Minnesota Forestry Research Notes

No. 251
July 15, 1974

Productivity of White Spruce Seed Sources in a Minnesota Test Planting[1/]

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Provenance studies of white spruce, Picea glauca (Moench) Voss, have shown that the juvenile height growth of several southeastern Ontario sources is frequently greater than that of local materials. This superiority has been consistent in test plantings from New Brunswick to North Dakota and frequently has exceeded 15 percent (Nienstaedt, 1969; Nienstaedt and Teich, 1972). The translation of these findings into the production of genetically better planting stock is biologically feasible and apparently economically attractive (Lester, 1972). Actual gains in productivity will depend upon the persistence of the superiority into maturity and the interaction between trees and a particular environment. Evidence from one older test suggests a strong juvenile-mature correlation (Nienstaedt, 1969); but an accumulation of data is needed before the magnitude of gains can be accurately estimated. This report summarizes measurements of growth and specific gravity in a test in northcentral Minnesota 15 years after establishment and provides further insight into the potential value of certain southeastern Ontario sources.

Materials and Methods

The test planting was established in Gunn Memorial Park near Grand Rapids, Minnesota (47.5°N) in the spring of 1958. Materials included the 19 white spruce seed sources from Ontario and Quebec and the three Minnesota sources listed in the table. The Canadian materials were grown for two years (1954 and 1955) by the Petawawa Forest Experiment Station at Chalk River, Ont. and transplanted to the Hugo-Sauer Nursery in Rhinelander, Wisconsin. In 1958 the 2-2 seedling were shipped to Minnesota for planting. The three Minnesota collections (see table) were representative of materials being planted at that time and were presumably grown from seed collected in Minnesota. Source 3393 was from the General Andrews State Nursery and Source 3365 was from the Knife River Nursery of the Kimberly-Clark Corporation. Both were made up of 2-2 transplants. Source 3394 was also obtained from the General Andrews State Nursery but consisted of 4-0 seedlings.

Each of the three replications planted contained a square plot of twenty-five trees from each source. Replications were surrounded by 2 border rows and each plot was surrounded by a single border row of Source 3393 (see table). Spacing was 5 x 5 feet. Early survival of the planting was excellent and only 48 plot trees were lost during the first three years after planting. These were replaced in the spring of 1961.

1/This study is being carried out in cooperation with the Petawawa Forest Experiment Station, Ontario and North Central Forest Experiment Station, USDA. Establishment and maintenance support has been provided in part by the Charles K. Blandin Foundation, Grand Rapids, Minnesota.

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In 1972, fifteen years after plantation establishment, survival, growth and the desire to increase flowering for research purposes dictated thinning. At that time trees averaged over 20 feet in height and 3.5 inches in diameter at breast height. Less than 4 percent of the "plot" trees were missing with roughly two-thirds of the losses occurring in 1965 when Christmas trees were inadvertently cut in the planting.

In the winter of 1972-73 the plantation was thinned systematically. Prior to thinning, diameters at 4 1/2 feet (dbh) were measured to the nearest .1 inch, and total heights were measured to the nearest .1 foot for all trees. During thinning a cross-section of the bole approximately 2 inches thick was taken from the base (approximately .3 foot above the ground) of six trees from each source. In addition, ten sample trees, each from a different source and representing a range of diameters, were selected and their bole diameters measured at 4 foot intervals from the base to the tip. On these trees bark thickness was determined and a cross-section of the bole taken at each measurement point. All wood samples were stored at low temperatures (40°F) in sealed polyethylene bags.

Heights and diameters were used to estimate whole tree cubic foot volume inside the bark using the equation developed for plantation grown white spruce by Popovich (1972) where:

$$\text{Volume} = \frac{(.02345 + .17977\ \text{dbh} + .34456\ \text{dbh}^2)}{144} H$$

Volumes obtained for the ten sample trees by this formula were compared to those computed using Smalian's formula for the 4 foot sections, treating the stump as a cylinder and considering the tip a paraboloid. Volumes estimated by the formula were consistently higher than those computed using actual stem measurements. Regression analysis indicated the relationship between the differences and the formula values was -.0107 + .1327 (Formula Value). All tree volumes were adjusted using this relationship, and source means computed.

Upon removal from storage the bark was removed from wood samples, and their volumes determined using an immersion technique (Desch, 1973). Samples were oven dried, weighed and their specific gravity calculated on a green volume basis. Specific gravity determinations were made for the samples from the bases of six trees per source and for all cross-sections from the ten sample trees. In the sample trees mean specific gravity decreased slightly from the base to the top of the first 4-foot section (from .318 to .307) and then increased with height (to .363 at 16 feet). This trend was unexpected and may reflect the high proportion of bole within the crown and/or be peculiar to the rapid growth of the plantation. Average specific gravity of a sample tree was estimated by weighing the values obtained from cross-sections by the volume of adjacent segments of the bole. Despite the change of specific gravity with height, the specific gravity of a sample from the trees base was close to the average value estimated for the whole tree with a mean difference of .009 for the ten sample trees. This close agreement between values for whole trees and samples from the bases led to the computation of mean specific gravity for each source using values obtained from the samples taken at the base of six trees.

Results

Plantation and source means for dbh, total height and volume are given in the table. Growth of the plantation has been exceptional and indicates the high potential of white spruce. Total volume of the plantation was estimated to be 1,122 cubic feet per acre. This compares favorably with the 1,072 cubic feet per acre caluclated using Wamback's (1967) prediction equation for red pine at a similar age and spacing given a site with an index of 75.

Table. Origin and productivity of 22 white spruce seed sources in a 15-year-old northcentral Minnesota plantation.

Number	Origin: Province (state), location	Origin: Altitude (feet)	Origin: Latitude (°N)	Origin: Longitude (°W)	Mean dbh (inch)[1]	Mean Height (feet)[1]	Mean Specific Gravity[2]	Mean Volume (ft^3)[1]	Volume x S.G.
3376	Ont., Maple Leaf	1250	45°15'	77°50'	4.0	22.8	.337	.944	.318
3375	Ont., Denbigh	1100	45°15'	77°20'	4.0	22.7	.332	.919	.305
3378	Ont., Carnarvon	1050	45°04'	78°42'	3.9	22.7	.330	.870	.287
3374	Ont., Vankleek, Hill	250	45°30'	74°40'	4.1	20.8	.306	.887	.271
3379	Ont., Sand Lake	1300	45°38'	79°10'	3.8	21.9	.331	.806	.267
3380	Ont., Sundridge	1100	45°45'	79°10'	3.8	21.8	.303	.778	.236
3390	Ont., Essa Twp.	950	44°18'	79°50'	3.7	21.1	.319	.734	.234
3387	P.Q., St. Maurice River	500	46°50'	72°46'	3.2	19.0	.367	.618	.227
3388	Ont., So. Monaghan Twp.	800	44°09'	78°18'	3.5	20.8	.319	.709	.226
3365	Mn., Knife River Nur.	----	-- --	-- --	3.6	19.4	.327	.667	.218
3377	Ont., Algonquin Park	1500	45°33'	78°40'	3.5	20.0	.325	.669	.217
3389	Ont., Rama Twp.	750	44°41'	79°18'	3.5	19.7	.326	.663	.216
3383	P.Q., l'Annonciation	900	46°25'	74°15'	3.4	20.2	.333	.628	.209
3386	P.Q., St. Charles DeMandeville	500	46°21'	73°21'	3.4	19.7	.325	.602	.195
3382	P.Q., Maniwaki	900	46°25'	74°52'	3.4	19.3	.324	.595	.192
3392	P.Q., Trois Pistoles	400	48°08'	69°10'	3.2	19.0	.361	.524	.189
3385	P.Q., St. Zenon	1500	46°35'	73°50'	3.2	18.7	.325	.574	.187
3391	Ont., Holland Twp.	1200	44°25'	80°50'	3.4	18.7	.309	.594	.183
3384	P.Q., Harrington Forest Farm	700	46°50'	74°40'	3.3	18.4	.326	.549	.179
3381	Ont., Potter	900	48°52'	80°01'	3.2	20.1	.327	.547	.179
3394	Mn., General Andrews Nursery	----	-- --	-- --	3.1	19.1	.323	.537	.173
3393	Mn., General Andrews Nursery	----	-- --	-- --	2.5	15.2	.389	.351	.136
All Sources Combined		----	-- --	-- --	3.5	20.1	.325	.671	.220

1/Based on all surviving trees in a source.

2/Average of samples from the bases of 6 trees.

Analyses of variance using plot means indicated significant differences (.05 level) among sources for the three growth parameters. As in previous studies (Genys, 1965; Nienstaedt and Teich, 1972) the most vigorous sources (3374, 3375, 3376, and 3378) were found among southeastern Ontario collections. Genys (1965) reported the height at 10 years from seed for a Maryland plantation containing 15 of the same Ontario and Quebec sources. The Maryland test suggested two clinal patterns in which growth potential decreased from east to west from points near the St. Maurice River in Quebec and near Denbigh in southeastern Ontario. In this test heights and volume tended to decrease with distance in all directions from southeastern Ontario. There was no clear indication of a cline among Quebec sources. Differences in patterns in the two tests probably reflect the testing environments.

Growth of all materials from Minnesota nurseries (sources 3365, 3393 and 3394) was below the plantation mean. Since seedlings from the three Minnesota sources were produced in different nurseries than the bulk of the materials, their relatively poor performance may not only reflect source differences. However, the volume of the best source (3376) was 42 percent greater than the best of the material from Minnesota nurseries (3365) and 41 percent greater than the plantation mean. The size of these differences suggest source effects which have practical as well as statistical significance.

The mean specific gravity for the plantation was .325, which is close to the average value of .335 reported for older, plantation grown white spruce by Chang and Kennedy (1967). Source values, given in the table, ranged from .303 for source 3380 (Sundridge, Ont.) to .389 for source 3393 (General Andrews Nursery). Analysis of variance indicated that the differences among sources were significant (.05 level). Mean volume and mean specific gravity of sources were negatively correlated with the r of -.43 significant at the .05 level.

The differences among sources in specific gravity and the negative correlation of specific gravity with volume led to the computation of the product of mean volume and mean specific gravity for each source as a measure of productivity. These values are given in the table and the sources are ordered using this measure. While there were some changes in ranking when this measure rather than volume was used, the impact was small. The best source exceeded the poorest in volume by a factor of 2.69, and the factor for specific gravity was only 1.27, which accounts for the minor changes in ranking.

To date, the most productive sources in the plantation, by any measure, are those from southeastern Ontario. The magnitude of the differences between these sources and materials from local nurseries and the plantation mean indicates the large impact seed source can have on plantation productivity and the great potential of southeastern Ontario sources in Minnesota. Outstanding sources such as Maple Leaf (3376), Dembigh (3375) and Carnarvon (3378) should be considered for both direct use and for breeding work in Minnesota.

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