PROVENANCE AND FAMILY VARIATION IN BALSAM FIR FROM MICHIGAN AND WISCONSIN

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ABSTRACT.--Variation in height, branching, and flushing was measured for wind-pollinated families from six provenances at age 11 in from one to four plantations. Seed collected at one location in the Lower Peninsula of Michigan produced trees that were 20 percent taller, had 40 percent more lateral branches in the top whorl, and had a flushing score 25 percent later than average. Variation among families within provenances was between 30 and 40 percent of respective provenance means. Both provenance and family effects were significant, but provenance effects were generally much larger. Provenance selection clearly would be worthwhile in the Lake States.

Balsam fir (*Abies balsamea* L.), a species widely distributed in North America and a major component of the boreal forest, has received little attention from tree breeders and geneticists. Although commonly harvested for pulpwood, balsam fir is rarely planted except for ornamental uses. Principal interest, from a genetic point of view, has been in the taxonomic status of the species and the morphologically similar Fraser fir (*A. fraseri* (Pursh) Poir.) and subalpine fir (*A. lasiocarpa* (Hook) Nutt.) (Boivin 1959, Zavarin and Snajberk 1972).

To determine patterns of geographic variation, seeds were collected in 1960 by R. G. Hitt of the University of Wisconsin. Initial sampling was in Michigan and Wisconsin as a part of a regional project on geographic variation in many forest tree species. The study was expanded in 1962 to include sampling of the species range.

The results reported here represent early performance of provenances for which seed was maintained separately by maternal parent. These results are intended to supplement the picture of geographic variation being developed from measurements on provenance plantings from range-wide sampling.

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MATERIALS AND METHODS

Six balsam fir stands in Michigan and Wisconsin were sampled (fig. 1). At each location, cones were collected from 10 trees located at least 100 feet apart. Seeds from each tree were stored separately at 2 ^{o}C until sowing in 1963. Seedlings were grown for 3 years at the Trout Lake State Forest Nursery in north-central Wisconsin, then distributed to cooperators who established four plantations (A, B, C, and D) (fig. 1). Plantations A and B trees were field planted as 3-2 stock in 1969 and plantation C and D trees were field planted as 3-3 stock in 1970. Plantations A and D are in areas averaging 150 or more frost-'free days; plantations B and C average less than 120 frost-free days (fig. 1). Soils at all locations are loams and each plantation is on an upland site.

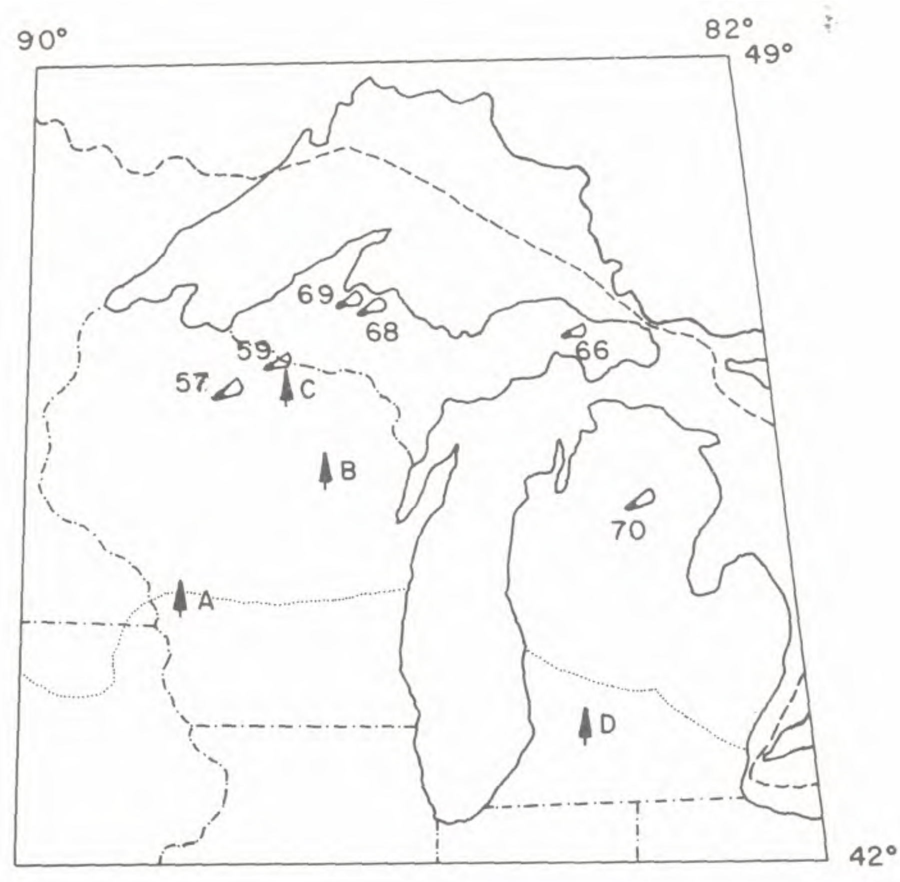

Figure 1.--Map of the study area with numbered provenance locations ( ) and plantation locations ( ). The southern boundary of the botanical range of balsam fir is indicated by a dotted line.

A call for data was issued to cooperators in 1974 and the most comprehensive data were standardized and analyzed for this summary of results.

Only a few families are represented in all plantations because numbers of seedlings in several families were small. Analyses of variance were based on randomized complete block designs using data only from families and numbers of blocks that were equally represented. A least-significant-difference was calculated following Waller and Duncan (1969). Components of variance were calculated using a random model.

RESULTS AND DISCUSSION

Means for total height show the superiority of Provenance 70 and the inferiority of Provenance 66 (table 1). The array of heights for this provenance sample from the Lake States is similar to the array from range-wide sampling except that some Quebec provenances had greater vigor and some Saskatchewan provenances had less.

Table 1.--Average performance of six balsam fir provenances for four traits at 11 years from seed (height was measured at plantations B, C, and D; lateral branch number at B and C; flushing score at C and D; and lateral bud number at C)

Provenance	Height	Lateral branches	Lateral buds	Flushing score[1/]
	Feet	Number	Number	
57	3.6	3.5	4.0	2.4
59	3.7	3.4	3.7	2.6
66	2.9	2.2	3.1	3.0
68	3.3	3.2	3.8	2.4
69	3.5	3.3	3.8	2.2
70	4.4	4.8	5.1	1.8
Least Significant Difference .05	0.2	0.4	0.2	0.5

1/ Scores range from 1 for least shoot growth initiation to 4 for most shoot growth initiation.

The number of lateral branches in the top whorl was chosen as a variable trait of some interest to Christmas tree growers. Although shearing can increase the density of crowns with few lateral branches, three or less laterals probably would reduce the quality of most Christmas trees. The range of variation again was similar to results from range-wide studies and Provenance 70 was the best.

The number of lateral buds in the top whorl also was variable. The average number of lateral buds is not directly comparable with average number of lateral branches because two plantations are represented in the former array and one in the latter. In plantation C, where both branches and buds were counted, an average of 0.4 bud per tree failed to develop in 1974.

Flushing scores for provenances showed a range of variation similar to that found for other traits. Ranking of provenance means was consistent in both plantations as well as in range-wide provenance data from nursery (Lester 1970) and field plantings. Flushing in Provenance 70 has been observed to be up to 10 days later than in most other provenances and frost damage has been rare. Conversely, Provenance 66 has been heavily frost-damaged in several years, presumably as the result of early flushing. In northeastern Wisconsin, a delay in flushing from May 5 to May 20 would reduce the probability of exposure to freezing temperatures by a factor of four.

When the four traits are viewed in aggregate, the provenances separate consistently into three groups. Provenance 70 is the most vigorous, forms the most lateral branches, and flushes latest. Provenance 66 is the converse of 70 and the other four provenances are intermediate to various degrees. These results raise the question whether differences in height and branching are a consequence of inherently different vigor or of the relation of early spring frost damage to variation in time of flushing. All plantations were damaged by frost in 1 or more years. Although joint effects of variation in vigor and in frost damage cannot be separated in these studies, patterns of shoot growth illustrated by periodic measurements in the nursery (Lester 1970) indicate that both inherent vigor and phenology of bud development are important in determining total height.

The effect of unseasonably low temperature on different stages of bud development needs further study. The loss of potential branches occurs at various stages from before exposure of new leaves to intermediate phases of branch elongation. Loss during early stages of branch elongation seems to be a direct response of succulent tissues to freezing and yet visible damage after frost often occurs only on some of the shoots that have elongated to the point of exposing most of their needles.

Among families within provenances, the range of variation for each trait was between 30 and 40 percent of the provenance mean. Families from Provenance 68 were the most variable for height (55 percent), number of buds (47 percent), and flushing score (54 percent). Families from Provenance 70 were least variable for height (21 percent) but highly variable for flushing score (48 percent).

Both provenance and family effects were almost always highly significant (table 2). Interactions were generally negligible and were relegated to the error term.

Table 2.--Summary of analyses of variance for height, number of lateral branches and buds in the top whorl, and flushing score for provenances and families of balsam fir

Source of variation	Plantation A: Height d.f.	Plantation A: Height F level	Plantation A: Number of branches d.f.	Plantation A: Number of branches F level	Plantation B: Height d.f.	Plantation B: Height F level	Plantation B: Number of branches d.f.	Plantation B: Number of branches F level
Blocks	8		5		8		6	
Provenances	2	**1/	2		5	**	5	**
Families/provenance	9	**	9	**	36	**	36	**
Error	87		55		326		240	

Source of variation	Plantation C: Height d.f.	Plantation C: Height F level	Plantation C: Number of branches F level	Plantation C: Number of buds F level	Plantation C: Flushing score F level
Blocks	9	**	**	**	
Provenances	5	**	**	**	**
Families/provenance	30	**	**	**	**
Error	315				
Plantation D					
Blocks	2				
Provenances	5	**			**
Families/provenance	30	*			*
Error	68				

1/ Means differ at a probability of 99 percent (**) or 95 percent (*)

Components of variance (table 3) show that variation attributable to provenances was three to four times greater than that attributable to families within provenance. Provenance selection is thus the indicated first step for improving balsam fir in the Lake States.

Table 3.--Summary of analysis of variance with variance components for height (plantations B, C, and D) and number of lateral branches in the top whorl (plantations B and C) for balsam fir provenances and families

Source of variation	Height: d.f.	Height: Significance level	Height: Variance component	Lateral Branches: d.f.	Lateral Branches: Significance level	Lateral Branches: Variance component
Locations 1/	2	** 2/	27 3/	1	**	25
Provenances	5	**	20	5	**	23
Families/Provenance	18	**	7	18	**	6
Error	190		46	311		46

1/ Location effects may be confounded with effects attributable to stock age at time of planting due to different years of planting.

2/ Means differ at a probability of 99 percent (**) or 95 percent (*).

3/ Percentage of total variance.

LITERATURE CITED

Boivin, B. 1959. Abies balsamea (Linne) Miller et ses variations. Nat. Can. 86:219-223.

Lester, D. T. 1970. Variation in seedling development of balsam fir associated with seed origin. Can. J. Bot. 48:1093-1097.

Waller, R. A., and D. B. Duncan. 1969. A Bayes rule for the symmetric multiple comparisons problem. J. Am. Stat. Assoc. 64:1484-1503.

Zavarin, E., and K. Snajberk. 1972. Geographical variability of monoterpenes from Abies balsamea and A. fraseri. Phytochemistry 11: 1407-1421.