THE RESEARCH PROGRAM OF THE INSTITUTE OF FOREST GENETICS AT RHINELANDER, WISCONSIN

by

David H. Dawson, Plant Geneticist

ABSTRACT

The Institute of Forest Genetics, a unit of the North Central Forest Experiment Station U.S.D A Forest Service, has conducted a research program in forest genetics in northern United States since 1957 Sixty technical and 20 nontechnical articles have been published to date, and more than 40 studies are currently in progress.

Racial variation tests are being carried out for white spruce, jack pine, red pine, white pine, tamarack, balsam fir, white cedar, Norway spruce, and yellow birch Other studies are designed to determine the heritability of flushing date in white spruce, and the correlation between growth rate of open-pollinated seedlings and that of their parents The relation of height growth to insect and disease resistance in jack pine is being investigated, and basic research programs in radiology, cytology and vegetative propagation are in progress.

Nurserymen can benefit from the research program by selecting proper seed sources, the best phenotypes within selected stands, and the fastest growing seedlings in the seedbeds Growers of white spruce are urged to try the southeastern Ontario source.

THE RESEARCH PROGRAM OF THE INSTITUTE OF FOREST GENETICS AT RHINELANDER, WISCONSIN

by

David H. Dawson, Plant Geneticist 1/
Institute of Forest Genetics
North Central Forest Experiment Station
Forest Service, U.S. Department of Agriculture

The concept of using genetically superior forest tree planting stock in the northern United States is by no means a recent development; Forest tree improvement in the broad sense began before 1900, when the adaptability of several exotic tree species was tested in early forest plantings However, experiments designed to determine variation within forest tree species and to identify the best race or strain for a certain area did not begin until 1928, when Carlos Bates of the Lake States Forest Experiment Station (now North Central) began a study of red pine seed sources, These and other older studies made it apparent that genetic tree improvement offered much promise for increasing the quality and quantity of timber products.

However, it was obvious that a more intensive and fundamental research program was necessary if the full potential of genetic tree improvement were to be realized, To meet this need, the Institute of Forest Genetics was established in 1957 at Rhinelander by the North Central (then Lake States) Forest Experiment Station, U.S. D.A. Forest Service, The Institute is a leader in basic forest genetic research in the northern United States, and is also responsible for applied genetic research in the seven-state area administered by the Experiment Station.

1/ Presented at the Regional Nurserymen's Convention at Delaware, Ohio, September 12, 1968.

The present objectives of the Institute are fourfold:

1. To determine the range and heritability of genetic variation for the more important northern tree species.

2. To increase understanding of the effects of radiation on forest trees.

3. To develop efficient means for vegetative propagation of forest trees.

4. To develop efficient breeding techniques and better strains of commercially important species.

Of all the objectives, the last one is probably of the most interest to practicing foresters because the results of studies can be put into direct use However, studies conducted in pursuit of the other objectives have also yielded immediately applicable results.

Remember that 8 to 10 years often elapse before enough can be learned from most genetics studies to provide a sound basis for tree breeding programs . In other words, before the fourth objective can be met, much research must be directed toward meeting the first three.

We have now begun to accumulate information rapidly; approximately 60 technical and 20 nontechnical articles have been published at the Institute since 1957, I will not attempt to give a detailed report of the current research program which at present encompasses over 40 studies on a variety of subjects, Instead, I will emphasize some of the recent findings that have practical applications in forestry, and also some that, although they have no immediate practical utility, will probably have a direct bearing on the course of future research and forest practice By citing a few of these studies and findings, I hope to illustrate the emphasis and direction of the total program.

Studies of Variation Within Species

To test variation among stands of the same species, the provenance or "seed source" test is used. These studies single out the geographic sources that are best adapted to the area in which the tests are conducted; they also provide a convenient source of material for controlled pollinations. To date we have established provenance tests for white spruce, jack pine, red pine, white pine, tamarack, balsam fir, white cedar and Norway spruce In addition, a test of 55 seed sources of yellow birch is underway.

Results of a white spruce seed source study will soon be published. In this study, seed from 28 sources of white spruce was collected over the entire range of the species from Alaska to Labrador and south to South Dakota, Michigan, and New York Seedlings from these sources were field tested for 5 years in 14 locations ranging from 42° to 489 N latitude, and from New Brunswick to North Dakota Five-year height growth ranged from 36.3 inches in a Grand Rapids, Minnesota plantation to 11.7 inches in a Bergland, Michigan, plantation.

Seedlings from seed sources from the southeastern portion of the range (Lake States, southern Ontario, parts of Quebec and New England) grew well on all the test sites, while seedlings from the northern sources grew more slowly, One Ontario source appeared to be particularly well-suited to the best sites. It is also interesting to note that after 29 years, seedlings from a Douglas, Ontario, seed source in a Wisconsin field planting maintained a 22 percent superiority over seedlings from seven other sources, and a 16 percent lead over seedlings from the local white spruce seed source.

The data suggest that the selection of white spruce in southeastern Ontario and adjacent areas in Quebec may yield particularly good genetic types.

2/ Nienstaedt, Hans. Variation and adaptive stability of white spruce seed sources. (Submitted in 1968 for publication in Proc. 11th Meet. Comm. Forest Tree Breeding in Canada.)

The jack pine seed source study involved 11 test plantations consisting of seedlings from 26 seed sources from Minnesota, Wisconsin, and Michigan, along with "local" commercial nursery stock from each of the general plantation locations „ Ten-year height data showed that seedlings from Lower Michigan seed sources performed best as a group throughout Michigan and Wisconsin, In northern Minnesota plantings, the seedlings from north central Minnesota sources did best Seed sources differed significantly in 10-year seedling height at every planting except the Chippewa National Forest. The sources ranged in seedling height from 25 percent below the plantation mean to 17 percent above the mean. At nine of the 11 plantings seedlings from the seed sources under test outgrew the commercial nursery stock by 12 to 28 percent:. Seedlings from the local seed source probably outperformed those from the local commercial source because the seed source collections came from stands considered good for their area, whereas commercial stock came from unselected stands (King 1966).

One of the older active studies at the Institute deals with red pine, More than 100 seed sources and individual tree progeny from throughout the natural range of the species have been tested since 1931., Small but significant seedling height growth differences exist among seed sources Seedlings from the poorest seed source grew an average of 1.14 feet per year while those from the best source averaged 1 36 feet per year. In terms of site index (the height to which a stand of trees grows in 50 years), the best progeny is 11 feet (19,2 percent) taller than the poorest and 8,9 percent taller than trees from local seed sources , Seed sources differed greatly in 30-year tree survival; in general, trees from the local (Minnesota) sources grew the fastest and had the best survival. Although red pine improvement may be slow and expensive, it should be profitable; a gain of only 3 to 4 percent in height growth amounts to an increase of about 9 percent in board-foot yield at 50 years . Considering the intensive red pine planting programs in the northern United States, improved red pine planting stock could increase timber yield 200 to 400 million board foot per rotation (Nienstaedt 1964, Lundgren and King 1966).

The seed source with the fastest-growing seedlings was not the same in four eastern white pine plantings in Minnesota, Wisconsin, and Michigan. The seedlings were studied in nurseries at Rhinelander and Watersmeet as well as in field plantings Seedlings from Lower Michigan, southern Wisconsin, and Tennessee sources were among the fastest growing in the nursery, although the seedlings from southern sources suffered the most winter damage--60 percent more than the average for seedlings from all sources , In the field plantings tree height growth varied significantly among sources. . A Tennessee source had the tallest trees in Lower Michigan but ranked 14th in the other three plantings , An Ontario source had the tallest trees in Minnesota, but ranked 13th in Lower Michigan.

Seedlings from the sources from milder climates showed the fastest growth rate in the protected nursery beds, but lost their superiority when exposed to severe winters Until more intensive studies of white pine sources can be made, foresters should confine collections of white pine seed to local stands.

As a part of a yellow birch seed source study, seed was collected from 55 stands throughout the range of the species and planted at theHugo Sauer Nursery at Rhinelander, Wisconsin. Height growth, which ranged from 86 1 mm. to 164.0 mm. after 2 years in the nursery, exhibited a completely random pattern that was not related to latitude, longitude, elevation, mean January temperature or other measureable environmental factors Time of flushing, however, seemed to be clinal in nature, seedlings from the sources from the more northern latitudes flushing earlier After two growing seasons in Wisconsin, seedlings from a lower Michigan sources were tallest, and seedlings from a West Virginia source second tallest.

In Lake States plantings the difference in seedling height growth between the best and the poorest seed sources was 34 percent for Minnesota sources, 36 percent for Wisconsin sources, and 53 percent for Michigan sources. Thus , much potential growth is lost if seedlings from a slow-growing seed source are used for reforestation purposes (Clausen 1968).

3/ King, James P. and Hans Nienstaedt. Early growth of eastern white pine seed sources in the Lake States. (In preparation for publication, N. Cent. Forest Exp. Sta., U.S.D.A. Forest Serv., St. Paul, Minn.)

Studies of Variation Among Trees Within Stands

Studies of this type provide information on the heritability of desirable tree characteristics and help tree breeders select an efficient breeding method.

One of the problems of planting white spruce in the Lake States is that late spring frosts frequently damage new growth. Because individual trees vary as much as 17 days in the date of bud opening selecting and breeding for late flushing substantially reduces frost injury. Equally significant is the fact that the later flushing types also appear to be faster growing.

In another study, annual growth rate of 4-year-old seedlings from 28 open-pollinated white spruce trees appeared strongly correlated to that of the parent trees When the progenies from parents of similar age were compared, annual growth of those from the five fastest growing parents was nearly 21 percent above the average, If the annual growth rate of the progenies from the five fastest growing parents is maintained throughout the rotation, an increase in merchantable volume of 21 percent will result. Achieving only a fraction of this increase would justify considerable cost in the selection of parent trees.

Increased vigor and pest resistance might be attained by crossing related species of trees. Not all species within a genus can be successfully crossed, however. To determine the crossability potential in the genus Betula, 60 combinations have been tried since 1962. About 25 percent of these produced viable seed, while 40 percent failed to produce any seed at all (Clausen 1966). Similar studies have been conducted within the genus Picea,

4/ Jeffers, Richard M. Parent-progeny growth correlations in white spruce. (Submitted in 1968 for publication Proc. 11th Meet. Comm. Forest Tree Breeding in Can.)

Studies of Disease and Insect Resistance

Breeding disease and insect resistant varieties of forest trees shows much promise for curtailing future timber losses, Studies at the Institute have shown that jack pine seedlings from various seed sources differ in resistance to white pine weevil, jack pine shoot borer, and pine-oak gall rust, In addition, the following relationships between height growth and pest incidence were observed: seedlings from the fastest-growing jack pine sources had the highest incidence of white pine weevil (although there were exceptions) , and seedlings from the shortest sources had the highest incidence of jack pine shoot borer and pine-oak gall rust.

Seedlings from some sources were resistant to one pest but highly susceptible to others; seedlings from other sources, however, were fast-growing and apparently resistant to several insects and diseases , Thus , breeding for fast-growing, pest resistant varieties appears feasible once host-pathogen and host-insect relations are fully understood, so that we can avoid improving resistance to one pest at the expense of increasing susceptibility to another.

The Radiation Genetics Program

The radiation genetics program at the Institute is directed toward four major objectives:

I, To determine the effects of ionizing radiation on forest tree species. Forest trees are continuously being bombarded by very low or "background" levels of ionizing radiation. It is estimated that perhaps as much as 40 percent of the natural variation in trees and other long-lived organisms originated as background radiation-induced genetic changes. Thus , ionizing radiation is an environmental factor influencing the long-term genetic makeup of tree species that in controlled experiments can be manipulated both in time and intensity, Furthermore, the present research would allow us to predict the effects of nuclear catastrophe on our forest resource.

2, To develop the use of ionizing radiation as a tool in basic genetic studies of forest tree species by inducing genetic and cytogenetic markers Little is known about the genetic structure of forest tree species . Radiation-induced genetic changes will aid in studies of the mode of inheritance of various characteristics and in the delineation of character associations or linkage groups.

3. To compare the effects of gamma radiation with other types of radiation and with other mutagenic agents.

4 To induce genetic changes that will be of value to the tree breeder in developing improved types in our important species (Rudolph 1964).

The radiation research at the Institute has yielded some interesting results When white spruce pollen was irradiated at 600R and 800R (relatively low dosages) seed production increased 23 and 27 percent Seed viability also showed a significant stimulation at the 600R level, Jack pine seed was X-rayed at 1000R and 4000R and planted in the nursery and the field At 4000R, no seedlings survived beyond 1 year of age; at 1000R, survival was 30 percent that of the controls at the end of 2 years In these studies, too, germination of cross pollinated seed was between 6 percent and 9 percent higher than the control. Studies of survival and growth of trees originating from irradiated seed showed that the effect of gamma radiation of jack pine seed cannot be fully evaluated in the first generation--at least two generations are Tequired (Rudolph 1965, 1967).

Cytological Research

When nuclear volumes were determined for nine conifer species, and responses of seed treated with acute radiation at 14 dosage levels were measured, it was apparent that nuclear volumes cannot reasonably be used to predict plant radiosensitivity.

Additional studies have involved the determination of DNA content (DNA is deoxyribonucleic acid within the chromatin of a living cell which contains the genetic code and transmits the hereditary pattern) . The quantity of DNA per cell of several gymnosperms was determined chemically and cytophotometrically (Miksche 1967)

Studies of white spruce indicated that in western populations, the sources from the north had a larger amount of DNA per cell; these sources were also slower-growing, suggesting a correlation between growth rate and cellular DNA.

Research on Vegetative Propagation of Forest Trees

Reliable methods of vegetative propagation are needed to enable tree breeders to take full advantage of desirable tree characteristics. Establishing plants on their own roots can be cheaper, more efficient and biologically sounder than grafting scions of selected trees on to rootstocks of others , However, only a few forest trees root readily from cuttings Past research on the rooting of cuttings has often been empirical in nature and has not increased our knowledge of the basic factors controlling root initiation, emergence, and development Basic research on these problems is in progress.

Opportunities for Applying Genetic Principles to Improve the Quality of Nursery Stock

Research has shown that forests can be made more productive by the use of genetically improved planting stock. Seed production areas and clonal seed orchards are excellent for providing an improved seed supply for a nursery.

There are several other ways of improving the quality of planting stock.

1, Abide as closely as possible to the recommended seed collection zones for the areas in which the trees are to be planted, This can make a considerable difference in yield or general adaptability to the planting site. For example, the jack pine seed source study showed that height growth of trees from various sources ranged from 25 percent below the mean plantation height to 17 percent above the mean plantation height , This suggests that a poor choice of seed for an area could result in a growth reduction of 42 percent . Although it is sometimes difficult for nurserymen to grow and distribute planting stock on the basis of the recommended seed sources, studies are showing that the choice of a seed source for planting in a particular area is sometimes as important as the choice of the species itself.

2 Collect seed from the best phenotypes in the best stands from the geographic sources best adapted to the area the nursery serves For help in selecting these superior phenotypes use the guides written by Rudolf (1956), Limstrom (1965), Clausen and Godman (1967), and the superior tree selection forms developed by Pitcher and Dorn (1967).

3. Within the seed sources tested for the area served by the nursery, select heavily in the nursery for superior individuals Clausen (1963) demonstrated that survival of two species of birch after 9 years in the field was directly related to the initial size of the nursery stock „ Height and diameter of the trees still reflected the original size classifications of the seedlings. Similarly, King, Nienstaedt, and Macon (1965) found that white spruce seedlings selected for superior nursery performance maintained their height growth advantage over average nursery stock after seven growing seasons in the field. These "super-spruce" also incurred less damage from late spring frosts than average stock.

4. Take advantage of the 5-year results of one study and the 29-year results of another that show the superiority of southeastern Ontario sources of white spruce in all regional plantings.

Literature Cited

Clausen, Knud E. 1963. Nursery selection affects survival and growth of birch, U.S.D.A. Forest Serv., Res. Note LS-31, 2 p, Lake States Forest Exp. Sta., St, Paul, Minn.

Clausen, Knud E. 1966. Studies of compatibility in Betula. In Second Genet. Workshop Soc. Amer, Forest, and Seventh Lake States Forest Tree Improve. Conf., Joint Proc., October 21-23, 1965. U.S .D.A. Forest Serv. Res, Pap. NC-6 N. Cent. Forest Exp, Sta., St. Paul, Minn. p. 48 - 52.

Clausen, Knud E, 1968s Variation in height growth and growth cessation of 55 yellow birch seed sources. In 8th Lake States Forest Tree Improve, Conf , Proc. September 12-13, 1967 U.S.D.A. Forest Serv, Res, Pap. NC-23, N, Cent. Forest Exp. Sta., St. Paul, Minn, p, 1-4.

Clausen, Knud E., and Godman, Richard M. 1967o Selection of superior yellow birch trees, a preliminary guide. U.S Forest Servo , Res, Pap. NC-20 10 p., illus. N. Cent, Forest Expt. Sta., St, Paul, Minn.

King, James P. 1966, Ten-year height growth variation in Lake States jack pine. In Second Genetics Workshop Soc. Amer, Forest. and Seventh Lake States Forest Tree Improve, Conf , October 21-23, 1965. U.S.D.A . Forest Serv. Res, Pap. NC-6, N. Cent. Forest Exp Sta„ St, Paul, Minn. p. 84-88 illus.

King, James P..; Nienstaedt, Hans; and Macon, John. 1965 Super spruce seedlings show continued superiority_ U.S.D.A. Forest Serv. Res. Note LS-66, 2 p0 Lake States Forest Exp, Sta., St . Paul, Minn.

Limstrom, Go A. 1965, Interim forest tree improvement guides for the Central States, U.S D.A. Forest Servo , Res. Pap, CS-12, 64 p., illus. Cent, States Forest Exp. Sta., Columbus, Ohio.

Lundgren, Allen L. and King, James P. 1966. Estimating financial returns from forest tree improvement programs , Soc. Amer. Forest Proc. 1965: 45-50., illus.

Miksche, J. P. 1967. Variation of DNA content of several gymnosperms. Can. J. Genet. Cytol. IX (4): 717-722., illus.

Nienstaedt, Hans. 1964. Red pine progeny test, 1931 and 1933 Minnesota Planting. Comm. on Forest Tree Breeding in Can. 9th Meeting Proc., Sept. 16-18, 1964: 151-156.

Pitcher, John A. , and Dorn, Donald A. 1967. A new form for reporting hardwood superior tree candidates. In 5th Cent. States Tree Impr. Conf. Proc. Oct. 6-7, 1966: 7-12. Ohio Agr. Res, and Develop. Center, Wooster.

Rudolf, Paul 0_ 1956. Guide for selecting superior forest trees and stands in the Lake States. U.S.D.A. Forest Serv., Lake States Forest Exp. Sta., Sta. Pap. 40, 32 p., illus.

Rudolph, T. D. 1964,, The radiation research project at the Institute of Forest Genetics, Rhinelander, Wis. In Comm. Forest Tree Breeding in Can, 9th Meet. Proc. Part II: 193-194.

Rudolph, T D 1965, The effect of gamma irradiation of pollen on seed characteristics in white spruce. In The use of mutations in plant breeding, FAO-1 AEA Meet. Rep , 1964: 185-191. illus.

Rudolph, T D, 1967, The effects of X-irradiation of seed on X, and X_2 generations in Pinus banksiana Lambert, Radiat. Bot 7: 303-312., illus.