TEN-YEAR HEIGHT GROWTH VARIATION IN LAKE STATES JACK PINE

by James P. King1

Jack pine *(Pines banksiana* Lamb.) is one of the major pulpwood producing species in the Lake States. It is found on a variety of sites, but its outstanding characteristic is its ability to make early rapid growth on dry sandy soils.

In 1951 the Lake States Forest Experiment Station and the University of Minnesota initiated a seed source study of Lake States jack pine. Federal, State, and private forestry agencies collected seed from 29 stands in Minnesota, Wisconsin, and Michigan. The seedlings were used to establish 17 permanent test plantations in the three States.

Several reports have already come from this study. Rudolf and Jensen (1955-1958) described first- and second-year survival and second-year height growth and causes of mortality in all 17 plantings. Stoeckeler and Rudolf (1956) described seed source differences in fall coloration in the Hugo Sauer Nursery at Rhinelander. Differences between sources in susceptibility to white-pine weevil on the Chippewa National Forest plantations in northern Minnesota were reported by Batzer (1961). Arend *et al.* (1961) summarized seed source differences in 5-year height growth and white-pine weevil incidence in three plantings in Lower Michigan. Rudolph (1964) reported on differences in Lammas growth and prolepsis of selected origins in four Minnesota and two Wisconsin plantings. Seed source differences in needle cast infection in a southern Wisconsin and a western Upper Michigan planting were described by King and Nienstaedt (1965).

This paper describes the height growth at the end of 10 growing seasons in 11 of the 17 plantations.

Methods

In 1951 seed was collected from 29 jack pine stands in Minnesota, Wisconsin, and Michigan. Each collection was made from dominant and codominant trees in a stand considered good for its locality.

In the spring of 1952, seed from all 29 stands were sown in both the General Andrews State Nursery at Willow River, Minn., and in the Hugo Sauer Nursery at Rhinelander, Wis.

In 1954 two-year-old seedlings were used to establish 17 test plantations throughout the three States. Seedlings from the General Andrews Nursery were used in the six Minnesota plantings and two western Wisconsin plantings, while seedlings from the Hugo Sauer Nursery were used to establish four Wisconsin and five Michigan plantations.

At each location a four-replicated, randomized, complete-block design was used. Each replication contained a square 64-tree plot of each experimental seed source plus one "local" seedlot of stock furnished by a commercial nursery in the same I area as the test plantation. Because of shortages within various seedlots, substitution had to be made in several plantings. Nevertheless, there were still 26 sources common to all plantings. The location of these 26 sources is shown in table 1 and figure 1.

Table 1.-- Seed source location data

Seed source number	County	Degrees of- Latitude	Longitude
	MINNESOTA		
1589	Cass	47.40	94.35
1590	Cass	47.05	94.52
1591	Itasca	47.55	94.05
1592	Lake	47.75	91.23
1593	Cook	48.00	90.33
1594	St.Louis	48.03	92.42
1595	Pine	45.95	92.55
1596	Pine	46.30	92.93
1597	Becker	47.08	95.47
1600	Cass	46.75	93.97
1601	Beltrami	47.48	95.00
1602	Itasca	47.75	93.28
	WISCONSIN		
1605	Bayfield	46.75	90.95
1606	Forest	46.02	88.93
1608	Burnett	45.92	92.03
1609	Marinette	45.28	88.00
1610	Oneida	45.75	89.93
1611	Wood	44.45	89.72
	MICHIGAN		
1612	Gogebic	46.22	89.20
1613	Ontonagon	46.56	89.02
1614	Alger	46.24	86.62
1615	Chippewa	46.26	84.84
1616	Manistee	44.26	86.26
1617	Ogemaw	44.34	84.12
1618	Alpena	45.00	83.54
1621	Luce	46.60	85.38

[1] *Associate Plant Geneticist, Institute of Forest Genetics, North. Central Forest Experiment Station, Forest Service, U. S. Department of Agriculture, Rhinelander, Wis.*

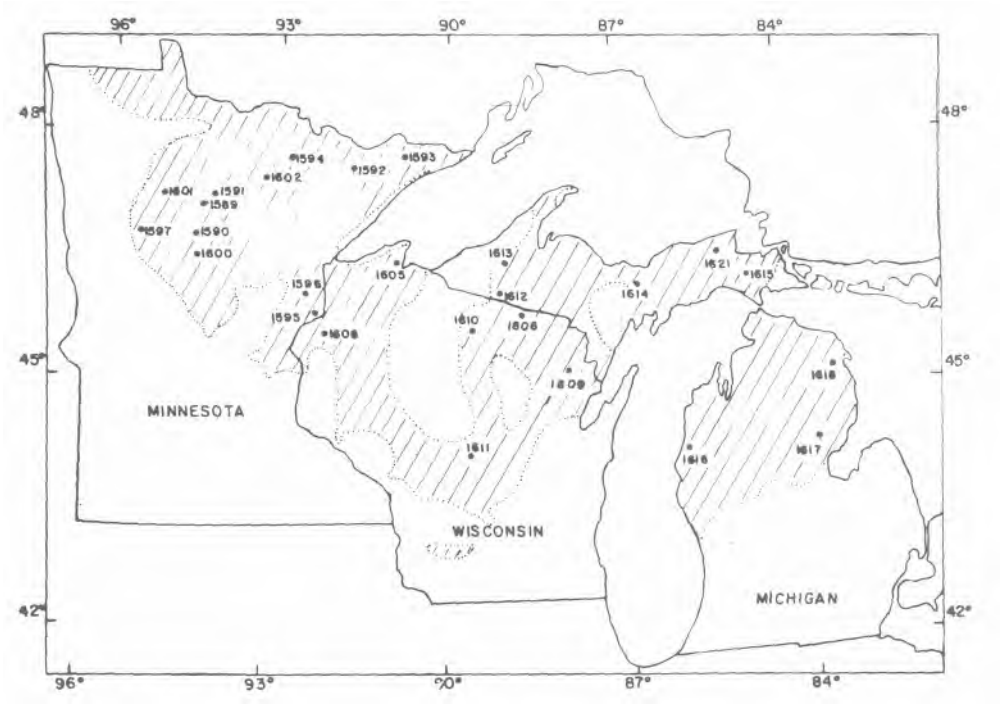

FIGURE 1 — Location of seed sources used in regional study. Shaded areas show main natural range of jack pine (Rudolf and Schoenike 1963).

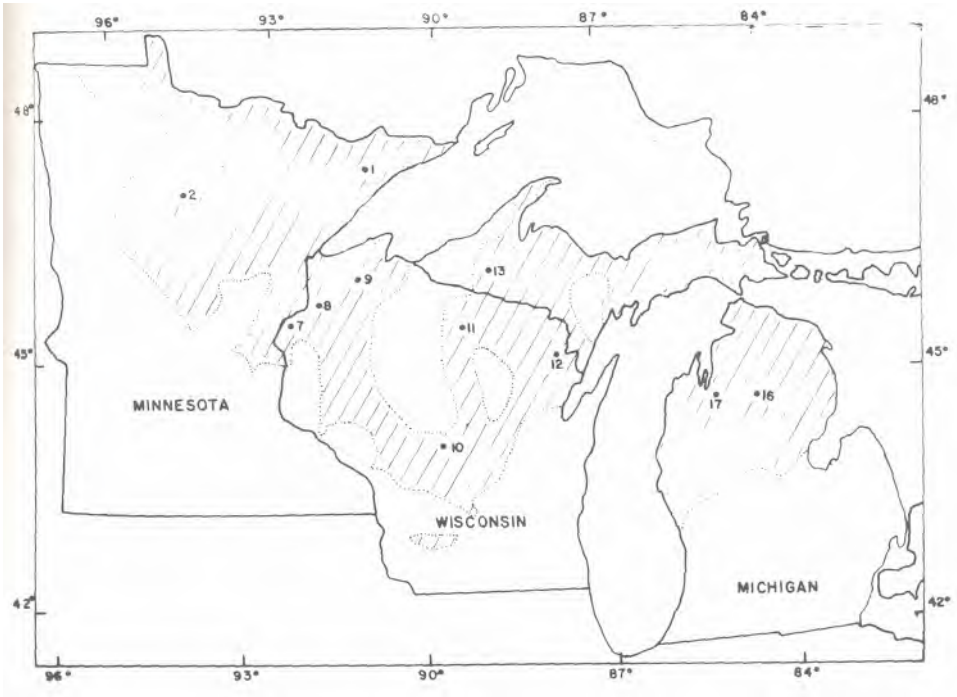

FIGURE 2. — Location of plantations measured in the fall of 1963. Shaded areas show main natural range of jack pine (Rudolf and Schoenike 1963).

In the fall of 1963, 11 of the test plantations (table 2, figure 2), then 10 years old, were measured for height, dbh, form, ramicorn branching, forking, and the presence or absence of seven insects and two diseases; 16 trees on each plot were systematically selected and measured.

Only the 10-year height (measured to the nearest 0.5 foot) of the 26 sources common to the 11 plantations and the local commercial seedlot will be presented here.

Table 2.-- Location of Jack pine test plantations measured in 1963

Plantation number	County	Forest[1]	Agency by which established	Degrees of- Lat.	Degrees of- Long.	Average second yr's. stocking (percent)[2]
			MINNESOTA			
1	Lake	Superior NF	U.S. Forest Service	47.6	91.4	97
2	Beltrami	Chippewa NF	U.S. Forest Service	47.4	94.6	88
			WISCONSIN			
7	Burnett	Burnett CF	Burnett County	45.6	92.8	93
8	Washburn	Mosinee IF	Mosinee Pulp & Paper Mills Co.	46.2	92.0	97
9	Bayfield	Chequamegon NF	U.S. Forest Service	46.3	91.3	92
10	Wood	Nepco IF	Nekoosa-Edwards Paper Co.	44.2	89.8	93
11	Forest	Argonne EF	U.S. Forest Service	45.7	89.0	98
12	Marinette	Marinette CF	Marinette County	45.6	88.0	95
			MICHIGAN			
13	Ontonagon	Ottawa NF	U.S. Forest Service	46.3	89.3	94
16	Crawford	Au Sable SF	Michigan Conserv. Dept.	44.5	84.7	97
17	Grand Traverse	Fife Lake SF	Michigan Conserv. Dept.	44.6	85.4	99

1/ NF = National Forest; CF = County Forest; IF = Industrial Forest; EF = Experimental Forest; SF = State Forest.

2/ Refers to percent of planted spots with thrifty trees (including replants) at end of second growing season (Rudolf and Jensen 1958).

Results

The mean height of the plantation at 10 years in the field varied from 9.58 feet on the Chippewa National Forest in northern Minnesota to 15.15 feet on the Marinette County Forest in northeastern Wisconsin as shown in the following tabulation:

Plantation	*Ave. height growth (feet)*
Minnesota	
Superior NF	10.86
Chippewa NF	9.58
Michigan	
Ottawa NF	12.16
Au Sable SF	9.94
Fife Lake SF	10.39
Wisconsin	
Burnette CF	14.11
Mosinee IF	11.81
Chequamegon NF	11.90
Nepco IF	13.71
Argonne EF	12.75
Marinette CF	15.15

The six plantings in northern Wisconsin made the best growth averaging from 11.81 to 15.15 feet. The two plantings in northern Minnesota and the two in Lower Michigan were the four shortest plantings with means ranging from 9.58 to 10.86 feet.

There were significant seed source differences in 10-year height at every planting except the Chippewa National Forest. The sources ranged from a low of 25 percent below the plantation mean to 17 percent above the plantation mean (table 3) .

At the two plantings in Lower Michigan and four of the Wisconsin plantings (Mosinee IF; Chequamegon NF; Nepco IF; Marinette CF), all three Lower Michigan sources (1616, 1617, and 1618) were in the five tallest sources. At the Burnette and the Ottawa NF plantings the five tallest sources included two from Lower Michigan.

In the two northern Minnesota plantations and one of the Wisconsin plantings (Argonne EF) the sources from north central Minnesota (1589, 1590, 1591, 1597, 1600, and 1601) did better as a group than the Lower Michigan sources (1616, 1617, and 1618). A combined analysis of data from these three plantings showed no significant seed source x plantation interaction. The Argonne planting is on a site that is colder and has a much shorter growing season than the immediately surrounding area. Thus it appears that the fast-growing Lower

Table 3.--Height growth of jack pine seed sources as a percent of the plantation mean

Seed source	Superior NF**	Chippewa NF	Burnette CF**	Mosinee IF**	Chequamegon NF**	Nepco IF**	Argonne EF**	Marinette CF**	Ottawa NF**	AuSable SF**	Fife Lake SF**
					MINNESOTA						
1593	104	96	94	79	88	90	88	90	90	94	95
1592	109[1/]	97	93	77	83	91	99	91	89	98	98
1594	104	92	91	75	78	86	96	90	90	90	91
1602	105	99	95	88	88	95	103	93	97	95	98
1601	102	97[1/]	105	105	103	98	105	101	100	103	105
1591	102	102	102	96	107	98	92	99	99	103	97
1589	101	102	99	99	107	106	102	105	106	103	103
1597	106	101	103	101	100	98	105	99	97	97	102
1590	98	103	103	105	98	99	98	102	105	106	99
1600	98	100	108	107	102	101	102	103	99	97	99
1596	104	107	105	108	104	104	104	100	99	99	101
1595	100	107	100	113	104	102	96	101	103	102	104
					WISCONSIN						
1608	114	102	104[1/]	110[1/]	112	108	101	101	109	104	102
1605	90	100	97	99	103[1/]	95	103	100	97	96	95
1610	100	100	103	102	100	105	108	105	105	104	105
1611	90	102	100	113	97	103	91	97	95	98	100
1609	92	101	102	108	101	104	98	102[1/]	103	98	101
1606	99	94	95	92	100	93	101[1/]	96	97	97	97
					MICHIGAN						
1612	99	99	101	106	104	104[1/]	105	97	106	96	100
1613	100	106	98	97	96	96	102	102	101[1/]	99	93
1614	102	104	97	98	97	105	103	99	93	94	91
1621	94	92	94	90	93	92	94	95	97	95	92
1615	98	97	95	92	96	95	101	101	99	93	95
1616	98	98	109	117	116	116	102	109	109	115	113[1/]
1617	93	97	110	111	109	110	97	114	106	110[1/]	111
1618	99	105	105	114	108	105	105	106	109	116	113
					LOCAL NURSERY						
	111	94	94	94	92	88	90	96	97	101	113

1/ Stand collection from nearest the planting site.
** F value shows a significant difference between at least two seed sources at the 1-percent level.
(Tabular F .01 = 2.07 with 25 and 75 degrees of freedom.)

Michigan sources (1616, 1617, and 1618) are not suited to areas that are colder than the average northern Wisconsin temperatures.

In each of the six Wisconsin plantings and the planting in the western portion of Upper Michigan (Ottawa NF), the best test source exceeded the local commercial nursery stock by 12 to 28 percent in height growth. Only on the Superior NF in Minnesota and the Fife Lake SF in Michigan did the commercial nursery stock fail to differ significantly from the best source in the planting.

In every plantation in Wisconsin and in two of the three Michigan plantations the seed source collection from nearest the planting exceeded the commercial nursery stock in height growth (although in some plantings this difference was not significant). Since these seed source collections were from stands considered good for their area whereas the commercial nursery stock was from unselected stands, even relatively mild phenotypic selection may be worthwhile in this species.

When data from the 11 plantations were combined into a single analysis, there was a significant amount of seed source x plantation interaction (interaction variance/error variance F ratio 2.61 with 250 and 750 degrees of freedom). The most notable source of this interaction was the change in height growth of the northern Minnesota (1592, 1593, 1594, and 1602) and Lower Michigan sources (1616, 1617, and 1618) between the Minnesota and Wisconsin-Michigan planting sites.

However, other sources contributed to the interaction as well. For example, when three Wisconsin plantings (Burnette CF; Mosinee IF; Chequamegon NF) and the planting in western Upper Michigan (Ottawa NF) are considered, the Lower Michigan sources (1616, 1617, and 1618) are the best group and the northeastern Minnesota sources (1592, 1593, 1594, and 1602) the poorest group, but there is still a highly significant amount of interaction present (F = 2.37 with 75 and 225 degrees of freedom). But since these interactions seldom involve the very best sources, they are of little practical consequence.

An interesting result of these interactions is their effect on correlations between seed source performance and seed source climatic and geographic factors. Were an experimenter computing correlations between 10-year height growth and seed source latitude based on the Lower Michigan plantations, he would find negative correlation (r = —.60 with 24 degrees of freedom). However,

were data from two northeastern Minnesota plantations used in the same computations, the correlations would be positive but nonsignificant ($r = .28$ with 24 degrees of freedom).

Moreover, were a researcher working only with data from the well differentiated Wisconsin and Michigan plantations, he might conclude that the jack pine in the Lake States was composed of a number of distinct subpopulations since the Lower Michigan sources (1616, 1617, and 1618), the Upper Michigan sources (1614, 1615, and 1621), and the northeastern Minnesota sources (1592, 1593, 1594, and 1602) all behave similarly within most plantings and still differ significantly from adjacent groups of seed sources.

However, were only data from the two Minnesota plantings plus the Argonne EF planting in northern Wisconsin considered, the researcher might conclude that the jack pine of the region was composed of a single population with an essentially random variation pattern.

This study thus emphasizes the difficulty in studying patterns of within-species genetic variation: Subpopulational differences may express themselves only where the growing conditions are especially favorable (or unfavorable) for a given subpopulation.

Seed Collection Recommendations

The data in this study were collected on relatively young trees. Even so, certain useful seed collection recommendations can be made.

Where the superiority of local seed sources is indicated as in the Lower Michigan plantations, we can safely recommend the use of local seed from carefully selected better-than-average stands as a means of increasing early growth rate.

However, where the superiority of nonlocal sources is indicated, such as in the Wisconsin plantations, the data must be used with caution. In this case one might consider planting mixtures of both local and nonlocal stock. This would give the forest manager some immediate growth increase and still leave him protected against some catastrophic failure of the nonlocal stock in later years.

Specifically, the following recommendations seem reasonable and safe:

1. Collect seed only from better-than-average appearing stands.
2. In Lower Michigan plantings, use only seed collected in Lower Michigan.
3. In Wisconsin and Upper Michigan collect seed from Lower Michigan and mix the Lower Michigan seedlings with seedlings from local stands.
4. In Minnesota collect seed from selected stands near the planting site.

Summary

In the fall of 1963, 10-year height was measured in the Lake States jack pine seed source study. Data on 26 seed sources from Minnesota, Wisconsin, and Michigan that were common to 11 test plantations in the three States are presented along with height growth of a local commercial nursery stock.

Seed sources from Lower Michigan performed best as a group throughout Michigan and Wisconsin. In the northern Minnesota plantings the group of sources from north central Minnesota did best.

At 9 of the 11 plantings the commercial nursery stock was shorter than the test sources by 12 to 28 percent. In almost all of the plantings the test seed source from nearest the planting outgrew commercial nursery stock (though not always significantly).

Whether one considers the variation pattern in jack pine to be continuous or discontinuous depends to some extent on the location and precision of the test plantations. However, in the most strongly differentiated plantings, the variation appears discontinuous.

The selection of "good" jack pine stands for seed collection (phenotypic selection) appears worthwhile in this species. However, selection of tested nonlocal stock will offer even greater improvement.

Literature Cited

Arend, John L., Norman F. Smith, Stephen H. Spurr, and Jonathan W. Wright. 1961. Jack pine geographic variation — five-year results from Lower Michigan tests. Mich. Acad. Sci., Arts, and Letters Proc. 46: 219-238.

Batzer, H. 0. 1961. Jack pine from Lake States seed sources differ in susceptibility to attack by white-pine weevil. U. S. Forest Serv., Lake States Forest Exp. Sta. Tech. Note 595, 2 pp.

King, James P. and Hans Nienstaedt. 1965. Variation in needle cast susceptibility among 29 jack pine seed sources. Silvae Genet. (in press).

Rudolf, Paul 0. and Raymond A. Jensen. 1955. First-year planting results of the regional jack pine seed source study: a report to cooperators. Lake States Forest Exp. Sta., St. Paul, Minn. (Mimeogr.)

_____ and _____. 1958. Second-year planting results of the regional jack pine seed source study: a report to cooperators. Lake States Forest Exp. Sta., St. Paul, Minn. (Mimeogr.)

_____ and R. L. Schoenike. 1963. Botanical and commercial range of jack pine in the Lake States. U. S. Forest Serv. Res. Note LS-15, 4 pp. Lake States Forest. Exp. Sta.

Rudolph, Thomas D. 1964. Lammas growth and prolepsis in jack pine in the Lake States. Forest Sci. Monogr. 6, 70 pp.

Stoeckeler, J. H. and P. 0. Rudolf. 1956. Winter coloration and growth of jack pine in the nursery as affected by seed source. Z. Forstgenet. u. Forstpflanzenzuchtung 5: 161-165.