SOME SEED SOURCE STUDIES OF SCOTCH PINE IN NEW YORK

Lawrence S, Hamilton[1] and Charles H. Frommer[2]

INTRODUCTION

Scotch pine (Pinus sylvestris L.) was widely used in the early reforestation program in New York State. It gradually came into disrepute as the plantations developed, because of the poor form of the majority of trees. Its use in reforestation tapered off rapidly until it gained market acceptance as a Christmas tree in the late nineteen-forties. Currently it leads all other species for use in Christ mas tree plantations, and the annual production from State nurseries alone is around 8.5 million trees. From 1902 to 1961, 160 million Scotch pine seedlings have been sent out from State nurseries.[3]

During the rise, fall and resurrection of Scotch pine, foresters have maintained interest in this species because of its rapid growth, wide site adaptability, and its considerable ecotypic variation. Even during the "fall" of this species in the thirties, E. W. Littlefield, H. H. York and E. J. Eliason of the New York State Conservation Department initiated several seed source studies, and with foresight, kept adequate records which made this present study possible.

[1] Associate Professor of Forestry, Department of Conservation, Cornell University Ithaca, N. Y.

[2] Forester, New York State Conservation Department, Albany, N. Y.

[3]Figures supplied by E. J. Eliason from State Conservation Department Records.

Naturalized stands of Scotch pine in the Woodgate-Boonville area of New York were observed and studied by York and Littlefield as early as 1925 (18). The relatively good form of the trees at Boonville led to seed collections from groups and individual trees, and the planting of the offspring in experimental plots throughout the State (10).

In addition, the early interest of these men in forest tree improvement manifested itself in the establishment of experimental plots where Scotch pine of different seed sources were planted in adjacent strips at one location or site. If the site indeed proved to be uniform, such plantings offer opportunity for seed source performance observations of considerable value in the "young" science of forest genetics.

This paper reports on some studies based upon these seed source records, and these experimental plots. Grateful acknowledgment is rendered to the New York State Conservation Department for its cooperation in making the records available; and in particular to E. W. Littlefield, E. J. Eliason and David B. Cook for their personal help in working through the files and records. The measurements were made in 1959 and 1960 by Charles Frommer and Frederick Wheeler respectively, under the direction of the senior author. This study was conducted as a portion of a Northeastern Regional Project (NE-27); a cooperative enterprise involving Agricultural Experiment Stations in the Northeast and supported in part by funds of the United States Department of Agriculture.

PART I. OBSERVATIONS OF SCOTCH PINE OFFSPRING FROM KNOWN SINGLE-PARENTS

Seed had been collected in the fall of 1930 from an open pollinated Scotch pine mother tree designated as Tree 44 in the Department's seed source records. This tree was located in a seed collection area adjacent to the cemetery in Boonville. Tree 14, in 1927, was described as follows: age 28 years; dominant tree 40 feet in height; 103 inches d.b.h.; bearing a heavy cone crop; showing no injury and rated as "medium" in a good-medium-poor stem-form classification. The 2-0 seedling offspring had been planted in 1933 at 6- by 6-feet spacing in various locations throughout the State. Three of,these outplantings were selected, where identification was positive, where there had been no thinning and where substantial inter-locational environmental variation existed (figure 1). Comparative site descriptions for these three study areas appear in table 1.

Tree 59, another individual in the Boonville seed collection area, was the source of seed collected in 1932 and 1933, and provided 2-0 offspring which were established at 6- by 6-feet spacing in several locations throughout the State from 1934 to 1937. The fact that these offspring are not from seed collected the same year increases the amount of genetic variability which might occur. In 1927, Tree 59 was described as follows: age 11 years; 11.7 feet in height; 2.5 inches d.b.h.; some crook, placing it as form 3 in a good-medium-poor classification.[1] Five plantings of the offspring were selected on the basis of positive identification, lack of thinning and substantial inter-locational environmental differences (figure 2). Comparative site descriptions for these five areas appear in table 2.

[1] Field notes made in 1927 by E. W. Littlefield. In files of State Conservation Department, Albany, N. Y.

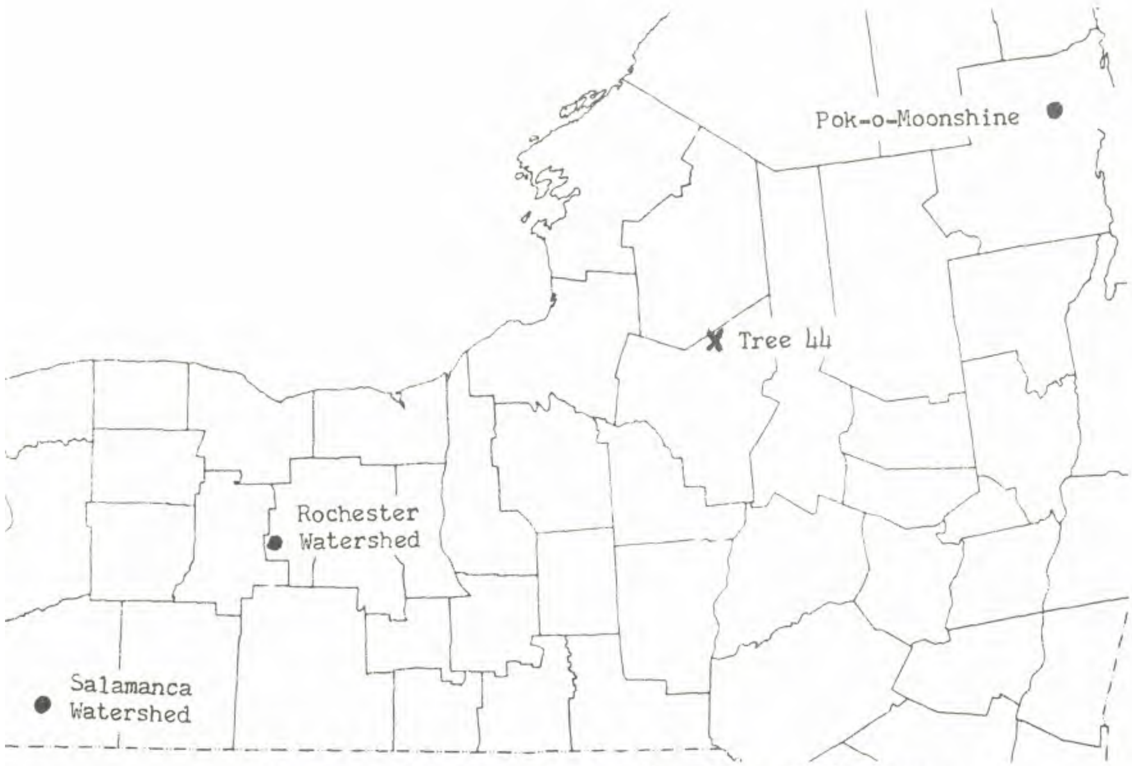

Figure 1.--Location of Tree 44 and the Study Areas.

Table 1. Comparison of Planting Sites for Offspring of Tree 44.

Plantation designation		Pok-O-Moonshine	Rochester Watershed	Salamanca Watershed
Nearest community		Lewis	Hemlock	Salamanca
Region		Adirondack	Finger Lakes	Southern Tier
Elevation (ft.)		1000	1200	1800
Slope position		lower slope	upper slope	ridge top
Aspect		south	west	west
Average precipitation (ins.)*		36	35	43
Average length of growing season (days)*		120	150	130
Soils				
depth to pan or mottling (ins.)		36"+	30"+	12"
texture		loamy sand	silt loam	silt loam
drainage		good	mod. good	imperfect-poor
organic matter (percent)		6.0	6.0	5.8
pH		5.0	5.3	4.3
phosphorus	(lbs. per acre)	3	4	5
nitrate nitrogen	(" " ")	10	12	12
ammonium nitrogen	(" " ")	28	16	18
calcium	(" " ")	300	1700	<50
magnesium	(" " ")	40	180	45
potassium	(" " ")	60	380	105
manganese	(" " ")	24	54	165
iron	(" " ")	16	17	70
aluminum	(" " ")	375	110	625

*Climatic data from nearest weather station.

Figure 2.--Location of Tree 59 and the Study Areas.

Table 2. Comparisons of Planting Sites for Offspring of Tree 59.

Plantation designation	Montgomery 1 Proposal M	Schoharie 20 Proposal A	Oneida 6 Proposal A	Allegany 3 Proposal F	Rochester Watershed
Nearest community	Charleston	Warnerville	Boonville	Almond	Hemlock
Region	Mohawk Valley	Catskills	Adirondack	Southern Tier	Finger Lakes
Elevation	1260	1960	1170	1800	1200
Slope position	plateau top	middle	valley terrace	plateau top	upper slope
Aspect	level	northwest	level	level	west
Av. precipitation (ins.)*	34	39	41	36	35
Av. length growing season (days)*	140	120	120	115	150
Soils					
depth to pan or mottling (ins.)	13	15	30+	10	24+
texture	silt loam	silt loam	sand	silt loam	silt loam
drainage	mod. good	mod. good	good	poor	mod. good
organic matter (%)	4.5	>6.0	2.4	>6	5.2
pH	4.5	4.7	4.6	5.7	5.4
phosphorus (lbs./acre)	1	3	1	1	2
nitrate nitrogen (lbs./acre)	7	8	5	5	8
ammonium nitrogen (lbs./acre)	11	10	5	7	5
calcium (lbs./acre)	50	500	<50	4700	2800
magnesium (lbs./acre)	15	65	5	250	370
potassium (lbs./acre)	70	190	15	175	215
manganese (lbs./acre)	14	43	35	30	30
iron (lbs./acre)	73	64	40	10	23
aluminum (lbs./acre)	460	340	250	110	110

*Climatic data from nearest weather station.

In each plantation interior (at least the height of the trees from the edge) a soil pit was excavated, the soil profile described and samples taken for analysis. These samples were analyzed for organic content and nutrients by the Soil Testing Laboratory, Department of Agronomy, Cornell University. Twenty dominant or co-dominant trees, free of any major stem damage, were selected as close to the soil pit as possible. Total height was measured with an aluminum telescoping pole of the kind described by Aird and Stone (1). Calipers were used to measure diameters outside bark at breast height. The mean branch angle, (the angle formed between the leader for that year, and the upper surface of each branch in the whorl) was determined from the second and third whorls above breast height, and was read by an angle gauge protractor. The number of branches in these same two whorls was counted and expressed as the mean number of branches per whorl. Five randomly selected needles from the current season's growth in the upper, sun-exposed part of the crown formed the basis for measurements of mean needle length. The maximum number of internodes still bearing needles was used as a measure of needle retention. Stem form was recorded in terms of number of occurrences of crook or sweep in the stem.

Survival of offspring from Tree 59 at the Alleghany 3 (Almond) site had been low, and it had been refilled with spruce and red pine. Because of this, height, diameter and stem form measurements were not taken in this plantation.

Means for each measured characteristic for the 20 trees at each location were computed. For most characteristics, both analysis of variance and tests for homogeneity of variance were carried out, Chi-square tests were used however for the stem form and needle retention data.

With the assistance of E. J. Eliason and Donald Carlson of the State Conservation Department, Tree No. 44 at Boonville was definitely located. This tree was 61 years of age, a good specimen of Scotch pine, but having slight sweep in the basal log and one crook. (See figure 3). Branch angle, branch number per whorl, needle length and needle retention measurements were taken, to supplement the measurement data taken by Littlefield in 1927. In spite of diligent effort, original Tree 59 could not be definitely relocated (numbered stake was missing and location on map could not pinpoint the tree with certainty.)

Results and Discussion

Tree 44 Offspring.

The means for each of the measured characteristics of the offspring of Tree 14 are presented in table 3, together with the results of the statistical analysis and the measurements of the mother tree.

With such site variation, it was anticipated that height growth differences among offspring at the three locations would differ significantly. It was not anticipated that significant differences would occur for almost all of the other characteristics, some of which had been thought to exhibit a high degree of genetic control. As this manuscript was being prepared a study by Callaham and Liddicoet was published which also showed the marked environmental influence on such characteristics as height growth, stem taper, branch number and needle retention for ponderosa and Jeffrey pines of one seed source (5). Theirs were eleva tional sources rather than from a single parent.

Table 3.--Differences among tree 44 offspring in three varying environments

	Salamanca Watershed	Rochester Watershed	Pok-o-Moonshine	Statistical analysis of differences	Mother tree 44
Mean total height (feet)	40.9	45.0	45.2	Highly sign.	41.4*
Mean d.b.h. (inches)	6.2	8.2	7.6	Highly sign.	10.3*
Mean branch angle (degrees)	68	70	62	Highly sign.	59
Mean branch number	7.3	7.5	6.7	Significant	7
Mean needle length (inches)	1.8	2.3	1.9	Highly sign.	1.6
Mean needle retention (years)	3.1	3.8	4.1	Highly sign.	3
No. of trees with stem sweep	19	16	16	Non-sign.	**
Total number of crooks	23	18	11	Not used	**

* Measurements taken when tree was 28 years of age, but height measurement in table has been increased by one year's average growth to allow better comparison with 29-year-old offspring.

** Mother tree had slight sweep and one crook when examined at age 61.

Figure 3.--Tree 44, one of the original mother trees of what has come to be known as "Boonville" Scotch pine.

While there was no significant difference in height growth between the two sites with drainage which was at least moderately good, the height achieved on the imperfectly drained site was significantly poorer.

Diameter growth differed significantly between all three locations, with the best performance at the Rochester Watershed. Stocking was lighter in this plantation, but it was felt that this was due not to lower survival but to greater expression of dominance and natural mortality. The better performance might be attributed at least in part to the longer growing season, and generally higher fertility of this site (highest in calcium, potassium, manganese and magnesium)„ The sampled trees averaged 2 inches larger in 29 years at Rochester Watershed compared with the Salamanca Watershed. The mother tree had achieved a diameter of 10.3 inches at this same age (29 years), but this is largely attributable to the low stand density noted in the Littlefield seed collection data.

Analysis of variance indicated highly significant differences in branch angle, with the Pok-O-Moonshine trees being significantly different than the two others. The greatest difference between means, however, was only 7 degrees. The precision in measuring this characteristic is not as high as for the other characteristics since branches sometimes leave the trunk in a convex curve, rather than in a straight line, and some judgment is necessary to approximate the "average" line forming the lower limb of the angle. This significant difference between progeny on different sites should therefore be accepted with some reservation.

The branch number of the offspring differed significantly between locations, with the greatest number per whorl on trees in the Rochester Watershed and a significantly lower number per whorl on trees at Pok-O-Moonshine. Callaham and Liddicoet (5) also found branch number to be significantly influenced by environment in ponderosa pine, and influenced by both environment and seed source in Jeffrey pine. The analysis of variance for Tree 44 offspring just barely showed significant difference ($F=3.78$ when $F_{.05}$ 3.15).

Needle length differences were highly significant. The needles averaged one-half inch longer at Rochester Watershed than at Salamanca Watershed and were also significantly longer than at Pok-O-Moonshine. It might well be expected that if there were locational differences, the longest needles would be produced on the site with the greatest fertility, and this was indeed the case.

Needle retention differences were highly significant with the poorest retention occurring on the most poorly drained site (Salamanca).

Stem form characteristics are indicated in the last two lines of table 3. Crook could be caused by external injuries such as deer and porcupine damage, low temperature, snow breakage, insect damage, and other studies have shown that seed sources vary in their susceptibility to these injuries, i.e. there is some genetic control (4, 11, 12, 13, 14, 17). Evaluating heritability of stem form using crook, however is, meaningless, unless done at one site where the damage potential is essentially uniform. Since the damage potential at the three widely scattered locations in this study could vary markedly, crook was not used in the analysis. Stem straightness as reflected by sweep was considered more useful in assessing environmental versus genetic control of stem form in this case. The differences in occurrence of sweep between the three locations were not significant.

Tree 59 Offspring

The means for each of the measured characteristics of the offspring of Tree 59 are presented in table 4, together with the results of the statistical analysis of differences. The trees at the time of measurement were 24, 25, 2 6 and 27 years from seed and consequently mean annual height and diameter measure ments were used rather than totals.

Table 4.--Observations of offspring from tree 59 planted on four different environments.

	Montgomery 1	Schoharie 20	Oneida 6	Alleghany 3	Rochester Watershed	Statistical analysis of differences
Mean annual height (inches)	16.5	17.2	15.6	*	20.4	Highly sign.
Mean annual diameter growth (inches)	0.23	0.23	0.22	*	0.25	Significant
Mean branch angle (degrees)	73	76	68	72	74	Highly sign.
Mean branch number	7.0	6.5	7.1	6.5	6.5	Significant
Mean needle length (inches)	1.8	1.7	1.6	2.2	2.1	Highly sign.
Mean needle retention (years)	3.0	3.2	3.2	3.0	3.4	Non-sign.
No. of trees with stem sweep	15	12	9	*	11	Non-sign.
Total number of crooks	5	6	4	*	6	Not used

*These measurements not made because of pronounced difference in stocking due to lower survival.

Height growth showed highly significant differences among sites. The Rochester Watershed trees grew significantly faster per year than the offspring at any of the other locations, and the trees at Oneida 6 grew significantly slower than those at Schoharie 20. Heights on the trees at Allegany 3 were not recorded due to plantation history, but were very poor. Thus the same height relationship with drainage does not occur as was the case for the offspring from Tree 44, except that heights were poorest at the poorly drained Allegany 3 site. The next poorest growth however was on the well-drained sand (Oneida 6). It is felt that this was due to the low fertility of this site (see table 2). The soil is lowest in potash, magnesium and nitrogen and a deficiency in these nutrients has been shown in other studies to have depressed growth (7, 9, 16). The site with the greatest fertility (Rochester Watershed) provided the best growth rate in height.

Diameter growth was also significantly greater at the Rochester Watershed than any of the other locations, and in fact no significant differences were found in this characteristic among Tree 59 offspring between Montgomery 1, Scholiarie 20 and Oneida 6 (Measurements were not made at Allegany 3 due to low stocking).

As was the case with the offspring of Tree 44, these offspring also showed highly significant differences in mean branch angle between locations, with a maximum difference in means of 8 degrees. Number of branches per whorl also showed significant differences as was the case before.

Needle length differences were highly significant. While there was no difference between the Rochester Watershed and Allegany 3 sites, these two showed statistically demonstrable differences when compared with any of the other three sites. As with Tree 44 offspring, the most fertile site (Rochester Watershed) produced the longest needles. For some inexplicable reason this needle length was equalled on the poorly drained site, where the trees were obviously growing under adverse conditions due to the water handling characteristics of this site. One speculates as to whether or not this is an "adversity reaction" similar in nature to "distress cones". The shortest mean needle length (though not significantly shorter than its two companion locations) was shown on the low-fertility Oneida 6 site.

No needle retention differences were exhibited by these offspring. This was the only characteristic which showed markedly different results than those obtained from the study of the Tree 44 offspring.

As before, and for the same reasons, number of crooks was not used as an indicator of stem form and the degree to which this is controlled genetically. Stem sweep prevalance was used as the criteria, and no significant differences were exhibited between sites.

Conclusions

Significant differences among offspring from the same Scotch pine mother tree when planted in different environments have been shown for the following characteristics: height growth, diameter growth, branch angle, branch number per whorl, and needle length. These have been demonstrated for two mother trees by studies conducted in two different years. It would appear that genetic control of these characteristics is somewhat loose and that environment is indeed responsible for some of the variation which we observe in Scotch pine.

In general, the poorer the drainage and the fertility of the site, the slower the height and diameter growth and the shorter the needles.

Christmas tree growers who have assumed that needle length, branch angle and number of branches per whorl were exclusively a matter of genetic control might ponder the differences shown in this study.

Stem form, on the other hand, as denoted by the occurrence of sweep showed no differences with different environments, and on the basis of this study would seem to be genetically, rather tightly controlled.

Conflicting results were obtained for needle retention. This characteristic is of considerable importance to Christmas tree growers and producers of ornamental stock. It is well known that in the pines, the number of years of needles retained will vary from year to year, apparently due to climatic effects. Even in years of severe fall foliage drop of the older needles, some individuals and plantations do not react as poorly as others. This phenomena is well worth further study, from the standpoint of possible genetic control, of tree physiology and of site factors which trigger this.

PART II. OBSERVATIONS OF SCOTCH PINE OFFSPRING FROM DIFFERENT SEED SOURCES

As "the other side of the coin," an investigation was undertaken in two plantations where offspring from several different European and New York seed collection areas had been planted in adjacent strips on State forest land.

One plantation, designated as "Subcompartment 14, Proposal B, in State Reforestation Area Schoharie 20," lay on the northwest slope of Petersburg Mountain near Warnerville, N. Y. at an elevation of about 2,200 feet This plantation had been established in 1936 with 2-0 stock of 5 different seed sources planted in adjacent strips The trees were 25 years from seed at the time of the observations The seed sources represented were:

1. Parishville (Seedlot E 164) - collected in 1932 in the Champney-Hinman plantation, St. Lawrence County, New York The trees were described at collection time as being narrow-crowned and having small branch angle.
2. Herbst Brothers (Seedlot 25) - "Special," purportedly a certified seed from North Central Prussia, near village of Neuhaldenslaben.
3. South Colton 33 (Seedlot E 174) - collected in 1933 from F. H. Reynolds plantation in St. Lawrence County, New York.
4. South Colton 32 (Seedlot E 165) collected in 1932 from F. H. Reynolds plantation in St. Lawrence County, New York.
5. Boonville - (Mixed seedlots) collected in 1932 from Boonville stands.

Each seed source was represented by approximately 500 trees, spaced 6 feet by 6 feet in narrow rectangular blocks with the long axes up and down the slope.

The slope was 12 percent and while not completely uniform throughout the length of the strips, it did not vary more than 2 percent from this average figure A series of 8 soil pits were excavated up and down the slope. These pits indicated that there were only slight differences in soils with respect to slope position. The upper position, in general, was not rocky and had a hardpan at 18 inches; the middle position was very rocky with a hardpan at 16 inches; the lower position was very rocky, with a hardpan at 17 inches All were moderately well-drained silt loams. Since there was this slight difference in soils and since the slope percent and surface configuration also showed differences at right angles to the seed source strips, the plantation was divided into three strata: upper, middle and lower. In each seed source strip, in each slope position, a soil pit was located which matched in physical features the preceding pit for the same slope position. Thus, there were 15 soil pits, with 5 pits in each slope position having similar profiles By this device it was hoped to have the edaphic environment as uniform as possible and to analyze the data separately, if necessary, by slope positions.

The second plantation, designated as "Lewis-Jefferson 2-C" was located near Adams Center, N. Y. Seven seed sources had been planted in adjacent strips in 1938 under the direction of E. W. Littlefield. The following sources were represented:

1. Finland (Seedlot E 215) - collected by the Forest Research Institute of Helsinki from a stand in the forest of Punkahaza, Finland
2. Germany (Seedlot 25) - collected somewhere in Germany as lot 3901 by Herbst Brothers.
3. South Colton (Seedlot E 174) - from 10 trees in F. FL Reynolds' plantation, St. Lawrence County, N, Y, collected 1933
4. Wurtemburg (Seedlot 30) collected from a stand in the Black Forest, Germany, for Herbst Brothers as lot 1339.
5. Czechoslovakia (Seedlots E 216 and E 219). mixed seed from three forest districts, collected by the State Seed Institute of Prague.

6. East Prussia (Seedlot 31) - from Fischausen State Forest in Prussia, imported by Herbst Brothers as lot 1340.
7. Forestport (Seedlot 5 265) - collected from Kernan plantation, Oneida County, N. Y.

All sources were planted as 2-1 stock, except the one from Finland, which was 2-2 stock. Plantation spacing was 6 by 6 feet and unfortunately the planta tion had been lightly thinned from below and crop trees pruned to 8 feet in height.

This second plantation was located on a low, gently rounded hill in a general area of low relief where bedrock was fairly close to the surface and swampy areas were abundant. The blocks studied were at an elevation of approximately 1370 feet on a formerly plowed, northerly facing slope. Throughout the seed source strips, elevational differences were no greater than 10-15 feet, slopes were under 4 percent and bedrock depth varied only 5 inches (from 22 to 27 inches below the surface). The site was therefore quite uniform and nor difficulty was experienced in locating soil pits of similar profile in each of the 7 seed source strips.

The locations of the two study areas and New York seed sources represented on them are shown in figure 4.

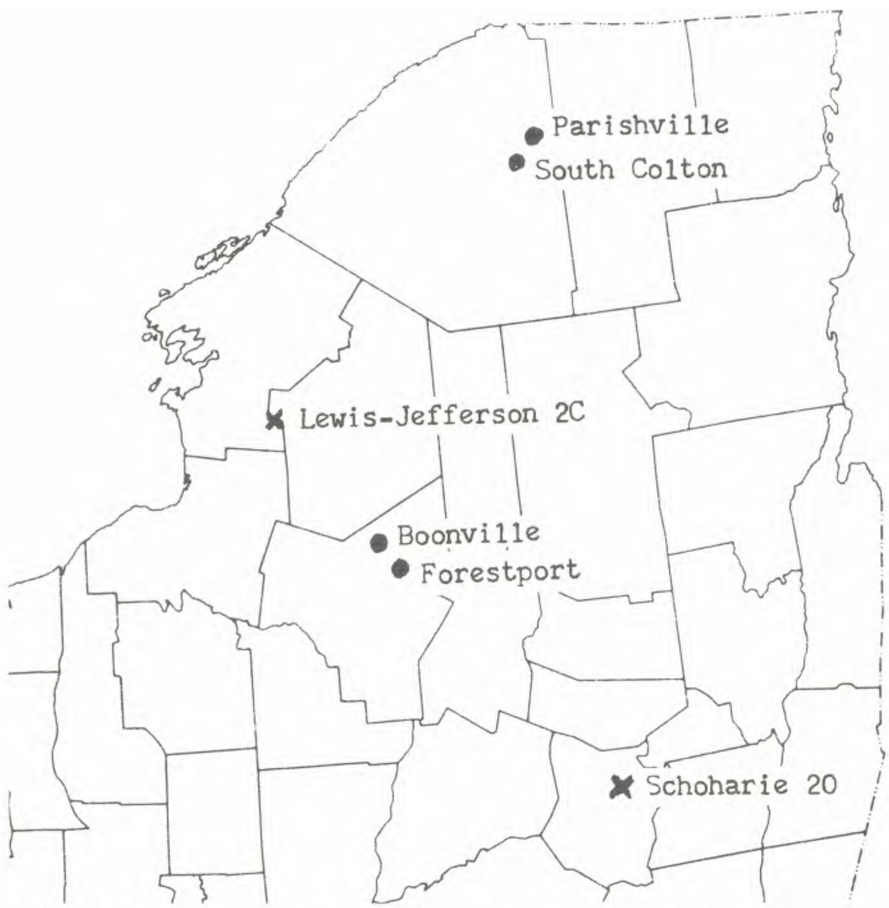

Figure 4.--Location of Schoharie 20 and Lewis-Jefferson Study Areas and the New York Seed Sources Represented.

Measurements

In general the procedure in taking measurements was the same as in Part I. Soil profiles were described and samples taken for organic matter, pH, and nutrient analysis. These analyses were carried out by the Soil Testing Laboratory of the Department of Agronomy, Cornell University.

Twenty dominant or codominant trees in each seed source planting were selected for measurement, as close to the soil pit as possible. In the case of the Schoharie 20 planting, the trees in each source were selected around the 3 pits in proportion to the slope position as follows: 8 from the upper slope, 6 from the middle slope and 6 from the lower slope. For each of the trees, the measurements were the same as those in Part I (height, diameter, branch angle, branch number, needle length, needle retention, number of crooks, and prevalence of sweep). In the case of the pruned trees at Lewis-Jefferson 2-C, the first two full whorls were used for branch measurements whenever a pruned tree was one of those selected. In addition, because of the known influence of seed source on the amount of winter yellowing (2, 4), needle color was measured in November. One pair of needles randomly selected from the upper, sun-exposed part of the crown was used, and the average color rating by Munsell color chips for the upper and lower needle surfaces, one-third the distance from the tip, was noted (6).

Results and Discussion

Schoharie 20 Area

The 15 soil samples ranged in organic matter from 3.2 to 5.2 percent, in pH from 4.3 to 4.6, and showed no appreciable differences in nutrient content. On the basis of this analysis and the soil profile descriptions, it was felt that the edaphic characteristics of the site for the 5 seed sources were fairly uniform and that the bulk of any variation in tree performance or characteristics could be attributed to ecotypic variation. It was found that there was no need to stratify within seed sources on the basis of slope position, for no differences occurred correlated with position. Therefore the means for 20 sampled trees were calculated and are presented in table 5. Chi-square tests of significant differences were used for needle retention and stem form characteristics. Homogeneity of variance and analysis of variance tests were applied to the data for the other characteristics, The results of these statistical tests are also presented in table 5.

The differences in total height achieved in 25 years from seed, or 23 years from planting., were highly significant. The Boonville and Parishville sources were significantly shorter than the Herbst Brothers and South Colton 33 sources. Seed-source height growth differences in Scotch pine have been demonstrated in New Hampshire, Michigan, Minnesota and Ontario (3, 8, 11, 12, 13, 15, 17), and in fact, in most of these studies, more striking differences occurred than between the sources which were used on Schoharie 20. Mean needle length showed highly significant differences, with the Boonville source being significantly shorter and the Parishville being significantly higher than all the rest. Stem form showed highly significant differences in this plantation, as expressed by number of trees with sweep and total number of crooks. While the Boonville source had twice as many trees with some sweep, as any other source, it had 66 percent fewer crooks than any other source. It does seem appropriate to use crook as a measure of stem

Table 5.--Observations of five seed sources, twenty-five years from seed. Planted on Schoharie 20 State Reforestation Area.

	Seed Source					Statistical analysis of differences
	Parish-ville	Herbst Bros.	South Colton '33	South Colton '32	Boon-ville	
Mean total height (feet)	33.1	36.2	36.5	34.3	32.4	Highly sign.
Mean d.b.h. (inches)	6.4	6.4	5.9	6.2	6.1	Non-sign.
Mean branch angle (degrees)	70.7	70.5	70.3	70.0	68.4	Non-sign.
Mean branch number	6.8	6.5	6.0	6.6	6.5	Non-sign.
Mean needle length (inches)	2.1	1.9	1.9	1.9	1.5	Highly sign.
Mean needle retention (years)	2.7	3.3	2.9	3.3	3.2	Non-sign.
Number of trees with stem sweep	3	5	1	4	12	Highly sign.
Total number of crooks	37	31	31	31	10	Highly sign.
Mean needle color (Munsell rating-Hue)	37.3	37.3	37.6	37.8	38.1	Non-sign.

Table 6.--Observation of seven seed sources, twenty-two years from planting. On Lewis-Jefferson 2-c State Reforestation Area.

	Seed Source							Statistical analysis of differences
	Fin-land	Forest-port	Ger-many	South Colton	Wurttem-burg	Czecho-slovakia	East Prussia	
Mean total height (feet)	25.7	40.1	39.5	39.2	36.2	37.4	36.6	Highly sign.
Mean d.b.h. (inches)	6.0	8.2	8.8	7.8	7.8	7.8	7.8	Highly sign.
Mean branch angle (degrees)	66	71	71	74	69	69	66	Highly sign.
Mean branch number	6.9	7.7	7.8	9.0	8.2	7.8	8.2	Significant
Mean needle length (inches)	1.9	2.5	2.6	2.5	2.4	2.5	2.6	Highly sign.
Mean needle retention (years)	3.3	3.0	3.1	3.1	3.1	3.2	3.2	Non-sign.
No. of trees with stem sweep	6	19	12	14	14	17	15	Highly sign.
Total number of crooks	13	12	16	8	13	14	16	Highly sign.
Mean needle color (Munsell rating)	31.0	37.0	36.5	35.5	36.0	35.0	34.0	Highly sign.

form variation in Part II studies, since the sources occupy one location and have the same exposure to most external factors which might cause this stem defect. No apparent explanation of these differences arises from the relative location of the seed source strips within the plantation. The Boonville source was an edge strip, on the southwest side of the block, adjacent to an open field Differences in stem defect due to crook and sweep have been previously shown for different Scotch pine races planted in this country in one location (3, 11, 13, 17).

None of the other characteristics measured showed significant differences, in spite of the fact that seed source differences have been shown on one site for at least diameter growth and winter foliage color (2, 11, 13). The relatively high Munsell rating (Green-Yellow Green=40.0) indicates that all of these sources in this environment would have satisfactory winter foliage color for Christmas tree purposes (i.e. no marked yellowing). The Boonville "strain" has been much sought by Christmas tree growers because of its good winter color.

Apparently the seed sources planted on this area represent only a small portion of the racial variation spectrum which occurs in this species. Hoping to obtain a better picture of the genetic variation which might occur on one site, the Lewis-Jefferson seed source experimental planting was investigated the following year.

Lewis-Jefferson 2-c Area.

The soils analysis indicated a high degree of uniformity in fertility, pH, and organic matter. Organic matter of the surface soils was in all cases greater than 6 percent, and pH varied only from 4.4 to 4.9. Depth to bedrock varied from 22 to 27 inches and the soils were all moderately well-drained loams. With such site uniformity it would seem that the bulk of any variation in characteristics or performance might be attributed to seed source differences.

The means for each of the characteristics for 20 trees of each of the 7 seed sources are presented in table 6, along with the results of the statistical analysis of the differences (the same statistical tests were used as for Schoharie 20). Significant differences between sources on this site were obtained for all characteristics except needle retention, and in fact the differences were highly significant for all of the remainder except mean branch number.

Much of the seed source difference found is attributable to the source from Finland. These trees grew slowest in height and diameter, had the shortest needles, the greatest winter yellowing and the least number of trees, with sweep (which was very high in all other sources), and this source was significantly different than all the others in these characteristics. While no statistical difference was demonstrable, it can be noted from table 6 that the Finnish source also had the smallest mean branch angle and along with the East Prussian source, had the sharpest mean branch angle. The Scotch pine provenance trials of the International Union of Forest Research Organizations have generally shown the Finnish or other Scandinavian sources to be among the slowest in growth (8, 15, 17,) among the best in stem straightness (3, 17) and to have the greatest degree of winter yellowing (2). The results of this study are in agreement for these three characteristics but show that the Finnish source may also have shorter needles than sources from lower latitudes.

The South Colton source had significantly fewer numbers of crooks than the others, but because of the prevalence of sweep, the stem form in general could not be rated as highly as the source from Finland. A comparison of these two sources, which indicates the remarkably good stem form of the Finnish source is shown in figures and 6. The Forestport and Czechoslovakian sources had the poorest stem form, in considering both crook and sweep.

Figure 5.--Scotch pine of Finnish provenance planted on Lewis-Jefferson 2-C State Forest.

Figure 6.--Scotch pine from seed collected near South Colton, N. Y., and planted on Lewis-Jefferson 2-C State Forest.

The number of branches per whorl for all of the seed sources at this location except the Finnish, was higher than for any other plantings examined during the course of this study. Part I of this study has suggested that branch number varies to some extent with environment. The occurrence of such large mean branch numbers at this Lewis-Jefferson site would also be suggestive of a degree of environmental influence on this characteristic.

Rudolph (13) noted differential susceptibility to porcupine damage in Michigan. Wright and Baldwin (17) also observed this in the IUFRO test in New Hampshire, and while their Scandinavian sources in general showed a low damage incidence, they mentioned particularly that a Finnish source had as high a percentage as many of the German provenances. While no measurements were taken of the incidence of porcupine damage in this New York study, differential porcupine damage was observed and recorded. There was little or no damage in the Finland and S. Colton sources, some scattered incidence in the German and Forestport sources and very heavy incidence in the Wurttemburg, E. Prussia and Czechoslovakia sources. No measurements were taken because the pattern of damage coincided with the seed source strip layout (i.e. the three sources furthest from the road had the heaviest damage, and two sources closest to the road were without damage). It was therefore assumed to be related to location rather than seed source In view of the findings in Michigan and New Hampshire, however, it is proposed that this be tested by examining an adjacent block where some of the same sources are represented but in a different pattern.

It is of some interest, and puzzlement, to compare the South Colton seed source (E 174) characteristics in this planting with those of the same seedlot (South Colton 33 - e 174) in the Schoharie 20 planting The mean heights were, of course, markedly different since both the age from planting and the site quality were not uniform. The greater average height attained by the 22-year-old trees on Lewis-Jefferson 2-C, as compared with the 25-year-old trees on Schoharie 20 indicated a better site at the former location The younger Lewis-Jefferson trees also showed greater mean diameter, although some of this better performance could be attributed to the light "thinning from below" previously alluded to Branch number per whorl and needle length of the trees from the same seedlot at the two locations were markedly different Mean number of branches per whorl was 3 greater and mean needle length 0.6 inches greater on the better site. This was in agreement with the findings in Part I which showed branch number and needle length differences among offspring from the same mother trees when planted on different sites. Moreover, the offspring from both Tree e4 and Tree 59 showed longer needles on the better sites. While the stem form of the South Colton seed source offspring was quite poor at both locations, at one location sweep was negligible and crook was very frequent, whereas sweep was common and crook very infrequent at the other site This is particularly puzzling in view of the results of Part I which showed no significant differences in occurrence of sweep among one-parent progeny on different sites. Unfortumately these two plantations were measured by two different men, and the dividing line between crook and sweep is not always sharp. It may have been that the standards used for this characteristic which involved the greatest amount of judgment of any of the measurements taken, was somewhat different for the two observers Such a difference in standards was only of importance in making this one inter-plantation comparison. All other comparisons are intraplantation where consistency of standards is the important thing.

Conclusions

There have been several investigations of plantations where Scotch pine of various seed sources or provenances have been planted in adjacent strips or rows on sites that were essentially uniform These studies have shown or implied that there are seed source differences in survival, height growth, diameter growth, stem form, winter foliage color, and in susceptibility to damage by porcupine, deer and white pine weevil. The demonstrability of such differences depends in part on the seed sources seLected from the range of ecotypes in this species. In one of the experimental plantations in the present study, the range was not large, and differences were shown only for height growth, needle length, and stem form. The second plantation included a greater range, and differences were shown for height growth, diameter growth, branch angle, number of branches per whorl, needle length, winter foliage color and stem form.

The first plantation (Schoharie 20) contained mostly New York State sources of unknown European provenance (probably German) and indicated little sharp difference which would distinguish one seed source as being more or less desirable as a source of future seed collections. All had good winter foliage color which would make them acceptable for Christmas tree production. The Boonville source had shorter needles than any of the other sources, grew more slowly in height than two of the other sources and although it had greater frequency of sweep, it had fewer crooks (a more serious stem defect.)

The second plantation (Lewis-Jefferson 2-c) contained several European provenances, and gave a better picture of the ecotypic variation in Scotch pine. The Finnish seed source stood out markedly from the others. It showed the slowest growth in height and diameter, the shortest needles, the best stem form and the greatest amount of winter yellowing of needles. This source also had a sharper branch angle than the source with the greatest branch angle, and fewer branches per node than the source with the greatest number, and while ranking lowest for both of these characteristics, was not significantly different than five of the other six sources.

The fortuitous inclusion of the same experimental seedlot in both plantations permitted some further observation of the effect of environment on certain tree characteristics. Differences in rate of height and diameter growth, in needle length and in number of branches per whorl were apparent, indicating that these characteristics are not genetically, tightly controlled.

LITERATURE CITED

1. Aird, P. L. and E L. Stone. 1954. A 45-foot tree measuring pole, Jour. Forestry 52: 203-204.
2. Baldwin, H, I. 1956. Winter foliage color of Scotch pine, Northeast. Forest Tree Improve, Conf. Proc. 3: 23-28.
3. Baldwin, H. I, 1956. Scotch pine surpasses red pine in early height growth. Fox Forest Notes No. 63. 1 p
4. Busgen, M. and E. Munch. 1931. The structure and life of forest trees. John Wiley and Sons. New York.
5. Callaham, R. Z and A. R. Liddicoet. 1961. Altitudinal variation at 20 years in ponderosa and Jeffrey pines. Jour. Forestry 59: 814-820.
6. Hamilton, Lawrence S. 1961. Further notes on the color description of foliage,. Jour. Forestry 59: 215-216.
7. Heiberg, S. O. and D. P. White. 1951. Potassium deficiency of reforested pine and spruce stands in Northern New York. Soil Science Soc. America Proc. 15: 369.
8. Hoist, Mark J. 1953. A provenance experiment in Scots pine (Pinus sylvestris). Canada Dept. Northern Affairs and Nat'l Resources, Silvicultural Leaflet 96. 4 pp.
9. Leyton, L. and K. A. Armson. 1955. Mineral composition of the foliage in relation to the growth of Scots pine. Forest Science 1: 210-218.
10. Littlefield, E. W. and E. J. Eliason. 1955. Seed collection and tree production of Boonville Scotch pine. N.Y. Forester 12(1): 18.
11. McGregor, W. H., D. D. Ross Cowan and Stephen H. Spurr, 1954. Three races of Scotch pine compared in Southeastern Michigan. Univ., Michigan. Michigan Forestry No. 5: 2 pp.
12. Rudolph, Paul O. 1948. Scotch pine seed sources for Northeastern Minnesota, Minnesota Acad. Science Proc. 16: 25-26.
13. Rudolph, Paul O, 1948. Variation in Scotch pine. Papers Michigan Acad. Science, Arts and Letters. 34: 57-68.
14. Rudolph, Paul O. 1949. Winter damage and seed source of planted pines in Northern Minnesota Minnesota Acad. Science Proc. 17: 74-79.

15. Rudolph, Paul O. and Paul E. Slabaugh. 1958. Growth and development of Scotch pine in Lower Michigan (15-year results) Lake States For. Expt. Sta. Tech. Note 536. 2 pp.

16. Stone, Earl L. Jr. 1953. Magnesium deficiency of some Northeastern pines. Soil Science Soc. America. Proc. 17 297-300.

17. Wright, Jonathan W. and Henry I. Baldwin. 1956. Report on an 18-year-old Scotch pine provenance test in New Hampshire. Northeast For. Tree Improve. Conf. Proc. 3: 18-21.

18.York, H. H. and E. W. Littlefield. 1942. The naturalization of Scotch pine, Northeastern Oneida County, N. Y. Jour. Forestry 40(7) 552-559.