Geographic Variation in Red Pine

11-year Data from the North Central States

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(Received June 1972)

Red pine (Pinus resinosa AIT.) was a common tree in the original forests of northeastern United States and adjacent Canada. It has not reproduced naturally as well as other native pines and large natural stands are rare today in many sections where the species was once common.

Plantations, however, are common. This species is well adapted to plantation culture, has excellent form, comparatively few serious pests and is productive on good sites. For example, one 43-year-old plantation in northern Michigan averaged 2½ cords per acre per year, a yield which compares favorably with yields of sub-tropical pines. For these reasons, red pine has been planted extensively throughout its natural range and plantations literally cover millions of acres.

Previous Work

Because it is the most commonly planted conifer in the Northeast, red pine has been the subject of tree improvement research for over four decades. A series of genetic experiments on geographic variation was started in 1928 by CARLOS G. BATES of the Lake States (now North Central) Forest Experiment Station. Trees were grown from seed collected from native stands in several parts of the Lake States and from a few places in Pennsylvania and New Hampshire. Seedlings were grown in the U. S. Forest Service Nursery at Cass Lake, Minnesota and distributed from there as 2-0 or 2-1 planting stock. Several plantations were established from 1931 to 1937 and four survived well enough to be the subject of published reports. Pertinent details of those four are given in Table *1*.

Eighteen seedlots were common to the two Superior National Forest plantations. The correlation in height growth between the two plantations was weak ($r = .38$, not significant at 5% level with 16 d. f.). In fact, a seedlot reported as slowest growing of the 18 by RUDOLF (1948) was reported as fastest growing by NIENSTAEDT (1964).

When the data from the four plantations are grouped according to region of origin the three Minnesota plantations give the general impression of very little geographic variation, at least among trees grown from seed collected in the Lake States (table 2). The Pennsylvania plantation offers some evidence of geographic variation — red pines from Michigan's Lower peninsula grew fastest.

The earliest experiments were established to investigate broad geographic trends. Two more recent experiments involve more intensive range sampling within single states. YAO et *al.* (1971) reported 10-year growth of the offspring of 272 single trees located in various parts of Michigan. The most important differences were between Upper (northern) and Lower Peninsula trees. In each of two Lower Peninsula plantations, Lower Peninsula trees grew 10% faster than Upper Peninsula trees (difference significant at 1% level). In each of two Upper Peninsula plantations, the Lower Peninsula trees grew 3% faster than Upper Peninsula trees (difference not significant).

LESTER (1971) reported 3-year height of the offspring of 43 different Wisconsin stands. In each stand he collected seed from 5 to 8 trees. Trees originating south of the 45th parallel grew 5% taller than trees originating in the northern half of the state. The between-region differences accounted for about 20% of the total genetic variance.

Neither YAO et al. nor LESTER found evidence of consistent geographic trends within the northern nor the southern parts of their states. Although the offspring of different stands in the same region differed significantly, no one portion of southern Wisconsin nor southern Michigan could be designated as likely to produce exceptionally fast growing red pines.

A further review of other aspects of the "Genetics of Red Pine" is contained in FOWLER and LESTER's (1970) review paper.

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Table 1. — Description of early geographic origin tests of red pine established by the U. S. Forest Service.

Location (National Forest and State), year of planting, author of latest report	No. of seedlots	Survival	At last measurement: Age from seed	At last measurement: Height	At last measurement: Range in seedlot means
	no.	%	years	feet	% of mean height
Superior, Minn. 1931 RUDOLF (1948)	37	68	18	13	33
Superior, Minn. 1931—33 NIENSTAEDT (1964)	69	20	34—36	40	16
Chippewa, Minn. 1937 BUCKMAN and BUCHMAN (1962)	48	—	27	40	12
Allegheny, Pa. 1937 HOUGH (1967)	50	89	28	40	12

Table 2. — Relative height of red pine grown from seed collected in different National Forests (NF) of the Lake States and Northeast[1])

Place of seed collection	Height as % of plantation mean when grown in			
	Superior NF Minn.	Superior NF Minn.	Chippewa NF Minn.	Allegheny NF Penna
Minnesota	104	102	100	96*
Wisconsin	100	101	99	100*
Michigan Upper Peninsula	97	98	99	101*
Michigan Lower Peninsula	95	100	101	107
New Hampshire	86*	—	—	100
Pennsylvania	—	—	—	102

[1]) The New Hampshire and Pennsylvania means are relatively unreliable, as they are based on only 1—2 seedlots per state in each plantation.
* Significantly shorter (5% level) than the tallest seedlots.

Material and Methods

The present experiment was undertaken to sample the gamut of genetic variation in red pine and to provide practical seed source information for tree planters in the north central states. Seeds were obtained from 77 natural stands and 3 plantations in all parts of the range in 1959; from 14 more natural stands in 1960. Most stands were represented by seeds from 10 or more average trees. The distribution of the parental stands is shown in *Figure 1.*

The 1959 seeds were sown in 1960 in a replicated nursery experiment at East Lansing, Michigan and grown there to 3-0 size. The 1960 seeds were sown in 1961 in the same nursery and grown there to 2-0 size. All stock was transferred to permanent test plantations in the spring of 1963. Further details of nursery practice and results are contained in a paper by WRIGHT *et al.* (1963).

Eight permanent test plantations worth measuring and four more which have been discarded because of extremely heavy initial mortality were established in five north central states. Each followed a randomized complete block design with 4 to 10 replications and 4-tree row plots. Spacing was 8 × 8 feet or 8 × 12 feet. It was our intention to test all seedlots at all sites but this was not possible because of limitations of space and planting stock. Hence each seedlot was distributed as widely as possible. Further details of the successful test plantations are contained in *Table 3.*

The Nebraska plantation was measured several times, the others once or twice. The last measurements were made in 1970 or 1971 and were confined to mortality, height and fruiting. Few form deficiencies or cases of serious insect injury were noted.

Each set of measurements for a single plantation was subjected to analysis of variance. Among-seedlot differences were in all cases statistically significant (1% level). However, average performance at all eight plantations is probably of more interest than performance at any one plantation. Hence an overall analysis of variance was performed, after converting all heights to a percentage of the mean height for each plantation. Such an analysis neglected among-plantation differences, which undoubtedly are significant.

Results

Mortality. — Mortality in the eight most successful plantations is shown in *Table 3.* Except in Nebraska, most deaths occurred within a year of planting and were unrelated to seed source. However, seedlots (nos. 791 and higher) which were planted as 2-0 stock suffered much higher mortality than the remainder which were planted as 3-0 stock.

High mortality in plantation 14—62 in Allegan County Michigan is probably the consequence of fall planting. That and four other red pine and Scotch pine (*Pinus sylvestris*

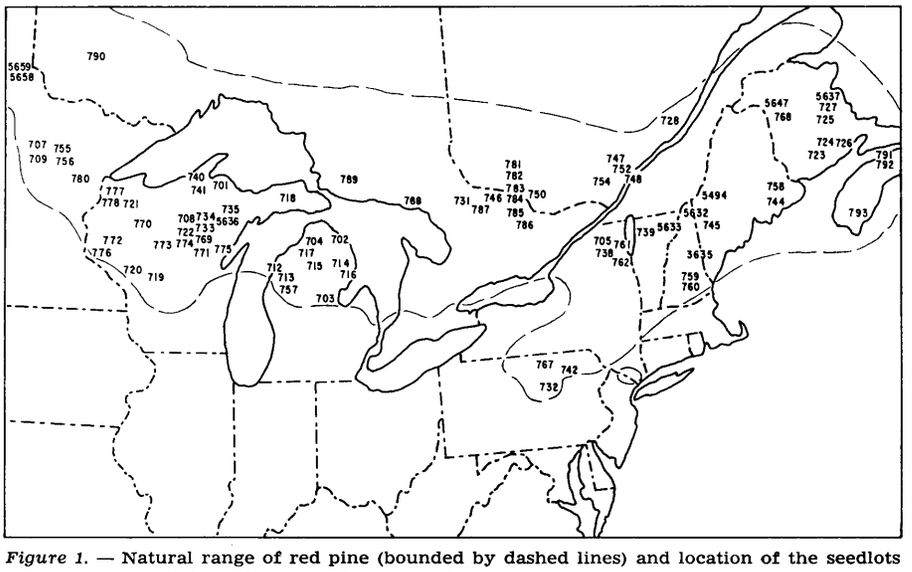

Figure 1. — Natural range of red pine (bounded by dashed lines) and location of the seedlots (indicated by numbers) tested in the present experiment.

Table 3. — Location, contents, mortality and height of eight plantations measured in the present experiment.

Plantation No., State and County	Number of seedlots	Mortality through 1970	Height and year at last measurement	
		%	feet	year
20—63 Minn., Carlton	48	5	7.9	1970
16—63 Wis., Juneau	38	13	9.6	1971
12—63 Mich., Chippewa	85	19	7.4	1970
2—63 Mich., Kalamazoo	63	12	6.9	1970
14—62 Mich., Allegan	89	63	5.0	1970
10—63 Mich., Cass	60	21	7.9	1970
23—63 Ind., Tippecanoe	18	14	6.7	1969
19—63 Neb., Cass	52	43	12.2	1971

L.) experimental plantations were established in southern Michigan in the fall of 1962, with results so poor that the practice has been discontinued.

Superiority of 3-0 stock. — Most seedlots were sown in 1960 and field-planted in 1963 as 3-0 stock; 14 seedlots (Nos. 791—793 and 5494—5659) were sown in 1961 and field planted as 2-0 stock. The 3-0 stock grew 11—15% (average 13%) taller than 2-0 stock from the same general region. Accordingly, the average heights of the late-sown seedlots were adjusted upward by 13% in the preparation of *Table 4.*

Correlation between nursery and later heights. — Heights of seedlots 701—790 were measured at ages 2 and 3 in the nursery. Those seedlot means were correlated with the all-plantation means with the following results. The correlations were:

r = .57 between 2-year and 11-year (from seed) height,
r = .43 between 3-year and 11-year (from seed) height.

Those correlations are statistically significant at the 1% level with 78 degrees of freedom. They are not nearly so high, however, as the correlation of r = .8 between 9- and 15-year (from seed) height reported by Lester and Barr (1966) for a Wisconsin red pine experiment.

In 1963 Wright *et al.* published on 3-year performance of seedlots 701—790 in Michigan. Several conclusions reached in that paper are still valid. But the apparent early superiority of New England trees is not so evident now. And a few seedlots which were outstanding in the nursery are now only slightly better than average.

Geographic differences in growth rate. — To facilitate comparisons, the seedlot means were converted to per-

Table 4. — Comparative height growth (expressed as % of plantation mean) of red pine grown from seed collected in 94 places and tested in 8 localities.

Seedlot No. & State	N. Lat.	W. Long.	Relative height growth in plantation: 20-63 Minn.	16-63 Wis.	12-63 Mich. Chip.	2-63 Mich. Kala.	14-62 Mich. Alle.	10-63 Mich. Cass	23-63 Ind.	19-63 Neb.	Mean Rel. Ht.
	°	°									
727 N.B.	47.2	65.4	--	--	94	--	80	--	--	--	85
768 N.B.	47.0	67.4	93	98	91	--	86	--	98	97	93
5647 N.B.	46.8	67.6	--	--	103	87	76	98	--	98	93
5637 N.B.	46.7	64.9	--	--	91	--	86	--	--	--	88
725 N.B.	46.6	65.6	98	85	95	101	79	86	--	71	88
724 N.B.	46.0	66.1	87	99	102	95	86	96	92	98	96
726 N.B.	46.0	64.8	--	--	--	82	93	--	--	--	89
723 N.B.	45.7	66.3	96	--	97	94	86	95	86	85	92
			**********								
791 N.S.	45.2	64.0	--	--	--	--	95	102	--	--	97
792 N.S.	45.1	63.9	--	--	--	--	90	96	--	--	92
793 N.S.	44.3	65.1	--	--	94	84	95	97	--	--	92
			**********								
728 QUE	46.9	71.4	100	--	106	104	101	--	--	92	102
747 QUE	46.4	73.3	97	--	88	--	95	95	--	--	94
754 QUE	46.2	73.9	98	85	96	--	109	107	99	96	98
752 QUE	46.1	73.3	--	120	95	111	112	--	119	113	109
748 QUE	46.1	73.3	--	92	106	104	110	108	--	104	105
750 QUE	45.9	76.6	100	98	104	--	125	--	94	93	104
			**********								
729 ONT	--	--	100	--	95	94	107	--	--	--	100
789 ONT	46.8	83.9	96	--	--	--	95	--	--	--	95
788 ONT	46.6	82.2	--	93	89	94	96	--	--	96	93
731 ONT	46.3	79.9	106	--	101	99	111	99	--	106	104
786 ONT	46.2	77.2	--	--	102	113	130	--	--	96	110
781 ONT	46.0	77.4	--	85	103	102	108	95	91	109	99
782 ONT	46.0	77.4	--	99	103	109	104	102	--	105	104
783 ONT	45.9	77.5	--	--	101	--	83	116	--	101	103
784 ONT	46.0	77.6	89	--	104	111	98	101	--	106	101
785 ONT	46.0	77.5	93	--	105	104	93	103	--	103	100
787 ONT	45.8	78.0	90	107	101	107	94	109	--	104	102
746 ONT	45.6	77.1	101	--	102	101	123	111	--	--	111
			**********								
5658 MAN	49.1	95.9	--	--	97	75	86	96	--	--	88
5659 MAN	49.1	95.9	--	--	95	77	89	113	--	--	94
790 ONT	49.8	83.9	97	--	92	88	94	--	--	--	93
			**********								
5494 MAI	45.2	70.1	--	--	97	--	95	--	--	100	99
758 MAI	45.0	67.8	--	84	93	85	109	91	--	--	92
744 MAI	44.7	67.8	--	--	86	--	94	--	--	--	88
745 MAI	44.3	70.1	--	--	103	--	94	97	--	--	99
5632 N.H.	44.4	71.2	--	--	101	90	90	102	--	--	96
5635 N.H.	43.8	71.2	--	--	100	99	88	101	--	--	98
759 N.H.	43.2	71.8	80	--	--	99	103	107	102	88	98
760 N.H.	43.1	71.7	108	--	104	--	99	110	--	103	105
5633 VT	44.8	71.9	--	--	97	102	96	94	--	--	97
739 VT	44.6	73.1	99	107	113	117	--	114	109	106	109

Seedlot No. & State	N. Lat.	W. Long.	Relative height growth in plantation: 20-63 Minn.	16-63 Wis.	12-63 Mich.	2-63 Mich.	14-62 Mich.	10-63 Mich.	23-63 Ind.	19-63 Neb.	Mean Rel. Ht.
	°	°									
705 N.Y.	44.5	74.2	89	--	97	79	103	82	--	--	92
738 N.Y.	44.5	74.3	95	96	101	97	104	102	102	98	99
761 N.Y.	44.3	73.7	90	99	102	98	108	--	105	100	101
762 N.Y.	44.3	73.7	90	--	--	--	--	--	--	103	97
765 N.Y.	Plantation		--	103	104	105	93	102	100	102	101
			**********								
730 PA	Commercial		--	--	103	104	--	--	--	--	103
742 PA	41.6	72.3	--	--	104	93	84	--	--	--	93
767 PA	41.6	76.2	--	--	107	--	100	108	--	--	105
732 PA	41.3	77.8	--	--	108	107	109	106	96	--	106
			**********								
707 MIN	47.5	94.0	--	--	94	78	98	--	--	--	92
709 MIN	47.5	94.0	--	--	102	89	80	--	--	--	92
755 MIN	47.5	94.3	107	104	104	--	91	--	--	101	100
756 MIN	47.3	94.5	118	109	112	--	118	106	116	95	112
780 MIN	46.7	92.5	89	89	94	92	107	100	--	86	92
			**********								
777 WIS	46.5	91.6	110	94	95	96	98	105	--	97	100
734 WIS	46.4	89.6	104	98	109	104	91	90	96	102	100
778 WIS	46.3	91.9	95	104	106	108	108	101	--	101	104
721 WIS	46.2	91.2	--	--	--	96	105	--	--	--	102
5636 WIS	46.1	84.7	--	--	100	104	95	105	--	--	101
733 WIS	46.1	89.6	105	--	103	110	109	--	--	91	104
708 WIS	46.0	88.5	--	--	92	99	94	--	--	--	95
722 WIS	46.0	89.5	106	101	111	104	107	105	--	103	106
769 WIS	45.8	89.1	--	96	112	98	107	111	--	--	106
770 WIS	45.8	90.4	--	101	103	--	112	--	90	94	102
771 WIS	45.6	89.7	95	91	105	107	96	89	--	99	98
773 WIS	45.6	89.8	106	117	109	111	107	111	--	105	110
774 WIS	45.6	88.8	111	107	106	100	106	99	--	98	103
775 WIS	45.6	88.2	--	--	102	99	113	110	--	--	106
776 WIS	45.2	92.0	97	--	107	96	93	87	--	102	97
772 WIS	44.8	91.4	110	--	104	103	99	114	--	106	106
720 WIS	44.8	91.3	104	--	105	99	89	100	--	107	101
719 WIS	44.3	89.8	--	--	108	--	109	101	--	88	103
			**********								
701 MIC UP	46.9	88.4	102	94	99	--	100	102	--	90	98
740 MIC UP	46.9	88.3	101	97	98	96	106	100	--	--	99
741 MIC UP	46.8	88.5	100	96	99	--	91	102	--	--	97
735 MIC UP	46.6	87.5	99	102	100	90	91	--	94	102	97
718 MIC UP	46.5	85.0	--	--	97	--	103	--	--	--	102
			**********								
702 MIC LP	45.6	84.2	113	103	107	98	116	112	--	--	107
704 MIC LP	45.3	84.3	107	114	98	102	107	101	--	--	105
714 MIC LP	44.5	83.9	110	--	107	104	106	111	--	--	107
716 MIC LP	44.5	83.5	--	--	106	111	104	--	--	--	106
717 MIC LP	44.5	85.5	--	--	101	--	98	100	--	--	100
712 MIC LP	44.2	85.9	--	--	102	101	117	108	--	113	107
713 MIC LP	44.2	85.5	110	103	112	104	110	102	--	112	108
757 MIC LP	44.2	85.5	102	121	110	--	105	116	112	108	110
703 MIC LP	43.9	84.5	110	114	--	106	119	109	-----	105	112
715 MIC LP	43.8	85.5	--	--	115	--	113	--	--	--	114

Table 5. — Comparative heights of red pines grown in eight plantations, summarized by province or state of origin. Single-plantation means are excluded if based upon one seedlot only per plantation.

Province or state of origin	Relative height growth in plantation								Mean Rel. Ht.
	20—63 Minn.	16—63 Wis.	12—63 Mich. Chip.	2—63 Mich. Kala.	14—62 Mich. Alle.	10—63 Mich. Cass	23—63 Ind.	19—63 Neb.	
	% of plantation mean								
N.B.	94	94	96	92	84	94	92	90	92
N.S.	—	—	—	—	93	98	—	—	94
QUE	99	99	99	106	109	103	104	99	103
ONT	96	96	101	103	103	104	—	103	102
MAN & W ONT	—	—	95	80	90	104	—	—	92
MAI N.H. VT	96	95	99	99	96	102	105	99	99
N.Y.	91	99	101	95	102	95	102	101	98
PA	—	—	105	101	98	107	—	—	104
MIN	105	101	101	87	99	103	—	96	100
WIS	104	101	105	102	102	102	98	99	102
MIC UP	100	97	99	93	98	101	—	96	98
MIC LP	109	111	106	104	110	108	—	109	108

centages of the plantation means. Also the seedlots were grouped according to political subdivisions, only the Upper vs. Lower Peninsula of Michigan distinction being a natural one. Within groups the seedlots were arranged from north to south. *Table 4* presents mean heights for all seedlots in all plantations and weighted mean heights for each seedlot in all plantations. *Table 5* is a summary, showing mean heights by groups of seedlots and plantations.

Red pines from Michigan's Lower Peninsula grew fastest in all plantations, except one. Only in plantation 2-63 (Kellogg Forest, Kalamazoo County, Michigan), were they surpassed slightly by trees from Quebec. That is probably the most important feature of the geographic variation pattern. The red pine forest of Lower Michigan is separated from the Upper Peninsula forest by the Straits of Mackinac which form a 4-mile tree-to-tree barrier to pollen and seed exchange. This barrier, which has existed for 9—10,000 years, permited natural selection to result in the formation of a faster growing race in the warmer Lower than in the cooler Upper Peninsula. This tendency has been noted in red pine (Yao *et al.*, 1971) as well as eastern white pine *(Pinus strobus* L.), jack pine *(Pinus banksiana* Lamb.) and tamarack *(Larix laricina* (Du Roi) K. Koch) (Wright, 1972).

As *Table 6* shows, the between-region growth rate differences were significant statistically. But the groups are not homogeneous and single seedlots growing as fast as many from Lower Michigan were obtained from several other states or provinces. For example, seedlots 756-MIN, 773-WIS, 746-ONT and 786-ONT also grew rapidly.

Political subdivisions seemed to be about as useful in grouping the data as any sort of subdivision based upon vegetation or climate. The average growth rate for Wisconsin trees was 102.4% vs. 99.6% for Minnesota and 98.1% for Upper Michigan trees. These differences are greater than the contrasts between southern (below latitude 45°) and northern Wisconsin trees, which had average growth rates of 103.6 and 102.2% respectively. Other attempts at natural subdivisions failed.

Table 6. — Analysis of variance of the height data in *Table 4*, including data from 75 seedlots (Nos. 701—789) from natural stands planted as 3-0 stock.

Source of variation	Degrees of freedom	Mean square	F value
Seedlot	74		
Between region	9	683.89	5.12**
Within region	65	124.94	2.76**
Seedlot × plantation interaction	313	45.43	
Total	387		

** = statistically significant at 1% level.

Fruiting. — By 1971 fruiting had occurred in three of the plantations, as follows:

Plantation No. and location	Percent of trees with cones in 1970 or 1971
2—63 S. Michigan	4
23—63 Indiana	34
19—63 Nebraska	6

Only an occasional tree produced more than a few cones. Wisconsin trees had average fruiting percentages of 6, 53 and 7% respectively in the three plantations. Their slight superiority was the only evidence of genetic differences in early fruiting ability.

Practical Application

There are now provenance data from 12 experimental plantations — 8 in this experiment and 4 in others. Those are supplemented by data from 4 half-sib progeny tests in Michigan. Our results agree well with those of Hough (1967) in Pennsylvania, agree less well with but do not contradict the results of Buckman and Buchman (1962) in northern Minnesota, and do not agree with the results of Rudolf (1948) in northern Minnesota. Yao *et al.* (1971) found that Lower Michigan red pine had a 10% growth rate superiority over Upper Michigan red pine in Lower Michigan, 3% superiority in Upper Michigan. In our experiment the superiority was 7—12% in Lower Michigan, 7% in Upper Michigan.

Weighing all results, it seems that red pine from Michigan's Lower Peninsula is the fastest growing in all parts of the north central states except northern Minnesota and possibly the coldest parts of northern Wisconsin and northern Michigan. An immediate gain would result if all nurserymen except those in extreme northern areas were to use seed collected from native stands in Lower Michigan. The size of the gain would depend on the present seed source and might vary from 2 to 10% in rate of height growth.

An equal or greater amount of gain could be achieved if seed were collected from any or all of those 10 exceptional

stands (752-QUE, 746-ONT, 756-MIN, 773-WIS, 703-MIC LP, etc.) which produced offspring exceeding the all-plantation average by 8% or more. Those stands are scattered and would have to be designated carefully because some are within a few miles of stands which produced average or below-average offspring.

New York has grown only "Adirondack" red pine, Michigan has grown only "Upper Peninsula" or "Lower Peninsula" red pine and most seedsmen have stocked only "red pine". Most nurserymen and seedsmen dealing with this species would prefer to collect from a large area such as Michigan's Lower Peninsula rather than to collect from many scattered stands. Hence, it will be more difficult in practice to organize seed collection from several scattered stands than from one large area such as Lower Michigan.

Michigan has started a series of half-sib progeny test-seed orchards of red pine, using seed from native Michigan (mostly Lower Peninsula)trees (YAO *et al.*, 1971). These will be thinned to leave offspring of the best trees in the best stands. Ten-year results indicate that the seed produced will grow 2—3% faster than the offspring of the good stands listed in *Table 4*. Wisconsin has a similar improvement project underway (LESTER, 1971) and 3-year results indicate gains similar to those predicted for Michigan.

Those seed orchards were undertaken for the benefit of Michigan and Wisconsin growers. But most data from the present experiment indicate that the improvement achieved could be utilized in most other places in the region except for the extreme north. *Tables 4—6* show a strong tendency for seedlots which grow well one place to grow well other places also. In fact, of the 10 seedlots which exceeded the all-plantation average by 8% or more, 4 grew well at all sites and the other 6 grew well at all except one or two places. Thus it is probable that those particular half-sib families retained for seed production because of their excellence in Wisconsin or Michigan will produce seed well adapted to Indiana and Nebraska.

A special type of statistical analysis was performed to study this question in more detail. We (1) listed seedlots common to plantations A and B, (2) grouped these seedlots according to whether their relative growth rates at plantation A were above or below the all-plantation averages, (3) computed relative (to all-plantation averages) growth rates of those two groups at plantation B and (4) used an F-test to determine whether the groups which were superior and inferior at A differed significantly at B. The process was repeated for each pair of plantations, for a total of $8 \times {}^{7}/_{2} = 28$ inter-plantation comparisons.

Of the 28 comparisons, only 4 were significant statistically at the 5% level (= *) or 1% level (= **). These four were between plantations

20—63 (Minn.) and 19—63 (Neb.) *
12—63 (N. Mich.) and 19—63 (Neb.) **
12—63 (N. Mich.) and 14—62 (SW. Mich.) *
16—63 (Wis.) and 14—62 (SW. Mich.) *

In these four cases, seedlots which grew 4—6% taller than the all-plantation average rate at the first-named plantation grew 2—3% shorter than the all-plantation average rate at the second plantation, and vice versa.

These analyses indicate that positive selection in northern Minnesota and northern Michigan may constitute negative selection for Nebraska conditions, and that positive selection in Wisconsin and northern Michigan may constitute negative selection for one of three southern Michigan sites. The other 24 non-significant comparisons among six plantations in Minnesota, Wisconsin, Michigan and Indiana indicate that average growth rate at all six sites is the best indicator of probable growth rate of a certain seedlot on a site similar to one of the six test sites.

Earliness of fruiting is important in seed orchard management. The southernmost (Indiana and Nebraska) plantations fruited most heavily. If, as the majority of the results indicate, selection practiced in Wisconsin or Michigan's Lower Peninsula can also be effective for more southerly states, one might assume that early-fruiting seed orchards could be developed in Indiana and Nebraska which would yield seed suited to many parts of the Lake States. At the least, this possibility should be considered when planning future seed orchard development work in the north central states.

Summary

Red pine grown from seed collected in 91 natural stands and 3 plantations was tested in 8 localities in the north central states. Trees from Michigan's Lower Peninsula grew fastest at all sites, averaging 8% taller at age 11 than the all-plantation average. Trees from New Brunswick, Manitoba and western Ontario grew slowest at all sites, averaging 8% shorter than the all-plantation average. In Michigan, the Straits of Mackinac form a natural barrier to crossing so that natural selection could result in the development of more or less distinct northern and southern races. Nowhere else was there evidence of a sharp natural boundary and most states or provinces contributed an exceptionally fast growing seedlot. Early fruiting was heaviest in the Indiana and Nebraska plantations; genetic differences in fruiting were slight.

The ten fastest growing seedlots grew rapidly at almost all sites whether planted in Minnesota, Wisconsin, Michigan, Indiana or Nebraska. Two other experiments indicate, however, that northern Minnesota and northern Michigan may need slightly different types of red pine than the southern parts of these states. Thus, one set of criteria may suffice for seed procurement and seed orchard development for all parts of the region except the extreme north.

Key words: Red pine, growth rate, site-genotype interaction.

Zusammenfassung

91 Herkünfte von natürlichen Beständen und 3 von Pflanzungen von *Pinus resinosa* wurden an 8 verschiedenen Orten der „North-Central-States" in den U.S.A. geprüft. Diejenigen aus dem südlichen Michigan (Lower Peninsula) wuchsen auf allen Standorten am schnellsten. Sie waren im Jahre 11 um 8% höher als der Durchschnitt aller Pflanzungen. Diejenigen aus New Brunswick, Manitoba und West-Ontario wuchsen am langsamsten auf allen Standorten. Sie waren um 8% niedriger als der Durchschnitt aller Pflanzungen. In Michigan bilden die „Straits of Mackinac" eine natürliche Barriere, so daß sich eine mehr oder weniger ausgeprägte nördliche und südliche Rasse der *P. resinosa* entwickeln konnte. Sonst gab es aber keine weitere natürliche Grenze, und die meisten Staaten und Provinzen lieferten ausgezeichnet schnellwachsende Herkunftsproben. Die Pflanzungen von Indiana und Nebraska fruktifizierten besonders früh; genetische Unterschiede waren dort aber nur geringfügig. — Die 10 raschwüchsigsten Herkünfte verhielten sich fast auf allen Standorten in den Pflanzungen von Minnesota, Michigan, Indiana und Nebraska gleich. 2 andere Versuche haben aber ergeben, daß der Norden Minnesotas und Michigans etwas andere Resinosa-Typen benötigt als der Süden. Mit Ausnahme des äußersten Nordens genügen demnach für alle Teile des Versuchsgebietes einheitliche Kriterien für die Samenbeschaffung und eine einheitliche Entwicklung von Samenplantagen.

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Screening of Haploxylon Pines for Resistance to the White Pine Weevil

II. Pinus strobus and other species and hybrids grafted on white pine[1])

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(Received June 1972)

Previously observations on weevil (*Pissodes strobi* PECK) resistance of *Pinus peuce* GRISEB. and *P. strobus* L. field-grafted on *P. sylvestris* L. were considered (HEIMBURGER and SULLIVAN, 1972). The present study reports on weevil resistance of additional white pine materials grafted on *P. strobus*.

Materials and Methods

A 3.3-acre (1.3 ha) plantation of *P. strobus* was established at 6 × 6 ft (1.83 × 1.83 m) spacing in 1957, in Kirkwood Township, Ontario. The trees were planted in north-south rows, and the plantation subdivided into 11 blocks by east-west lines. All grafting was done in the spring, with one scion on each stock tree. Series 1, 1961, utilized the five southern blocks, Series 2, 1962, blocks 6—10 and Series 3, 1963, block 11, at the north end (*Table 1*). The clones have been selected as resistant to blister rust (*Cronartium ribicola* FISCHER).

The origin of the *P. strobus* clones 153, 154 and 157 is the same as that of the five unattacked *P. strobus* of the preceding study. They are one generation removed from a natural stand of good growth form and with a low weevil population. *P. peuce* clones 700 and 709 have also been included in the preceding study. Within each block the ramets are distributed at random. Weevil attacks on all leaders were recorded on the basis of a target made avail-

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Table 1. — Grafting record.

Species	Clone	Origin	Series[1])
Pinus koraiensis SIEB. & ZUCC.	362, 369	Orono, Ont.	2, 2
Pinus monticola DOUGL.	346, 349, 350	Garibaldi, B. C.	1, 1, 1
Pinus peuce GRISEB.	92, 94	Jamaica Plain, Mass.	1, 3
	700, 709	Havelock, Ont.	1, 1
	229, 230, 196, 198	Rochester, N. Y.	2, 2, 3, 3
	740, 741	Ottawa, Ont.	2, 2
Pinus strobus L.	56, 60, 62, 56, 55	Pte. Platon, P. Q.	1, 1, 1, 2, 3
	153 154, 157	Midhurst, Ont.	1, 1, 1
	500, 512, 519, 539	Ottawa, Ont.	2, 2, 2, 2
	541, 546, 616, 622	Ottawa, Ont.	2, 2, 2, 2
	624, 625, 644, 645	Ottawa, Ont.	2, 2, 2, 2
	646, 683	Ottawa, Ont.	2, 2
	30	Kroglund, Denmark	3
	120	Wisconsin Rapids, Wis.	3
Pinus wallichiana A. B. JACKSON	315	Jamaica Plain, Mass.	1
	326	Elmhurst, Ill.	1
Pinus peuce × *strobus*	689, 691, 693	Petawawa F. E. S.	1, 1, 1
	28	Charlottenlund, Denmark	3
	262, 263	St. Williams, Ont.	3, 3
Pinus strobus × *himekomatsu* MIYABE & KUDO	307, 308, 319	Wellesley, Mass.	1, 1, 1
Pinus wallichiana × *strobus*	739	Toronto, Ont.	1

[1]) In Series 1 and Series 2, 47—52 (mostly 50) scions of each clone were grafted, and 24—25 (mostly 25) in Series 3.