FIFTEEN-YEAR RESULTS OF A BALSAM FIR PROVENANCE TEST IN THE LAKE STATES

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Abstract-- After 15 years in the field, balsam fir (Abies balsamea (L.) Miller) provenances from the eastern portion of the range, and from several Lake States areas, continue to be the most vigorous. Provenances from north and northwest of the Lake States are generally the poorest performers. Much of this pattern of variation in height growth is accounted for by variation in phenology, with susceptibility to spring frost damage being most prevalent among provenances from western Ontario, Saskatchewan and Manitoba provinces. Age-age correlations between measurements taken at 5, 11, and 15 years from seed are variable, with most 5-11 and 5-15 year correlations being very low and even negative in one case.

Balsam fir (Abies balsamea (L.) Miller) is a small to medium sized tree of the boreal forest region of eastern North America. Balsam fir extends from the Canadian Maritime Provinces westward to Lesser Slave Lake and the Athabasca River in Alberta and southward through New England and the Lake States areas to Pennsylvania. Isolated populations also occur in northeastern Iowa, Virginia, and West Virginia.

Even though balsam fir is considered demanding in terms of nutrient and moisture requirements, it is a predominant tree species in large areas of Canada. A contributing fact is the shade tolerance of balsam fir, which provides seedlings with the advantage of establishment under closed canopies. Economic interest in balsam fir centers around the pulpwood and christmas tree markets.

A provenance study of balsam fir established in 1963 at several locations in the Lake States has shown considerable seed source variation in height growth, frost damage, and phenology of shoot elongation (Lester, 1970; Lester et al., 1976a; Lester et al., 1976b). Provenances from the eastern portion of the range were generally taller and produced more lateral branches than those from the western portion, but the pattern of growth rate variation was confounded by spring frost damage. Certain provenances appear to be fast-growing because of delayed bud break and flushing, thereby avoiding spring frosts (Lester, 1970; Lester et al., 1976a,b). Shoot growth initiation has been shown to be positively correlated with mean annual maximum daily temperature at the seed origin and total height is related to the moisture regime at the seed origin (Lester, 1970; Lowe et al., 1977).

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This study examines provenance variation in height growth at 15 years in the field. In addition, height measurements at 5, 11, and 15 years of age were used to estimate age to age correlations.

MATERIALS AND METHODS

Seed was collected in 1960-62 from 100 stands throughout the geographical range of balsam fir. Collections were sown in October, 1963 at Trout Lake Nursery, Vilas County, Wisconsin. Germination of seedlings was adequate to develop test plantings using 30 to 60 provenances (Figure 1). A planting in a central Wisconsin nursery was replicated with three randomized complete blocks containing 40 to 60 trees per source.

Plantations were established with 3-2 or 3-3 stock on upland loam or sandy loam soils during 1968-69 at Kellogg Forest, Kalamazoo County, Michigan; Polar, Langlade County, Wisconsin; Coulee, La Crosse County, Wisconsin; Grand Rapids, Itasca County, Minnesota; and Cloquet Experimental Forest, Carlton County, Minnesota. The plantations are arranged in a randomized complete block design with 4 or 5 tree row plots and 3 to 10 blocks per location. As a consequence of poor seedling survival some provenances are not represented in all five locations. Initially there were seven plantations, but due to severe deer browsing and spring frost damage, two plantations were abandoned.

At 5 years from seed, total height of 10 seedlings of each seed lot from two nurseries and 10 seedlings from each of the 3 replicates in the central Wisconsin nursery were measured. This was a non-random sample as only seedlings undamaged by a severe frost in May, 1968 were measured. At 11 and 15 years of age from seed tests were remeasured for total height at these five locations.

A coefficient of variation was calculated for each plantation. Correlation coefficients were calculated to show age - age correlations for total height— at 5, 11, and 15 years.

RESULTS AND DISCUSSION

Height Growth

Relative height at 15 years from seed varied considerably between provenances planted at five Lake States locations (Table 1). The best provenance (#70 Higgins Lake, Roscommon County, Michigan) was over 2 1/2 times taller then the shortest provenance (#0 Pesane, Saskatchewan). This large height growth variation indicates that provenance selection would be useful for improvement of balsam fir in the Lake States, as noted earlier by Lester et al. (1976a). Provenances from the eastern portion of the range and from the Lake States are among the most vigorous, while provenances from Manitoba, Saskatchewan and western Ontario are generally the poorest performers (Figure 2).

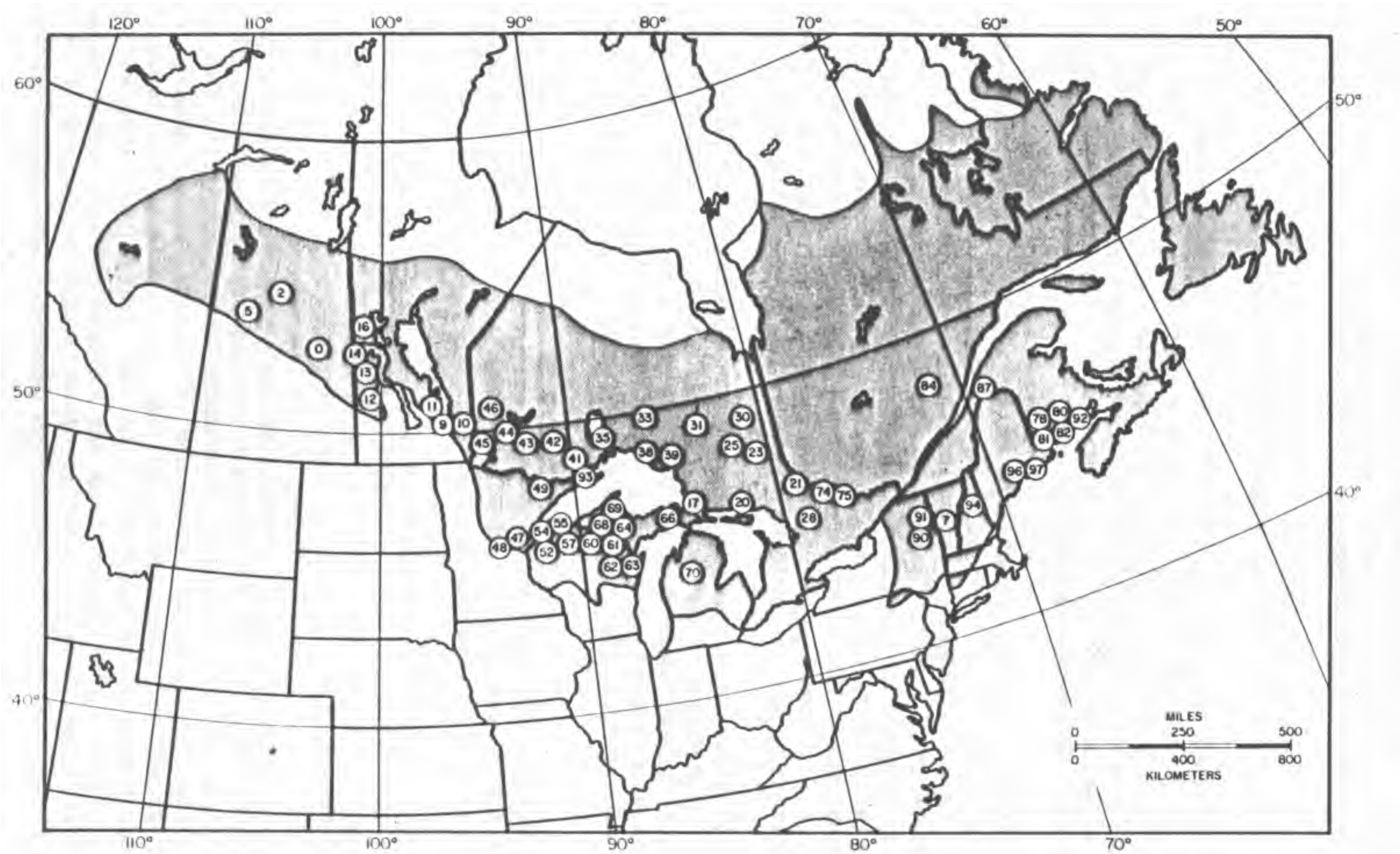


Figure 1. Location of collection sites for balsam fir seed.

Table 1. Origin and relative height of the tallest and shortest balsam fir provenances at 15 years from seed at five Lake States locations.

PROVENANCE NUMBER	LOCATION	AVERAGE HEIGHT (% OF MEAN)	PLANTATION HEIGHT (% of mean) WISCONSIN A	WISCONSIN B	MICHIGAN C	MINNESOTA D	MINNESOTA E
70	CENTRAL MICHIGAN	146.7	122.5	126.0	193.4	144.9	--
61	NORTHEASTERN WISCONSIN	128.1	118.7	112.6	166.5	129.1	113.5
78	SOUTHERN NEW BRUNSWICK	124.3	117.7	123.8	154.5	101.2	--
7	CENTRAL VERMONT	***	124.1	--	--	--	--
57	NORTHERN WISCONSIN	119.6	96.2	116.1	147.5	118.5	--
84	CENTRAL QUEBEC	118.4	123.3	113.6	--	--	--
82	SOUTHERN NEW BRUNSWICK	116.1	128.6	103.6	--	--	--
23	EASTERN ONTARIO	***	115.3	--	--	--	--
63	NORTHEASTERN WISCONSIN	115.3	113.6	114.9	129.2	105.9	112.8
62	NORTHEASTERN WISCONSIN	115.0	111.9	118.2	--	--	--
80	SOUTHERN NEW BRUNSWICK	114.2	110.2	110.8	148.0	87.8	--
91	NORTHERN NEW YORK	112.8	107.7	103.5	143.4	93.4	115.8
90	CENTRAL NEW YORK	112.0	118.2	109.4	--	123.4	96.8
25	CENTRAL ONTARIO	111.1	102.6	102.8	147.7	100.6	101.9
69	NORTHERN MICHIGAN	110.8	102.3	104.6	136.5	99.6	--
81	SOUTHERN NEW BRUNSWICK	110.1	114.1	--	123.2	100.4	102.8
21	EASTERN ONTARIO	109.8	106.8	119.9	97.5	128.9	96.1
54	NORTHWESTERN WISCONSIN	108.1	111.7	104.5	--	--	--
39	CENTRAL ONTARIO	108.0	94.2	--	--	113.3	116.4
94	CENTRAL NEW HAMPSHIRE	107.5	111.3	106.5	122.4	89.9	--
20	EASTERN ONTARIO	107.4	110.6	118.3	--	93.9	106.6
52	NORTHWESTERN WISCONSIN	106.5	92.8	94.7	124.1	119.3	101.5
92	SOUTHERN NEW BRUNSWICK	106.0	109.3	89.2	135.4	90.1	--
96	EASTERN MAINE	105.8	103.3	105.7	152.4	77.2	90.2
30	EASTERN ONTARIO	***	104.6	--	--	--	--
74	EASTERN ONTARIO	***	--	104.0	--	--	--
75	EASTERN ONTARIO	103.5	113.1	112.8	98.7	89.5	103.6
60	NORTHEASTERN WISCONSIN	***	103.3	--	--	--	--
49	NORTHEASTERN MINNESOTA	102.1	96.7	88.0	117.8	105.9	--
87	EASTERN QUEBEC	102.1	115.0	121.1	75.8	96.4	--
53	NORTHWESTERN WISCONSIN	100.6	--	--	116.6	98.1	87.0
38	SOUTHERN ONTARIO	100.0	95.4	99.4	--	99.0	106.1
17	SOUTHERN ONTARIO	98.2	96.3	98.0	96.8	88.2	111.8
41	SOUTHERN ONTARIO	97.7	--	91.8	--	91.9	109.4
46	WESTERN ONTARIO	95.7	91.4	73.9	--	114.0	103.6
48	EASTERN MINNESOTA	95.3	92.2	81.0	106.3	92.0	104.9
55	NORTHWESTERN WISCONSIN	94.3	86.1	99.0	96.1	94.2	96.3
44	SOUTHWESTERN ONTARIO	93.8	95.3	90.4	--	94.1	95.6
64	NORTHERN MICHIGAN	92.9	91.8	114.4	59.0	106.6	92.5
10	SOUTHEASTERN MANITOBA	92.7	82.0	90.8	--	105.4	--
68	NORTHERN MICHIGAN	92.4	104.9	--	--	79.9	--
9	SOUTHEASTERN MANITOBA	92.4	90.6	98.3	75.1	105.4	--
97	EASTERN MAINE	91.6	101.1	95.4	--	64.0	105.7
14	WESTERN MANITOBA	91.3	82.5	102.9	75.9	103.8	--
12	WESTERN MANITOBA	91.0	89.8	90.3	83.9	100.2	--
11	SOUTHERN MANITOBA	90.0	96.7	83.2	--	--	--

33	CENTRAL ONTARIO	89.2	95.0	92.2	64.6	105.1	--
93	SOUTHERN ONTARIO	89.2	91.7	86.6	--	--	--
13	WESTERN MANITOBA	88.1	92.7	--	57.1	118.0	84.6
28	EASTERN ONTARIO	87.0	98.9	101.1	57.0	86.6	91.2
45	SOUTHWESTERN ONTARIO	86.0	82.6	89.3	--	--	--
5	CENTRAL SASKATCHEWAN	***	85.1	--	--	--	--
43	SOUTHWESTERN ONTARIO	84.4	87.7	81.1	--	--	--
35	SOUTHERN ONTARIO	84.2	80.5	98.6	55.1	97.3	89.3
31	CENTRAL ONTARIO	83.6	79.1	94.8	43.6	102.4	98.2
66	NORTHERN MICHIGAN	79.6	89.8	87.0	45.8	82.4	93.0
47	EASTERN MINNESOTA	79.4	87.4	--	42.0	97.7	90.4
42	SOUTHERN ONTARIO	76.2	89.3	--	32.5	84.1	98.9
16	CENTRAL MANITOBA	69.5	79.1	71.2	45.1	--	82.7
2	CENTRAL SASKATCHEWAN	***	--	64.5	--	--	--
0	CENTRAL SASKATCHEWAN	59.7	65.2	--	33.6	80.3	--
CV(%)			13.6	14.0	43.2	15.2	9.3
Plantation mean height (cm)			409.8	287.6	196.6	176.0	293.3
Total number of provenances			57	48	36	45	30

*** REPRESENTED AT ONLY ONE TEST SITE

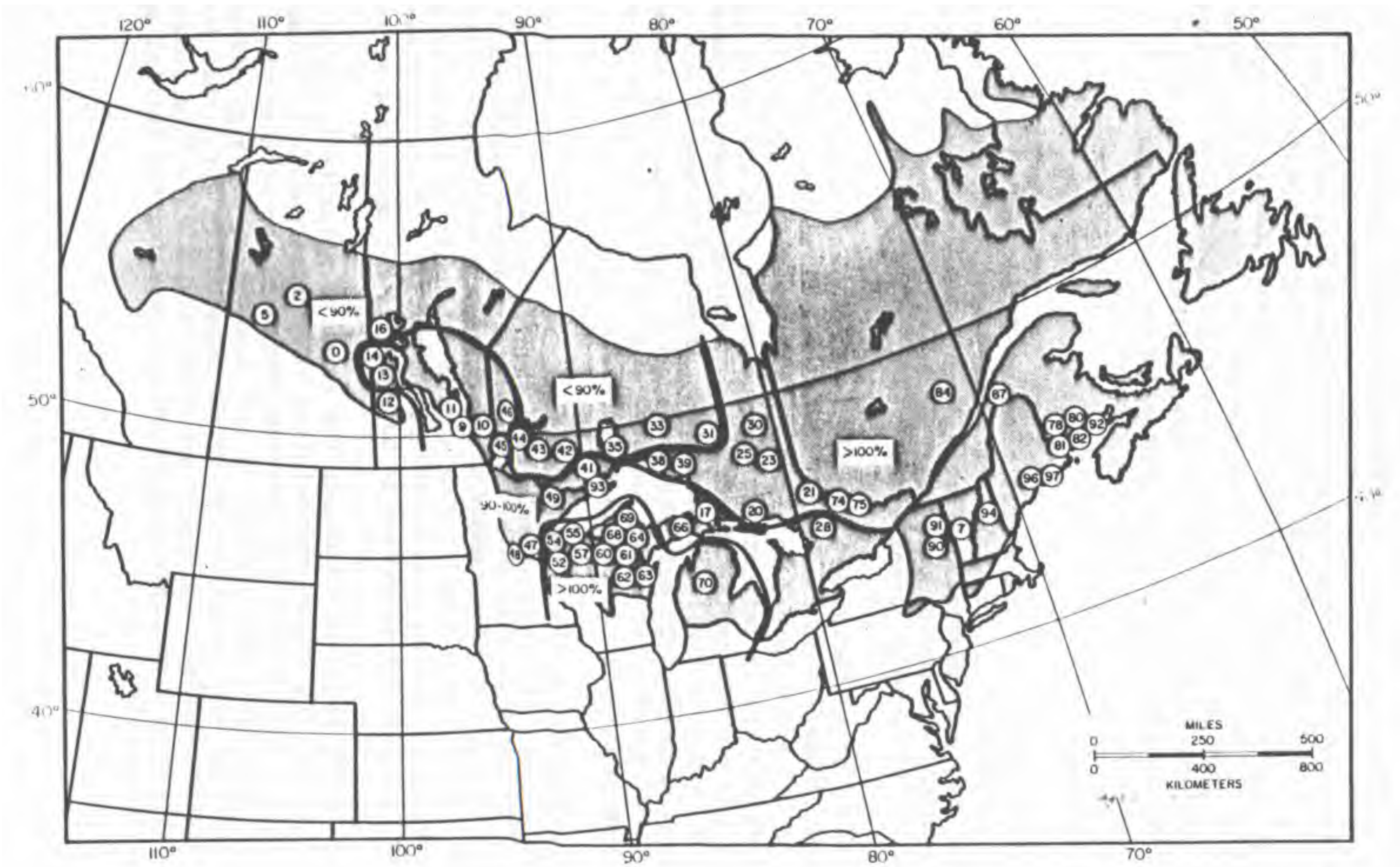


Figure 2. Groupings of balsam fir provenances based upon height growth at five locations in the Lake States.

An important factor influencing the overall vigor of balsam fir in the Lake States involves phenology of bud break and flushing. Early flushing of balsam fir is not a desirable trait because it increases the susceptibility to spring frost damage. A delay in flushing from early to mid-May reduces the chances of frost damage by 75% (Lester et al., 1976b). The early flushing of many provenances north and northwest of the Lake States makes them highly susceptible to late spring frosts. The large variation observed (Table 1) at the Kellogg Forest, Michigan, plantation is a direct result of repeated spring frost damage to the earliest flushing provenances. For example, provenances 70, 61, and 57 are included among the tallest five provenance (Table 1), and also are among the latest flushing provenances (Lester et al., 1976b). All three provenances are from the Lake States region and all exhibit a high degree of adaptation to local climatic conditions.

Age-Age Correlations

Height measurements of balsam fir taken at 5, 11, and 15 years from seed at the five plantations in the Lake States were used to estimate age - age correlations for each plantation (Table 2). The rate of genetic improvement of a tree can be increased by early testing and selection if a high correlation exists between juvenile and mature phases.

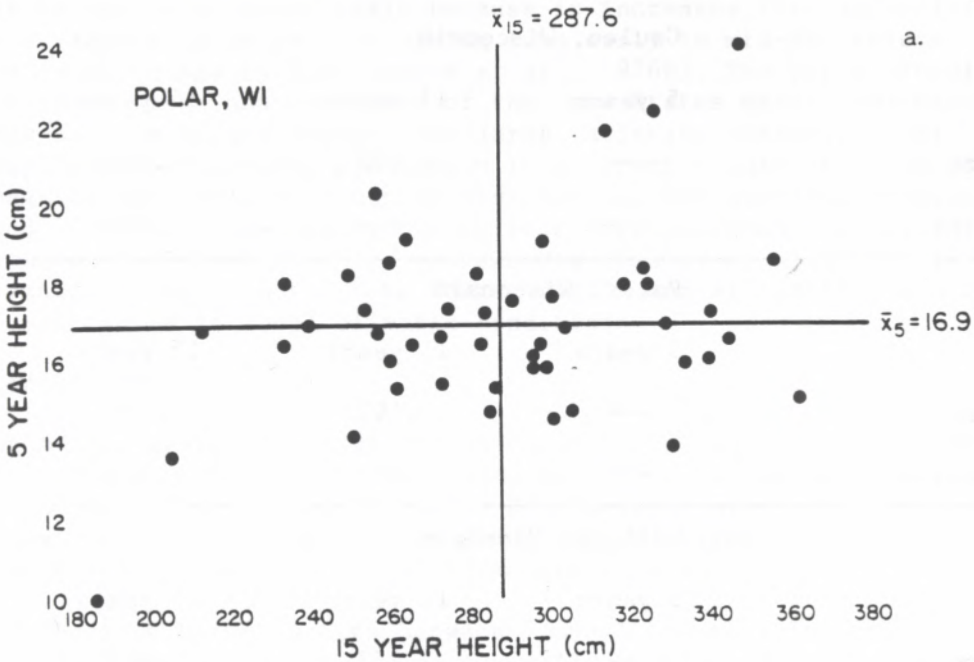
Correlations of height growth between 5 and 11 years from seed, and between 5 and 15 years from seed were generally weak and in one case, even negative. As 3-2 stock raised in Wisconsin was planted at all study sites, these correlations really reflect performance at age 5 in Wisconsin and later ages in Michigan and Minnesota. Correlations in height growth between 11 and 15 years from seed were considerably higher and ranged between 0.758 and 0.928 depending upon plantation. If only the provenances that performed above average at five years of age were selected, several very good provenances at age 15 would have been eliminated in the nursery (Figure 3).

Squillace and Gansel (1974) proposed that for traits with weak juvenile-mature correlations, the time of selection should be based on genetic gain per year and not on final genetic gain. This leads to shorter generation intervals and a correspondingly greater number of families and individuals being screened and, ultimately, a greater selection intensity with greater genetic gains (Nanson, 1970; quoted from Squillace and Gansel, 1974). This seems to be a reasonable approach for selection in balsam fir, but more data is needed.

Franklin (1979) suggests hastening the onset of maturity by inducing fast growth at close spacing and by manipulating other environmental factors. This procedure would simply reduce the juvenile period in the life of the tree. A plantation of this type was established for slash pine, and high offspring-parent correlations were obtained for height between the 3-year-old progeny and the 25-year-old parents (Franklin and Squillace, 1973). This reduction of the juvenile phase is a possible proceedure for reducing the initial age of selection in balsam fir.

TABLE 2. Age-age correlations for balsam fir at 5, 11, and 15 years of age at five Lake States locations.

age	5 years	11 years	15 years
Coulee, Wisconsin			
5 years	---	.498	.535
11 years	---	---	.928
Polar, Wisconsin			
5 years	---	.493	.334
11 years	---	---	.916
Kellogg, Michigan			
5 years	---	.252	.105
11 years	---	---	.894
Cloquet, Minnesota			
5 years	---	.212	.138
11 years	---	---	.813
Grand Rapids, Minnesota			
5 years	---	.008	-.021
11 years	---	---	.758



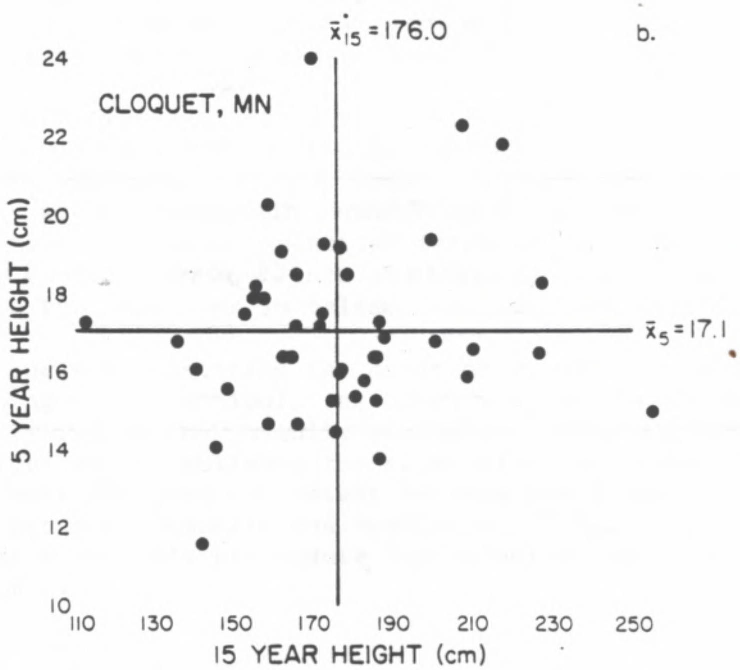


Figure 3. Age-age correlations at five and fifteen years from seed for provenances of balsam fir at two locations in the Lake States.

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