JACK PINE PROVENANCE STUDY IN EASTERN NEBRASKA

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Abstract.--A 9-year provenance test indicated that height, form, cone production, and needle length of southern origins exceeded northern origins. Foliage color during winter was yellow green on northern origins but green on southern origins. Fast-growing origins developed dense, compact, well-shaped crowns because of the multi-nodal growth characteristic of jack pine. A Petawawa, Ontario origin, of rapid growth and superior form, is recommended for plantings in Nebraska.

Key Words: Pinus banksiana, provenances, tree form, windbreaks.

PREFACE

The provenance study described in this paper is one of a dozen experimental plantations of various tree species established on the Horning State Farm near Plattsmouth, Nebraska, which is administered by the Department of Horticulture and Forestry of the University of Nebraska. The USDA Forest Service, through its Rocky Mountain Forest and Range Experiment Station work unit at Lincoln, cooperates with the Nebraska Agricultural Experiment Station on this research.

The purpose of this work is to find and develop better-adapted genetic tree materials for use in all kinds of plantings, environmental and commercial, throughout Nebraska and the central Great Plains. These provenance studies of different species provide basic materials of known origin for evaluation of adaptability, for study of genetic variation, and for selection, propagation, and breeding for resistance to disease and insect pests.

The diversity of tree planting materials under study at this and many other locations in the Plains was made possible through cooperation in a Regional Tree Improvement Project (NC-99, formerly NC-51) of the North Central States Agricultural Experiment Stations.

Credits are due Jonathan W. Wright, Professor of Forestry, Michigan State University, for initiating the Regional study and providing the planting stock, and to Walter T. Bagley, Associate Professor of Horticulture and Forestry, University of Nebraska, for cooperation in planting and maintenance of the plantations.

INTRODUCTION

Provenance tests are used to determine the natural variation within a species, as well as the relative adaptability of various seed sources throughout a species natural range to areas outside that range. Knowledge

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of the genetic variation within the natural geographic range of a species provides a foundation for further tree breeding programs. Moreover, information derived from provenance tests can insure maximum success in introducing trees to the relatively treeless prairies of the central Great Plains for windbreaks, landscaping, and Christmas tree plantations.

The objective of this study was to determine the natural variation, adaptability, and growth in eastern Nebraska of a wide range of seed origins of jack pine (Pinus banksiana Lamb.). The primary goal was to determine which seed origins are well adapted for use in future plantings in the Plains. The study was conducted as part of a cooperative Regional Tree Improvement Project (NC-99) of the North Central States Agricultural Experiment Stations.

PREVIOUS WORK

The natural range of jack pine extends from Nova Scotia west to the foothills of the Northern Rockies in Alberta and Northwest Territory, Canada, where it reaches 65° north latitude. It occurs throughout the Lake States and as far south as northern Indiana. This species is believed to be very diverse genetically because of its wide distribution in the boreal forests of North America (Fowells 1965). Past research has indeed indicated important differences within the species, which can be attributed to genetic variation.

The earliest record of jack pine planting in the central Great Plains was in 1891 on the Bruner property in the sandhills of Holt County, Nebraska (Pool 1953). That planting, which included other conifers, was judged a success after 10 years. It provided the stimulus for the creation, in 1902, and the subsequent tree planting program of the Nebraska Forest Reserves (now the Nebraska National Forest) in the sandhills along the Middle Loup River in central Nebraska. In 1903, 70,000 jack pine seedlings were dug in the native forests of Minnesota and planted in this Forest Reserve. Planting of jack pine seedlings of Minnesota and Wisconsin origins was continued through the 1940's until about 4,600 acres were established.

The drought of the 1930's caused high mortality in the Nebraska National Forest jack pine plantations, particularly in poorly stocked areas (Christiansen 1940). However, timber sales which began in 1929 in the 19-year-old plantations produced corral poles, fence posts, cabin logs, turkey roosts, and fuelwood for local use (Dayharsh 1940). Growth and development through a 48-year period, including response to thinning at age 12, and comparisons with native sites in the Lake States, were described by Boldt (1969). Despite the large area planted to jack pine outside its natural range, it is not possible to evaluate those plantations for performance of seed origins with any degree of reliability. Origin was not specifically documented, and no statistical design was used in the plantings.

Provenance tests in other regions indicate that height growth of jack pine from southern seed origins exceeds that of northern origins. Schantz-Hansen and Jensen (1952) determined that a provenance from the Bass River State Forest, New Jersey, grew faster than all others at a Cloquet, Minnesota test site. Canavera and Wright (1973) found that jack pines from southern Michigan and Wisconsin seed origins were three times as tall as those from the Northwest Territories of Canada after 4 years of growth in two Michigan

plantations. A comparison of Lake States provenances by Arend et al. (1961) at three test sites in lower Michigan indicated that lower Michigan seed origins grew fastest, whereas upper Michigan Peninsula origins produced slow-growing trees. An Indiana study demonstrated that trees from the southern half of a seed collection area covering Michigan, Wisconsin, and Minnesota averaged 4.8 ft. height after 7 years, while those from the northern half averaged 4.2 ft. (Williams and Beers 1959).

Seedling foliage of northern seed origins turned purple during winter through the third year, and yellow thereafter. Those of southern origins remained green during winter (Stoeckeler and Rudolf 1956, Canavera and Wright 1973).

Other characteristics positively correlated with southern seed origins were abundant flowering, laminas growth, and high degree of stem crook (Canavera and Wright 1973). King and Nienstaedt (1965) concluded that, among Lake State provenances, lower Michigan stock was most resistant to jack pine needle cast (Hyperdermella ampla Dearn.), whereas northern Minnesota stock was least resistant. Northern seed origins produced trees with many serotinous cones, but southern seed sources had a large proportion of open cones (Schoenike et al. 1959). Survival of field plantings ranged from 82 to 100 percent in the above studies.

METHODS

Seed from 95 geographic origins throughout the natural range of jack pine were collected over a 5-year period under direction of Mark Holst, Petawawa Forest Experiment Station, Chalk River, Ontario. Samples of these seeds were planted by J. W. Wright in a Michigan State University nursery at East Lansing, Michigan, and 1-year-old seedlings were distributed to North Central States cooperators in 1965. Seedlings of 28 of the 96 origins, representative of the species range, were planted in spring 1965 at the Horning State Farm experimental area of the Department of Horticulture and Forestry, University of Nebraska, near Plattsmouth, Nebraska. Location is 41° north latitude, 96° west longitude, and 1,100 ft. (330 m.) elevation. The plantation is located on a gentle southwest-facing slope of silt loam soils derived from loess. Growing season averages 170 days and mean annual precipitation is 30 inches.

Seedlings were machine planted in randomly placed 4-tree linear plots of each of the 28 seed origins in each replicate. The plantation contains six replications in 18 rows, spaced 12 feet apart on the contour; trees in each row were spaced 6 ft. apart. The plantation has been maintained by mowing between rows and applying simazine (4 pounds per acre) in a 20-in. band on both sides of each tree row for 6 years following planting.

Height and survival were measured at the end of growing seasons from 1966 through 1971. Severe rains 6 weeks after the plantation was established in 1965 washed out 35 percent of the seedlings. These were not included in survival counts, and were replaced with 1+1 stock from on the site in the spring of 1966. Periodically, the plantation was checked for damage by insects, disease, or heavy snow. Current measurements made in November 1973 included the following:

.Total height.
.Average annual height growth for the past 6 years.
.Form rating (a numerical rating from 0 to 40 given each tree based on straightness of stem, crown density, crown balance, and branch angle).2/
.Winter foliage color.
.Average length of 1-year-old needles.
.Cone production.

Correlation analyses were made to determine the degree of association between measured characteristics and origin latitude. An isodata cluster analysis was made to determine if geographical ecotypes could be delineated.

RESULTS

Seedling Survival

Overall plantation survival was 94 percent after two growing seasons and 92 percent after three (table 1). Thereafter, mortality was negligible. Survival rates of origins were so influenced by the heavy rains that they could not be correlated with latitude, longitude, or elevation.

Height and Growth Rates

Trees from northern latitudes were shorter and slower growing, while those from southern latitudes were taller and grew faster (table 1). Com--puted correlation coefficients were -0.78 and -0.79. The average plantation height after 9 years was 12.4 ft. Trees from Fort Coulonge, Que. (3244), were tallest, averaging 14.3 ft. The tallest individual tree was 17.1 ft. The shortest trees, averaging 7.6 ft., were from Wrigley, N.W.T. (3299) (table 1). An analysis of variance showed significant differences in heights among the 28 origins. Multiple range tests indicated that the tallest origin (Fort Coulonge, Que.-3244) was significantly taller than the 14 origins averaging 12.5 ft. or less. Trees from Murray Bay, Que. (3229), Little Calumet River, Que. (3221), Nipekamew River Sas. (3289), and Wrigley, N.W.T. (3299) were significantly shorter than all others tested (table 1).

Plantation height growth rates averaged 1.7 ft. per year. Marl Lake, Mich. (3274) and Mosinee, Wis. (3269) trees averaged 2.0 ft. height growth per year over the last 6 years, faster than all other origins. 3/ Trees from

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2/ Branch angle refers to the angle of the lateral branches relative to the main stem. Crown balance refers to the uniformity of lateral branching on all sides of a tree. Each of the four morphological characteristics was given a numerical rating from 0 to 10. The sum of the four equals the form rating. Trees with acute branch angles, straight stems, and dense, balanced crowns were given the highest form ratings.

3/ The fastest growing origins were not necessarily the tallest, because growth rates were based on the last 6 years in the plantation and heights were based on 9 years.

Table 1. Locations, survival, and heights of jack pine origins tested in eastern Nebraska.

Michigan State Univ. origin no.	State or Province	North lat.	West long.	Elev.	Survival after 3 yrs.	Height 9-year total	Height percent of plantation mean	Mean annual height growth 1968 - 1973
		degrees	degrees	feet	percent	feet	1/ percent	feet
3244	QUEBEC	45.8	76.7	400	100	14.3	115	1.9
3269	WISCONSIN	44.8	89.7	1200	100	14.2	114	2.0
3271	MICHIGAN (LP)	44.1	86.1	900	88	14.1	113	1.9
3256	ONTARIO	44.5	80.0	600	96	14.0	113	1.9
3246	ONTARIO	45.8	77.4	600	92	13.9	112	1.9
3274	MICHIGAN (LP)	44.5	84.8	1145	96	13.8	112	2.0
3267	WISCONSIN	44.3	89.7	970	86	13.7	111	1.9
3239	ONTARIO	44.6	77.9	800	83	13.6	110	1.8
3278	MINNESOTA	46.3	94.2	1150	98	13.4	108	1.8
3275	MICHIGAN (UP)	46.0	86.5	650	96	13.2	107	1.9
3243	ONTARIO	45.5	76.1	250	96	13.2	107	1.8
3273	MICHIGAN (LP)	44.5	84.7	1193	83	13.2	106	1.8
3284	ONTARIO	49.8	93.4	1300	92	12.8	104	1.8
3223	NEW YORK	44.3	73.8	950	100	12.8	103	1.7
3247	QUEBEC	46.4	76.2	600	96	12.5	101	1.7
3242	ONTARIO	45.5	76.9	500	79	12.3	99	1.7
3233	QUEBEC	47.3	73.9	1350	100	11.8	95	1.7
3208 *	NEW BRUNSWICK	46.0	65.0	250	96	11.7	95	1.6
3240	ONTARIO	44.6	77.0	700	71	11.6	94	1.6
3248	QUEBEC	46.8	76.1	800	92	11.6	93	1.6
3209	NEW BRUNSWICK	46.0	66.1	25	96	11.5	93	1.6
3249 *	QUEBEC	47.8	76.7	1500	88	10.9	88	1.5
3207 *	PRINCE EDWARD IS.	46.6	63.9	100	96	10.5	85	1.5
3220 *	QUEBEC	49.7	68.4	250	100	10.4	84	1.4
3229 *	QUEBEC	47.6	70.2	300	96	9.9	82	1.4
3221 *	QUEBEC	49.7	67.2	100	100	8.9	72	1.2
3289 *	SASKATCHEWAN	54.2	104.9	2000	76	8.6	69	1.2
3299 *	N.W. TERRITORIES	63.2	123.4	550	92	7.6	61	1.0
	Plantation Average				92	12.4		1.7

1/ Duncan's range test: Means within same bracket do not differ at 5% level. Means of equal value may be separated by brackets due to rounding off.

* Northern origins.

these two origins grew significantly faster than all origins which grew 1.8 ft. per year or less. Height growth rates for individual trees varied widely. A tree from Wrigley, N.W.T. (3299) averaged 0.03 ft. per year, whereas a Fort Coulonge, Que. (3244), tree averaged 2.45 ft. per year.

Form

Slow-growing trees from northern origins definitely had the poorest form, while fast-growing trees from southern origins generally developed dense, well-balanced crowns (tables 1 and 2). The average form rating was 28.8 (best possible--40). Trees with the best forms were from Petawawa, Ont. (3246), averaging 31.6. One tree from this origin rated 37, the highest form rating in the plantation. Nipekamew River, Sas. (3289), trees had the poorest form, averaging 25.3. The seven origins of poorest form were also the shortest. Conversely, origins displaying above-average form were generally the tallest.

Other Characteristics

Average length of 1-year-old needles was 1.3 inches. The shortest, slowest growing trees had the shortest needles (tables 1 and 2). The correlation between needle length and latitude of origin was fairly weak. Trees from southern origins had green foliage during winter, whereas northern origins were yellow-green. Winter foliage color was the characteristic found to be most strongly correlated with latitude of origin:

Characteristic	Correlation Coefficient r
Yellow winter foliage	0.80
Average annual height growth	-0.79
Height	-0.78
Cone production	-0.75
Form rating	-0.72
Needle length	-0.41

Cone production was very high relative to other species of pines of the same age in this experimental area. At 10 years of age, the average tree had approximately 40 cones. Trees from the two extreme northern origins (Nipekamew River, Sas.-3289 and Wrigley, N.W.T.-3299) were noticeably less prolific, averaging 25 cones per tree. Cone production was negatively correlated with latitude of origin.

No damage from insects or disease was detected. Heavy snow and freezing rain, which frequently break limbs on trees in the central Great Plains, caused no noticeable damage to the jack pines. The top 10 inches of some terminals on the tallest trees had lost their needles, probably as they were whipped by the wind during late summer.

Genetic Variation Among Provenances

Variations in the measured characteristics of trees from different origins growing in the relatively uniform environment of this Nebraska plantation are probably reasonable expressions of genetic variation across the natural range

Table 2.--Form, needle length, winter needle color, and cone production of jack pine origins 9 years after planting.

State and origin no.	Average form rating 1/	Needle characteristics		Average cone 2/ production per tree
		Mean length: inches	Winter color: percent yellow	
ONT 3246	31.6	1.3	0	H
ONT 3240	31.2	1.2	0	H
WIS 3267	30.4	1.3	0	H
ONT 3239	30.3	1.4	11	H
MIC 3271	30.0	1.3	0	H
ONT 3243	29.9	1.4	0	H
MIC 3274	29.9	1.4	5	H
WIS 3269	29.7	1.4	0	H
ONT 3256	29.7	1.4	0	H
MIC 3273	29.6	1.4	14	H
ONT 3284	29.5	1.2	59	M
QUE 3247	29.4	1.3	5	H
MIN 3278	29.4	1.3	5	H
MIC 3275	29.2	1.4	10	H
ONT 3242	29.2	1.3	10	H
NBR 3209	29.1	1.1	9	H
NY 3223	28.8	1.3	4	H
QUE 3244	28.3	1.3	4	H
QUE 3233	28.3	1.1	39	H
QUE 3248	28.3	1.3	36	H
NBR 3208*	27.7	1.2	25	M
QUE 3220*	27.4	1.1	25	M
QUE 3229*	27.3	1.1	31	M
PEI 3207*	27.3	1.1	9	M
QUE 3221*	26.4	1.1	40	M
QUE 3249*	26.0	1.1	53	M
NWT 3299*	25.4	1.2	73	M
SAS 3289*	25.3	1.1	93	M
Plantation average	28.8	1.3	19	

1/ 0 = lowest 40 = highest

2/ M = 20 to 40, H = > 40 cones

3/ Duncan's range test: Means within same bracket do not differ at 5% level. Means of equal value may be separated by brackets due to rounding off.

* Northern origins

of the species. Data for the variables total height, last 6 years of growth, and form rating were therefore combined in a cluster isodata analysis. The 28 origins tended to fit into two major groups: eight northern origins were somewhat distinct from 20 central and southern origins. No further geographic division appeared plausible. Additional data on more provenances, particularly from the northern and western range of jack pine, are necessary for a complete analysis of genetic variation within the species.

DISCUSSION

The excellent survival of all origins confirms that jack pine is well adapted to climatic conditions in eastern Nebraska. Provenance studies elsewhere in the United States have found that jack pine survival rates exceed other species tested. Although jack pine is known to excel on sandy soils, it had no problem adapting to the silty clay loam soils of eastern Nebraska.

The study area was in extreme eastern Nebraska, where growing season and precipitation are highest for the State. Therefore, growth rates at the study site are maximum to be expected in Nebraska.

Jack pine has been growing in the sandhills of west-central Nebraska, on the Bessey Division of the Nebraska National Forest, since the early 1900's. Of the 25 conifer species planted there during the last 75 years, only three have passed the test of time and drought, and are considered adaptable. Jack pine is one of these. The species has proved successful because of high rates of survival and rapid juvenile growth, despite attacks by the pine tip moth (Rhyacionia sp.), a serious pest of pines in central and western Nebraska. Jack pine seedlings have become established following fires, which have periodically wiped out other species. The greatest threat to jack pines in the sandhills has been extreme drought, such as occurred in the 1930's and again in the mid-1950's.

The absence of damage from insects and disease, and better-than-average growth rates at the Horning plantation, were highly encouraging.

Southern origins had greener winter foliage and grew faster than northern origins, which reaffirms the results from jack pine provenance tests in the Lake States (Schantz-Hansen and Jensen 1952, Canavera and Wright 1973, Williams and Beers 1959). Consequently, northern origins of jack pine are not recommended for plantings in Nebraska.

Seven of the eight tallest origins had form ratings among the top nine (tables 1 and 2). This positive relationship between rapid growth and superior form differs from previous experiences with other species of pine. Generally, the fastest growing trees have sparse, limby crowns containing gaps between whorls of laterals. The fastest growing jack pines developed dense, compact crowns, however, with foliage that remained green during the dormant season. This is most likely a function of the multinodal type of growth, a strong genetic trait of the species. These form and color characteristics are highly desirable in trees used for windbreaks, Christmas trees, and landscaping purposes. These seven origins (Mosinee, Wis.-3269, Freesoil, Mich.-3271, Wasaga Beach, Ont.-3256, Petawawa, Ont.-3246, Marl Lake, Mich.-3274, Nekoosa, Wis.-3267, and Twin Lakes, Ont.-3239), which combined rapid growth with esthetic appeal, have great potential for various types of plantings in Nebraska.

Trees from Petawawa, Ont. (3246) display superior form, comparable to the best Scots pines (Pinus sylvestris L.) which are so popular for Christmas trees. Their main stems are among the straightest in the plantation. Crowns of these trees are exceptionally compact, because the lateral branches consistently sweep upward from the main stem. Thus, seedlings of Petawawa, Ont. (3246) origin are recommended over all others in plantings for posts, poles, windbreaks, greenbelts, Christmas trees, or landscaping purposes. Hopefully, superior jack pine seedlings from this origin will be grown and made available through the Clarke-McNary program for future planting programs.

Jack pine can be expected to grow best in eastern Nebraska, where precipitation is maximum and tip moth has not been a serious problem. Slower growth rates can be expected in central Nebraska because of tip moth damage and less precipitation. Tip moth can be controlled, however, by spraying trees with insecticides (Roselle 1973). Where average annual precipitation is less than 20 inches, it is suggested that jack pine be planted only where irrigation facilities are available in case of extreme drought.

Lower branches of jack pines planted in the middle of stands or rows tend to die back from lack of light. Therefore, to obtain wind protection to ground level, jack pine should be planted in the outside rows of windbreaks containing several rows. Shade-tolerant shrubs or trees such as eastern redcedar, Juniperus virginiana L., and lilac, Syringa vulgaris L., which retain lower branches and foliaged should be planted in adjacent rows.

Landowners in Nebraska can expect above-average growth from jack pine with a minimum of maintenance.

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