without an examination of the soils.

GROWTH AND YIELDS

Height Growth

As there were few older stands and no stem analyses could be made in any of them, it was found difficult to make accurate site indexes. However, it was thought worth while to attempt to show the general trend of total height development in the indexes representing the greater numbers of plots.

Anamorphosis* of the material, clearly gave unnatural results (175). So a simple set of harmonized curves was developed by using MacDonald's figures for the portions covered (indexes fifty to eighty feet at fifty years and ages twenty-five to seventy years) (188). The English curves fitted the plot averages very well in the ages included, and were extended downward covering the points from the younger plots.

* Changing a set of curves from the skewed form into straight lines by shifting the spacing of the vertical ordinates. With a set of curves such as those described, the trend of all anamorphosed curves is based on that of the central curve.

Four plots indicate the existence of a ninety-foot index, but there was only one older plot, thirty-seven years of age, falling at an index of eighty-five feet to support this, so it must be regarded as questionable for the present. Seven plots under thirty years of age showed an index

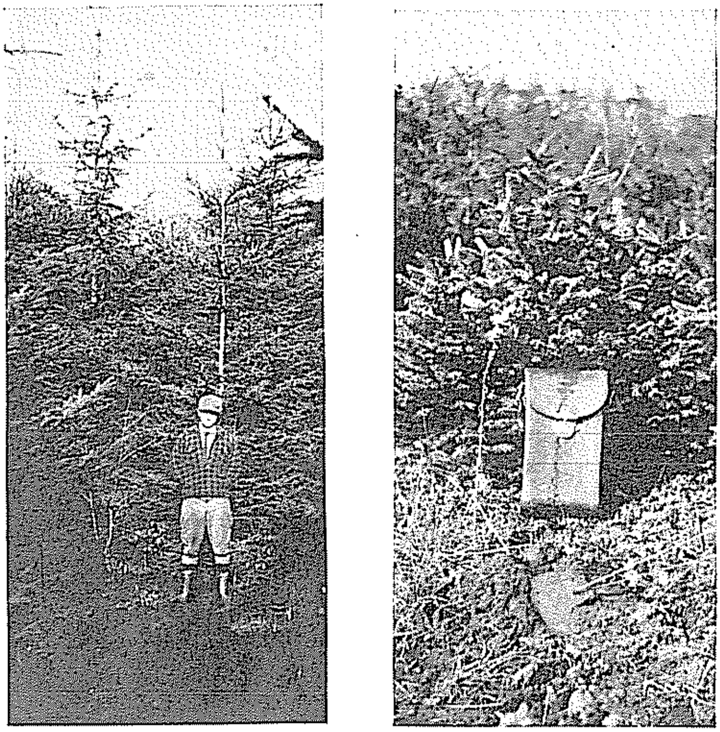

FIGURE 2 NORWAY SPRUCE GROWTH ON DIFFERENT SOILS.

These stands, fourteen years old, were planted about five hundred feet apart with the same stock and planting method. The taller stand was on a good loam soil, while the other was on a gravel outwash.

falling at forty feet or below; but in these cases either the site was not at all adapted to spruce, or the slow height growth could be attributed to animal damage or to an overwood. This index is certainly found in young spruce plantings over the region covered. However, it is problematical how these stands will develop at older ages, as some will apparently grow very slowly or die; while others, relieved of the influence holding them back, will undoubtedly reach higher indexes later. This agrees with the experience in England (188).

The following table shows the height development in the stands studied.

TABLE 3

RELATION OF HEIGHT GROWTH TO AGE IN THE PLOTS STUDIED

Age in Years	Site Index 50	60	70	80
	Height of Average Dominant and Codominant Trees in Feet			
10	3½	5	7	9
20	15	20½	25	30½
30	28½	36½	43	51
40	40	49	58	66
50	50	60	70	80
60	58	68	79½	91½
70	64	75	86	100

Blocking shows distribution of plots.

These figures are slightly lower at young and old ages than those given for Russia in the universal height growth tables of Tjurin (202). Our best plots in the Northeast show the greatest height growth of any known stands of the species. No mention is made by MacDonald of heights above eighty feet at fifty years, while a few of our plots are above his eighty-foot curve. The growth in England is better than any given for the continent of Europe with the exception of Switzerland. The heights given for the best sites in some European tables of yield are as follows (181, 188):

Over the region studied there was a surprising uniformity of average site index. Only one section showed

TABLE 4

HEIGHT GROWTH AS GIVEN IN EUROPEAN YIELD TABLES

Section	Author	Date	50-year Height
So. Finland	Ilvessalo	1920	33
Saxony	Kunze	1878	62½
Tyrol	von Guttenberg	1915	62½
Germany	Gerhardt	1923	66*
Russia	Tjurin	1916	68
Prussia	Schwappach	1902	70
Germany	Schiffel	1904	76½
Switzerland	Flury	1907	80

* Made up from four previous yield tables including Schiffel and Schwappach as above.

a striking variation. In the region of New York east of Ithaca and south of the Mohawk River, nine of a total of eleven plots had site indexes of eighty or ninety. The following table shows the distribution of site indexes for the plots in the sections studied. The one Connecticut plot was far below the average index, but was, of course, not significant alone.

TABLE 5

SITE INDEXES BY SECTIONS

Section	No. Plots	Site Index Minimum	Site Index Maximum	Site Index Average
Vermont	8	40	75	61
Massachusetts	19	40	70	57
Connecticut	1*	30	30	30
Northern and western New York	22	40	90	56
Southeastern New York	11	50	90	80

* On poor land and not representative of the state.

When compared with the available figures for the other spruces of importance in the region, Norway spruce seems to be well ahead in height growth. The best growth found in the Northeast in natural stands of red spruce

(189) was fifty-eight feet at fifty years; the best reported for white spruce in five regions of Minnesota (187) was about fifty-five feet in fifty years; and in the Northeast (189) fifty-eight feet in fifty years. During twenty years' experience on a large planting project in Quebec, Canada, Wilson* found that the average height growth of Norway spruce up to twenty-five feet in height was sixteen inches per year and that of white spruce fourteen inches. At the time when economic conditions caused cessation of the planting, the proportion of Norway spruce was being increased over that of white.

Diameter Growth

The study of diameter growth in stands which have never been thinned is, of course, bound to give comparatively low figures. Because of the great shade tolerance of the species, the stands do not thin themselves, and the result is a very acute and long continued stagnation.

In order to compare diameter growth on the plots studied with that from thinned stands in Great Britain, the following table was constructed for comparable ages and site indexes.

In no case were the diameters reached in the Northeast equal to those in Great Britain, even in stands understocked at the ages given. This fact can, in general, be explained by MacDonald's statement that the British stands were thinned early and heavily to produce better conditions for game. This policy has apparently led to a better selection and development of crop trees than has been the case with stands which have developed unthinned with wider original spacings in this country. It is interesting to note the effect of degree of stocking on diameters in the plots studied as compared with those in England. Thus, on a plot having only 64 per cent of the

* Ellwood Wilson in a letter to the author concerning plantations of the Laurentide Company, Grand' Mere, P.Q.

TABLE 6

COMPARISON OF NUMBER OF TREES PER ACRE AND AVERAGE DIAMETERS WITH THOSE GIVEN FOR GREAT BRITAIN (188)

Age in Years	Trees per Acre G.B.	Trees per Acre N.E.U.S.	Av. D.B.H. G.B.	Av. D.B.H. N.E.U.S.	Per cent of British values Trees per acre	Per cent of British values Average D.b.h.
			Site Index 50 Ft.			
52	542	487	9.1	7.9	90	87
			Site Index 60 Ft.			
35	930	1086	6.4	6.1	117	95
			Site Index 70 Ft.			
63	222	437	15.4	12.2	197	79
63	222	618	15.4	8.6	278	56
			Site Index 80 Ft.			
32	640	1040	7.9	5.8	162	74
32	640	968	7.9	5.8	151	73
37	485	880	9.5	6.6	181	69
50	280	180	13.4	13.0	64	97

number of trees given in the English tables, the average diameter was 97 per cent of the English diameters; while in an overstocked plot with 278 per cent in number of trees, the diameter was only 56 per cent that given for England.

The diameters developed in our plantations are twice to three times those given for the same indexes for red spruce and about double those for white spruce given by Meyer (189); but the red and white spruce stands had, in general, at least twice as many trees per acre at the ages represented.

Basal Area Development

Basal area showed such a wide variation within a given site index and so much overlapping between indexes that no attempt was made to develop a correlation.

Volume Production

In Europe, Norway spruce has long been noted for its heavy yields. Woolsey (22) says, "Of all (European) forest species, spruce probably forms the densest stands and yields the largest amount of wood." According to Dengler (4) the name of "Goldbaum" (tree of gold) has become common in Germany on account of the high yield of spruce. Certainly one of its most striking characteristics in America is the high yield which has been produced in the older plantations on better sites. The few plantations in the Northeast that have reached ages from thirty-five to sixty-five years show far higher yields than any other species, native or exotic, grown here to date.

The yield plots were so few in number (eighteen) and their histories so varied that it was impossible to construct yield curves with any assurance of accuracy. Accordingly the yields of the plots are presented in the following table to show in a general way what may be expected without thinning from stands in the region.

The zone of plotted points representing the relation of yield to age corresponds very closely with that for MacDonald's yield tables for the main crop, but the lack of thinning in our stands seems to affect the yield far more than site index does. This is especially true in the higher indexes where high densities of stocking in some cases decrease the volume to correspond with that of the next lower site index, and where low densities place the volumes with those of the next higher index.

As a guide to what may be expected from managed stands, MacDonald's yield table converted to a basis of diameter breast high is presented on page 66 in the appendix (188).

When a converting factor of ninety-five cubic feet to one cord is used, the yields of our better plantations in cords is very striking. In northern Massachusetts a stand sixty-three years old and growing on a loam soil with a site index of sixty gave an average volume from two plots of one hundred twelve cords (Fig. 3). Another in south central New York falling in the ninety-foot site index and with an age of thirty-seven years had a volume of eighty-six cords per acre, indicating a much higher sixty-year yield than the Massachusetts stand.

TABLE 7

YIELDS IN CUBIC FEET INSIDE BARK FOR VARYING AGES AND SITE INDEXES

Age in Years	Site Indexes (Ft.) 50	60	70	80	90
	Yields in Cubic Feet, Inside Bark				
14					590
19		480			
20	330				
25	1140	1180			
28	1220				
29				3285	
32	2180			4250*	4410
35		3230			
37				7760	8160
50				5790	
52	3930				
63			10640*		

* Average of two plots.

FIGURE 3. NORWAY SPRUCE STAND SIXTY-THREE YEARS OLD, GEORGETOWN, MASSACHUSETTS.

Average height, 79 ft.; average diameter breast high, all trees, 12.2 in.; volume per acre, 10,640 cu. ft.

SILVICULTURE OF THE SPECIES

NURSERY PRACTICE

The first consideration in growing a crop of spruce in the nursery is the seed source. This species apparently does not vary in racial characteristics as widely as many others do. The plantations already growing in this region do not seem to vary noticeably in silvicultural characteristics. This is probably due to the fact that most of the seed was obtained from lower elevations in central Europe where the races do not differ widely. While Sylven (37) recognizes ten forms in Sweden, only the comb types with drooping branchlets on the main side branches seem to be common here. From the standpoint of growth and resistance to adverse climate, these are the most desirable races.

The relative merits of the forms which start early and late in spring are an open question in Europe. The late starting form does best in colder regions where late frosts would kill back the early starting form. It would seem, however, that, since the late starting form comes from the higher mountains and frost pockets (34) and would not be able to lengthen its natural short growing season (29) in the more favorable climate of the northeastern United States, European seed should be obtained only from the lower elevations and from the more southern part of the range.

Now that our own plantations have, in a few cases, reached seed-bearing age, we should not miss the opportunity of getting seed from trees already "naturalized." Efforts to gather seed from trees less than forty years old are apt to be disappointing on account of the small amount in a cone and of its poor germination.

Details of nursery practice are as varied as the localities in which they are carried on, but general methods based on the characteristics of a species apply in successful work everywhere.

Seedlings to be grown to two years of age should not be at densities of more than one hundred per square foot, and the studies of Steven (92) led to the belief that about fifty per square foot was best. High densities of two hundred or more per square foot usually result in stunted yellow seedlings in all but a narrow ring at the border of the bed. The use of concentrated fertilzers has been successful in growing dense beds without the poorer shoot growth in the middle. However, until more is known about the root-shoot ratios of seedlings grown with high nitrogen and phosphorus concentrations, it is dangerous to assume that this stock grown in high densities will be as suitable for transplanting and field use as that grown with wider spacing.

Toumey (94) found that germination of Norway spruce in a closed bed was much better than in either open or mulched ones. He also found that losses due to hot, dry weather were less under shade than without it. Of twelve coniferous species studied, five days after germination Norway spruce had the shallowest root penetration (one and two-tenths inches) of any. At thirty days it was second with only two and four-tenths inches. So it is plain that surface soil moisture of even the top inch is very important during the early seedling stage. Very good results can be obtained by keeping the beds entirely shaded, top and sides, until germination of the seeds is nearly complete. Then half of the overhead shade should be removed and the rest left until seasonal growth is completed, when the covers should be taken off to allow the plants to harden up before frosts come.

Damping-off may in some cases require chemical treatment (95). On well drained soils, such as loamy sands and sands, drying of the surface soil by removing the seedbed covers following heavy rains usually controls the disease.

Frost heaving in seedbeds, caused by the formation of anchor ice in the soil, can be controlled by mulching with hardwood leaves or covering the seed frame with burlap as soon as the ground is thoroughly frozen in the fall and keeping the plants covered until frosts are past in the spring.

In the transplant rows, mulching is necessary in the more northerly part of the region because, even on gravelly soils, frost heaving will often kill or stunt the tree. The damage is, of course, much worse on heavier soils. Sphagnum is a very good mulch and helps considerably in the control of weeds. A very cheap and effective method of mulching transplants has been developed by A. H. Upham, Superintendent of the Harvard Forest. Following the last cultivation in late September barley is broadcast over the transplant beds using about the same quantity of seed per unit area as for a grain crop. The barley gets nearly as tall as the transplants by the time it is killed by frost and forms a very effective mulch during the winter and spring. It breaks up readily in the spring and forms no hindrance to cultivation.

In transplanting, no cull plants should be used. These have been found to continue poor growth and to show high mortality. Plants to be grown to 2-2 size should be spaced two to three inches apart in the row. Closer spacing allows too little development of side branches as well as roots (92).

PLANTING

Size of Stock

The size of stock to be used depends largely on the site to be planted and the combination of species planted. On land where there is little competition from any sort of vegetation 2-1 or even 2-0 stock can be used. With a heavy ground cover or on cut-over land where hardwood sprouts will be plentiful, the use of small stock is not justified (106). Where there is much brush, at least one, and often two, extra weedings are needed to get the spruce through; and that extra cost alone more than equals that for older stock. Under strong competition, it takes from five to ten years longer for small stock to reach a given size than for 2-2 stock.

Compared with such species as red and white pine, spruce is slow to start after planting. The first year a 2-2 plant will grow only an inch or two, while on the same site the pine will add about six inches. About the fourth year, spruce of this size begins to hit its stride, making growth equal to that of the pine. From then on, it will at least equal the pine in height growth on soils adapted to it.

Season of Planting

While most spruce is planted here in the spring, fall planting seems generally to be successful. The weather of the particular season, however, is a most important factor. Planting during a dry fall would, of course, be risky. Early summer droughts also bring high mortality, but are very uncommon in the northeastern states. Fall planting must, of course, be done after the plants become dormant and before hard freezes come. September and October of favorable autumns are best. In spring, the sooner planting can be done after frost is out of the ground, the better the results.

Planting Methods

Practically all planting in the region has been done by the mattock hole and the slit methods. Comparison of the results of the two methods in the older plantings is usually impossible because of the lack of definite information on establishment. Three of the best plantations thirty-two years old were planted with a notching spade.

Experience at the Harvard Forest and elsewhere has shown that the most important factor in the survival of planted spruce is depth of planting. The secondary roots of a normal plant of transplanting size rarely go more than two inches below the soil surface in the nursery and when these roots, which may be eight inches long, are directed downward in planting and the whole root system is set perhaps three inches deeper than normal, the chance of survival is very poor. The plants so set must develop a secondary root system at the natural depth, and many of them die before this is accomplished (100). Dipping the roots in mud increases the tendency toward matting and too deep planting. Reuss (111) concluded after a study of results on roots of spruces up to forty-eight years old that it was not slit planting but the abuse of it which gave poor results (Fig. 4). Snow- and wind-throwing, root rot, and poor yields were found to be the result of these abuses.

FIGURE 4. RESULTS OF POOR PLANTING.

The roots were drawn into a slit from the side instead of being placed in their normal, spread position.

Spacing

American plantings, especially the older ones, varied in spacing from five by five to fifteen by fifteen feet. Aside from the large branches of widely spaced plantations, the trees seem to be uniformly of good form. There was not enough material available to study the effect of these spacings on the yield, and of course their significance would be largely lost unless the closely spaced stands were thinned early and often.

In Saxony Fritsche (102), working with a series of sixteen permanent sample plot records covering a period of fifty years, arrived at some interesting conclusions on spacing. The plots were on a poor, stony, loam soil. Spacings of six and one-half and five and two-tenths were decided to be too wide because of low production. The square planted, two and eight-tenths foot plot gave the highest stem wood volume (10,654 cu. ft.). He concluded, however, that such dense stands are practical only under the most intensive conditions and that on good sites in a moist climate no mistake is made in using a spacing of five feet. Using value of the stand as his criterion, he found the best spacing was three and seven-tenths feet. Within the limits of the experiment, spacing did not influence stem form or clearness of the bole to any appreciable degree.

In the region covered by the present study, where spacings ranged from four by four to fifteen by fifteen feet, there was a definite increase in average knot size along the dead length with increasing spacing. Twenty-three plots showed that the average knot size of a four by four planting was one-half inch, and that this average increased at the rate of almost exactly one-tenth inch per foot increase in spacing up to ten by ten feet. Beyond this there seemed to be no significant increase. The largest average knot size found was one and one-half inches.

The question of spacing to be used should depend on local factors. Where early thinnings can be marketed as Christmas trees and pulpwood, there is no question but that close spacings will produce more return; but inaccessible land cannot profitably be treated the same way. The fact that spacing does not affect knot size in spruce as much as in such species as white and red pine allows the use of planting distances up to about eight feet. However, the fact that "pasture" spruce is not being bought at present by pulp mills in the Northeast shows the inadvisability of using extremely wide spacings.

Mixtures

In the Northeast one of the greatest questions in the minds of foresters developing planting programs is what to plant. Mixtures are unquestionably much more desirable than pure stands; but under a given set of conditions, what species can we plant in mixture and be reasonably sure the combination will succeed? Some of the plantings where Norway spruce was mixed with other species are now old enough to show something of the behavior of the components.

Norway Spruce and White Pine

On sites adapted to the spruce this combination seems to be a good one. It combines a tolerant species with a comparatively intolerant one; the stand can produce both pulpwood and sawtimber; the root systems occupy different soil strata; and the rates of growth on loam soils are nearly equal. The following table from plots taken in the study shows how the two species in alternate rows compare in height growth.

On coarse sandy soils where even white pine growth is slow, spruce in mixture with it is overtopped almost from the start and is soon hopelessly lost. A plot at

TABLE 8

RATE OF HEIGHT GROWTH OF NORWAY SPRUCE—WHITE PINE MIXTURES

Age	Spruce Site Index	Soil Type	Average Height (Feet) Norway Spruce	White Pine
19	60	loam	16	17
20	50	loam	15	18
21	60	loam	18	20
28	50	loam	26	27
35	80	fine sand loam	56	56
40	50	medium sand	43	39

Rainbow, Connecticut, on a medium sand which had been impoverished by tobacco growing, showed this difference very strikingly. At twenty-four years of age the white pine was twenty-two feet tall and the spruce only five feet (184).

Where there is a market for pulpwood, this mixture is especially good; for the spruce can be removed in thinnings while still small, leaving the pine for the final crop. However, where the white pine weevil is abundant, white pine, even in mixture, is a poor choice on open land unless the spacing is made close (119).

Norway Spruce and Red Pine

While older plantations of this combination are lacking, the development of the two species in pure stands indicates that the mixture, as far as growth is concerned, is a good one, at least on sites ranging from indexes fifty-five to eighty for spruce. The following comparison of height growth is made from a study of red pine by Reed (192), and the comparable growth figures for an average of the better sites for Norway spruce from this study.

TABLE 9

RELATIVE HEIGHT GROWTH OF NORWAY SPRUCE AND RED PINE

Age	Height in Feet Norway Spruce Site Index 70	 Red Pine (Medium Soils)
20	21	22
30	37	39
40	54	53
50	70	63
60	87	70

One plot near Syracuse, New York, planted with the two species in alternate rows on a fine sand loam soil with a spruce site index of eighty feet showed the following growth at twenty years:

	Norway Spruce	Red Pine
Average height	23.0	23.6
Average diameter breast high	3.3	4.9

On poorer sandy soils red pine will outgrow spruce from the start.

The red pine root system is deep and wide-spreading (19), which, of course, adds windfirmness to the spruce in mixture with it. Red pine is somewhat less shade tolerant than northern white pine. In regions where weevil damage is high, this mixture promises very great usefulness, because red pine itself is almost never weeviled and gives some weevil protection to the spruce at the same time. As red pine is well adapted to the production of lumber and dimension stock, the mixture has a variety of uses. On the other hand, the European pine shoot moth, which is at present causing such great losses in Connecticut, New York, and Ontario, makes the use

FIGURE 5. A MIXED STAND OF NORWAY SPRUCE AND EUROPEAN LARCH FORTY-TWO YEARS OLD. WOODSTOCK, VERMONT.

of red pine as a prospective crop tree in these regions, at least, rather hazardous.

Norway Spruce and European Larch

This combination is one which grows naturally in the mountains of central Europe.

The larch is very intolerant of shade and fast growing up to forty years of age (Fig. 5). It is tap rooted, and its foliage is noted in Europe for its ability to improve soil conditions. Three plantations of this mixture were found during the study.

TABLE 10

RELATIVE HEIGHT GROWTH OF NORWAY SPRUCE AND EUROPEAN LARCH

Age		Soil Type	Spruce Site Index	Average Height	
Spruce	Larch			Spruce	Larch
24	22	sand	60	28.5	26
40	40	medium sand	50	43	31
42	42	fine sand loam	60	48	58

These plots show that, although larch outgrows spruce on the better soils up to middle age, it is unable to keep up with the spruce on sands, even on those where the spruce makes fair growth.

One of the most striking features of the mixture is the effective pruning of the larch by the spruce (Fig. 6). The large lower limbs shown in the figure are due to the wide spacing (twelve by twelve).

Larch should be planted either as occasional single trees or in small groups among the spruce. The effect of such groups on the regeneration of the stand is indicated by Fig. 8, which shows very good natural reproduction of spruce under a larch group in the forty-two-year-old plantation mentioned above. This result bears out

FIGURE 6. MIXTURE OF NORWAY SPRUCE AND EUROPEAN LARCH FORTY-TWO YEARS OLD, WOODSTOCK, VERMONT

Note the pruning of the larch by the spruce. The large lower limbs are due to the wide spacing, twelve by twelve feet.

European experience which has shown that the rich needle fall of larch does not hinder the development of thick spruce undergrowth (81). On sites where there is strong competition from grass or shrubs (123), the planting stock of larch should be stocky and from eight to twelve inches tall.

Larch is a good species to use for the production of posts, poles, ties, and dimension, and will give usable thinnings at younger ages than the spruce (123). Europeans consider that larch in mixture with spruce adds greatly to the forest value per hectare from the standpoints of both silviculture and actual worth.

In Europe two species of aphid, *Adelges strobilobius* and *A. viridis*, were thought to alternate between the larch and the spruce as hosts and to do considerable damage. The first species is reported in America by Peirson (218). However, Steven (219) found that the alternation was not necessary in the life cycle of either species and that the elimination of either tree from a mixture already attacked would give no appreciable help in controlling the insect once it had become established. Fumigation of stock before planting to free it from the insects has resulted in satisfactory control on sites where good growth was possible.

Norway Spruce and Scotch Pine

This type of stand exists in Europe in all proportions from pine with an understory of spruce to spruce with a small amount of pine. The mixture is favored there because it develops neither the openness of the pure pine nor the raw humus soil condition of the pure spruce. It is less subject to storm and insect damage than pure stands of either species (4).

However, the difficulty of getting races of Scotch pine adapted to any particular section of this country is shown by the poor form of practically all our stands. At least until we have races of known form acclimated in a given region, white or red pine in mixture with spruce gives much greater promise.

Norway Spruce and Hardwoods

The esteem in which spruce-beech stands are held in Europe is well known. The abundant and vigorous hardwood advance growth on our heavier soils gives plenty of material for the creation of mixtures. Under the oldest spruce stands the borders are beginning to develop a hardwood advance growth of various species; and it is apparent that if spruce reproduction occurs in the second rotation on such sites, it will be in mixture with the hardwoods. Whether natural reproduction will provide such a mixture in properly treated stands remains to be seen; but one of the uses to which spruce is well adapted is that of filling in areas of inferior species or of poor stocking in good hardwood reproduction. The species is not injured by shade so much as the pines, but the terminal buds seem to be rubbed off more easily and weedings are necessary to free them. Once the spruce begins rapid height growth, it soon equals the rate of the hardwoods.

A special case of spruce-hardwood stands is that in which spruce is planted under young poplar stands such as those so characteristic of burns in the Adirondacks. The State of New York has some plantations of this kind in which the spruce is growing well and is in a position to form the main stand when the short-lived poplar breaks up (Fig. 7). Of course, spruce planted beneath the densest poplar thickets could make little growth, but in the more open stands it does well.

Wherever there is an appreciable amount of hardwood brush of either seedling or sprout origin, planted spruce must be weeded in order to make good growth. While spruce will persist beneath hardwood for many years, the trees are only umbrella-shaped dwarfs. Moreover, if the spruce is in a position to be whipped by the hardwoods, the leader will be killed and further height growth greatly reduced. Where such species as gray birch, fire cherry, etc. have seeded in to make a scattered stand, one

FIGURE 7. NORWAY SPRUCE TWENTY-EIGHT YEARS OLD PLANTED BENEATH A POPLAR STAND ON AN OLD BURN.

or two weedings, requiring a maximum of eight man-hours per acre will usually bring the planted spruce through. Where spruce is planted groupwise to supplement natural hardwood reproduction following a cutting, three weedings are usually required to get good development of both elements. The time required is from fourteen to thirty man-hours per acre (125).

Norway Spruce on Cut-over Cordwood Land

Norway spruce is a good species to use on cut-over cordwood land to produce a pure coniferous stand instead of the sprout cordwood which naturally follows such a cutting. The planting should be done with large stock the spring after cutting. A wide spacing of about eight by eight feet can be used, planting only in the spaces several feet from hardwood stumps. Three weedings are usually necessary, the time required being essentially the same as when the spruce is planted groupwise with hardwoods of sawtimber species. The wider spacing of the plants saves enough planting stock and money to cover a substantial part, and sometimes all, of the weeding cost.

PRUNING

Whether spruce should be pruned has been a controversial subject in Europe. While most authors admit the desirability of pruning dead limbs, some writers (129, 131) claim that green pruning results in slow healing, pitch pockets, and rot. More recently the attitude toward limited green pruning seems to be more liberal. Dengler (4) and Heck (127) consider pruned logs far superior in value to unpruned ones. Green pruning should be limited to smaller branches and should be done during late winter to allow the wounds to cover as much as possible before the start of growth. Pruning should be limited to crop trees only (4).

It is evident from the older plantations that no clear length will develop naturally in rotations up to sixty years. The branches usually harden rather than rot, and no natural pruning takes place. Development of dead length (portion of the bole on which branches have been killed by shading) is very rapid after the stand closes until it is thinned. The average of eighteen older plantations with original spacings of six by six feet or less gave the following dead lengths at their respective ages.

TABLE 11

RELATION OF DEAD LENGTH TO AGE IN UNTHINNED STANDS

Age	Dead Length Feet	Dead Length Per Cent of Total Height
15	1	13
20	6	28
25	14	41
30	25	53
35	38	66

This shows that the pruning of dead branches can be started at about twenty-five years of age, when a log length can be cleared.

THINNING

One of the most important phases in spruce silviculture and the one most neglected in American plantations is that of thinning. Since spruce is so shade tolerant, mortality is very low even after the stands close, and older stands established with any commonly used spacing and left unthinned are universally stagnated in growth because of overstocking. In Europe under such circumstances and especially on poorer sites, soil conditions get progressively poorer on account of the accumulation of a thick raw humus layer and the development of a podsol profile (4,166). The fact that in our older, unthinned stands there is no advance growth or herbaceous vegetation of any sort except where side light reaches the forest floor shows the unmistakable need for thinning. Furthermore, diameter growth as well as intermediate yields can be greatly increased by proper thinnings.

There are two schools of spruce thinning in Europe. One, as advocated by Schwappach (150, 151), recommends medium thinnings to keep the crown length from one-third to one-half the total height; the other, as typified by Bohdannecky (135), aims at trees always free on all sides with the crown length about two-thirds the total height. The Schwappach school of thought seems to be dominant in Germany and also is more applicable to our less intensive economic conditions.

All authorities seem agreed that thinnings should be started when dead length reaches fifty to sixty per cent of total height in all stands with close spacings. Stands originally spaced ten by ten feet or wider may not need thinning before fifty years or later. Drastic opening-up is dangerous at any age. Rather, the aim should be to keep the stands dense until a small knot size is established in the butt and then to thin just enough to keep crown lengths from one-third to one-half total height. Special attention should be given to breaking up dense groups of trees.

In this study thinning was found to be needed in stands planted five by five or six by six feet at about thirty years of age. Early thinnings needed were of C grade, including suppressed and intermediate trees which would break the crown canopy for only five years at most. Later thinnings should be frequent and light rather than seldom and heavy. As the stands approach maturity, the severity of thinning can well be increased to take some codominant trees (D grade). In the field, eleven of the older plots were studied with a view to finding what thinning was needed. None of them had been previously treated more than to remove dead or dying trees. The following table shows something of the history of these stands, the thinnings recommended, and the material which would be removed.

TABLE 12

THINNINGS NEEDED IN OLDER PLANTATIONS STUDIED

Age (Yrs.)	Site Index (Ft.)	Original Spacing	Present Trees per Acre	Dead Length (%)	Thinning Needed	Thinning Recommended			
						% B. A.	% Vol.	% Trees	Cords per A
32	80	5′ x 5′	968	58	badly	19	25	31	10.7
32	80	5′ x 5′	1040	66	yes	26	22	38	10.5
32	90	5′ x 5′	920	66	yes	21	27	35	12.6
32	50	5′ x 5′	1000	58	yes	11	11	30	2.4
35	60	6′ x 6′	1086	47	yes	39	35	57	11.1
37	90	6′ x 6′	640	70	yes	14	12	25	10.1
37	80	6′ x 4′	880	73	yes	20	18	35	14.3
50	80	14′ x 14′	180		no	..	..	..	..
52	50	8′ x 8′	487	71	yes	29	28	50	10.6
63	70	irregular	437	57	no			.	..
63	70	6′ x 7′	618	62	yes	19	19	30	16.2

If delayed until the stands are thirty years old, thinnings may produce some profit, as indicated in the table. Pulpwood is now used to small top diameters in the Northeast, and well-formed tops can often be sold as Christmas trees for good prices.

SEEDS AND SEED PRODUCTION

Norway spruce begins to bear fertile seed on good sites at about thirty years, but it is safer to collect from trees at least forty years old, unless examination shows the seeds to be well filled. Seed years average one heavy crop and one light one in six to eight years (22, 10).

The time when the seed ripens depends on the weather. When the late summer has been warm and sunny, good seed can be collected in late September or October; but otherwise it will not ripen before November. Early ripened seed is, in general, disseminated early. However, this is influenced by the fall and winter weather. If the fall is warm and dry, the cones may open by November;

but if the fall is cold and wet and the winter has few exceptionally warm and dry days, much of the seed may be held until early spring (66).

The cones are easily collected because of their large size and their usual concentration at the top of the tree. Furthermore, if squirrels are feeding on the seed, they usually cut off many times the number of cones they can cache, and these can be picked from the ground. When collecting it is well to leave out the smaller cones from each tree, because Friedrich (65) has shown that the larger cones not only produce more and better seed but that the plants produced are much better all through the seedling stages.

Norway spruce cones open very easily at relatively low temperatures. Cones spread out at ordinary room temperatures are fully opened in a short time.

The seed germinates well. Toumey (74) gives the minimum viability at 49.7 per cent and the maximum at 96.7 per cent. The seed is viable for three or four years (22). The size of the seed varies within wide limits, increasing in general toward the south. Seeds from northern Norway weighed 4.01 grams per thousand as compared with 9.01 grams for those from Germany (74).

NATURAL REPRODUCTION

Spruce silviculture in central Europe has most often meant clear cutting and planting; but the pendulum is swinging, and now natural reproduction in the "Dauerwald" (continuous forest) is the leading philosophy. One of the most successful modifications of this is the "Blendesaumschlag" (border shelterwood), which is a strip system moving usually from north to south and providing partial protection from the sun for the young seedlings. In the past it was thought that even-aged stands were most desirable and that planting was the only practical way of establishing the new stand; but it has been found that under favorable conditions good reproduction can be obtained naturally. Difficulty in establishing this reproduction does not seem to be regional, for success has sometimes been attained from Norway to the southern limit of the range. However, certain requirements have to be met wherever natural reproduction is established. Heavy spruce litter makes establishment impossible, since the seed must come in contact with mineral soil or humus of another species in order to germinate. Spruce seedlings are unable to survive in any numbers in heavy ground covers of moss, blueberry, club moss, ferns, grasses, or berry bushes. The unfavorable effect is greatest on poor sites under an overwood and on the best sites on cuttings. Hardwood leaves may be favorable or unfavorable according to their nature and amount. Relatively small leaves which shrink in drying, such as those of hazel, offer little hindrance to the spruce; while a heavy fall of large, leathery leaves, such as those of aspen, practically prevents spruce reproduction. The favorable effect is best brought out in mixtures with spruce where the hardwood leaves limit the amount of moss which can develop and are not plentiful enough to cause trouble in themselves (81). As large openings in the stand allow weeds rather than spruce to establish themselves, the seed cuttings should be light and the final clearings made soon after reproduction is established. Regeneration is much easier in mixed stands (22).

The fact that the older spruce plantations in the Northeast have not generally reproduced themselves is not surprising. None of them has been thinned to produce a condition at all suitable for reproduction. The fact that in mixture with European larch (Fig. 8) and around the borders of pure plantings (Fig. 9) reproduction is coming in shows that the species will regenerate here if

FIGURE 8. NATURAL NORWAY SPRUCE REPRODUCTION UNDER A EUROPEAN LARCH GROUP IN A MIXED STAND OF SPRUCE AND LARCH FORTY-TWO YEARS OLD. WOODSTOCK, VERMONT.

properly handled. From the spruce-larch mixture, which was 42 years old and covered several acres, 1000 spruce seedlings were removed to furnish stock for a new plantation.

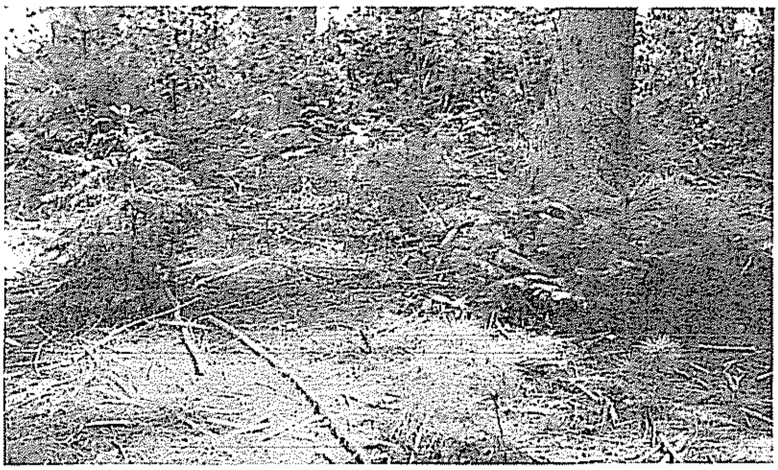

FIGURE 9. NATURAL REPRODUCTION AT THE EDGE OF A SIXTY-THREE-YEAR-OLD NORWAY SPRUCE STAND.

DAMAGE TO PLANTATIONS

WHITE PINE WEEVIL

THE greatest insect enemy of Norway spruce in the Northeast is the white pine weevil, *Pissodes strobi* Peck. According to Graham (214), the tree is second in preference to white pine; and both Blackman (212) and Peirson (217) find that the weevil occasionally does serious damage to the species.

Special care was taken to record the damage in the plantations studied. It was found to be less serious than many suppose. Of the pure spruce plantings, fifty-four per cent had not been noticeably attacked at any time; thirty-three per cent showed attacks at some point in less than twenty per cent of the trees; only five per cent had twenty to fifty per cent of the trees weeviled; and eight per cent had over fifty per cent. In mixtures with other conifers, spruce suffered less than in pure stands. In nine mixtures of Norway spruce and white pine, five showed no spruce injury, while two showed light and two heavy weevil injury. There was one case in which injury to both species was light; one with spruce medium and pine heavy; and two with medium injury to both species. In seven other mixtures with such species as red and Scotch pine, European larch, etc., there was only one case of weeviling in spruce and it was light.

While weeviling may be heavy in places during certain years, the results are not nearly so discouraging as with the same intensity in white pine. With spruce, if the whole leader is not killed, a strong shoot is sent out just below the dead portion and continues upward with a bend so slight that it disappears with a few years' growth. Where the whole leader is killed, the first whorl of branches seems to develop a single leader better than white pine, and the resulting crook is not so great.

The best control measures are planting in mixtures with species not strongly weeviled, and close spacing in the planting to insure quicker and more complete recovery after weeviling.

SPRUCE SAWFLY

During the last few years a European sawfly, *Diprion polytomum* (Hartig), has been seriously damaging mature white and black spruce stands over a large part of the Gaspé Peninsula in Quebec. This insect has been known for a hundred years in Europe as a defoliator of spruces, but seems never to have caused serious damage there. While the future of the Gaspé outbreak cannot well be predicted at present, the fact that white spruce is being strongly attacked while Norway seems to have been little damaged in Europe makes it appear advisable to plant Norway spruce in the Northeast perhaps in preference to white (210, 211).*

CHERMES

While the spruce gall aphid, *Adelges abietis* Kaltenbach, was noticed in six of the plantations studied, it did not seem to be of primary importance in any of them. It was found on trees ranging from a few years up to thirty-two years of age, but the bad infestations were found on trees weak from other causes. As was found to be the case in England, the insect is usually confined to the poorer sites (209). The injury is often serious on ornamental trees, especially in hedges (215). The control of the aphid seems to lie in planting only on sites adapted to

* This sawfly has now (1936) been found in all the New England states except Rhode Island and in New York as far west as Syracuse. For recent developments in this region see MacAloney, H. J., "The European spruce sawfly in the United States," Journal of Forestry 34(2):125-129, 1936.

the tree and in keeping the stands vigorous through thinnings (219).

Two other species of the same genus, *Adelges strobilobius* and *A. viridis,* alternate between Norway spruce and European larch in Europe. Steven has shown that there are several parthenogenetic forms in each of these species and the one doing practically all the damage to either host is a non-migrating form. He points out that these insects cannot be considered a serious obstacle in growing the two trees in mixture, and that only adverse soil or climatic conditions cause the insects to be serious. *A. strobilobius* has been reported in this country (218).

RED SQUIRREL

During periods of deep snow when the red squirrel (*Sciurus hudsonicus* Erxleben) has its usual food supply cut off, it eats the inner buds of several coniferous species including Norway spruce. The terminal bud of the spruce with its heavy armor of needles is hollowed out in place, but branch tips up to several inches in length are cut off and carried back to some convenient resting place where the buds are eaten. Often dozens of branches are cut from a single, small tree; some plantations are hit so hard and so regularly that their growth is almost arrested. The injury was present in ten of the plantations studied. Uninterrupted recovery from the injury is rapid; and since only the terminal bud is usually removed from the leader, one of the lateral buds takes the lead and a bad crook is usually avoided (234, 236).

STORM DAMAGE

Snow does not seem to damage spruce in the Northeast; but severe ice storms, such as the one of 1921-22 in Massachusetts, occasionally do. Of the stands examined, only three showed evidence of ice damage, and in two of these less than five per cent of the trees suffered. The only severely injured stand was at Georgetown, Massachusetts, where the weight of the ice can be judged from the fact that six to ten inch tops were broken off from seventy-five foot trees. An adjoining white pine stand seemed to be more severely injured than the spruce. That the branching habit of spruce makes it very resistant to ice breakage is brought out in a study made in Wisconsin during a two-day ice storm. It was found that, compared with nineteen hardwood species, the increase in weight of spruce twigs was about the middle of the range (average ratio of weights, loaded to normal, eighteen to one). The accumulation of ice on the drooping branches tends to produce a pulling load instead of a bending one, so little damage results. In a list of thirty-seven hardwood and two coniferous species studied, *P. Abies* was second in resistance to ice (231, 232).

Along the sea shore, wind tends to thin out or kill the tops of border trees in a plantation, but spruce seems to be more resistant here than white or Scotch pine.

FROST

While frost damage seems to be important in the life of young spruce plantings on frosty sites abroad, the climate of the Northeast does not seem to cause serious damage except in frost pockets. In one case of a local frost in late May new spruce growth on a young plantation was killed. The frost was very unusual and was severe enough to kill the leaves of oak and other hardwoods. No effect of the damage was noticeable the following year.

FUNGI

While there is a rather widespread opinion in Europe that the first generation of spruce planted on old fields is very apt to show fungal attacks, this was not found to be the case in even the oldest plantations studied. Increment borings were made below stump height in most of the plantations, usually in suppressed or dying trees, and no rot was found. This immunity is especially striking because none of the stands had been thinned, and the number of weakened trees was large. In one thirty-seven-year-old stand containing six hundred forty trees per acre, shoestring fungus, *Armillaria mellea,* was fruiting at the bases of some trees and will undoubtedly cause loss later. The real significance of the rôle of fungi in Norway spruce cannot be decided until more stands reach the older age classes and until proper thinnings show what can be done to keep the stands healthy.

THE TIMBER AND ITS USES

The heart wood of Norway spruce is white to yellowish white in color with thin, white sapwood. The wood is relatively light in weight (air dry specific gravity .35 to .60), straight grained, and easily split. It is strong for its weight, of medium hardness, shrinks little, and works easily, but is not durable in contact with the soil. It has resin ducts, but is not pitchy (18, 22).

The wood has an almost endless number of uses. Within its European range it is the chief material in construction and the wood-using industries. Some of the great number of other uses are for fuel, masts, rowboats and ships' knees, oars, cabinet work, packing boxes, tubs, buckets, chests, matches, carvings, shingles, screen frames, piano and organ sounding boards, poles, posts for fences and vines, charcoal, and baskets. The bark, also, can be used in tanning and for fuel; and products from the resin are turpentine, rosin, Burgundian tar, and lamp black. Vanillin comes from the sap of the cambium.

Because of its low resin content, long fibers, and the high grade of pulp produced, spruce will undoubtedly continue as the most desirable pulpwood grown in the Northeast. Some idea of the importance of native spruce to the paper industry of the northeastern United States can be obtained from the latest available statistics.

In 1922 the United States used 8,003,000 tons of paper requiring 9,148,000 cords of wood. It was estimated that by 1950 this requirement would reach 13,400,000 tons and require 15,000,000 cords of wood (240). According to 1922 census figures fifty-five per cent of the pulpwood then being used was spruce (242). In 1921 New England

and New York consumed forty-seven per cent of all pulpwood used in the United States, thirty-nine per cent of the total domestic wood, and eighty-three per cent of that imported. In terms of cords, New England and New York used 4,300,000 cords of pulpwood and were estimated to be growing only 1,370,000 cords of spruce and fir. This growth could be greatly increased by silviculture. As Clapp and Boyce put it, "The total (possible yield) of 3,850,000 cords (in New England) is so far above present requirements, even when supplemented by imports from Canada, that it will well justify the most intensive efforts to bring it about" (240).

The part Norway spruce can play in this development is great. Its wood is heavier than that of any of the native eastern spruces (oven-dry weight per cubic foot, green volume, around thirty pounds) and according to the few tests made, its yield per cent by either the sulphite or sulphate pulping processes is essentially the same as for the native species. Under the various processes pulp can be made from it adapted for use as newsprint, book, high grade printing, bond, wrapping, and kraft papers, fiber board, and any other product which can be made from ground wood (242). This adaptability coupled with the high yields produced makes the species most desirable for pulpwood plantings. The fact that much of our construction lumber has been and, in the northern part of the region, still is sawn from spruce is another very good recommendation for spruce planting.

SUMMARY

THE study covers data from fifty-seven plantations between the ages of seven and seventy years in Massachusetts, Vermont, Connecticut, and New York, supplemented by references from European sources.

The natural range of Norway spruce covers northern and central Europe as far south as the Alps, Cevennes and Pyrenees. To the east it merges with Siberian spruce, *Picea obovata*.

The tree reaches a height of 100-150 feet, and a diameter of about three feet. It normally has a very straight stem, and seldom forks.

The earliest planting found here was made about 1860. Through 1932 Norway spruce ranked second in the amount of stock distributed by state nurseries in the Northeast (113,083,866 plants).

In the region studied, variations in mean annual temperature and precipitation showed no correlation with growth.

The "spruce sickness" of pure stands in Saxony has been found to be due to poor soil conditions caused by insufficient thinning, a lack of admixtures of hardwoods or other conifers, and in some cases by long continued litter removal coupled with severe drought periods. Our droughts are not so severe; following thinning, hardwood advance growth will undoubtedly come in on heavier soils as our spruce plantations get older, and there is little reason to expect our stands to become "sick" if they are reasonably handled.

Norway spruce grows well on loam or sand loam soils and poorly on sands and clays.

Height growth of the species in the Northeast has

been very good with some of our older stands, showing a site index of eighty feet at fifty years, and of even better possibilities for a few stands. This growth is as good as the best found in Europe.

Diameter growth in the plantations studied has been poor due to a complete lack of thinning.

Volume production of our older stands has been very good, corresponding well with that on similar sites in Great Britain.

Seed for use in establishing plantations in the Northeast should come from the more southern European range or, better still, from our own older plantations.

Two-year seedlings should not be grown at densities of more than one hundred per square foot. The roots of the seedlings are very shallow, and the maintenance of surface soil moisture in seedbeds is correspondingly important. Mulching to prevent frost heaving is necessary in both seedbeds and transplant rows in the Northeast.

Planting stock for areas with little ground cover may be 2-1 or 2-0, but where there is much competing vegetation, as on cut-over land, 2-2 stock pays for its greater cost through reduced weeding expense.

While spring planting has been the rule, success can be expected from that done during falls when there is plenty of moisture in the soil.

Either the mattock hole or slit method of planting is satisfactory if properly carried out.

Average dead knot-size varies between one-half inch for four-by-four foot spacings to one and one-tenth inches for ten-by-ten feet, beyond which there is no significant increase.

Mixtures of Norway spruce and white pine grow well on better soils but, of course, are subject to heavy weeviling in some sections. Norway spruce and red pine also do well together, but red pine is not to be recommended where the European pine shoot moth promises to attack it. Norway spruce and European larch grow together naturally, and planted mixtures have done well in the Northeast. The spruce has been able to reproduce itself under the larch groups. Norway spruce and Scotch pine form another natural mixture, but the difficulty in getting Scotch pine races adapted to our conditions makes the use of other mixtures much more promising at present. Norway spruce is well adapted to use in the mixture with hardwoods on cut-over land. It can also be used to underplant thin poplar stands.

Our older plantations show that no clear lumber will be produced in rotations up to sixty years unless pruning can be used. However, pruning of the species must prove to be beneficial before it is widely used.

The greatest single need of our older plantations is thinning. The stands should be thinned when dead length (length of bole on which branches have been killed by shading) reaches fifty to sixty per cent of total height. Crown lengths of the crop trees should be kept at from one-third to one-half total height.

Norway spruce begins bearing seed at from thirty to forty years of age. The seed ripens between late September and November. It is easy to collect the cones and extract the seed. The seed germinates well.

The lack of natural reproduction under our dense plantations is not surprising, since light and soil conditions are not at all favorable for it.

The Norway spruce is second to white pine in preference as a host by the white pine weevil. The spruce is not often damaged as much as the pine in a given section and recovery is also better in the spruce.

The European sawfly, *Diprion polytomum*, now killing mature white and black spruce in the Gaspé Peninsula of Quebec, has never been considered a serious pest of Norway spruce in Europe.

The spruce gall aphid limits most of its attack to trees weak from other causes. Two European species of aphid previously thought to prevent the use of spruce-larch mixtures have been found capable of control by nursery stock fumigation.

The red squirrel causes serious damage to some Norway spruce plantations through budding.

Due to its pendant branching habit, Norway spruce is very resistant to injury by ice and snow.

Frost damage in the region studied seemed to be confined to frost pockets.

Increment borings in suppressed trees in most of the plantations studied showed no traces of rot; but *Armillaria mellea* was found fruiting in one very dense, thirty-seven year stand.

The wood of the species has almost endless uses. It is light in weight, easily worked, fairly strong, and shrinks little, but is not durable in contact with the soil. One of the greatest uses is, of course, for paper pulp, for which it is especially suited.

Form-class volume tables for the species were converted from the work of Jonson in Sweden, and a yield table from MacDonald's studies in Great Britain. A summary of the data from the plots studied is presented.

APPENDIX

VOLUME TABLES AND THEIR APPLICATION

Since form-class volume tables for Norway spruce had been constructed by Jonson in Sweden (186), no attempt was made in this study to develop new ones. The following tables were made up in English units by the use of the form factors given by Jonson. Breast height as given was taken at one and three-tenths meters (four and three-tenths feet); but the plotting of partial tree diagrams from the percentile tapers showed that this difference in point of measurement would not change the figures one-tenth of an inch in any of the material covered by this study. Therefore this difference was disregarded. In the construction, a table was made up giving the volumes of cylinders with heights from twenty to eighty feet and diameters from four to twenty inches. Then a table of breast-high form factors for given heights in feet and form classes was converted from Jonson's table by curving. Form-class tables of volumes in cubic feet outside bark were next made by using the form factors and cylinder volumes. No bark thicknesses could be taken on living trees in the plantations studied; but measurements on stumps and dead trees showed the material to be well within the thin-barked type of Jonson (bark thickness two-tenths inches for trees four inches d.b.h. to sixty-five hundredths inches for trees fifteen inches d.b.h.). In order to get volumes inside bark, a curve giving bark volume in per cent of total volume was constructed from Jonson's figures for the thin-barked type and the volume table figures reduced accordingly.

The relation of d.b.h. to bark volume in this class is as follows:

TABLE 13

RELATION OF BARK VOLUME TO DIAMETER BREAST HIGH

D.B.H. Inches	Bark Volume Per Cent
2	15*
3	14*
4	14
5	13
6	12
7	11
8	11
9	10
10	10
11	10
12	9
13	9
14	9
15	8

* From curve extension.

TABLE 14

FORM CLASS VOLUME TABLES FOR NORWAY SPRUCE

Form Class .55*

D.B.H. Inches	Total Height in Feet — Volume Inside Bark, Cubic Feet					
	20	30	40	50	60	70
2	.2	.3	.3			
3	.5	.6	.7			
4	.8	1.1	1.3	1.6		
5	1.3	1.7	2.1	2.5		
6	1.8	2.4	3.0	3.6	4.2	
7	2.5	3.4	4.2	5.0	5.8	
8	3.4	4.5	5.5	6.5	7.6	8.7
9		5.6	7.0	8.4	9.8	11.1
10		6.9	8.6	10.3	12.1	13.8
11		8.4	10.5	12.6	14.6	16.7
12			12.6	15.1	17.5	20.0
13			14.8	17.7	20.6	23.6
14			17.2	20.6	24.1	27.5
15			19.8	23.7	27.7	31.6

* To smooth the volume figures, those from each form class were curved in both directions. The range of sizes given in each table is slightly larger than that found in the plantations. Total height is above stump.

Form Class .60

D.B.H. Inches	20	30	40	50	60	70	80
			Total Height in Feet — Volume Inside Bark, Cubic Feet				
2	.2	.3	.3				
3	.5	.6	.8				
4	.8	1.2	1.4	1.7	1.9		
5	1.3	1.8	2.2	2.7	3.1		
6	1.9	2.6	3.2	4.0	4.6	5.3	
7		3.5	4.4	5.4	6.3	7.2	8.2
8		4.6	5.8	7.0	8.2	9.5	10.6
9			7.4	8.9	10.4	12.0	13.5
10			9.2	11.1	13.0	14.9	16.8
11			11.2	13.5	15.8	18.2	20.6
12			13.3	16.1	18.9	21.7	24.5
13				18.9	22.2	25.5	28.8
14				22.0	25.8	29.7	33.6
15				25.4	29.7	34.2	38.5
16				29.1	33.8	39.0	43.9
17					38.4	44.1	49.6
18					43.2	49.6	55.9
19					48.3	55.6	62.8
20	. .	. .	. .	. .	53.7	61.7	69.8

Form Class .65

D.B.H. Inches	20	30	40	50	60	70	80
			Total Height in Feet — Volume Inside Bark, Cubic Feet				
2	.2	.3	.4				
3	.5	.7	.8				
4	.9	1.2	1.5	1.8			
5	1.4	1.9	2.4	2.8	3.4		
6	1.9	2.7	3.4	4.2	4.9	5.7	
7	2.7	3.7	4.7	5.8	6.8	7.8	8.8
8		4.8	6.2	7.5	8.9	10.2	11.6
9			7.9	9.7	11.4	13.1	14.8
10			9.8	11.9	14.0	16.2	18.2
11				14.4	16.9	19.5	22.1
12				17.4	20.4	23.5	26.6
13				20.4	24.0	27.6	31.2
14					27.7	32.1	36.2
15					32.1	37.2	42.0
16					36.6	42.2	47.8
17					41.4	47.7	54.0
18					46.6	53.5	60.4
19					52.3	60.1	67.9
20	. .	. .	. .	. .	57.9	66.7	75.5

Form Class .70

D.B.H. Inches	20	30	Total Height in Feet 40	50 Volume Inside Bark, Cubic Feet	60	70	80
4	.9	1.2	1.6	2.0			
5	1.4	2.0	2.5	3.1	3.7		
6	2.1	2.9	3.7	4.5	5.3	6.1	
7		3.9	5.1	6.2	7.3	8.4	
8			6.7	8.1	9.5	10.9	
9			8.5	10.4	12.3	14.2	16.1
10				13.0	15.3	17.6	19.9
11				15.9	18.5	21.1	23.7
12				18.8	22.1	25.4	28.7
13					26.2	30.0	33.8
14					30.4	35.0	39.6
15					34.8	40.1	45.4
16					39.9	45.6	51.4
17					45.2	51.5	57.8
18					50.5	57.8	65.2
19					56.7	64.6	73.3
20					62.6	72.0	81.6

Form Class .75

D.B.H. Inches	20	30	Total Height in Feet 40	50 Volume Inside Bark, Cubic Feet	60	70	80
4	.9	1.3	1.7	2.1			
5	1.5	2.1	2.7	3.3	4.0		
6	2.2	3.1	4.0	4.9	5.8		
7		4.3	5.5	6.7	7.9	9.1	
8			7.2	8.8	10.4	12.0	13.6
9				11.3	13.3	15.4	17.5
10				14.0	16.6	19.1	21.7
11				16.9	20.0	23.1	26.1
12					24.1	27.7	31.4
13					28.3	32.6	36.9
14					32.8	37.8	42.8
15					38.1	43.9	49.6
16					43.2	49.9	56.5
17					48.7	56.3	63.8
18					54.8	63.2	71.8
19					61.3	70.7	80.3
20					68.2	78.7	89.2

The form point method of determining average form quotient of the stand was found to be very satisfactory with the species. In using this method the center of wind pressure on the crown is estimated by eye and, by using a modified Christen hypsometer with ten equal divisions, the height of this center of wind pressure (form point) is estimated in per cent of height above breast height. Little variation was found between individual trees in the stands studied, so that the form point of ten to twenty trees gave reliable results. Actually, measurements of the diameter at one-half the height above breast height and comparison with that estimated from form point on fifteen sample trees where climbing was possible showed an extreme variation of eleven and an average variation of four form quotient units.

The relation of form class to form point and total height was converted from Jonson's table.

TABLE 15

RELATION OF FORM POINT TO FORM QUOTIENT

Total Height Feet	Form Class 50	55	60	65	70	75
	Form Point Height in Per Cent of Total Height					
15	36	46	56	66	77	90
20	36	45	54	65	76	89
25	35	44	53	63	76	88
30	35	43	53	63	75	87
35	34	43	52	63	74	86
40	34	43	52	63	74	86
50	34	43	52	62	74	86
60	34	42	52	62	74	86
70	34	42	52	62	74	86
80	34	42	52	62	73	86

It was also found that, with the uniform spacing of the plantations studied, age has a very definite relation to form class. The following figures from twenty yield plots have a standard deviation of .72. Since the minimum value showing high significance is given as .561*, the following table is very useful for estimating the form class of plantations.

TABLE 16

RELATION OF AVERAGE FORM CLASS TO AGE IN PLANTATIONS STUDIED

Age in Years	Average Form Class
20	.575
30	.65
40	.70
50	.725
60	.725

* Correlation and Machine Calculation. Wallace, H. A., and George W. Snedecor. Iowa State College of Ag. and Mech. Arts, Ames, Iowa, 1931. pp. 1-71.

YIELD TABLES

TABLE 17

YIELD TABLES FOR NORWAY SPRUCE IN GREAT BRITAIN*

QUALITY CLASS 80 FT. (50 YRS.)

Age	Mean Ht. (ft.)	Mean Dia. (in.)	Trees per Acre	Basal Area (sq. ft.)	Main Crop Form Factor	Volume (cu. ft. i.b.)	Trees per Acre	Thinnings Volume (cu. ft. i.b.)	Total Thinnings (cu. ft.)	Total Yield (cu. ft.)
25	41	5.7	1080	193	.385	3055	.	.	.	3055
30	51	7.3	710	218	.401	4455	379	520	520	4975
35	59	8.9	535	233	.407	5600	175	560	1080	6680
40	66½	10.5	410	247	.407	6680	125	615	1695	8375
45	73½	12.1	335	258	.404	7675	75	625	2320	9995
50	80	13.4	280	269	.401	8605	55	600	2920	11525
55	86	14.6	240	276	.398	9445	40	565	3485	12930
60	91	15.9	210	284	.395	10210	30	530	4015	14225
65	96	16.9	190	290	.391	10860	20	440	4455	15310
70	100	17.8	175	294	.388	11405	15	405	4860	16265
					70 Ft.					
25	35½	4.8	1440	179	.382	2430	.	.	.	2430
30	43½	6.4	920	204	.408	3615	520	280	280	3895
35	51	8.0	640	224	.410	4685	280	380	660	5345
40	58	9.5	500	241	.410	5715	140	405	1065	6780
45	64½	10.8	400	253	.409	6685	100	445	1510	8195
50	70	12.1	325	263	.407	7500	75	445	1955	9455
55	75	13.4	275	272	.402	8210	50	435	2390	10600
60	79	14.6	240	280	.399	8835	35	420	2810	11645
65	83	15.9	210	286	.396	9405	30	400	3210	12615
70	87	16.9	190	291	.392	9930	20	320	3530	13460

					60 Ft.					
30	36½	5.1	1310	186	.402	2725	.	.	. .	2725
35	43	6.4	930	206	.422	3755	380	230	230	3985
40	49	8.0	665	225	.424	4685	265	265	495	5180
45	55	9.2	500	239	.420	5550	165	305	800	6350
50	60	10.5	410	252	.415	6275	90	345	1145	7420
55	64	11.8	350	261	.414	6925	60	355	1500	8425
60	68	13.0	300	270	.409	7525	50	330	1830	9355
65	72	14.0	260	279	.402	8070	40	305	2135	10205
70	75	15.0	230	285	.401	8565	30	255	2390	10955
					50 Ft.					
35	34½	4.8	1450	181	.412	2570	.	.	.	2570
40	40	6.0	1000	200	.427	3425	450	125	125	3550
45	45	7.3	755	219	.430	4225	245	150	275	4500
50	50	8.6	590	233	.426	4965	165	190	465	5430
55	54½	9.9	470	246	.421	5640	120	230	695	6335
60	58	10.8	400	256	.419	6225	70	250	945	7170
65	61½	11.8	340	265	.415	6760	60	240	1185	7945
70	64½	12.7	300	272	.410	7205	40	215	1400	8605
					40 Ft.					
40	31	4.5	1500	165	.414	2125	.	.	.	2125
45	36	5.7	1020	188	.428	2915	480	115	115	3030
50	40	7.0	765	206	.435	3590	255	140	255	3845
55	44	8.3	615	220	.432	4190	150	165	420	4610
60	47½	9.2	500	233	.427	4710	155	190	610	5320
65	50½	10.2	430	243	.424	5195	70	205	815	6010
70	53	11.1	375	251	.422	5600	55	195	1010	6610

* Great Britain Forestry Commission Bulletin 10, pp. 44-45, 1928. (188) Diameters, basal areas and volumes converted from quarter girth system into true measure by the present author.

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TABLE 18

PARTIAL SUMMARY OF SAMPLE PLOT DATA

Location	Species	Age from Seed (Yrs.)	Elev. Above Sea Level (Ft.)	Soil Type *	Original Spacing	Est'd Crown Canopy	Vigor	50-Yr. Site Index (Feet)	Trees per Acre	Av. D.b.h. (In.) All Trees	Av. D.b.h. (In.) Dominants	Av. Total Ht. (Ft.) Av. Tree	Av. Total Ht. (Ft.) Dominants	Vol. per Acre (Cu. Ft.)	Av. Dead Length Ft.	Av. Dead Length %	Av. Form Point Ht. (%)	Av. Form Quotient	Av. Form Factor	Litter	Humus	Remarks
Little Falls, N. Y.	N. Sp.	7	1450	L. S.	6 x 6'	..	Good	60	..	..	..	2.0	..	..	..	..	..	..	..	None	None	
Glens Falls, N. Y.	N. Sp.	11	1100	S. L.	6 x 6'	..	Grow'g. 22"/yr.	70	..	..	..	8.2	..	..	..	..	..	..	..	..	..	
Glens Falls, N. Y.	N. Sp.	11	1100	L.	6 x 6'	..	..	60	..	..	..	6.6	..	..	..	..	..	..	..	None	None	
	N. Sp.	11	1100	Fine S.	6 x 6'	..	..	40	..	..	..	2.4	..	..	..	..	..	..	..	None	None	Slow growth areas wet
Hamilton, Mass.	N. Sp.	11	100	L.	4 x 4'	Closed 2'	Grow'g. 1-3'/yr.	60	..	..	..	6.6	..	..	..	..	..	..	..	None	None	
Little Falls, N. Y.	N. Sp.	12	1450	L.	6 x 6'	..	Medium	60	..	..	..	7.0	..	..	..	..	..	..	..	None	None	Subsoil hardpan over slate
Little Falls, N. Y.	N. Sp.	12	1450	L.	6 x 6'	..	Slow growth	60	..	..	..	6.7	..	..	..	..	..	..	..	None	None	Yellow clay at 18"
Cross River, N. Y.	N. Sp.	12	..	L.	6 x 6'	..	Grow'g. 2'/yr.	90	..	2.4	..	16.0	19.0	..	..	..	..	..	..	Trace	None	
Cross River, N. Y.	N. Sp.	12	..	L.	10 x 10'	..	Grow'g. 2'/yr.	90	..	3.8	..	20.0	23.0	..	..	..	..	..	..	..	..	Yellow sand loam at 20"
Petersham, Mass.	N. Sp.	13	1100	L.	6 x 6'	..	Good	70	..	1.4	..	10.6	..	..	..	..	..	..	..	1½" needles	½"	
Petersham, Mass.	N. Sp.	13	1325	S. L.	6 x 6'	..	Good	50	..	..	..	6.7	..	..	..	..	..	..	..	None	..	
Petersham, Mass.	N. Sp.	13	1325	S. L.	6 x 6'	..	Fair	40	..	..	..	4.6	..	..	..	..	..	..	..	..	..	Sand at 6"
Hamilton, Mass.	N. Sp.	13	100	L.	4 x 4'	..	..	40	..	..	..	2.7	..	..	..	..	..	..	..	..	..	
Glens Falls, N. Y.	N. Sp.	14	1100	L.	6 x 6'	.9	Very good	90	1071	3.4	3.8	20.0	21.0	590	4	20	47	.56	.546	½" needles	..	Small brook through plot
Glens Falls, N. Y.	N. Sp.	14	1100	S. L.	5 x 5'	..	Fair	50	..	..	..	6.2	..	..	..	..	..	..	..	None	..	Soil stratified in thin layers
Hancock, Vt.	N. Sp.	14	1350	C. L.	6 x 6'	..	Slow growth	40	..	..	..	2.8	..	..	..	..	..	..	..	None	..	Water table almost at surface
	N. Sp.	14	1350	L.	6 x 6'	..	Fair	60	..	..	..	8.5	..	..	..	..	..	..	..	None	..	
Petersham, Mass.	N. Sp.	15	1325	S. L.	6 x 6'	..	Very good	60	..	1.8	..	12.2	..	..	1	8	..	..	..	..	..	Med. sand at 24"
Woodstock, Vt.	N. Sp.	15	725	L	8 x 8'	..	Good	60	..	1.8	..	12.8	..	..	..	..	..	..	..	None	None	Good agricultural soil
Barneveld, N. Y.	N. Sp.	16?	800	F. S. L.	7 x 7'	..	Grow'g. 18"/yr.	60	..	2.0	..	12.0	..	..	..	..	..	..	..	None	None	Medium sand at 18"
Cross River, N. Y.	N. Sp., R. & Sc. P.	16	..	S. L.	6 x 6'	..	Grow'g. 15-30"/yr.	70	..	..	..	15.0	18.0	..	..	..	..	..	..	None	None	Trees on sand area 4' tall
Croton Res'r, N. Y.	N. Sp. & W. P.	16	300	S. L.	6 x 6'	..	Grow'g. 12-30"/yr.	80	..	..	..	21.0	23.0	..	3	14	..	..	..	..	..	White mold under spruces
Hamilton, Mass.	N. Sp.	16	100	L.	4 x 4'	Closed 6'	Very good	60	..	1.8	2.1	14.0	..	..	2½	18	46	.55	.625	½" needles	..	
Woodstock, Vt.	N. Sp.	17	1200	Fine S. L.	8 x 8'	..	Very healthy	60	..	2.3	..	13.4	..	..	..	..	..	..	..	None	None	Subsoil at 30" fine sand
Saratago Sp'gs., N. Y.	N. Sp.	17	300	S. L.	6 x 6'	Closed 6'	Grow'g. 2'/yr.	60	..	2.1	2.2	13.7	15.0	..	1	7	..	..	..	None	None	Subsoil coarse, deep sand
Sydney, N. Y.	N. Sp.	17?	..	C.	5 x 5'	Closed 4'	Poor	40	..	..	..	6.0	..	..	..	..	..	..	..	None	None	Water table at 18"
	W. P.	17?	..	..	..	..	..	..	..	..	..	8.0	..	..	..	..	..	..	..	None	None	
Hamilton, Mass.	N. Sp.	18	100	L.	4 x 4'	.9	Very good	60	..	2.4	..	17.4	..	..	5	29	53	.59	.630	¾" needles	None	Trees very straight
Hancock, Vt.	N. Sp.	19	1300	Heavy L.	6 x 6'	.9	Very good	60	1018	3.2	..	17.0	..	480	3	16	44	.55	.574	1" needles	¼"	Subsoil at 20" clay loam
Sherburne, N. Y.	N. Sp.	19	1320	L.	5 x 6'	Closed 10'	Grow'g. 18"/yr.	60	..	3.3	..	17.8	20.0	..	1[1]	6	..	..	..	None	None	[1] Limbs dead inside crown only
Hemlock Lake, N. Y.	N. Sp.	19	1100	C.	6 x 6'	..	Grow'g. 6"/yr.	40	..	..	..	5.7	..	..	..	..	..	..	..	None	None	Area with clay layer at 6" had av. ht. of 3'
Hemlock Lake, N. Y.	N. Sp.	19	1100	L.	6 x 6'	Closed 8'	Grow'g. 1'/yr.	50	..	..	..	13.2	..	..	..	..	..	..	..	None	None	
Hemlock Lake, N. Y.	N. Sp.	19	1000	L.	6 x 6'	Closed 12'	Grow'g. 18"/yr.	60	1440	2.4	2.5	16.0	..	..	3	18	45	.55	.591	1" needles	None	Soil crumbly at 12"
	W. P.	19	..	..	..	..	Grow'g. 24-30"/yr.	..	..	3.1	3.1	17.0	..	..	4	24	..	.49	..	..	..	
Hamilton, Mass.	N. Sp.	20	100	L.	4 x 4'	1.0	Good	50	..	2.2	2.5	15.0	16.0	..	5	33	53	.58	.625	¾" needles	None	
	W. P.	20	..	..	..	..	..	..	..	2.7	3.0	18.0	19.0	..	..	..	..	..	..	..	..	
Phoenix, N. Y.	N. Sp.	20	..	Fine S.	6 x 6'	.9	Very good	80	1153	3.3	3.9	23.0	28.0	..	7	30	..	..	..	¾" needles	¼"	Sp. limbs very tough
	R. P.	20	..	..	..	..	..	..	..	4.9	5.3	23.6	25.0	..	10	43	..	..	..	..	..	Pine limbs rotted. Good looking mixture
Norwich, N. Y. B*	N. Sp.	20	1200	Fine S. L.	..	..	Good	50	1800	2.6	..	16.0	..	329	2	12	43	.53	..	needles	..	
Hemlock Lake, N. Y.	N. Sp.	21	900	L.	6 x 6'	.9	Very good	60	1080	3.6	3.8	18.5	20.0	..	8	43	62	.63	.585	¾" needles	None	Good, brown loam at 30"
	W. P.	21	..	..	..	..	..	..	..	4.0	4.1	19.9	20.0	..	10	50	..	..	..	..	..	
Rainbow, Ct.	N. Sp.	24	..	S.	5 x 5'	..	Poor	30±	..	1.0	..	5.0	..	..	..	..	..	..	..	2" Pine needles	¼"	Spruce badly suppressed
	W. P.	24	..	..	..	..	Good	..	..	5.0	..	22.0	22.0	..	..	..	..	..	..	..	..	Gravel at 24"
S. Orleans, Mass.	N. Sp.	24	40	Coarse S.	10 x 10'	.4	Good	70	..	7.7	..	28.5	..	..	..	..	..	..	..	½" needles	None	
	E. Lr.	24?	..	..	..	..	..	..	..	7.2	..	26.0	..	..	..	..	..	..	..	..	..	
Norwich, N. Y. B*	N. Sp.	25	1200	Fine S. L.	..	..	Good	60	1800	3.5	3.9	25.0	26.0	1182	10	40	60	.63	..	¼" needles	None	
Princeton, Mass.	N. Sp.	25	1500	Fine S. L.	6 x 6'	.8	Very good	50	1192	4.0	4.2	23.0	24.0	1140	6	26	51	.59	.531	¾" needles	..	No treatment needed
Hemlock Lake, N. Y.	N. Sp.	28	1300	L.	6 x 6'	.8	Grow'g. 18"/yr.	50	..	5.3	..	26.1	..	..	..	..	..	..	..	1½" needles (1)	..	(1) ½" felted
	W. P.	28	..	..	..	..	..	..	..	7.2	..	26.6	..	..	..	..	..	..	..	..	..	Badly weeviled
Lake Clear, N. Y.	N. Sp.	28	1700	L.	5 x 5'	.9	Good △	50	1240	4.0	4.8	18.0	22.0	1220	8	42	60	.63	.587	¾" needles	None	△ Grown under poplar. Shallow soil over bed rock.
Millbrook, N. Y. A*	N. Sp.	29	700	L.	5 x 5'	..	Good	80	1032	5.2	..	46.5	..	3285	..	..	..	.70	..	needles	..	
Millbrook, N. Y.	N. Sp.	32	700	L.	5 x 5'	.9	Very good	80	1040	5.8	6.4	53.0	54.0	4460	35	66	75	.72	.543	¾" needles	¼"	Needs thinning
Millbrook, N. Y.	N. Sp.	32	700	L.	5 x 5'	.9	Very good	90	920	5.9	7.0	56.0	60.0	4410	37	66	77	.71	.526	¼" needles	None	Needs thinning
Millbrook, N. Y.	N. Sp.	32	800	C. L.	5 x 5'	.9	Medium	50	1000	5.0	5.9	31.0	34.0	2180	13	58	71	.675	.539	½" needles	..	Limbs very persistent
Millbrook, N. Y. A	N. Sp.	32	700	L.	5 x 5'	.9	Very good	80	968	5.8	6.5	52.0	55.0	4040	30	58	74	.72	.526	½" needles	½"	Needs thinning
Ipswich, Mass.	N. Sp.	35	60	S. L.	6 x 6'	1.0	Very good	60	1086	6.1	7.3	43.0	45.0	3230	20	47	65	.65	.495	½" needles	1" (1)	Good agricultural soil. (1) Felted
Woodstock, Vt.	N. Sp.	35	1200	Fine S. L.	10 x 12'	1.0	..	80	..	10.2	..	56.0	..	..	20	36	..	..	..	1½" needles	None	
	W. P.	35	..	..	..	..	..	..	..	11.7	..	56.0	..	..	30	54	..	..	..	..	..	No treatment needed
Groton, N. Y.	N. Sp.	37	1380	L.	6 x 6'	.9	Very good	90	640	8.4	8.7	66.0	67.0	8160	46	70	83	.74	.548	1" needles	None	Limbs tough
Groton, N. Y.	N. Sp.	37	1380	L.	4 x 6'	.9	Very good	80	880	6.6	7.3	64.0	65.0	7760	44	73	81	.73	.534	2" needles (1)	..	(1) 1½" felted. Thinning badly needed
Orleans, Mass.	N. Sp.	40	30	S.	10 x 10'	.8	Good	50	..	9.7	..	43.0	..	..	12	28	..	..	..	1½" needles	½"	Exposed to sea wind; spruce looks best of 3 species
	W. P.	40	..	..	..	..	..	..	..	10.1	..	39.0	..	..	..	..	..	..	..	..	..	
	Sc. P.	40	..	..	..	..	..	..	..	9.3	..	42.0	..	..	..	..	..	..	..	..	..	
Orleans, Mass.	N. Sp.	40	40	Medium S.	15 x 15'	.7	Grow'g. 1'/yr.	50	..	10.3	..	43.0	..	..	..	..	..	..	..	..	..	Exposed to sea wind; some tops thin
	E. Lr.	40	..	..	..	..	..	..	..	8.0	..	31.0	..	..	..	..	..	..	..	..	..	
Woodstock, Vt.	N. Sp.	42	800	F. S. L.	12 x 12'	.6	Very good	60	210	10.3	10.7	48.0	51.0	..	10	20	..	..	..	1" needles	..	Few suppressed hard maples in stand
	E. Lr.	42	..	..	..	..	..	..	..	9.4	9.4	58.0	58.0	..	30	51	..	..	..	..	..	1000 natural spruce seedlings removed from stand
Woodstock, Vt.	N. Sp.	50	750	F. S. L.	14 x 14'	.8	Very good	80	180	13.0	..	77.0	..	5790	..	..	73	.70	.506	1" needles	None	
White Lake, N. Y.	N. Sp.	52	1460	Coarse S.	8 x 8'	.7	Grow'g. 1'/yr.	50	487	7.9	9.7	52.0	56.0	3930	30	58	71	.69	.514	1¼" needles (1)	..	(1) ½" felted. Many trees suppressed
E. Harwich, Mass.	N. Sp.	55	80	Coarse S.	10 x 11'	..	Very good	60	..	12.5	..	63.0	..	..	20	32	..	..	..	None	None	Few seedlings where grass not mown
Harwich, Mass.	N. Sp.	58	60	Coarse S.	..	..	Good △	60	..	12.5	..	68.0	..	..	40	60	..	..	..	None	None	△ 50% of tops thin. Occasional seedling up to 3'
Georgetown, Mass.	N. Sp.	63	280	L.	6 x 7'	.9	Good	70	618	8.6	9.3	73.0	77.0	8560	45	62	74	.70	.507	2" needles (1)	..	(1) 1½" felted. Some border reproduction
Georgetown, Mass.	N. Sp.	63	250	L.	Irregular	.9	Good	70	437	12.2	..	79.0	..	12720	45	57	71	.69	.498	1½" needles (1)	..	Some tops snow broken. (1) 1" felted
Woods Hole, Mass.	N. Sp. in mixture	70	160	S. L.	10 x 10'	.8	Stagnated last 10 yrs.	50	..	13.1	..	59.0	..	..	40	68	..	..	..	1½" needles	½"	Windy knoll; many tops thin

* N. Y. State Conservation Dep't. data. A-A, B-B—Same plantations measured twice. * S—Sand. L—Loam. C—Clay.