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PLANTATIONS OF THE ACADIA FOREST EXPERIMENT STATION

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Project M. 331

BY

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INTRODUCTION

The climate of the Maritime Provinces normally encourages natural regeneration, and hitherto there has been little need for artificial regeneration. Despite the normal abundance of natural regeneration, however, there are many areas now in need of planting or reseeding.

Large areas have been cut and burned, and are reproducing to little but shrubs, or low-grade aspen and wire birch. Abandoned farms, never very suitable for agriculture, should be growing trees. Overcutting of softwoods has converted great areas in southern Nova Scotia and southwestern New Brunswick to red maple, aspen, beech, and white birch, which are of low value; planting appears to be the most feasible means of reconverting these stands to softwoods or mixedwoods during this generation. The percentage of spruce in stands susceptible to budworm might well be increased by planting skidding roads after logging.

Planting is expensive and much money may be wasted by planting the wrong tree in the wrong place by the wrong method. The purpose of this Technical Note is to make available information which has been gained from the plantations at the Acadia Forest Experiment Station, near Fredericton, New Brunswick.

Work is now in progress to determine whether outstanding races of spruce and fir for growing in the Maritimes do exist, and to lay foundations for breeding better stock.

DESCRIPTION OF STATION

Geology and Soil

The Acadia Forest Experiment Station is located on a gently undulating lowland underlain chiefly by flat-lying Pennsylvanian sandstones and shales, and lies mostly between 200 and 300 feet above sea level. The subsoil is a compact boulder clay; the upper foot or two of it is usually friable, varies from fine sandy to clayey loam and includes numerous rock fragments and occasional boulders. In some areas, this is overlain by a layer of reddish-brown sand to sandy loam containing some rock fragments. The soils are acid and infertile. They are podsols on the well-drained uplands and gleis in the wetter spots; in numerous profiles both processes operate during different times of the year.

Forest Cover

The station is in the A3 section of the Acadia Forest Region (1) at a latitude of about 46° North. Large areas have been burned over several times during the

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last 100 years. Black spruce[2] and pure or mixed stands of trembling aspen, largetooth aspen, red maple, white birch, and grey birch of fire origin comprise much of the forest now. With the possible exception of red maple, conifers are gradually replacing the hardwoods. Hemlock, red spruce, balsam fir, and red maple are believed to be the local climax species on most sites. Widely scattered mature white pine are present, and large burned white pine stumps are still much in evidence. Larch is plentiful on some wet areas.

Climate

The climate of New Brunswick, especially of the more inland sections, is somewhat continental. Comparatively cold winters and warm summers are usual; and during all but the summer months, temperatures drop sharply at night. The experiment station is apparently situated on a cold plain with poor air drainage, as temperatures are often several degrees below those in Fredericton, 16 miles to the west. Since 1935, the average frost-free period at Acadia Station headquarters has been 102 days. The climate is comparatively moist with an average annual precipitation of 41 inches.

Table 1 summarizes some weather records taken at the Acadia Station headquarters for the months of May to September.

TABLE 1.—TEMPERATURES AND RAINFALL AT THE ACADIA STATION

	Mean temperatures, °F			Rainfall in inches	
	Maximum	Minimum	Mean	Mean	Range
May	62	38	50	3·13	0·96– 4·99
June	73	46	59	3·58	1·27– 6·18
July	78	52	65	3·22	1·00– 7·80
August	77	51	64	3·33	1·47– 6·65
September	66	42	54	4·25	0·88–10·55

(Note—These values are for the period 1935-42, and 1947-52.)

Site

Sites at Acadia are generally poor. The subsoil of boulder clay is compact and rather impervious to tree roots, so that trees do not become large where top soil layers are thin. Soils are poorly drained because of this boulder clay and the rather flat topography. The most productive sites occur where the boulder clay is capped with several inches to several feet of permeable sandy loam, and at the lower parts of well-drained, moist to fresh slopes with underground seepage water.

ESTABLISHMENT OF PLANTATIONS

Permanent Plantation Plots and Their Purpose

More than 60 permanent plantation plots covering a total of about 154 acres have been established. These vary in size from a fraction of an acre to several acres in extent, and may contain several to many sub-plots, most of which are $\frac{1}{4}$-acre in area. Most of the planting has been done in May; two plantations were established near the end of October.

[2] See Appendix I for botanical names.

The plantations were established with one or more of the following objectives in mind:

(1) To convert stands of low-grade hardwood to conifers;

(2) To determine the relative growth of native and exotic conifers of various provenance under Maritime conditions;

(3) To determine the suitability of various mixtures of conifers for plantations.

Planting and Maintenance of Plantations

The first plantations were established in 1934, generally under young, sparsely stocked stands of intolerant hardwoods; but subsequently, plantation plots were established chiefly where intolerant hardwood stands had been clear-cut or cut heavily. A list of tree species that have been planted is given in Appendix I.

Because of the rockiness of the soil and the abundance of vegetation, only a few of the different planting methods have been used at Acadia. Those interested may consult publications by Rudolph (6) and the Ontario Department of Lands and Forests (4) for comprehensive discussions of techniques in land preparation and planting.

Planting has been done chiefly in holes made with the grub hoe, mattock, shovel, and spade. Locally manufactured Baldwin planting hoes[3] were used in slit planting in 1952 and appeared to work well where the soil was not too rocky. Combinations of tools used in different planting operations have been mattock and round-mouthed shovel, grub hoe and round-mouthed shovel, grub hoe and round-pointed shovel, and spade and grub hoe.

Commonly, 2-2 stock[4] has been planted at a spacing of 6 by 6 feet, but spacing has ranged from 4 by 4 to 8 by 8 feet. Most plantations are of one species, but the following mixtures have been planted with the species in alternate rows:

Red and white pine

Red spruce, and red and white pine

Red spruce and red pine

White spruce and red pine

Norway spruce and red pine

Red and white spruce, and red pine

White spruce and white pine

Red and Norway spruce, and red and white pine

One or more cleanings of the underbrush and sprouts have been necessary in some plantations during the first 10 years or so after planting. Owing to rapid increase of such competition after cutting, it seems advisable to clean most coniferous plantations established on cut-overs about 2 years after planting and again later if required. Chemical control measures now becoming popular are proving successful for this purpose. The North Central Weed Control Conference (3) issues a yearly research report summarizing progress in the field of chemical control of weeds.

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[3] The Baldwin planting hoe consists of a steel blade 3½ inches wide by 10½ inches long, slightly curved, tapered edgewise to a bevelled cutting edge, and bolted to a carpenter's adze handle.

[4] 2-2 means that the plants spent 2 years in seedbeds and 2 years in transplant beds before being planted in the field.

GROWTH AND MORTALITY IN PLANTATIONS

Many factors, such as site, provenance of the seed, local climate, etc., had influence on the success of planting. The following pages contain discussions of growth and mortality as affected by some of these factors. Unless otherwise stated, 2-2 planting stock was used.

Climate

In general, the climate of the Acadia Forest Experiment Station has been too severe for growing Sitka spruce and coastal varieties of Douglas fir. Differences in length of growing season also probably account for poor performance of some western strains of white spruce and certain lots of Norway spruce. In general, however, the continental spruces, for example, white, Norway, Engelmann, and Siberian spruce, have thrived.

Late spring frosts have not usually caused much damage to the spruces, except to Sitka spruce; but on the night of June 11/12, 1950, the temperature fell to 26°F, and damage was widespread even to native conifers.

In one white spruce plantation, nearly 70 per cent of the plants were damaged, 12 per cent of them severely (*see* Figure 1). The plantation, however, is probably in a natural pocket; it is situated in a clearing of about one acre on a gentle southeast slope. Late spring frosts appear to be somewhat more frequent in northern than in central New Brunswick.

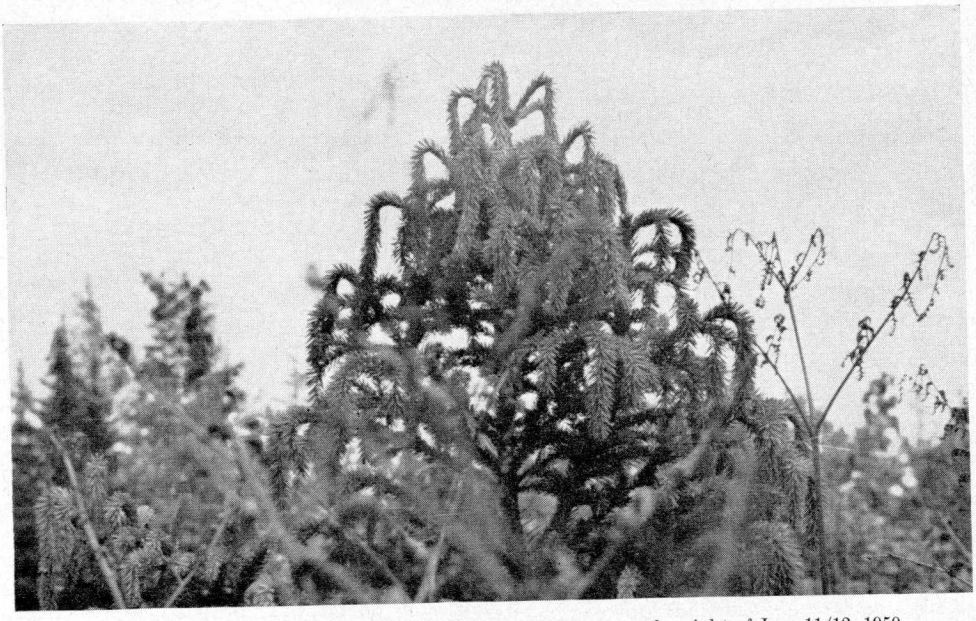

FIGURE 1.—White spruce plant severely damaged by frost on the night of June 11/12, 1950.

Provenance

Provenance, or place of origin of seed, has considerable influence on growth of plants. Although plants of numerous species and provenance have been planted at the Station, the only comprehensive experiment has been the establishment in 1941 and 1942 of 11 plantation plots each of white and Norway spruce of different provenances.

White Spruce

Average height of the white spruce plants does not differ greatly (Table 2), although the plants from seed of old-field spruce at Valcartier, Quebec, were comparatively tall. Generally, the average height of plants from seed collected in Saskatchewan was lowest.

TABLE 2.—MEAN HEIGHTS, CONDITION OF LIVING PLANTS, AND MORTALITY OF WHITE SPRUCE ORIGINATING FROM SEED OF VARIOUS PROVENANCES[1]

(NOTE—Heights are for 11 growing seasons for plots 7B, 8B, 2D and 3D, and for 10 growing seasons for the remaining plots.)

Plots	Mean heights of healthy plants	Condition of living plants		Mortality
		Healthy	Damaged	
	feet	per cent	per cent	per cent
2B (1740)[2]	4.3	53	47	10
3B (1740)	3.8	68	32	11
4B (1740)	4.3	85	15	7
5B (1740)	3.7	85	15	11
6B (1740)	3.6	79	21	7
7B (1740)	4.2	78	22	23
8B (1740)	4.8	86	14	19
7C (1740)	4.1	95	5	13
8C (1740)	4.8	97	3	30
2D (1200)	4.2	77	23	23
3D (1200)	6.1	81	19	13

[1] *See* tabulation following this table for provenances.

[2] Numbers of trees planted per acre.

Plot	Provenance
2B	Lesser Slave Lake, Alta., lat. *ca.* 55½°N.
3B	Harlam Forests, Sask.
4B	Bruce County, Ont. between Lake Huron and Georgian Bay, lat. *ca* 45°N.
5B	Nipawin district, Sask., lat. *ca* 54°N.
6B	Nipawin district, Sask., lat. *ca* 54°N.
7B	Terrace, B.C., lat. 55°N., elev. 250 ft.
8B	Aleza Lake, B.C., lat. *ca.* 54°N.
7C	Grandview, Man.
8C	Lesser Slave Lake, Alta., lat. *ca.* 55½°N.
2D	Kananaskis, Alta., lat. *ca.* 51°N., elev. 4,300 ft.
3D	Valcartier, Que. (old-field spruce), lat. *ca.* 47°N.

Average height, however, is only part of the picture. The value of these plantations is not so much in their general development as in the occurrence of outstanding trees in them which may be of worth as a source for breeding material. For example, the best trees coming from Ontario seed had very luxuriant foliage and were somewhat larger in 1952 than those from the other seed (Appendix II, Table 10). There were two particularly tall plants averaging nearly 11 feet in two plots, the seed for which came from Lesser Slave Lake, Alberta. This growth is rather remarkable considering that Lesser Slave Lake is some 9° further north than the Acadia Forest Experiment Station.

Mortality was heaviest among the plants originating from British Columbia and Alberta seed. Survival in most plantations, however, was very good, although many plants were damaged by the late spring frost in 1950. The most frost damage occurred in one plot of trees from Lesser Slave Lake seed, but the least frost damage occurred in the other plot of the same origin. The lack of damage in the latter, however, may have been owing to the plot being on a moderately steep slope where air drainage is probably good.

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Norway Spruce

Probably owing to more exacting site requirements, the growth of Norway spruce has been a little poorer than that of white spruce (Table 3). Plants originating from seed from the Carpathian Mountains (Plot 4D) and Quebec had considerably greater average heights than the other plants, though the difference is partly owing to an additional year's growth. But these plots did not necessarily contain the best individual trees (Appendix II, Table 11), although one plant from Quebec seed was 10.8 feet tall. A plant of Norwegian provenance in Plot 4A was 12.0 feet high.

TABLE 3.—MEAN HEIGHTS, CONDITION OF LIVING PLANTS, AND MORTALITY OF NORWAY SPRUCE ORIGINATING FROM SEED OF VARIOUS PROVENANCES[1]

(Note—Heights are for 11 growing seasons for plots 4D and 6D, and for 10 growing seasons for the remaining plots.)

Plots	Mean heights of healthy plants	Condition of living plants		Mortality
		Healthy	Damaged	
	feet	per cent	per cent	per cent
1A (1740)[2]	3·7	96	4	52
2A (1740)	3·9	90	10	48
3A (1740)	3·6	96	4	41
4A (1740)	3·7	97	3	10
5A (1740)	3·2	99	1	18
6A (1740)	3·3	81	19	15
7A (1740)	3·7	76	24	13
8A (1740)	3·7	91	9	12
2C (1740)	4·0	56	44	24
4D (1200)	4·9	70	30	9
6D (1200)	5·3	70	30	14

[1] *See* tabulation following this table for provenances.
[2] Numbers of trees planted per acre.

Plot	Provenance
1A	Czechoslovakia, lat. *ca.* 50°N., elev. 600-1,600 ft.
2A	Carpathian Mts. and Tyrol, elev. 1,600-4,000 ft.
3A	Aust Adger, Norway, lat. 58°30′N., elev. 650-1,300 ft., rainfall 47.2 in., July temp. 59.9°F.
4A	Hadeland in Opland, Norway, lat. 61°40′N., elev. 800 ft., rainfall 15.7 in., July temp. 59°F.
5A	Aust Adger, Norway, lat. 58°30′N., elev. 0-650 ft. rainfall 47.2 in., July temp. 60.8°F.
6A	Gjerpen in Telemark, Norway, lat. 59°10′N., elev. 150-300 ft., rainfall 31.5 in. July temp. 60.8°F.
7A	Aust Adger, Norway, lat. 59°N., elev. 1,300-2,000 ft., rainfall 35.4 in., July temp. 58.6°F.
8A	Riga, Latvia, lat. *ca.* 57°N.
2C	Rakkastad in Ostfold, Norway, lat. 59°20′N., elev. 300 ft., rainfall 27.6 in., July temp. 60.8°F.
4D	Carpathian Mts.
6D	Laurentide Plantations, Quebec, lat. *ca.* 47°N.

The late spring frost of 1950 caused much of the damage indicated in Table 3. Plot 2C and the two fastest growing plantations, 4D and 6D, suffered most.

Engelmann and Sitka Spruce

Among the other species planted in this same area, healthy plants of Engelmann spruce originating from seed from Blue River, British Columbia (elevation 2,600 feet, latitude 56° North) have attained mean heights of 5.2 feet in 11 growing seasons, thus comparing favourably with white spruce. Only 4 per cent of the plants have died. (*See* Appendix II, Table 12, for details.)

Sitka spruce from coastal British Columbia has proved to be completely unadaptable to local conditions. In three small plots, growth has been negligible, and in one of the plots, which has received little protection from other vegetation, nearly every plant has died because of a relatively severe microclimate.

Lodgepole Pine

Lodgepole pine from Terrace, British Columbia, and Kananaskis, Alberta, has been planted, but growth has not been too encouraging (*see* Appendix II, Table 13). The mean height of the best undamaged stock, that from British Columbia, is only 12.4 feet in 10 growing seasons, which is poorer than growth of local jack pine.

Douglas fir

The reaction of Douglas fir has varied considerably depending on its provenance (*see* Appendix II, Table 14). Growth has usually been poor and mortality high. Plot 29/43, however, contained plants up to 9 feet high, and some trees have lately been growing $1\frac{1}{2}$ feet per year. Unfortunately, the origin of this stock is unknown.

Most of the damage to plants on all plots was from frost and rabbits. Mortality was low in one plot (6C); it is situated on a 20 per cent slope where frost damage was probably lessened owing to good air drainage. The plants originated from seed collected at Tete Jaune in eastern British Columbia.

Site

In 1951, H. D. Long (2) devised a site classification for the station based on vegetation; an outline of his main site types appears in Table 4.

TABLE 4.—SCHEME OF SITE CLASSIFICATION

	Associations (stable or climax)		
	Red maple	Red spruce—fir	Black spruce
Increasing soil moisture ↓		A_2	
	D_1	D_2	D_3
	F_1	F_2	F_3
	M_1	M_2	M_3
	W_1	W_2	W_3
	Increasing fertility ←		

(NOTE: A=arid, D=dry, F=fresh, M=moist, W=wet.)

Not included in the table are open bog, a cedar type, and a transitional type. The term 'association' is used here to indicate a group of sites related by having a given species or pair of species dominant in the overstory of stands that have reached a moderately stable state of equilibrium with their surrounding. Within a given association, the entire vegetation is used in identification of sites, and these are separated roughly on the basis of drainage.

Height measurements made by Long suggest that the best sites are M_1 and F_{2a}. The former is a moist red maple site and the latter is a transitional fresh red spruce—balsam fir site usually occurring at or near the bottom of long slopes with underground seepage water. On this site the lesser vegetation somewhat resembles that of the red maple site.

Planting has been restricted to a few sites at the Acadia Station, and has not been carried out on what appear to be the two best sites, the M_1 and F_{2a}. In general, of the sites that have been planted, growth has been best on the F_1 (fresh, red maple) site where the soil is a well-drained sandy loam. Examples follow to illustrate this trend for a number of species.

Red and White Spruce, and Red Pine

As the data in Table 5 indicate, growth of these species has been much better on the F_1 site than it has been on the F_2 (fresh, red spruce—balsam fir) site despite the fact that the planting stock on both plantations came from common seedlots.

TABLE 5.—MEAN HEIGHTS AND DIAMETERS (BREAST HIGH) OF RED AND WHITE SPRUCE AND RED PINE PLANTED IN MIXTURE ON F_1 AND F_2 SITES IN 1939

Site	Plot	Red spruce		White spruce		Red pine	
		Height	d.b.h.	Height	d.b.h.	Height	d.b.h.
		feet	inches	feet	inches	feet	inches
F^1	15/39	16·4	2·2	16·2	2·2	22·4	4·3
F^2	16/39	10·1	1·3	12·3	1·7	17·8	3·9

(NOTE—Each value is the mean of 10 of the tallest trees of each species on July 21, 1952.)

The tendency for white spruce to grow better on the F_1 than on the F_2 site is further illustrated by the data in Table 6. The soil on the F_1 site is sufficiently better drained, warmer, and probably richer in available nutrients than that of the F_2, and this would account for the better growth of trees on it.

TABLE 6.—MORTALITY AND MEAN HEIGHTS OF HEALTHY WHITE SPRUCE ON F_1 AND F_2 SITES, 5 YEARS AFTER PLANTING

Site	Plot	Mortality	Height	Plants 2·5 to 4·0 feet tall
		per cent	feet	
F^1	26/43B (1220)[1]	29	2·6	567
F^2	25/43C (1210)	65	1·3	3

[1] Number of trees planted per acre.

White spruce tends to be somewhat more exacting in its soil requirements than red or black spruce in southern New Brunswick. As an example of this, the average height of healthy white spruce plants on another F_2 site was only 3.3 feet after about 14 growing seasons. The fertility of this latter planting site, however, may have been impaired by destruction of humus by a severe fire in 1923.

Black Spruce

Only a small quantity of black spruce has been planted at the Station, but healthy plants of one lot from seed collected at Petawawa, Ontario, have attained an average height of 8.8 feet in about 11 growing seasons on an F_2 site. Since growth is very slow for the first 2 or 3 years after planting, this performance is good.

Siberian Spruce

Siberian spruce is another species that has grown moderately well on an F_2 site. Although the average height of the stem is not great (Table 7), some individual plants grew nearly 11 feet in 11 years.

TABLE 7.—MEAN HEIGHTS, CONDITION OF LIVING PLANTS, AND MORTALITY OF SIBERIAN SPRUCE ON F_2 SITES

Plot	Mean heights of healthy plants	Condition of living plants		Mortality
		Healthy	Damaged	
	feet	per cent	per cent	per cent
3C	5·1	59	41	18
5D	4·5	57	43	18

(Note—The percentage mortality is based on original stocking of 1,740 and 1,200 trees per acre and the heights on 10 and about 11 growing seasons for 3C and 5D, respectively.)

Red Pine

The good growth of red pine on well-drained F_1 sites has already been indicated in Table 5. Its growth on F_2 sites has been fair. One plantation established in 1934 reached an average height of 18 feet in 19 growing seasons, which is not a bad performance for trees planted in 4- by 4-foot spacing. Its growth on a D_2 (dry, red spruce—balsam fir) site on a sandy terrace was poorer, and healthy plants were only about 11 feet tall after 14 growing seasons. However, this site may also have been somewhat impoverished by a severe fire in 1923.

White Pine

White pine has been planted on F_2 sites only, and has been so severely attacked by the white pine weevil (*Pissodes strobi* (Peck)) that its growth potential there has been obscured. In all probability, however, it would grow better on the F_1 site.

Jack and Scots Pine

As Table 8 shows, jack and Scots pine have grown well on F_2 sites. Healthy plants of both species have averaged more than a foot of height growth per year since planting; jack pine has grown nearly 2 feet per year during the last 5-year period. The number of plants damaged is very low, but Scots pine has suffered considerable mortality and its form is very poor.

TABLE 8.—MEAN HEIGHT AND MORTALITY OF JACK AND SCOTS PINE ON AN F_2 SITE AFTER 16 GROWING SEASONS

Species	Plot	Mean height in feet	Percentage mortality
Jack pine	15/36[1]	21·0	7
Scots pine	14/36[2]	21·5	27

[1] 8- by 6-foot spacing.
[2] 8- by 8-foot spacing.

Hardwoods

The local climate and soil are apparently unsuitable for all hardwoods but native intolerant species. Hybrid poplars, black and white ash, yellow birch,

FIGURE 2.—A mixed plantation of red pine, red spruce, and white spruce at the time of establishment in 1939 under a thinned stand of red maple and white birch. The F_1 (fresh, red maple) site, well-drained sandy loam, is one of the best at the Acadia Station. Spacing was approximately 6 by 6 feet.

FIGURE 3.—The same plantation after 8 years of growth.

FIGURE 4.—The same plantation as in Figures 2 and 3 after 16 years of growth. The red pine in right foreground is approximately 18 feet high

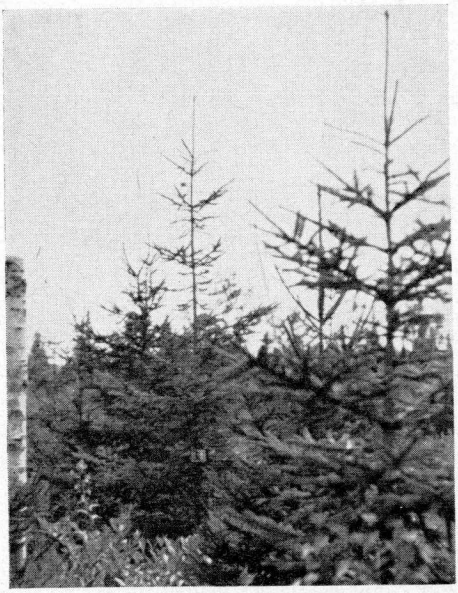

FIGURE 5.—Siberian spruce after 12 years of growth on a F_2 (fresh, red spruce—fir) site. The numbered spruce is a relatively tall, superior plant.

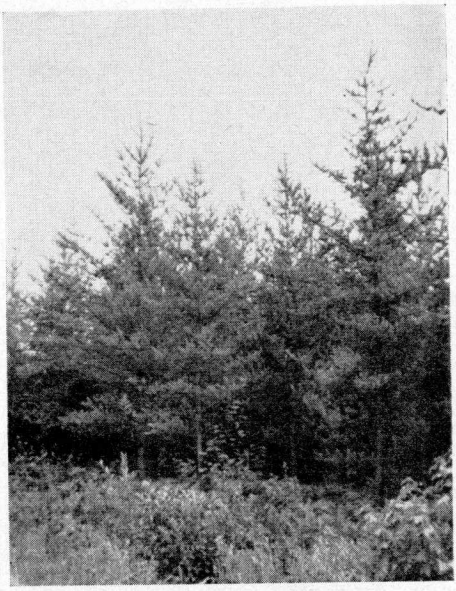

FIGURE 6.—A jack pine plantation after 16 years of growth on a F_2 (fresh, red spruce—fir) site. The plants were spaced 8 by 6 feet.

sugar maple, black walnut, and butternut have been planted. Without exception these plantations have been failures, although poor choice of planting site may often have been largely responsible for the failure. Some species suffered severely from browsing and frost. Rabbits appeared to regard every exotic hardwood as a special delicacy planted for their benefit.

The Biotic Environment

At the Acadia Station, periodic inspections and cleanings of plantations are necessary because of the rapid growth of weed trees and lesser vegetation. Also, the plantations are apt to be damaged by animals, insects, and diseases.

Competition

White and red spruce. White spruce can survive but grows slowly under moderately heavy competition. In heavy competition, however, mortalities as great as 46 and 64 per cent have been recorded 5 years after planting on two plantations. Red spruce behaves similarly where competition is heavy, although it is possibly a little more tolerant than white spruce. Many of the plantations are situated on cut-overs, formerly burned over, which reproduce initially to such vegetation as red maple and intolerant hardwood sprouts and suckers, blueberry, bracken, lambkill, and wild-raisin.

Balsam fir. In two plots with an abundance of sprouts and low vegetation, balsam fir survived well (Table 9). The comparatively low mortality may be an indication that young balsam fir is more tolerant than young white or red spruce. Height growth was slow, but competition may have been only partially responsible because individual plants relatively free of competition in one of the plots were observed to be growing slowly also. Most of the damaged plants were browsed by deer.

TABLE 9.—MEAN HEIGHTS, CONDITION OF LIVING PLANTS, AND MORTALITY OF BALSAM FIR GROWING IN COMPETITION WITH ABUNDANT NATURAL VEGETATION

(NOTE—Heights are for 5 growing seasons.)

Plot	Mean heights of healthy plants	Condition of living plants		Mortality
		Healthy	Damaged	
	feet	per cent	per cent	per cent
25/43A (1208)[1]	1·6	70	30	24
39/45 (1200)	1·5	47	53	12

[1] Number of trees planted per acre.

White and red pine. Survival and growth of white pine in the first three plantations of this species established at Acadia have been very poor because of natural competition and rabbits clipping the leading shoots of the plants. The planting was done in 1934 under a young understocked stand of mixedwoods. By 1947, the average height of the white pine was only about 2 feet and mortality ranged from 44 to 59 per cent. Damage to living plants ranged from 83 to 96 per cent.

Most of the white pine mortality was probably caused by competition, either directly by suppressing the pine or indirectly by retarding their growth enough to keep the plants within the reach of rabbits year after year. Surviving plants were very spindly and suppressed. Red pine has suffered similarly.

Mammals and Insects

Severe rabbit damage to young red and white pine has already been mentioned in the discussion of competition. Nine to eleven years after planting, 41 to 77 per cent of the red spruce have suffered injury, mostly from rabbits, in three mixed plantation plots of spruces and pines. Yet, in a similar plantation plot, damage to red spruce has been light. In another mixed plot, 96 per cent of the living Norway spruce were damaged 11 years after planting. Repeated nipping over several seasons has caused growth to be negligible on many plants and has made them bushy and umbrella-like in appearance.

In the only jack pine plot at Acadia, leading shoots suffered heavy damage early in the life of the plantation, possibly from rabbits. Douglas fir suffered from rabbit injuries as well as from frost.

From the preceding data it is not apparent which species rabbits prefer the most. Probably the environment in which the plantations are situated, and also the time they were established with respect to rabbit populations, are two of the most important factors.

Five of ten coniferous plantations examined in 1952 had been attacked by porcupines (5). Damage caused by this animal was generally negligible, although in one mixed plantation of red pine, white spruce, and red spruce planted in 1939, considerable numbers of red pine trees in small patches were heavily damaged by girdling and gnawing of the bark. The porcupines appeared to prefer trees 3 inches d.b.h. or larger. The heavy damage in this plantation was probably owing to a porcupine den situated close by.

The chief insect damage has been caused by the pitch nodule maker (*Petrova albicapitana* (Busck)) to lodgepole pine and by the white pine weevil to white pine. In two 10-year-old lodgepole pine plantations, the nodule maker had attacked about 90 per cent of the living plants, killing branches and causing forking.

One of the oldest white pine plantations on the station was first attacked by weevil when it was 6 years old; 13 years later, in 1953, nearly every plant had been weeviled at least once and many several times. Light shade is often recommended as a control measure, but in a 9-year-old plantation established under a moderate overstory of red maple and grey birch on a good site, 32 per cent of the pine had been weeviled two or more times and many of the remainder had been attacked once. A tree may outgrow a single attack, but repeated attacks leave it badly deformed.

DISCUSSION

The physical limitations of the terrain and the youth and limited scope of the plantings at the Acadia Station make it dangerous to apply this experience to the Maritimes as a whole. Several native and exotic conifers are growing moderately well; but even in the oldest plantations the canopies have been closed for only a short time and site may exercise an increasing influence as age and competition increase.

Heavy texture and rockiness of soil has made planting in holes dug with shovel and grub hoe about the only practical method at Acadia. This, combined with the abundance of competing vegetation, has made planting expensive, and Acadia experience in the actual technique of ground preparation and planting is not too instructive. Natural vegetation promptly invades cut-over areas, and one or more early cleanings are necessary if plantations are to grow satisfactorily.

Among the continental spruces and pines, trees grown from local seed will probably do best in the long run if experience elsewhere is a safe criterion. Unfortunately, local seed has not been collected until recently, and there are no plantations of local strains of any great age to compare with plantations of outside provenance. In the meantime, however, the safest procedure would be to restrict use of imported seed to experimental plantations for research purposes.

Native red and white spruce have grown moderately well, averaging about a third of a foot a year in height growth since planting; however, growth during the first 5 or 6 years after planting tends to be slow and these values give an erroneous idea of what may be expected from older plantations. Both species do moderately well on F_2 (fresh, red spruce and balsam fir) sites, but grow better on the well-drained F_1 (fresh, red maple) sites. The only black spruce planted on the area has grown about three-quarters of a foot a year on an F_2 site.

Red and black spruce may be planted on imperfectly drained, heavy soils. White spruce, however, requires richer and better aerated soils for good growth. In addition, because of its early start of growth in the spring, it should be limited to sites with good air drainage.

Among the exotic spruces, continental species such as Norway, Engelmann and Siberian spruce have grown moderately well, averaging about a third of a foot in height growth since planting. Norway spruce is similar to white spruce in needing well-drained loamy soils on sites with good air drainage.

Sitka spruce has been unable to stand the local climate and has been killed back repeatedly by frost. Six- by six-foot spacing is probably adequate for all the spruces.

Only a small quantity of fir has been planted, and in view of its normally prolific regeneration in the Maritimes and of its susceptibility to the spruce budworm (*Choristoneura fumiferana* (Clem.)) and balsam woolly aphid (*Adelges piceae* (Ratz.)), one may question the desirability of planting fir except for Christmas trees.

Douglas fir has usually been unable to stand the climate or has grown so poorly as to show little promise for reforestation. Conceivably, some strains of the mountain form of Douglas fir may be adaptable to Maritime conditions, but these have not yet been discovered.

Native red, white, and jack pine have grown moderately well on rather moist soils, despite their reputation of being dry land species. However, red pine does grow better on the F_1 than on the F_2 site. White and jack pine have been planted only on F_2 sites. Since planting, red and jack pine have averaged about a foot a year in height growth; during the second decade of growth, they often average nearly 2 feet.

Lodgepole and Scots pine have grown about one foot per year in height since planting on F_2 sites. Their form, however, has been poor, and lodgepole pine has been severely damaged by the pitch nodule maker. Conceivably, however, other strains of these species might be adapted to Maritime conditions. Since Scots pine is a bog species in northern Europe, planting it on such sites here might be worth trying; it might be more productive than black spruce on some bogs.

In general, the pines ought to be planted on deep sandy loams to sands, with white and red pine being used on the better of these sites. Red pine should not be planted on very fertile soil because experience elsewhere shows that it tends to suffer severely there from root rot. Although healthy white pine grows well, the risk of attack by white pine weevil and blister rust (*Cronartium ribicola* Fisch.) is considerable. Red pine, therefore, is a more popular tree for reforestation, and until recently has been free of serious enemies. But vast acreages of pure red pine have been planted in northeastern United States and southern Ontario, and these have suffered considerable damage from the European pine shoot moth (*Rhyacionia buoliana* (Schiff.)) and a root rot (*Fomes annosus* (Fr.) Cke.). Therefore, neither of these species should be planted indiscriminately over large areas, though red pine is probably the safer choice of the two.

Unless there is a Christmas tree market for early thinnings, red and jack pine ought to be planted at a spacing of about 8 by 8 feet. White pine needs closer spacing, 6 by 6 or 5 by 5 feet, to force it to grow straight after weevil attack; and plantations should not be thinned until stems have attained the height of one straight log length.

In the long run, mixed plantations are probably safer than pure ones; but with mixtures of relatively intolerent species such as the pines, a checker board pattern of small pure groups or several rows of one species alternating with several rows of another are preferable to single alternate rows of each species. In the last arrangement, red pine always outgrows and suppresses white pine because of the latter's susceptibility to weevil attack. Locally, red pine and red and white spruce appear to grow well together on F_1 sites.

Efforts to establish plantations of hardwoods have been completely unsuccessful. The soil at Acadia is probably too infertile and poorly drained for exacting species of hardwoods. Although there are many areas in the Maritimes where they would probably thrive, large-scale planting of hardwoods is not recommended.

SUMMARY

More than 60 permanent plantation plots covering a total of about 154 acres have been established at the Acadia Forest Experiment Station. Planting has been nearly all in clearcut or partially cut natural stands. Only a few methods of planting have been used because of the abundance of vegetation and the rocki-

ness of the soil. Commonly, 2-2 coniferous stock has been planted at a spacing of 6 by 6 feet. Most plantations are of one species but some mixtures have been planted.

The soils are acid and infertile. The subsoil consists of compact boulder clay till, the upper 1 to 3 feet of which is usually friable, varies from fine sandy to clayey loam and includes numerous rock fragments and occasional boulders. In some areas this is overlain by a layer of reddish-brown sand to sandy loam containing some rock fragments. The climate is somewhat continental, and the average annual precipitation is 41 inches.

Planting has been restricted to only a few sites. In general, however, growth has been best and mortality least on well-drained F_1 (fresh, red maple) sites, where the surface layer of mineral soil is a permeable sandy loam. The soil and climate at Acadia are apparently unsuitable for all but the native intolerant hardwoods.

General statements about development of the plantations as affected by provenance are difficult as several species from various seed sources in Canada and Europe have grown reasonably well. In planting native species, best results may probably be expected from stock originating from seed collected in the Maritimes, Ontario, and Quebec.

Annual height growth of the plants has generally been very slow during the first 5 years after planting, but much faster during the second 5-year period. Jack pine and Scots pine have grown fastest, followed by lodgepole pine and red pine.

Growth of plantations at Acadia has probably been retarded considerably because of competition from hardwood sprouts after cutting and from underbrush and ground cover. However, most of the plantation plots have been cleaned once or twice since planting.

Mortality of most coniferous species has generally ranged between 10 and 30 per cent of planted stock within 10 years of planting.

Rabbits have caused serious damage to several species in some plantations by the repeated nipping of leading shoots of plants. The white pine weevil generally caused extensive damage in white pine plantations. Lodgepole pine has been heavily attacked by the pitch nodule maker. Sitka spruce, Douglas fir, and hardwoods have suffered frost damage repeatedly.

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APPENDIX I

Botanical Names of Tree Species Planted and Other Species of Trees and Lesser Vegetation Referred to in This Report

Common Name	*Botanical Name*
Ash, black*	*Fraxinus nigra* Marsh.
Ash, white*	*Fraxinus americana* L.
Aspen, largetooth	*Populus grandidentata* Michx.
Aspen, trembling	*Populus tremuloides* Michx.
Beech	*Fagus grandifolia* Ehrh.
Birch, grey	*Betula populifolia* Marsh.
Birch, white	*Betula papyrifera* Marsh.
Birch, yellow*	*Betula lutea* Michx. f.
Butternut*	*Juglans cinerea* L.
Cedar, eastern white*	*Thuja occidentalis* L.
Fir, balsam*	*Abies balsamea* (L.) Mill.
Fir, Douglas*	*Pseudotsuga taxifolia* (Poir.) Britton
Hemlock	*Tsuga canadensis* (L.) Carr.
Larch, eastern*	*Larix laricina* (Du Roi) K. Koch
Maple, red	*Acer rubrum* L.
Maple, sugar*	*Acer saccharum* Marsh.
Pine, jack*	*Pinus banksiana* Lamb.
Pine, lodgepole*	*Pinus contorta* Dougl.
Pine, red*	*Pinus resinosa* Ait.
Pine, Scots*	*Pinus sylvestris* L.
Pine, white*	*Pinus strobus* L.
Poplar, Geneva*	*Populus* sp. hybrid
Poplar, Maine*	*Populus* sp. hybrid
Spruce, black*	*Picea mariana* (Mill.) BSP.
Spruce, Engelmann*	*Picea engelmanni* Parry
Spruce, Norway*	*Picea abies* (L.) Karst.
Spruce, red*	*Picea rubens* Sarg.
Spruce, Siberian*	*Picea obovata* Ledeb.
Spruce, Sitka*	*Picea sitchensis* (Bong.) Carr.
Spruce, white*	*Picea glauca* (Moench) Voss
Walnut, black*	*Juglans nigra* L.
Blueberry	*Vaccinium angustifolium laevifolium* (Ait.) House
Bracken	*Pteridium aquilinum latiusculum* (Desv.) Underw.
Lambkill	*Kalmia angustifolia* L.
Wild-raisin	*Viburnum cassinoides* L.

*Tree species that have been planted at the Acadia Station.

APPENDIX II

Tables

TABLE 10.—MEAN HEIGHTS AND DIAMETERS (BREAST HIGH) OF 20 OF THE TALLEST WHITE SPRUCE IN EACH PLOT

(NOTE—Measurements are based on about 11 growing seasons for 2D and 3D, and about 12 growing seasons for the remaining plots.)

Plot	Average height (feet)	Average d.b.h. (inches)
2B	8·2	0·82
3B	7·9	·78
4B	9·4	1·09
5B	7·7	·77
6B	6·9	·66
7B	7·8	·78
8B	8·2	·90
7C	7·3	·76
8C	8·6	·95
2D	6·5	·55
3D	9·1	1·00

TABLE 11.—MEAN HEIGHTS AND DIAMETERS (BREAST HIGH) OF 20 OF THE TALLEST NORWAY SPRUCE IN EACH PLOT

(NOTE—Measurements are based on about 11 growing seasons for 4D and 6D, and about 12 growing seasons for the remaining plots.)

Plot	Average height (feet)	Average d.b.h. (inches)
1A	8·9	0·97
2A	9·3	1·06
3A	8·1	·79
4A	7·3	·89
5A	7·6	·73
6A	7·3	·64
7A	7·5	·70
8A	8·6	·83
2C	8·1	·78
4D	7·7	·76
6D	8·4	·86

TABLE 12.—MEAN HEIGHTS, CONDITION OF LIVING PLANTS, AND MORTALITY OF ENGELMANN SPRUCE ORIGINATING FROM SEED COLLECTED IN BRITISH COLUMBIA

(NOTE—Heights are for 11 growing seasons; 1,740 trees were planted per acre.)

Mean heights of healthy plants	Condition of living plants		Mortality
	Healthy	Damaged	
feet	per cent	per cent	per cent
5·2	76	24	4

TABLE 13.—MEAN HEIGHTS, CONDITION OF LIVING PLANTS, AND MORTALITY OF LODGEPOLE PINE ORIGINATING FROM SEED OF VARIOUS PROVENANCES

(NOTE—Heights are for 10 growing seasons for 5C, and about 11 growing seasons for the remaining plots.)

Plot	Provenance	Mean heights of healthy plants	Condition of living plants		Mortality
			Healthy	Damaged	
		feet	per cent	per cent	per cent
5C (1740)[1]	Terrace, B.C., lat. 55°N., elev. 250 ft.	12·4	83	17	19
7D (890)	Kananaskis, Alta., elev. 4,300 ft.	8·5	39	61	29
8D (1200)	Terrace, B.C., lat. 55°N., elev. 250 ft.	10·4	51[1]	49	11

[1] Number of trees planted per acre.

TABLE 14.—MEAN HEIGHTS, CONDITION OF LIVING PLANTS, AND MORTALITY OF DOUGLAS FIR ORIGINATING FROM SEED OF VARIOUS PROVENANCES

(NOTE—Heights are for 16 growing seasons for 17/36, 10 seasons for 6C and 29/43, about 11 seasons for 1E, and about 6 seasons for 2E.)

Plot	Provenance	Mean heights of healthy plants	Condition of living plants		Mortality
			Healthy	Damaged	
		feet	per cent	per cent	per cent
17/36[1]		2·4	37	63	77
(2000)[2]	.....	3·7	59	41	9
6C (1740)	Tete Jaune, B.C., lat. *ca* 53°N.	3·1	10	90	55
1E (1200)	Kananaskis, Alta.	1·0	38	62	96
2E[3] (1200)	Larch Hills, Salmon Arm., B.C.	5·0	48	52	0
29/43[4]	.....				

[1] Planted with 3-0 stock.

[2] Number of trees planted per acre.

[3] Planted with *Pseudotsuga taxifolia causia*.

[4] Number of trees planted not clear, but spaced approximately 6 by 6 feet.

APPENDIX III

THE MEAN ANNUAL HEIGHT GROWTH OF HEALTHY PLANTS OF VARIOUS SPECIES IN DIFFERENT PLANTATIONS AT THE ACADIA FOREST EXPERIMENT STATION

Species	Plantation	Annual height growth (feet)
White spruce	2B	0·34
"	3B	·31
"	4B	·35
"	5B	·28
"	6B	·24
"	7B	·30
"	8B	·37
"	7C	·33
"	8C	·39
"	2D	·32
"	3D	·49
"	15C	·08
"	26B	·36
"	12	·18
"	15	·51
Red spruce	16	·51
"	15	·47
"	16	·32
	Average	·34
Black spruce		·74
Norway spruce	1A	·28
"	2A	·30
"	3A	·29
"	4A	·29
"	5A	·24
"	6A	·24
"	7A	·29
"	8A	·30
"	2C	·32
"	4D	·38
Engelmann spruce	6D	·42
Siberian spruce	4C	·40
"	3C	·39
"	5D	·35
	Average	·32
Red pine	7	·89
"	11	·71
"	15	1·08
Jack pine	16	·88
	15	1·25
	Average	·96
Scots pine	14	1·28
Lodgepole pine	5C	1·14
"	7D	·69
"	8D	·86
	Average	·99
Douglas fir	17	·09
"	6C	·28
"	1E	·22
"	29	·40
	Average	·25