PRACTICAL BREEDING PROGRAMS FOR JACK PINE IN THE LAKE STATES

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Jack pine *(Pinus banksiana* Lamb.) is the most common pine in the Lake States and is expected to play an increasingly important role in Lake States planting programs. This species is easy to plant successfully even on dry, sandy soils. Its rapid growth during the first 30 years makes it suitable for intensive-culture, short-rotation forestry. And it is suitable for kraft process pulping — particularly important because of the expanding kraft mill capacity in the Lake States.

Research on genetic improvement of jack pine has been underway since 1940. Results from these studies have formed the basis for two recently started jack pine seed orchard programs — one in Michigan and one in Minnesota.

This paper briefly summarizes some of the past jack pine studies and proposes a short- and long-term jack pine breeding program for the Lake States.

HIGHLIGHTS OF PAST RESEARCH

Seed Source Variation

The Canadian Rangewide Study

This is the youngest of the jack pine seed source studies and was started by the Canadian Department of Fisheries and Forestry. Seed was collected from 100 natural stands throughout the entire species range and nursery-sown in Canada and Wisconsin in 1962 and in Michigan in 1964. Five permanent test plantings have been established in Michigan, two in Wisconsin, and one in Minnesota.

Early results show that the sources from the three Lake States are the fastest growing in the test plantations; i.e., the seed sources best suited for Minnesota, Wisconsin and Michigan are to be found within the region.[1, 2]

The Cloquet Study

This is the oldest jack pine seed source study in this country. It was started by the University of Minnesota in 1940; 32 seed sources (22 from the U.S. and 10 from Canada) were planted near Cloquet, Minnesota. As of 1957, results indicated that trees from seed sources located south of the planting site in Pine and Fillmore Counties, Minnesota, grew from 7 to 13 percent faster than the local seed source (Schantz-Hansen and Jensen 1954, Schoenike *et al.* 1962).

Some of these parental seed sources were selected specifically for good or poor form. Yet at age 10 all the sources were of poor form and the form of the trees bore little relation to the form of the parental seed source. Neither was the growth of the trees related to parental stand site or age.

In the winter of 1947-48 trees in seed sources from Lower Michigan showed severe winter injury, but their survival and subsequent growth was unaffected.

The Lake States Jack Pine Seed Source Study

In 1952 the University of Minnesota and the North Central (then Lake States) Forest Experiment Station

[1] *Canavera, David S. Geographic variation in jack pine. (Manuscript in preparation.)*

[2] *Data on file, USDA Forest Service, North Central Forest Experiment Station, Institute of Forest Genetics, Rhinelander, Wisconsin.*

started a cooperative study of variation in Lake States seed sources of jack pine. Seedlings grown from seed collected in 29 natural stands in Minnesota, Wisconsin, and Michigan were used to establish 17 permanent test plantings in the three States (Rudolf and Jensen 1955, Jensen *et al.* 1960, Arend *et al.* 1961).

After 10 years in the field, trees from the Lower Michigan seed sources were the fastest growing in plantings throughout Michigan and most of Wisconsin (King 1966). Even in the Minnesota plantings located south of Duluth, two of the five tallest seed sources were from Lower Michigan (Alm *et al.* 1966, Alm and Jensen 1969). But in the Minnesota plantings located from Duluth northward, and in some of the colder sites of Wisconsin, trees from north-central Minnesota seed sources grew faster than those from the Lower Michigan seed sources. The best source in each planting averaged from 7 to 17 percent above the mean for all the sources.

Form and stem curvature were also evaluated in this study.[3] Occasional differences between seed sources were found but these differences were not consistent between sites. Differences in stem curvature were much greater between plantation locations than between seed sources within a plantation.

As in the other jack pine seed source studies, survival is excellent. When seed source differences in survival were found, even the sources with the lowest survival produced enough seedlings to form a well-stocked stand.

Seed source differences in insect and disease incidence were also fowl in this study (King 1971), but there were indication's that sources resistant to one pest may be highly susceptible to others. Until more is known about the interrelationships between various jack pine pests, it may be best not to select intensively for pest resistance.

Individual Tree Variation

Michigan

In 1965 and 1966 seed was collected from 382 single trees in 61 natural jack pine stands in the Lower Peninsula of Michigan. Trees were selected for open cones and above- and below-average height grown and stem straightness. The seedlings were grown at the Tree Research Center, Michigan State University, and used to establish six test plantations in Lower Michigan.

Based on 2- and 3-year nursery data, Canavera concluded that parental selection for growth rate was ineffective; i.e., using his method of selection, there was no correlation between parental growth and progeny growth. Good parents could, on the basis of progeny testing, be chosen from stands that are phenotypically good or poor. The fastest growing progeny ranged from 17 percent above the mean in 2-year height to 28 percent above the mean in 3-year height.

Canavera found a north-south trend in the Lower Michigan trees and recommended that in a selection program for an area the size of Lower Michigan, parents should be chosen from the southern half of the area.

There were seedlot differences in the number of trees with lammas growth, but these differences could be ignored because lammas growth was not correlated with either growth rate or winter hardiness. Selection for early flowering also appears unnecessary as all families flowered early.

Minnesota

In the spring of 1971 material for an individual-tree study was nursery-sown in the Northwest Paper Company nursery near Cloquet, Minnesota. About 320 seed collections made from individual jack pine in Minnesota are involved. No results have been reported as yet.

CONCLUSIONS FROM PAST RESEARCH

Growth Rate

Substantial improvement in growth rate is possible in jack pine. This improvement may arise from: (1) selection of superior seed sources and (2) selection of superior parents within the superior seed sources.

[3] *Data on file, USDA Forest Service, North Central Forest Experiment Station, Institute of Forest Genetics, Rhinelander, Wisconsin.*

Canavera, David S. Variation among jack pine (Pinus. banksiana *Lamb.) half-sib families from 61 stands in Lower Michigan. (Manuscript in preparation for publication.)*

Depending on the planting area in question, and on the quality of seed presently being used, we can expect growth rate increases of 7 to 15 percent with the choice of better seed sources. The data from the Lower Michigan study suggest that we can get an additional increase of the same magnitude by progeny testing and selecting the best parents within the superior stands. Thus, we can expect to find jack pine seedlings whose growth rate exceeds the present average-run jack pine by about 10 to 25 percent.

It must be emphasized that locating such superior parents will require a well-planned progeny testing program. The phenotypic growth rate of the parents is no indicator of the growth rate of the progeny.

Survival

It now seems clear that planting failures with jack pine are the result of either poor planting practice or poor site selection. Given reasonable care, all Lake States seed sources provided satisfactory survival on Lake States planting sites.

The penalty for selecting the wrong seed source is a reduction of increment and not of stocking.

PROPOSED IMPROVEMENT PROGRAMS

Short-Term Program

I suggest we could combine the principle of seed production areas (SPA's) with the results of our provenance tests to produce improved seed for the Lake States quickly and cheaply.

Seed-production areas are natural stands that have been thinned to favor increased seed production. The chief advantage of SPA's is the small initial investment, and the short time interval before seed harvesting. Their chief disadvantage (particularly with a species such as jack pine) is the unknown genetic quality of the seed because SPA's are not usually progeny tested.

To offset this disadvantage, I propose that we consider our presently existing seed source studies to be (stand) progeny tests. We would choose the best parent stands on the basis of our seed source studies, relocate these parent stands, and convert the parent stands into seed-production areas.

Commercial quantities of seed would be available within 5 years, and the seed would be superior to the present run-of-the-mill seed because it would be from tested parent stands. We could expect a 5 to 15 percent genetic gain due to seed source selection, but none due to individual tree selection within stands.

Listed below are some of the seed sources that might be developed into seed-production areas in Minnesota, Wisconsin, and Michigan:

Planting area	*Recommended seed source*[5]
Minnesota, east of a line from Duluth to International Falls	1592 Lake County, Minn.
	1602 Itasca County, Minn.
Minnesota, west of a line from Duluth to International Falls	1595 Pine County, Minn.
	1596 Pine County, Minn.
Minnesota, south of Duluth	1610 Oneida County, Wis.
Wisconsin and Michigan	1616 Manistee County, Mich.
	1618 Alpena County, Mich.

To initiate this program we would partially remeasure several of the established test plantings of our Lake States Jack Pine Seed Source Study. Only trees from the five or six tallest sources would be remeasured in each planting to confirm the superiority of the selected seed sources. The parental stands would then be relocated and thinned to about 60 trees per acre to become a seed-production area. Although individual phenotypic tree selection is of little value in jack pine, the thinning should be on the basis of spacing, growth rate, and form.

Remeasurement and relocation of the parent stands would take less than four man-months. In all, we could probably develop six 5-acre seed-production areas [6] for less than $7,000. There would, of course, be additional annual costs in seed collection and SPA maintenance, but all these costs would be only a small fraction of the value of even a minimal 5 percent increase in jack pine yield.

Long-Term Program

In the long run, the greatest genetic improvement in jack pine will come from a program based on continued cycles of progeny testing, selections, and interbreeding the selected parents. A practical way of starting such a program lies in the development of seedling seed orchards.

[5] *For exact legal description of parent stand location, see Rudolf and Jensen (1955).*

[6] *A 5-acre jack pine area containing about 210 trees would produce enough seed to furnish 1 million plantable seedlings per year (Rudolf 1959).*

Seedling seed orchards are essentially progeny tests in which the progeny are used as seed parents. Thus, the initial investment in progeny testing is offset by the practical benefit of obtaining improved seed from the seed orchard. This approach also yields the type of information needed to plan additional cycles of genetic selection.

This proposed long-term program is almost identical to the program started in Lower Michigan and in Minnesota (see previous section on individual tree variation). It would begin with the selection of areas where better seed sources might be found (according to the results of our provenance tests) for a particular planting region.

Between 300 and 400 trees overall would be chosen from within several stands with no more than 15 individuals per stand. Open-pollinated seed would be collected from each of the 300 to 400 trees.

Keeping the seedlots separate by individuals, the seed would be sown in a replicated arrangement and insofar as possible in a nursery that is located near the center of the planting area. (This should minimize the seedlot x environment interaction in future field planting programs and thus make the nursery measurements more reliable indicators of mature tree performance within the planting region.)

On the basis of 2 years' nursery growth, only trees from the 200 fastest growing seedlots would be used to establish two or three test plantations over the planting area.

The progeny test plantings will be converted to seed orchards when the trees begin to bear regular pollen and cone crops. This should be about 7 or 8 years after field planting. The plantings would be measured at that time. On the basis of these measurements, the plantings will be thinned (1) by removing all the individuals in the below-average seedlots and (2) by removing some of the poorer individuals in the above-average seedlots.

Removing all seedlings from the poorest seedlots (half-sib family selection) would give the greatest gain in the genetic quality of the seed from these orchards. Removing individuals within superior seedlots might also yield some gain, but the primary consideration when thinning within seedlots should be spacing of the remaining trees.

About half of the seedlots would be removed at the first measurement and thinning. At age 12 to 14, the planting would be remeasured and thinned to leave one tree in four of the best 25 seedlots (about 40 to 50 trees per acre). Such heavy culling would not only improve the quality of the seed, but would promote heavy crown development and improve seed production among the parent trees.

To develop the next cycle of seed orchards we would artificially hybridize the remaining parents in as many combinations as possible. The identity of each tree x tree combination would be maintained separately and these two-parent families used to establish more seedling seed orchards. Such full-sib orchards should give almost twice the genetic improvement of the open-pollinated orchards and would eventually replace them.

Over the first few cycles of breeding we can probably except to increase the growth rate of jack pine by 5 to 8 percent per generation.

This long-term seedling seed orchard program would, of course, require a much greater investment than the short-term seed-production area program. Because of the large number of variables involved it is difficult to evaluate the profitability of the long-term program. For instance, Lundgren and King (1965) found that in evaluating financial returns from a hypothetical jack pine improvement program, planting site quality was an important variable. Planting genetically superior stock pays off more on high quality sites than on low quality sites. Annual planting acreage is also very important.

Without going into detailed calculations, it would seem on the basis of Lundgren and King's (1965) data that the first cycle of the seedling seed orchard program proposed here would offer a 7 to 9 percent return on the initial investment.

It would therefore seem that tree improvement programs in jack pine are a low-cost method of increasing future pulpwood supply.

LITERATURE CITED

Alm, Alvin A., Bruce A. Brown, and Raymond A. Jensen. 1966. Height and diameter variation in a Minnesota jack pine seed source plantation. Minn. For. Notes 178, 2 p.

Alm, Alvin A., and R. A. Jensen. 1969. Results of a Lake States jack pine seed source test in east-central Minnesota. Minn. For. Res. Notes 200, 4 p.

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

Jensen, Raymond A., T. Schantz-Hansen, Paul 0. Rudolf. 1960. A study of jack pine seed sources in the Lake States. Minn. For. Notes 88, 2 p.

King, James P. 1966. Ten-year growth variation in Lake States jack pine. *In:* Joint Proc. Second Genet. Workshop of the SAF and the Seventh Lake States For. Tree Impr. Conf. USDA For. Serv. Res. Pap. NC-6: 84-88. North Cent. For. Exp. Stn., St. Paul, Minn.

King, James P. 1971. Pest susceptibility variation in Lake States jack pine seed sources. USDA For. Serv. Res. Pap. NC-53, 10 p. North Cent. For. Exp. Stn., St. Paul, Minn.

Lundgren, Allen L., and James P. King. 1965. Estimating financial returns from forest tree improvement programs. Soc. Amer. For. 1965 Proc.: 45-50.

Rudolf, Paul 0. 1959. Seed production areas in the Lake States. USDA For. Serv. Lake States For. Exp. Stn., Stn. Pap. 73, 15 p., illus.

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 For. Exp. Stn., St. Paul, Minn.

Schantz-Hansen, T., and R. A. Jensen. 1954. A study of jack pine source of seed. Minn. For. Notes 25, 2 p.

Schoenike, R. E., T. D. Rudolph, and R. A. Jensen. 1962. Branch characteristics in a jack pine seed source plantation. Minn. For. Notes 113, 2 p.