24 Year Results of a Norway Spruce Seed Source Test in New York State

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ABSTRACT: -- Height, diameter, and survival measurements were recorded after 24 years in a Norway spruce (Picea abies) seed source study. Seven seedlots were tested in New York State on 3 dramatically different sites with 4 replications per site. To eliminate edge effects, a central 6 tree by 6 tree subplot within each 90 to 100 tree plot was measured.

Three seed sources were from New York State and have undergone one or more generations of natural selection. Collectively these sources were taller and produced greater volume growth than the European seed sources.

The highly significant interaction between seedlots and location for volume production indicates that it will be necessary to subdivide New York State into two Norway spruce planting zones: Central and Southern zone and a Northern Adirondack zone.

OBJECTIVE

To determine if a single broadly based population of Norway spruce (Picea abies) can be expected to perform well in New York State across all reasonable sites for the species.

MATERIALS AND METHODS

Experimental design

A factorial design was used with 7 seedlots, 3 planting sites, and 4 randomized complete blocks per site. Each of the seven seedlots was represented once per block by 100 tree plots (ten-10 tree rows per plot) at Heiberg Forest and Star Lake. At Pack Forest 90 tree plots (nine-10 tree rows/plot) were used. No border rows were planted between plots, but each planting was surrounded on all sides by two or more rows of border trees to reduce edge effects. Bareroot 2-3 seedlings were used for all plots and border rows.

Site description and plantation establishment

Three test sites were planted in May, 1956 (Figure 1). One at Heiberg Memorial Forest near Tully, New York, on a west facing 0 to 5% slope using tractor made holes. Heiberg Forest is representative of growing conditions in the southern tier region of New York in terms of soil characteristics, length of growing season, and rainfall patterns. The second test was planted using a Syracuse tree plow at the Lathrop Pack Memorial Forest near Warrensburg, New York, on a flat to slightly rolling site on the floodplain of the Hudson River. This site is representative of the southern portion of the Adirondack region in terms of soil type, length of growing season, and rainfall patterns. The third test site was located near Star Lake, New York, on private property owned by Glenn Brown. The Star Lake site is the poorest of the three sites and is representative of the northern Adirondack region (Table 1).

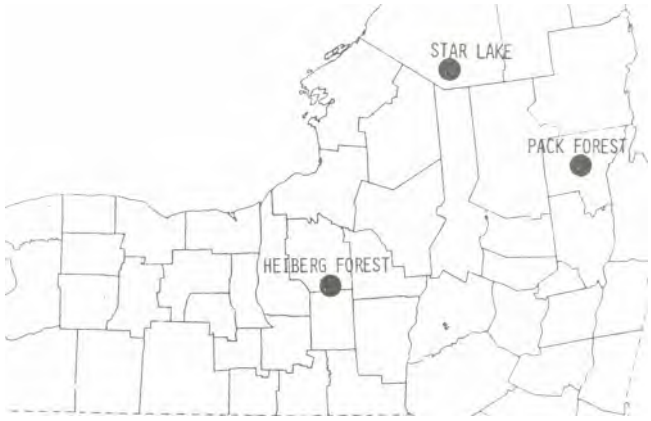

FIGURE 1. NORWAY SPRUCE SEED SOURCE TEST SITES, PLANTED 1956.

Table[1]: Soil Characteristics of Norway spruce Seed Source Test Sites

Location	Sample Depth (in.)	Texture	Percent Sand	Silt	Clay	pH	Organic Matter	Cation exc. Capacity (Mg/100g)	N(%)	P (ppm)	K (ppm)	Ca (PM)	Mg (ppm)	Mn (ppm)
Heiberg Forest	0-6	Loam	43	42	16	4.7	9.0	24	0.3	13	103	1077	89	34
	6-12	Loam	39	45	15	5.0	6.8	20	0.2	5	51	789	56	14
	12-18	-[1]						16	0.2	2	43	678	38	11
Pack Forest	0-6	Sand	87	10	4	4.8	6.8	18	0.2	12.0	42	142	8	10
	6-12	Sand	87	11	3	5.1	4.4	13	0.12	5.0	7.8	46	5	6
	12-18	Sand	88	9	3	5.5	3.3	12	0.08	3.0	6	70	3	
Star Lake	0-6	Loamy Sand	78	19	4	5.0	7.1	16	0.17	8.0	26	168	15	6
	6-12	Loamy Sand	80	t	3	5.6	5.0	14	0.12	3.0	6.5	199		2
	12-18	Loamy Sand	85	12	3	5.4	3.0	9.7	0.06	4.0	7.0	78		

[1]insufficient sample to conduct these analyses.

Seedlot description

Seven Norway spruce seedlots were tested. Four of the seedlots were collected in stands in New York. Of these, two of the seedlots came from the same stand but were collected in different years. The original European source of these local seedlots is unknown. The other three seedlots were from central France, central Austria, and southeastern Sweden. They were purchased from a commercial seed dealer and more precise locations were not available (Table 2).

Table 2 : Norway spruce seedlots included in 1956 test plantings.

Experimental Planting No.	Original Seedlot Number	Name	Description
1	50-1	Great Bear Springs (1950)	Collected by Experiment Station personnel from the Great Bear Springs Plantations south of Fulton, N.Y. The seed was obtained from cones cut by squirrels. Plantation was planted about 1906.
	50-4	Huntington Forest	Obtained from the plantation located near the top of the first hill to the east of the entrance road into Huntington Forest. The cones were squirrel cut. Plantation seed source unknown, planted about 1915.
3	50-3	Woodgate	Collected by Prof. Heiberg and his class from the Mason Home Camp north of Round Lake at Woodgate, N.Y. Seed source of the planting is unknown. The stand was established by direct seeding, in mixture with Scotch pine.
	50-7	Central Austria	Seed purchased from Schumacher. Information in addition to general region not available.
5	47-5	Great Bear Springs (1947)	Seed obtained from Great Bear Springs plantations but collected in 1947.
6	50-8	South East Sweden	Seed purchased from Schumacher. Additional information beyond general region not available.
	50-6	Central France	Seed obtained by purchase from Schumacher. Additional information beyond general region not available.

Intermediate treatments

Two years after establishment, Pack Forest plantings were treated with 200 lb./acre muriate of potash 0-0-60. In 1970 every other row in the Heiberg plots was removed (50% thinning). In 1981 every other row and every other tree in the remaining rows were removed (75% thinning) from the Pack Forest plantation. No treatments have been recorded for the Star Lake planting.

Data collection and analysis

In evaluating these three plantings, the factors of interest were survival and growth. The variables chosen to measure these factors were the number of live trees on each plot, height, and DBH. From the field measurements, average volume per tree and volume per acre were calculated.

The 1970 thinning had reduced the Heiberg Forest plots to 5 rows x 10 trees per row. To reduce edge effects, an interior 3 row x 6 trees per row subplot was measured. At Pack Forest measurements were taken from all trees removed in the systematic thinning, but to eliminate edge effects, the analysis was again limited to an interior plot of approximately 18 trees. At the Star Lake site, trees 3 through 8 in rows 3, 5, and 7 were measured. Thus, on all 3 sites a systematically chosen interior subplot containing approximately 18 trees was measured. Plot means were computed and analysis of variance was used to partition the variability due to location, seed source, and, as one measure of provenance stability, location x seed source interaction. The *variance* components were calculated to examine which factors had the strongest influence on growth parameters. The Duncan's multiple range test was used to determine which treatment means differed significantly (5% probability level).

RESULTS

Effects of site on growth parameters

As expected, the largest factor influencing growth rate and form was variation in soil and climatic factors among the 3 test sites. Almost 75 percent of the total variation in volume per acre was due to differences among sites (Table 3). Estimated standing total volume per acre on the Heiberg Forest site was twice that found on the Pack Forest site and over 4-1/2 times that found on the Star Lake site (Table 4). Even this sizeable difference is an underestimate because the volume removed by the 50 percent thinning in 1970 is not included in the Heiberg estimates.

Table 3: Volume per acre variance components. Combined analysis for all 3 locations.

(R^2 = 0.81)

	Degrees of Freedom	Sums of Squares (X10-4)	Variance Components (%)	
Location	2	4289	74.4	***
Block	9	89	0	NS
Seed Source	6	753	7.45	***
Exotic vs Land Race	(1)	(445)	(5.95)	***
Location x Seed Source	12	376	5.29	**
Error	54	536	12.82	
Corrected Total	83	5506	99.96	

N.S. No statistically significant difference, P = .05.

** Statistically significant difference, P = .005.

** Statistically significant difference, P = .0001.

Table 4: Mean values for growth factors for each site averaged over all seed lots.

Location	Ht.	DBH	Volume per tree (cubic ft.)	Volume per acre (cubic ft.)	Survival (%)
Heiberg Forest	32.8 a[1]	5.3a	2.84 a	2302 a	94 a
Pack Forest	23.2	3.5b	1.01 b	1150 b	92 a
Star Lake	12.1	1.7c	0.39 c	495 c	74 b

1 Means followed by the same letter do not differ significantly (P = 0.05.) Duncan's multiple range test, (Helwig et al., 1979).

Effects of seed source on growth parameters

Differences in growth among the 7 seedlots were also highly significant (P=.001 or greater) for volume per acre (Table 3). There was a 2.75 fold difference in volume per acre between the best seed source, "Great Bear Springs," and the poorest seed source, "Central Austria." No significant differences (P=0.05) among seedlots in survival was found (Table 5).

Table 5: Mean values for growth factors for each seedlot averaged over all three sites.

#	Seedlot	Ht. (ft.)	DBH (in)	Volume per tree (cubic ft.)	Volume per acre (cubic ft.)	Survival (%)
1	Great Bear Springs'[1]	25.0 a,b	3.8 a	1.59 a	1637 a	89 a
2	Huntington Forest	25.9 a	3.7 a	1.64 a	1530 a	85 a
3	Woodgate	23.5 a,b	3.8 a	1.73 a	1456 a	84 a
4	Central Austria	15.5 c	2.7 b	0.77 c	726 c	87 a
5	Great Bear Springs'	24.4 a,b	3.7 a	1.55 a	1521 a	90 a
6	South Eastern Sweden	21.8 b	3.4 a	1.08 b	1018 b	87 a
7	Central France	22.8 a, b	3.5 a	1.55 a	1419 a	85 a

[1] Seedlots 1 and 5 were collected in the same stands in 1950 & 1947 respectively.

Genotype site interaction

Preliminary analysis showed that the interaction component between site and seedlot was not significant (P=.05) for height, diameter or survival. (File data not included in publication.) It was, therefore, surprising to find highly significant differences (P=0.001 or greater) among the 2 variables derived directly from these more simple variables: volume per tree and volume per acre (Tables 3, 4).

When the variance components were estimated, for volume per acre, the seed source variance component accounts for 7.45 percent of the total and the location seed source component accounts for 5.29 percent (Table 3). Because of this highly significant seed source x site interaction, several alternate analyses were conducted. The Star Lake site had the poorest survival and growth so this location was eliminated from the analysis. This step reduced the seed source x site interaction component of variance from 5.29 to 4.8 percent and almost doubled the proportion of the total variance due to seed source from 7.45 to 14.1 percent (Table 6).

Table 6: Volume per acre variance components excluding Star Lake location.

(R^2 = 0.86)

	Degrees of Freedom	Sums of Squares (X10-4)	Variance Components	
Location	1	1787.6	64.7	***
Block	6	61.0	0	NS
Seed Source	6	870.0	14.1	***
Exotic vs Land Race	(1)	456.6	(lu 0)	***
Location x Seed Source	6	240.6	4.8	*
Error	34	481.2	16.0	
Corrected Total	53	2959.1	99.6	

N.S. No statistically significant difference, P = 0.05.

* Statistically significant differences, P = 0.05.

*** Statistically significant differences, P = .0001.

Analysis of variance performed on each site indicated that volume production per acre was under substantial genetic control with 58.6 percent and 52.3 percent of the total variation being due to seed source at Heiberg and Pack Forests respectively. The Star Lake planting was so highly variable that none of the treatment effects were significant (P=0.05) (Table 7).

Survival

Survival at Pack Forest and Heiberg Forest averaged 94 percent and 92 percent and did not differ significantly (P = 0.05) between the two sites. The Star Lake planting averaged 74 percent survival and did differ significantly (P=0.05) from the other two locations (Table 4). Differences in survival among seedlots were not significant (Table 5).

Differences between local seedlots and European sources

When mean values were averaged over all three locations and seed sources were grouped on the basis of whether they were of local origin or were brought directly from Europe, the local sources performed significantly better or matched the performance of the exotics in all respects. They were 4.7 feet taller, 0.5 inches larger in diameter, averaged 0.5 cubic feet per tree, and 478 cubic feet per acre more total volume. All these differences were highly significant (P=0.001 or>) . Somewhat surprisingly there was no significant difference in survival between the two groups (Table 8).

Table 7. Volume per acre variance components by location.

Sources of Variation	Degrees of Freedom	Heiberg Forest (R^2=0.71) Sums of Squares (X10 -4)	Heiberg Forest Variance Components (%)	Pack Forest (R^2=0.71) Sums of Squares (X10-4)	Pack Forest Variance Components (%)	Star Lake (R2=0.46) Sums of Squares (X10-4)	Star Lake Variance Components (%)
Block	2	38.5	01 NS	22.5	6.9 NS	138.4	20.7 NS
Seed Source	6	984.4	58.6 ***	126.1	52.3 ***	255.9	0 1 NS
Exotic vs Land race	(1)	(463.5)	(42.2) **	(74.2)	(48.8) ***	(3.1)	(0)1 NS
Error	18	422.4	41.4	61.8	40.8	464.4	79.3
Corrected Total	27	1 445.4	100.	210.4	1 00.	858.7	100.

N.S. No statistically significant differenceswere detected, P = 0.05.

** Statistically significant differences were detected, P = 0.005.

*** Statistically significant differences were detected, P = 0.0001.

Table 8: Mean values for growth factors for the mean performance of the local seedlots vs. the 3 European provenances.

Seedlot	Ht. (ft.)	DBH (in.)	Volume per tree (cubic ft.)	Volume per acre (cubic ft.)	Survival
Local Sources	24.7 [1] a	3.7 a	1.63 a	1534 a	87.1 a
European Sources	20.0 b	3.2 b	1.13 b	1056 b	86.5 a

1 Means followed by the same letter do not differ significantly (P =0·05 .) Duncan's multiple range test, (Helwig et al., 1979).

DISCUSSION

Usually the genetic entry x site interaction component increases as the genetic variability within the entry being tested decreases (Kleinschmit, J. 1979). Clonal tests often have a high genotype x site interaction, full-sib families next, followed by half-sib families. Often there is enough buffering capacity among the different genotypes within a provenance that provenance x site interactions are small enough to ignore. However, in this study the provenance x site interaction is not only statistically significant, but of a sufficient magnitude to be biologically important.

Norway spruce improvement strategy

On the basis of these tests, two seed zones will be considered in future planting and improvement efforts: a Southern and Central zone and a Northern Adirondack zone.

The poor and highly variable performance of Norway spruce at the Star Lake site indicates that the populations currently available are not suited for the Northern Adirondack zone. If it is found to be important to develop a strain for these areas, the best option will be to seek cooperators in the Scandinavian countries where there are several well developed improvement programs already underway. A provenance study limited to the more northerly part of the natural range of Norway spruce will provide populations adapted to these harsh growing conditions.

Because of the greater growth rate found on the Heiberg planting and the general observation from many commercial plantations that the southern portion of the state is superior for Norway spruce, selection of superior trees and progeny testing of those trees will be concentrated in the Central and

Southern zone. Existing populations are well suited to this zone and will continue to supply the bulk of the seed for immediate use. Selected "+" trees from commercial plantations established from these seed sources have been established in grafted seed orchards and more selections are being made.

At present, differentiating between these two zones will be of limited use in that suitable seed is only available for the Central and Southern zone. But, by dividing the state in this way, the lack of Norway spruce populations suitable for the harsher zone is clearly identified and will hopefully be corrected.

These zones should be looked upon as initial approximations. More intensive testing of individual families and clones will probably lead to subdivision within one or both.

CONCLUSIONS AND RECOMMENDATIONS

1. The State of New York should be divided into two planting zones for Norway spruce: a Central and Southern zone and a Northern Adirondack zone.

2. The three local populations of Norway spruce grow well in the Central and Southern zone and the bulk of commercial plantings should be established from these or other naturalized populations.

3. No suitable Norway spruce seed is currently available for the Northern Adirondack zone.

4. If Norway spruce is to be planted in the Northern Adirondack zone a limited range provenance test should be conducted with seed from the Scandinavian countries.

5. The variation among the three local seedlots indicates that considerable genetic gain can be realized from further provenance testing as well as selecting superior phenotypes from stands established from these seedlots.

LITERATURE CITED

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