EVALUATION OF OPEN POLLINATED PAPER BIRCH (*BETULA PAPYRIFERA* MARSH.) SEED SOURCES GROWN IN DIFFERENT CONTAINERS AND MEDIA*

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ABSTRACT.--Twelve week growth of paper birch seedlings from 50 individual tree sources was evaluated using two container and media types. Growth was significantly greater in Spencer-Lemaire Book Planters than in Plant Band containers. Seedlings grown in Pro-Mix BX were larger than those grown in peat-vermiculite (4:1).

Seedlings from plus trees were significantly greater in height and root collar diameter than those from average parents. Regional differences in performance were observed.

INTRODUCTION

Paper birch is an economically and aesthetically important forest tree species in the Northeastern United States, and several Canadian Provinces (Cliff 1969, McDonald 1969, Quigley and Babcock 1969). Existing research pertaining to artificial regeneration of the species, particularly that which would utilize superior genetic strains is rare, while basic research in birch genetics has faired reasonable well. Improvement of growth rate

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which will increase wood production, is highly desirable, but research for genetic improvement of tree quality deserves the greatest attention (Clausen and Garrett 1969).

Researchers have pointed out the value of using containers in growing hardwoods, both as a research tool for the forest scientist (Brooks and Cech 1979), and for superiority of container-grown seedlings over bare-root stock for artificial regeneration (White, et al. 1970, Wheeler and Anderson 1979, Tinus, et al. 1974, Tinus and McDonald 1979). The uniform environment required for study of genotype-environment interaction can be provided in a greenhouse and equal treatments can be applied to the various seed sources. Thus, the relative superiority of a seed source under a prescribed cultural treatment may be expressed during the early growth period (Namkoong 1979).

Successful establishment of hardwood plantations has not always been a reality. Hardwood seedlings, to be successful, must often be able to survive harsh site conditions. Rapid early growth with sufficient root and shoot development must occur for the seedling to withstand the rigors of early competition (Stern and Roche 1974). Such accelerated growth can be obtained in controlled environments (Krizek 1972, Hanover and Bongarten 1977). Further, faster seedling growth possible in container systems reduces the time interval from seed collection to outplanting, minimizing generation time in progeny testing and seed orchard establishment.

In this paper, we report on variation in height, root collar diameter, and number of leaves in paper birch progeny from 42 open-pollinated superior and average seed sources at age 12 weeks. Two container types, and two media were tested.

MATERIALS AND METHODS

Open-pollinated seed from 50 individual tree sources was supplied by the U. S. Forest Service, Northeastern Forest Experiment Station, and by the University of Maine. Twenty-five sources were from average selections and 25 from plus trees. Germination was initiated on March 16, 1979, in a greenhouse under 24h photoperiod with supplemental fluorescent light. Seeds were placed on filter paper in petri dishes. A 1% hydrochloric acid solution was used to retard fungal growth on seeds. Sharp fluctuations in temperature inhibited germination so after 10 days the petri dishes were moved to a germination room, and were placed under 24h incandescent and fluorescent lighting at 32±3C. In addition, the 50 seed sources were replicated to replace any damaged seed and to insure against loss to fungal growth.

Two container types were selected for testing. The Spencer-

Lemaire Book Planter (SL)[1] was chosen for its control of root spiral by lateral ribbing, and Plant Bands (PB) (4.5 x 8 x 20 cm) for their large cubic volume. A commercially available medium, Pro-Mix BX, and a 4:1 sphagnum peat and vermiculite mix were tested in the SL containers.

Containers were arranged on two greenhouse benches according to a randomized complete block design with three blocks. Pro-Mix and the peat-vermiculite mixture were each tested in three blocks of SL containers. Three blocks of PB containers were tested with Pro-Mix. Each seed source was represented as a 16 tree plot located in each block. Seedlings grown in the three blocks of SL containers with Pro-Mix, were outplanted near Twin Mountain, New Hampshire, upon completion of the 12-week greenhouse experiment.

The germinants were transplanted from petri dish to container (one cell) when the first primary leaf appeared in at least 16 seeds, allowing one complete plot to be filled for a seed source in a given block. Seedlings were planted first in the Pro-Mix/SL blocks, second in the peat-vermiculite/SL blocks, and third in the three PB blocks. This was done to insure more uniform seed source distribution across all SL blocks (six total). Survival in all containers and media was excellent, but due to low germination (approximately 45%) in the petri dishes, there were 42 complete tree plots in the Pro-Mix/SL blocks, 25 seed sources complete in the peat-vermiculite/SL blocks, and 15 were complete for the PB blocks. Time of planting for each completed seed source per block was recorded for use as a covariate in statistical analyses.

Containers were maintained under 20h photoperiod with supplemental fluorescent light. Watering was done twice a day with a fan nozzle. During the first two weeks of development, seedlings were provided with 16-32-16 (N:P:K) fertilizer application to stimulate initial growth. This was followed by a weekly application of 20-20-20 fertilizer.

After 10 weeks in the greenhouse, those seed sources that contained a full complement of seedlings across all replications were moved to a lathe house (45% shade) for a two week period of hardening off. Following the 12 week growth period, seedling height, root collar diameter, and number of leaves were measured. One- and two-way analysis of variance and covariance were performed to detect variation within and among seed sources, media, and containers for all measurements. Multiple comparison among treatment means were computed using the Bayesian K-ratio t (LSD) Rule (Chew 1977, Smith 1978).

RESULTS

Variation in Containers and Media Type

Container performance -- Differences in seedling height, root collar diameter, and number of leaves were quite pronounced between seedlings grown in Plant Bands (PB) and Spencer-Lemaire Book Plants (SL). Two-way ANOVA was performed on covariance adjusted means of 15 seed sources grown in Pro-Mix BX.

Variation between container types was statistically significant (1%) for all three variables. The SL Seedlings performed significantly better than their PB counterparts (Table 1). Spencer-Lemaire seedlings had a greater average number of leaves (14.9 vs. 10.6), produced greater root collar diameter per seedling (.331 cm vs. .139 cm), and showed greater average height performance (26.7 cm vs. 4.4 cm).

Media performances -- ANOVA was performed on covariance adjusted means from 25 sources between the Pro-Mix media and peat-vermiculite, all of which were grown in the SL container type. Seed source performance (for height and root collar diameter) was significantly (1%) greater in Pro-Mix BX (Table 1). Mean Pro-Mix seedling heights were twice as great as the peat-veimiculite seedlings (24.0 cm vs. 12.5 cm), and root collar diameter was greater in Pro-Mix (.308 cm vs. .235 cm). Variation in number of leaves was low but there were significantly more leaves in peat-vermiculite (13.7 vs. 15.0).

Variation in Seed Source

Performance differences between average and select seed sources -- One-way ANOVA of covariance adjusted means was used to establish any differences between 24 superior seed sources and 18 average seed sources grown in SL/Pro-Mix (Table 2). Statistically significant differences (1%) were observed between the two types of seed sources for seedling height and root collar diameter. No significant difference was observed in number of leaves.

Regional performances -- Individual seed sources were grouped according to region: 1. White Mountain National Forest, 2. Green Mountain National Forest, 3. Maine, 4. Michigan, and 5. Canada. One-way ANOVA's were performed between all combinations of regions with 38 seed sources in all. Estimates were taken from sources grown in the Spencer-Lemaire/Pro-Mix BX blocks since this allowed for largest total number of seed source comparisons.

Significant differences were observed in several regional comparisons for seedling height and root collar diameter (Table 3). In the first four comparisons, progeny from region one (White Mountain National Forest) were significantly larger than those from

Table 1.--Performance of 12 week paper birch seedlings in two container systems and two media types.[a]

Container Type[b]	Seedling Height (cm)[c]	Root Collar Diameter (cm)[c]	Number of Leaves[c]
Spencer-Lemaire	26.7 ± .7[d]	.3313 ± .01	14.03 ± .46
Plant Bands	4.4 ± .3	.1395 ± .00	10.65 ± .50

Media Type[e]	Seedling Height (cm)	Root Collar Diameter (cm)	Number of Leaves
Pro-Mix BX	24.04 ± .6	.3082 ± .01	13.66 ± .37
Peat-Vermiculite	12.54 ± .4	.2347 ± .01	14.96 ± .37

[a] All values are significantly different at the .01 level

[b] Pro-Mix BX used in both containers

[c] All data are covariance adjusted means

[d] 95% confidence limits

[e] Both in Spencer-Lemaire container type

Table 2.--Comparison of open pollinated 12 week paper birch seedlings from select and average parents[a]

	Seedling Height (cm)[b]	Root Collar Diameter (cm)[b]	Number of Leaves[c]
Mean with confidence interval			
Superior	22.8 ± 1.6[d]	.297 ± .02	13.2 ± 0.8
Average	17.9 ± 2.7	.242 ± .03	12.3 ± 1.2
Range			
Superior	17.2 - 28.8	.214 - .350	8.95 - 17.37
Average	8.4 - 26.5	.125 - .321	7.92 - 16.92

[a] All data are covariance adjusted mean values

[b] Significantly different at the .01 level

[c] Not significantly different

[d] 95% confidence limits

regions two, three and five (Green Mountain National Forest, Maine and Canada respectively), but not region four, the Michigan sources. In comparison ten, the Michigan region was significantly greater for height than region five (Canada). Number of leaves was significantly greater in White Mountain sources when compared with Maine sources, but was reasonably uniform across other regions.

For all three characteristics, the White Mountain National Forest seed sources outperformed all others (see Appendix). The Michigan sources, for all three measurements, were second in superiority, with Green Mountain, Maine, and Canadian sources following. Wide differences were observed in height and root collar diameter, whereas little variation was evident in number of leaves.

Seedlings from 42 seed sources, grown in the SL/Pro-Mix combination, were evaluated based on covariance adjusted mean values using the Bayesian K-Ratio t (LSD) Rule [for multiple comparisons] (Chew 1977, Smith 1978). Comparisons among the twelve sources with greatest height and root collar diameters are shown in Table 4. Number of leaves was not included since this variable apparently does not reflect seed source superiority in this study. White Mountain sources predominate in the top 5 ranked sources with one strong performing source from Somerset County, Maine.

DISCUSSION

Significant differences observed between the Spencer-Lemaire Book Planters and the Plant Bands, were surprisingly large. Variation in root configuration, particularly presence or absence of root spiralling, could not be determined since Plant Band seedlings did not develop sufficiently. Root spiralling was not observed in SL containers. Inadequate development in PB containers might be attributed to a fungus which developed on Pro-Mix in the Plant Bands. Depletion of nutrients and water content by the fungus may have reduced seedling growth. It has been noted among greenhouse managers, that Pro-Mix BX has, in addition to serving as an excellent medium for greenhouse plants, been a favorable medium for fungi.

Pro-Mix BX proved superior for birch seedling growth over the peat-vermiculite medium. Root development was sufficient in both media indicating adequate porosity. Sphagnum peat is an effective medium in that it inhibits damping off, and increases the mixture's moisture and nutrient holding capacity (Hartmann and Kester 1975). High proportion of sphagnum peat may result in deterioration of roots and leaching if over-watered. Pro-Mix BX contains less sphagnum peat than the peat-vermiculite mixture tested, therefore, may have sustained less nutrient loss during watering.

Seedlings from select parents were significantly greater in

Table 3.--Test of regional comparisons--one-way analysis of variance[a]

	Regional Comparisons[b]									
	1 1,2	2 1,3	3 1,4	4 1,5	5 2,3	6 2,4	7 2,5	8 3,4	9 3,5	10 4,5
Seedling Height	*	*	NS	**	NS	NS	NS	NS	NS	*
Root Collar Diameter (cm)	*	**	NS	**	NS	NS	NS	NS	NS	NS
Number of Leaves	NS	*	NS	NS	NS	NS	NS	NS	NS	NS

[a] *, ** Significantly different at the .05, .01% level, respectively.
NS No significant difference

[b] 1 = White Mountain National Forest; 2 = Green Mountain National Forest; 3 = Maine; 4 = Michigan; and 5 = Canada

Table 4.--The 12 best paper birch seed sources of 42 sources tested[a]

	Seedling Height (cm)			95%	Root Collar Diameter (cm)			
Rank	Seed Source[c]	Mean		Confidence Interval	Seed Source[c]	Mean		Confidence Interval
1	WM24[s][b]	28.8	±	.364	1332[s]	.350	±	.0055
2	WM70[s]	27.7	±	.510	WM50[s]	.349	±	.0053
3	1332[s]	27.4	±	.532	WM24[s]	.342	±	.0037
4	WM79[s]	27.2	±	.576	WM96[s]	.329	±	.0055
5	WM96[s]	27.0	±	.517	WM87[s]	.323	±	.0008
6	1098	26.5	±	.346	1018	.321	±	.0060
7	WM50[s]	26.3	±	.408	1101	.318	±	.0055
8	WM41A[s]	26.0	±	.436	WM70[s]	.318	±	.0050
9	1101	25.9	±	.497	1312[s]	.314	±	.0040
10	WM64[s]	25.8	±	.438	1363[s]	.310	±	.0039
11	1363[s]	25.7	±	.394	WM41A[s]	.309	±	.0042
12	1020	24.8	±	.356	1367[s]	.307	±	.0057

[a] All values are covariance adjusted means. Those appearing beside the same line are notsignificantly different from each other (1%) according to the Bayesian K-ratio t (LSD) Rule.

[b] s = Select.

[c] Refer to appendix for geographical seed source data.

height and diameter growth than those from average parents in SL containers containing Pro-Mix. This result suggests that superior paper birch were effectively selected in the field and further suggests that early growth rate is heritable.

Seedling growth varied according to region. Progeny from select White Mountain parents and Michigan outgrew seedlings from select parents in the Green Mountains. Performance of the White Mountain progeny was significantly better than Green Mountain sources but was not significantly different from Michigan sources. These results suggest that population differences may be distinguishable among these three areas, but further sampling and testing is required to make that determination. The comparison tree method was utilized for selection of all plus trees but since all selections were not made by one person, biases in selection could account for some of the differences between Green Mountain and Michigan performance.

The top 25% (twelve total) of individual seed sources were selected for multiple comparisons using the Bayesian K-ratio t (LSD) Rule. These are ranked for their relative superiority in terms of height and diameter growth (Table 4). Significant variation was observed in the twelve ranked means, with greater variation evident among the root collar diameters. Seedlings from the White Mountain National Forest and Maine dominated the top twelve along with regional comparisons. These comparisons suggest that sources from the White Mountains; Somerset County, Maine; Gould City, Michigan; Stevens Point, Wisconsin; and Oxford County, Maine would be good choices for early rapid growth in containerized systems. It is necessary to be cautious, however, since these early performances may not be an expression of superiority under plantation or natural competitive conditions.

CONCLUSION

Spencer-Lemaire Book Planters and Pro-Mix BX media provided a suitable containerized system for paper birch seedlings. Plant Band containers and Pro-Mix BX media in combination showed susceptability to fungal growth, which can inhibit paper birch seedling development. Peat-vermiculite media-mix, in Spencer-Lemaire containers, did not result in satisfactory seedling development.

Sources of select origin showed superior growth for seedling height and root collar diameter in comparison with average seed sources. Significant regional differences were observed. White Mountain National Forest seed sources displayed superior early growth, compared with four other regions. It has been noted, though, that Michigan seed sources, all of average parental stock, performed better than Green Mountain National Forest seed sources, all of which are of superior origin. Seed sources which showed su-

perior height and root collar development were identified and compared.

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FOOTNOTES

[1]The Spencer-Lemaire Book Planter or Spencer-Lemaire Industries Limited, 10310-112, Edmonton, Alberta, Canada T5K 1N1, and Plant Bands from the Monarch MFG Company, 13154 Country Road 140, Salida, Colorado 81201. Mention of product names does not indicate endorsement of product use by New Hampshire Agricultural Experiment Station.

Appendix--Variation among 42 seed sources of paper birch

Seed Source No.	Location: State, County Province of Nearest Location	Geographic Origin: Latitude °	'	Longitude °	'	Elevation (ft.)	Characteristics (Mean Values)**: Seedling Height (cm)	Root Collar Diameter (cm)	Number of Leaves	Parental Source
WM	White Mt. National Forest (New Hampshire)									
24	Carroll Co.	44	10	71	15	800	28.8	.350	17.4	+
50	Coos Co.	44	15	71	15	1400	26.7	.349	15.0	+
66	Grafton Co.	44	15	71	40	1500	20.4	.294	14.7	+
41A	Carroll Co.	44	05	71	20	--	26.1	.309	11.8	+
64	Coos Co.	44	20	71	10	1300	25.8	.298	12.9	+
87	Strafford Co.	44	20	71	50	750	22.8	.323	13.8	+
45	Coos Co.	44	20	71	10	900	20.	.260	12.1	+
79	Grafton Co.	43	40	71	50	1500	27.2	.305	14.9	+
96	Grafton Co.	43	50	71	45	1300	27.0	.329	13.0	+
70	Grafton Co.	44	10	71	20	1200	27.7	.318	14.7	+
						$\bar{x}$	25.2	.313	14.0	
GM	Green Mt. National Forest (Vermont)									
48	Addison Co.	43	55	73	05	1440	19.9	.296	12.7	+
39	Rutland Co.	-	-	-	-	1820	22.2	.289	11.0	+
37	Windsor Co.	43	15	72	55	2000	17.2	.221	10.9	+
07	Rutland Co.	43	44	73	50	1500	23.7	.288	13.1	+
60	Windsor Co.	43	20	73	50	2000	18.9	.294	14.8	+
						$\bar{x}$	20.4	.278	12.5	
	Maine (*USFS)									
1043-44*	Byron	44	42	70	36	1200	15.5	.198	7.9	A
1332	Somerset Co.	45	20	70	11	1080	27.5	.350	15.7	+
1090*	T7, R7	46	13	68	39	800	11.9	.192	10.7	A
1367	Penobscot Co.	45	19	68	04	440	19.8	.307	14.7	+
1091*	T7, R10	46	16	69	00	800	16.0	.251	11.5	A
1303	Hancock Co.	44	49	68	07	570	18.0	.303	14.7	+
1312	Piscatquis Co.	45	22	67	26	940	23.5	.314	13.5	+
1374	Penobscot Co.	45	14	68	42	300	17.3	.218	10.2	+
1306	Oxford Co.	44	22	70	45	1000	18.4	.214	8.9	+
1363	Oxford Co.	44	42	70	36	1300	25.7	.310	12.4	+
1342	Somerset Co.	44	57	69	58	660	20.1	.284	10.9	+
1322	Oxford Co	44	08	70	23	600	23.2	.296	13.2	+
						$\bar{x}$	19.7	.270	12.0	
	Michigan (USFS Sources)									
1098	Gould City	46	00	85	49	650	26.5	.306	13.9	A
1018	Houghton	47	15	88	32	700	24.8	.321	14.2	A
1019	Michigan Tech Campus	47	05	88	33	850	24.3	.305	13.7	A
1077-86	Ogemaw Co.	44	30	84	00	1320	16.5	.233	12.8	A
						$\bar{x}$	22.9	.291	13.7	
	Canada (USFS Sources)									
1020	New Lowell, Ontario	44	20	80	00	700	24.8	.282	13.1	A
1065	Quebec (Valcartie Exp.Sta.)	46	57	71	32	700	17.9	.254	13.7	A
1020-31	Simcoe, Ontario	44	20	80	00	700	8.4	.125	8.0	A
1120	Thunder Bay, Ontario	48	19	89	12	620	18.8	.295	13.9	A
1268	Grand Falls, New Foundland	48	50	55	50	600	15.3	.210	9.5	A
1122	Wiarton, Ontario	44	47	81	12	590	18.1	.254	12.3	A
1123	Lot 1, Minder Twp., Ontario	45	01	78	15	1200	14.7	.254	13.7	A
						$\bar{x}$	16.9	.239	12.0	
	Miscellaneous (USFS Sources)									
1104	Lee, Massachusetts	42	21	73	14	1500	16.0	.233	11.4	A
1101	Stevens Point, Wisc.	44	32	89	34	1100	25.9	.318	16.9	A
1206	Savoy, Massachusetts	42	37	73	02	1980	16.3	.236	13.8	A
1129	Bald Eagle Ridge, Penn.	40	50	77	57	1500	11.2	.172	9.4	A
						$\bar{x}$	17.4	.240	12.9	
Grand Mean							21.6	.287	13.2	
Adjusted Grand Mean for Covariate							20.4	.272	12.8	

* Progeny of select candidate trees (+) or of average parental stock (A)
** Adjusted means for covariate