Acknowledgments

The Ninth Lake States Forest Tree Improvement Conference was held at Itasca State Junior College and the University of Minnesota, North Central Forest Experiment Station, Grand Rapids, Minnesota, on August 22-23, 1969. The School of Forestry, University of Minnesota, St. Paul, was the host institution.

At the Conference, tree breeders, forest geneticists, and foresters from the Lake States were joined by the participants in the Lake States Post Conference Tour of the 2nd World Consultation of Forest Tree Breeding. Eleven visitors from Australia, Canada, Finland, Greece, Malaysia, Republic of South Africa, Sweden, and the U.S.A. discussed research results and breeding techniques with the Lake States tree breeders.

For the benefit of the foreign visitors, there were brief reviews of the current status and recent results of tree improvement endeavors in the Lake States, which appear in these Proceedings. Also included are descriptions of field-trip stops to the University of Minnesota's genetics tests in the vicinity of Grand Rapids, Minnesota. Descriptions of the stops at the Cloquet Forest Research Center of the University of Minnesota have not been included since most of the research and demonstrations pertained to silviculture and forest management.

The Tree Improvement Committee wishes to thank the University of Minnesota and its staff for hosting the Conference, the Blandin Paper Company for refreshments on the field trip, and the North Central Forest Experiment Station of the USDA Forest Service for publishing these Proceedings.

Scott S. Pauley, Chairman[1]
LAKE STATES FOREST TREE IMPROVEMENT COMMITTEE

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1 *Prepared prior to Professor Pauley's death, April 18, 1970.*

CONTENTS

FOREST GENETICS RESEARCH AT THE UNIVERSITY OF MICHIGAN

Burton V. Barnes
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Tree Genetics

(Burton V. Barnes)

The purpose of the research program, as evidenced by results as well as current research and future direction, is to add to the knowledge of the ecology and genetics of forest trees. Although we are interested in the practical gains that are possible and being realized in practical tree improvement, our contribution is in basic studies that stimulate and challenge young scientists and provide the basis for silviculture and tree improvement practice. Our main interests lie in genecology and evolution of woody plants.

Major emphasis is placed on the aspens (*Populus tremuloides Michx.*, trembling aspen and P. *grandidentata Michx.*, bigtooth aspen) and birches (primarily *Betula alleghaniensis Britton*, yellow birch but also associated species *B. papyrifera Marsh.*, paper birch; *B. lenta L.*, sweet birch; *B. nigra L.*, river birch; and *B. pumila L.*, bog birch). Studies of natural variation and hybridization have been or are being conducted in other hardwood genera; *Prunus*, *Fraxinus*, *Acer*, and *Quercus*.

We have emphasized the clonal growth habit of aspens (Barnes 1966) as the basis of ecological and genetic studies. This was used effectively in a study supported by the North Central Forest Experiment Station by Copony (1969) who found significant differences among clones in the incidence of hypoxylon canker of trembling aspen. The range in canker incidence for all clones was 10 to 90 percent; the range was wide in all five sites studied. In many cases, nearby or adjacent clones showed significant and striking differences. The marked phenotypic differences between clones and low variability within clones suggests a relatively strong genetic control.

Natural hybridization between bigtooth and trembling aspen is relatively common in southeastern Michigan, but apparently much rarer farther north. We are studying hybridization and hope to learn if introgression is subtly changing the genetic composition of the southeastern Michigan areas and away from it. Five hybrids were recently found by Andrejak (1968) in a seedling population in Washtenaw County. Analysis of leaf and bud characters indicated they were F_1 hybrids. Considerable overlap was observed in flowering of the parent species, so it is clear that flowering time is not a complete isolating barrier. Seeds of hybrids were highly germinable. Although introgression has not been adequately demonstrated there does not seem to be any genetic barrier to hybridization or backcrossing. We have found hybrids competing successfully with both parents well into fruiting age.

We are also investigating the possibility that trembling aspen in certain areas of the West is of ancient hybrid origin. Barnes (1967) hypothesized that *P. grandidentata*, or an Asian aspen such as *P. tremula* var. *Davidiana Schneid.*, which are likely members of the mid-Cenozoic forests of western North America, may have hybridized with trembling aspen.

Other active aspen research includes a study of clonal structure and suckering behavior of trembling aspen in Manitoba, Canada, by doctoral student G. A. Steneker, and a study of the significance of corticular photosynthesis by doctoral student Robert K. Shepard.

Intensive investigations of natural variation and hybridization of yellow birch and associated species are being conducted in the Lake States and the Appalachian Mountains. Dark and tight-barked birches, often observed in southern Michigan and elsewhere at the southern edge of the range of yellow birch (Dancik 1969), were investigated (Dancik 1967). Despite reports of their being sweet birch, they are closely related to the classically described yellow birch in chromosome number ($6x = 84$) and foliage characters. Studies in other portions of the range of yellow birch are underway to establish the pattern of phenotypic variation along ecological gradients and between widely separated populations such as those in northern and southern Michigan.

As the basis for these studies and companion ones, populations of yellow birch and sweet birch were sampled in various regions of the Appalachians exhibiting different climate, topography, soils, and vegetation. For example, in the Appalachian Mountains collections of foliage, fruit, pollen, and wood cores were made by doctoral student Terry L. Sharik along altitudinal transects in each of 5 physiographic regions from southwest North Carolina to northern Vermont. Currently, phenotypic variation is being related to site types and ecological gradients. Based upon this framework the mechanisms of genetic differentiation along certain environmental gradients will be investigated in the next phase of the study.

Hybridization in birches is also under study. Hybrids of yellow birch and bog birch are frequent in southeastern Michigan. However, evidence of intogression was not found (Dancik and Barnes, in press). Approximately 15 natural hybrids of yellow birch and paper birch have been found in Michigan, and others located in New Hampshire and Minnesota. We are studying the amount of gene flow between these species. Two individuals, putative allopolyploides of *B. X. purpusii* Schneid. (yellow birch and bog birch) have been found.

Since 1958 we have participated in an international provenance test of European larch organized by Professor R. Schober, University of Göttingen, Germany. Two test plantations were established in 1960 and 1961 in Washtenaw County involving 12 and 20 sources respectively. Survival of all sources was satisfactory to excellent. The best height growth was by plantation sources such as Schlitz, Dobris, and Neumünster. Sudeten larch sources from Czechoslovakia have done about as well. Poorest growth was exhibited by high elevation sources in the French alps. Average total height for the fastest growing source (Schlitz) was 24 feet in 11 years from seed; the slowest growing source averaged only 9.5 feet in 10 years. Results of these tests are encouraging and it is now time to test the fastest growing sources on a commercial basis.

Tree Physiology

(Robert Zahner, Professor)

Research in wood formation at the University of Michigan is centered around the influence of site and weather on cambial growth in hardwoods. Before the true effects of these external factors can be assessed, much remains to be learned about intrinsic growth patterns in both ring porous and diffuse porous types. Thus, in several studies we are attempting to sort out the effects of poor soils and adverse weather conditions on the relative production of fibers and vessels as compared with normal annual ring growth. We are working with three species of ring porous trees (*Quercus rubra L., Fraxinus americana L.,* and *Carya glabra Mill. Sweet*), and with three of diffuse porous types (*Populus grandidentata, Betula papyrifera,* and *Acer rubrum L.*). Studies include numbers, sizes, and distribution of vessels and fibers currently produced in trees preconditioned the year before by drought, and in trees on dry, infertile sites; both as compared with those produced in "normal" trees. Results indicate that the ratio of fiber to vessel production in some species (e.g., pignut hickory and paper birch) is far more sensitive to environmental influence than in others (e.g., red oak and bigtooth aspen).

Entomology

(Fred B. Knight, Professor)

Stem Borers in Aspen

The work on two *Cerambycid* borers of small aspen stems has continued during 1968-69. We have completed partial life tables on both species *(Oberea schaumi and Saperda inornata)* and have identified the critical periods in their life cycles. These periods are associated with the adult and egg stages of the beetles. The adults appear to be sensitive to many mortality factors. Then when eggs are laid, many fail to hatch or if hatching does occur, the larvae often fail to become established. We are concentrating our biological research on these critical times in the life cycles.

This year we have been doing some specialized research on clonal relationships. Early and purely tentative results show that the faster growing clones are resistant. Adults readily lay eggs on all clones but larval establishment may be directly related to these clonal characteristics. We plan to continue this work during the next few years.

Insects on Sugar Maple

This summer (1969) we began studying some of the insects causing deformities in sugar maple. We will concentrate first on those feeding early in the season on buds and later in the summer causing leaf rolls on the trees. The species are known, but little is understood of their host preferences and bionomics. We know that a large portion of bud mortality is insect caused and that therefore much of the deformity in trees may be insect related. Further research on these insects may contribute much to the improvement of sugar maple.

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PROVENANCE TESTING AT MICHIGAN TECHNOLOGICAL UNIVERSITY

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The location of M.T.U. in the Keweenaw Peninsula of Upper Michigan provides some unique advantages and disadvantages in provenance testing and tree improvement research. Extremes in summer and winter temperatures are uncommon because of the moderating effect of Lake Superior. Near the Lake we have about 140 frost-free days while inland the frost-free season is only 80 days or less. Many exotic species of plants will grow in the Houghton locality but are prevented from naturally migrating here because of the cold belt to the immediate south.

Heavy snowfall does occur, averaging about 200 inches per year, and is a serious problem in provenance testing. Heavy snow accumulations affect even small pole-sized trees. The lower 4 feet of branches are repeatedly pulled down and out, weakening the stem at the node. Most trees in plantations have some type of basal crook.

Scotch Pine

Scattered plantings of Scotch pine are found throughout our area. The seed source is unknown but in most of these plantings, some of which are 30 or more years old, growth and reproduction is excellent. Where Scotch pine has been planted in mixtures with other conifers, the reproduction is almost all Scotch pine.

Our first effort in provenance testing was the NC-51 Scotch Pine Project initiated by Dr. Wright of Michigan State University. This was planted in 1961. Eight replicates of eighty sources were planted on the Keweenaw Peninsula and two replicates were planted at the Ford Forestry Center, 50 miles south. This report considers only the Keweenaw planting, the Ford Center planting having suffered excessive mortality. Analysis through the 1968 growing season indicates that:

(1) The varieties from western and central Europe: var. *haguenensis*, var. *hercynica*, var. *borussica*, var. *polonica*, and var. *pannonica*, are best suited for our area on the basis of height growth. The best of these are the Belgian sources, var. *haguenensis*, which have averaged two feet of height growth per year. Our results compare closely with Khalil's recommendations for central Minnesota, although his recommendations for northern Minnesota include some sources which are just average in our plantings.

(2) Among the sources tested, the Belgian group had the highest mortality, poorest form, and have produced the greatest number of lammas shoots.

(3) South European varieties had the most insect infestation but the incidence was not serious.

(4) Belgian sources had the most cones, with south European sources a close second. Only 6 percent of all trees had cones in 1969, however.

(5) Spanish sources have survived well, have slightly better than average height growth and appear to be one of the best for Christmas trees.

Tamarack

Our tamarack planting is part of the NC-51 Project initiated by Dr. S. S. Pauley of the University of Minnesota. The planting is part of the 1962 Accession and consists of 27 sources from Minnesota, Wisconsin, Michigan, Illinois, Ohio, Maine, Ontario, and Manitoba. The trees were planted in 1967 in sod and mulched with 3-foot squares of black polyethylene. Survival was over 90 percent through the fall of 1968. All of the trees were bent and about 25 percent of the trees were partially broken due to heavy snows of the past winter. We have tried to repair this damage and the results look good but height growth will likely be affected for several years.

The best source so far on a basis of height growth is from Clare, Michigan. These trees grew about 3 feet in 1968. The trend to date indicates the sources from central Minnesota, central Wisconsin, and central Michigan are best suited for our area with respect to height growth. Some of the more southern sources are comparable to these but adjacent southern sources grow poorly. Elgin, Illinois, and West Bend, Wisconsin, rank with the best, but Waukesha, Wisconsin, has performed relatively poorly. Poorest height growth is from the Canadian sources from Manitoba and Ontario.

The 1964 Accession was planted in 1968 and consists of 21 sources with a greater geographic range than the 1962 Accession. Thus far survival has been over 95 percent.

Yellow Birch

The yellow birch planting consists of 30 sources, range-wide, and was initiated by Dr. K. E. Clausen of the North Central Forest Experiment Station's Institute of Forest Genetics, Rhinelander, Wisconsin. The trees were outplanted in the spring of 1968 and are clean cultivated. Survival has been over 80 percent but nearly every tree has been damaged by snow.

Sugar Maple

The sugar maple planting consists of 26 range-wide sources and is in cooperation with Dr. W. J. Gabriel, Northeastern Forest Experiment Station, Burlington, Vermont. Sugar maple has also been severely damaged by snow the past year. The stems have been broken and in many cases 1969 growth is entirely from sprouts. These trees are only slightly taller now than they were in the nursery two years ago.

Our other provenance plantings include Douglas-fir, ponderosa pine, white spruce, red pine, Austrian pine, white pine, red oak, and cottonwood. Analysis of these plantations is incomplete but information will be provided to anyone who may be interested in a particular planting.

Our other tree improvement work has been a study of phenotypic variation in specific gravity of sugar maple and in fertilization of northern hardwoods. Limited samples for the specific gravity study have been collected range-wide, and a more intensive sampling has been obtained from Upper Michigan. Preliminary results indicate as much variation within the merchantable part of the stem as among trees within a stand.

The study of fertilization of northern hardwoods is in cooperation with the Connor Lumber Company and is under the direction of Dr. Stephen G. Shetron and graduate student Ronald Heninger. These are first-year results in small and medium-sized sawlog stands for 600 trees stratified as to site. Sugar maple, red maple and basswood responded with about a 10 percent increase in diameter growth. There was no response with yellow birch.

NATIONAL FORESTS: RECENT TREE IMPROVEMENT DEVELOPMENTS

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This paper discusses the current status of a number of projects now under way on the National Forests in the Eastern Region of the USDA Forest Service.

Selection of Superior Trees

Initial selections are complete for one 50-clone orchard and nearly complete for a second orchard of white spruce. We are actively searching for superior tree candidates in black spruce, jack pine and red pine in the conifers, and in yellow birch, sugar maple and red oak among the hardwoods.

This year we revised our record form so that all of our superior tree records are now processed by ADP. We now have records on over 1,500 selections in all species. Keeping track of changes, records of grafting, etc., was becoming a big chore. This new system can be kept current with a minimum of effort.

Grafting

We had another busy year with our grafting program in white and black spruce and eastern white pine. We do all our grafting in greenhouses at the Toumey and Eveleth nurseries. This year we completed over 9,000 grafts with very high success. Our "take" on white pine has averaged 99 percent for the past 3 years. The spruces, while somewhat lower at 85 to 95 percent "take," are much higher than those reported in the literature. No small part of this success is due to the skill of the nursery crews and the nurseryman.

Oconto River Seed Orchard

Perhaps our biggest news item is the purchase of some farm land near Langlade within the Nicolet National Forest (Wisconsin). Nearly 500 acres of this tract has been under cultivation. We plan to develop most of our seed orchards within this area, making it one of the largest seed orchard developments in the U.S. Topographic work has been completed on the open areas. Soil analysis shows excellent structure. A contract has been awarded for a deer exclosure fence. We plan to establish two seed orchards and a large clonal breeding arboretum here in 1969.

Our seed orchards are computer-designed by the University of Wisconsin, using a program built by Dr. G. Stairs. This program randomizes the placement of ramets on a hexagonal pattern but with conditions. It maximizes the crossing pattern between clones and equalizes the number of times each clone appears in the orchard. We're using this same program with an 85-acre seed orchard for Missouri shortleaf pine.

Rust-Resistant White Pine Program

Selection of Candidates

The selection data are now complete for all cooperators except the State of Michigan and the University of Wisconsin. As of this writing, 946 selections have been reported, 921 have been screened, 686 have been accepted, and 25 selections remain to be checked.

Grafting

The cooperation we received in the scion collection work was again excellent this year. We collected scions from 219 selections, completing the grafting phase of the program for all cooperators except the State of Michigan and the University of Wisconsin. The few remaining trees will be grafted next year.

Seed Orchard

This spring all of the white pine grafts made during 1966 and 1967 will be outplanted in the Oconto River Seed Orchard. Five grafts from each accepted candidate will be planted in a clonal breeding arboretum where they will receive intensive care to help stimulate flowering. When the grafts begin to flower, we will start a controlled pollination program to produce seed for testing. This will supplement the field pollinations already in progress.

We also intend to plant an interim seed orchard consisting of 29 clones that we received from Dr. C. Heimburger in Canada, and five clones from Dr. R. Patton of the University of Wisconsin. These clones have all been tested for resistance to blister rust. The seed produced in this orchard will be tested to determine the clones that transmit the rust-resistance to their offspring.

Hybridization

Many of the scions grafted this winter produced conelets, suggesting that there will be a good cone crop for our pollination work this spring. We hope to repeat the crosses that did not produce the required amount of seed the first time, and begin pollination work on as many new selections as possible.

Additional work is being carried out in the development of black cherry on the Allegheny and Monongahela National Forests. We are also cooperating with Region 8 in the development of shortleaf pine.

TEN YEARS OF PROVENANCE RESEARCH AT MICHIGAN STATE UNIVERSITY AND THE NEXT STEPS IN TREE IMPROVEMENT

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Michigan State University's first provenance test was started in 1958, a little more than a decade ago. Tests in three more species were started in 1959. Others have been added until the list of species covered now totals 28. There are such experiments in eight species of pine, six of elm, three of spruce, two each of larch and the true firs, and one each of Douglas-fir, poplar, birch, cherry, walnut, arborvitae and oak. Some were started by Michigan State University. In other cases we received planting stock or seeds from outside the State. Almost all the experiments are part of the NC-51 regional tree improvement project and involve cooperation with others.

The decision to place major emphasis on provenance research was based on the supposition that the major portion of the genetic variability in any species is associated with geographic origin of the seed and that some superior nonlocal types could be found.

Genetic differences among trees originating from different parts of a species' range have been very large in Scotch pine, jack pine, ponderosa pine, southwestern white pine, Douglas-fir, white spruce, and white fir. In each of these species there have been two-fold or three-fold differences in growth rate between trees from different geographic areas. There were equally striking differences in other traits such as foliage color, hardiness, leaf length and terpene composition. In fact the list of variable traits is governed mostly by time available for study.

Important but less marked differences were found in another group of species. Eastern white pine trees from Tennessee and southern Ontario grew 10 to 20 percent faster than trees from more northern areas in southern Michigan plantations. (Southern Appalachian trees were not suited, however, to the northern Lake States.) Austrian pine from Greece outgrew the more commonly planted Austrian variety. Yellow birch from the southern Appalachians leafs out later than more northern types but so far in the Michigan tests all types have grown equally fast.[1] Differences in growth rate were minor in Japanese larch but trees from Mt. Fuji produced cones earliest and trees from the northeastern part of the range were slightly more hardy than others.

The provenance research has uncovered virtually no differences in two species only. Many years ago Paul Rudolf and Ashley Hough of the USDA Forest Service established red pine experiments in the Lake States and Pennsylvania. The trees are now more than 40 feet tall. According to the last measurements, the best and poorest origins were almost alike. We have a younger study which includes more origins but the results are the same. Northern white-cedar may fall into the same category. Scott Pauley sent seed from all parts of the range. The seed germinated well and produced an excellent nursery experiment. The origins were indistinguishable at age 3.

Most experiments include several different plantations, often in different States. When

1 *Results of a Wisconsin test of the same material is discussed in the paper by R. M. Jeffers on page 18.*

possible, the same seedlots were planted in each plantation. Generally speaking, an origin which grew well in one plantation grew well at many other test sites. For example, eastern white pine from Tennessee grew most rapidly when planted in North Carolina, Tennessee, southern Michigan, and Iowa; white pine from the southern parts of the Lake States grew well when planted in several parts of the northern Lake States. This tendency was much more pronounced than was the tendency for the local origin to be superior. Seed procurement rules must constantly be revised as the provenance experiments provide data.

Reliability of the Results

The following practical recommendations can be made for tree planters in southern and central Michigan. Similar lists can be made for other areas.

When planting this species	*Use seed collected from natural stands in these areas*
Eastern white pine	Tennessee, southern Ontario
Scotch pine	Spain (for Christmas trees) Belgium and northern France (for fast growth)
Red pine	Most parts of range
Jack pine	Michigan's Lower Peninsula
Southwestern white pine	Central parts of Arizona and New Mexico
Ponderosa pine	Eastern Washington and Oregon
Austrian pine	Parts of Greece
White spruce	E. Ontario, S. Manitoba, also parts of Wisconsin and Michigan
Douglas-fir	Northern Idaho or central parts of Arizona and New Mexico
White fir	Central parts of Arizona and New Mexico
Japanese larch	Almost any part of natural range

The red and jack pine recommendations are based on 18 to 30 years growth in plantations of the North Central Forest Experiment Station. The others are based on much younger experiments and further results can be expected soon from experiments which are now very young. How reliable are such data?

A student, Warren Nance, studied this question during the past year. He remeasured our oldest plantations of Scotch pine, ponderosa pine, and eastern white pine. The nursery data on growth and hardiness were excellent indicators of future growth rate. As it turned out, our tentative recommendations at age 2 were almost as good as our most recent ones. The jack and red pine stories have changed little with increasing age. Few surprises have been forthcoming in other experiments up to 8 years old.

Pest damage complicates the picture, however. Several insects are now active in 10-year-old Scotch pine plantations, and a wait will be necessary to learn the resistance of different varieties. A 15-year wait may be necessary when selecting elms for disease resistance.

Time has not helped cure mistakes made in the nursery. If uneven germination or uneven watering produced uneven seedbeds, the experiment is still uneven and relatively unproductive of results after a lapse of 5 to 10 years. Similarly, the results of poor weed control or poor planting are nearly as evident now as the year after planting. The moral is clear – do an excellent job from the start.

Upsets in Theory

Theory also received a great deal of attention. A decade ago I hoped that the provenance research would lead to a very clear understanding of the processes of genetic formation of races and clines, and that with such an understanding we would be able to forecast what would happen under any set of circumstances. The answers are still far from good.

As of 10 years ago there were theoretical generalizations that races from warm climates grew fastest and that races from cold climates were hardiest. Both generalizations proved true in general, but there are some very embarassing exceptions. Eastern white pine from warm Virginia grows more slowly than does the same species from colder Pennsylvania and New York. The parental stands in Virginia were not selfed, were not on particularly cold microsites, or on poor soils. In the grand-white fir complex of the Rockies, grand fir from high elevations in northern Idaho suffered extreme winter injury (in southern Michigan) whereas there was no such injury on white fir from Arizona or on Douglas-fir and ponderosa pine from lower elevations in Idaho.

In each of four Rocky Mountain species an Arizona-New Mexico race grew rapidly and was distinct from races to the north. Migration between these races was inhibited by a wide treeless barrier. And in each of the four species the slowest growing trees came from Utah. But there the similarity in patterns ended. Selection pressure operated to produce a large amount of genetic variability within the Colorado population of Douglas-fir whereas there is little difference between Colorado and Alberta limber pine. Different responses to the same selection gradient were also evident in two European species. Spain produces Scotch pine with exceptionally short and dark green needles; Spain produces Austrian pine with exceptionally long and yellow-green needles.

Theoretically, 24 origins of white spruce, well scattered over the entire natural range, should cover the gamut of genetic variability in the species. Not so. We planted Hans Nienstaedt's white spruce experiment at Kellogg Forest in southern Michigan and used border stock of unknown origin (probably some place in Wisconsin or Michigan). The border trees have been unique in producing many cones and suffering heavy attack by a gall aphid although the crowns have not yet closed.

Progress on cause-and-effect relationships has been slow. There is as yet no good explanation for the resistance of the Ural Mountain variety of Scotch pine to the black-headed pine sawfly, for the earliest flower production on slow-growing sources of eastern white pine but fast-growing sources of Scotch pine, or for the high content of four different elements in the foliage of the coastal variety of ponderosa pine.

These problems are challenging, not frustrating. Evolution has been complex. Much more work is required before we can forecast whether a genetically unknown species will behave like eastern white pine (considerable geographic variation) or red pine (almost no geographic variation), the effect on height growth of a genetic increase in nitrogen assimilation rate, or whether the genetic variation in a particular region will be continuous or discontinuous.

Many of these theoretical questions have important practical implications and need solution. In general the solutions will come only from further experimental work because there are too many gaps in existing population genetic theory.

The Future

Insofar as Michigan is concerned, the job of starting large range-wide provenance tests is nearly completed. Maintenance and measurement will continue on those now in the ground, but I believe that most of the important results will be forthcoming in the first 10 to 15 years of each experiment.

An interdisciplinary approach promises to be successful in the solution of some of the theoretical problems mentioned earlier. Dr. Hanover is bringing his physiological talents to bear in some of the provenance experiments and is studying differences in terpene chemistry, photosynthetic rates, and other internal characteristics. He hopes to learn why some of the trees are fast growing. This would help when attempting to breed new trees for specific purposes.

The provenance experiments were preliminary and were meant to point to best regions from which to obtain trees for more intensive breeding work. Two followup experiments have been started in eastern white pine. Seeds were collected in 1960 from 125 single trees located in various parts of Michigan; seeds were collected in 1964 from 170 single trees or stands in the southern Appalachians. Similar progeny tests have also been started in jack, red, and Scotch pines.

These followup experiments have already yielded some information on local variation patterns and on the amount of genetic variability in important growth traits. Differences among stands have generally been more pronounced than differences among trees within stands. The correlations between characteristics of the parents and of their offspring have been disappointingly low. Thus, the practicing forester interested in good seed for the immediate future need not practice stringent selection in his cone collection work. And the tree breeder interested in a better strain for the future needs to progeny-test his selections.

For the past 3 years Dr. H. D. Gerhold of Pennsylvania State University and I have been using one plantation of the Scotch pine provenance experiment as a breeding arboretum. We have made crosses between distinct varieties, hoping to produce hybrids with hybrid vigor or with a combination of the best characteristics of different varieties. The crosses are easily made but we still have to wait for the results. Much more of this work will be done as other species flower.

The provenance experiments also offer new opportunities in hybridization between species. Many successful hybrid combinations are now known. Among them are Japanese red pine X Austrian pine, Japanese red pine X Scotch pine, eastern white pine X western white pine, Japanese larch X European larch, Japanese larch X Korean larch and white spruce X Engelmann spruce. Average parents were used to make most of the hybrids available now. Even so, many exhibit desirable growth characteristics. It is virtually certain that even better hybrids can be produced by crossing selected types of the parental species.

RESEARCH IN FOREST GENETICS AND TREE BREEDING AT THE UNIVERSITY OF WISCONSIN [1]

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The genetics and breeding group in the Department of Forestry now has two faculty members and five graduate students. We are now a part of the Plant Breeding and Plant Genetics Group which includes six departments and twenty-six faculty members in an interdepartmental program of graduate teaching and research. Close cooperators are the Department of Plant Pathology at the University of Wisconsin, the Department of Natural Resources, and the U.S. Forest Service, North Central Forest Experiment Station, Institute of Forest Genetics, Rhinelander, Wisconsin. Our research materials include four coniferous genera and one hardwood genus. Current research is summarized below for each genus.

Abies

Geographic Variation in Balsam Fir

Provenance and one-parent progeny studies were initiated with seed collections in 1960-62. Three-year-old seedlings were distributed for nursery transplanting in Michigan, Minnesota, and Wisconsin, and were measured after two seasons in nursery transplant beds at three locations.[2] For the provenance material the range of mean total height was moderate (13.1 to 23.8 cm.). Effects of nursery location and seed source were statistically significant (99 percent probability). The geographic pattern of variation was not clear, except for the concentration of eastern provenances as the five tallest. The shortest provenances were from the western portion of the range yet variable performance of collections from Manitoba and western Ontario precluded an interpretation of an east-west axis of variation.

Analysis of variation in frequency of frost damage was made possible by an early May frost in the central Wisconsin transplant beds during the fifth growing season. No other station reported frost damage. Fortunately, the seedlings in central Wisconsin were planted in three replicates. The range of variation expressed as the percentage of undamaged seedlings was large (12 to 98 percent). Replicate and seed source effects were statistically significant (99 percent probability). The pattern of variation for frost damage was markedly different than the pattern for height growth. The five least damaged provenances were from Wisconsin and Michigan. The five most damaged were from Manitoba and western Ontario. Simple linear regressions of frequency of frost damage on latitude and frost-free period of the seed origin were not statistically significant.

1 *Research reported is funded by Federal Hatch Act and McIntire-Stennis appropriations, the Wisconsin Department of Natural Resources, the University of Wisconsin Graduate School, and the University of Wisconsin School of Natural Resources.*

2 *Mr. Richard Jeffers, Dr. Scott Pauley, and Dr. J. W. Wright assisted with height measurements.*

Seed source height growth potential, as measured by total height of seedlings whose terminal shoot was undamaged, showed no association with frequency of frost damage within the population. This suggests that increased height growth may not necessarily involve increased danger of frost damage. For example, among the three tallest seed sources one ranked eighth (out of 59) in frequency of undamaged seedlings (58 percent); another ranked 48th (13 percent).

Variation in total height and frost damage was clarified somewhat by periodic measurements on elongating shoots during the fifth growing season. The least frost-damaged provenance (Lower Peninsula of Michigan) was shown to have escaped frost by flushing about 10 days later than other measured provenances. Whether late flushing is common to other Lake States provenances is unknown. The value of late flushing as a frost-escape mechanism is uncertain because observations were limited to one growing season. Spring frosts are not uncommon in late May for central and northern Wisconsin, so that the results noted here may be largely incidental. The patterns of shoot elongation in one season suggested that rate rather than duration may be the principal determinant of differences in total height.

A nested sampling of maternal progenies within six Wisconsin and Michigan stands showed unexpectedly high variation. The range of variation was similar to the range-wide provenance variation. Progeny effects were greater than provenance effects for total height, whereas provenance effects were greater for frost damage as the result of one extensively frost-damaged provenance from the eastern Upper Peninsula.

The transplants in central Wisconsin were field planted at three Wisconsin locations in 1969. The transplants in Minnesota were field planted at one location and the material in Michigan is scheduled for field planting in 1970. Survival has been excellent in all field plantings to date.

Larix

Interspecific Hybridization with Japanese Larch

Interspecific hybrids of Japanese larch with western larch, tamarack, Siberian larch, and Dahurian larch have been produced to identify species combinations with high growth potential. Crosses between Japanese larch and tamarack seem especially promising in terms of growth rate. Hybrid seedlings will be grown one more season in the seedbed before field planting. The seedlings will provide material for studies on techniques for hybrid identification with emphasis on terpenes and other biochemical constituents.

Picea

Mutation Breeding in White and Norway Spruce

The effects of pollen irradiation on genetic variation are being studied in controlled crosses and selfings made with irradiated and nonirradiated pollen. The seedlings are completing their first season of growth. A first evaluation of radiation effects will be made in the nursery next year and subsequent evaluations will be made on field plantings.

Enzyme Analysis of White Spruce

Electrophoretic techniques for enzyme analysis are being used on leaf extractions to isolate enzyme systems suitable for genetic study and for demonstration of Mendelian segregation for isoenzymes. The objective of this approach is to provide techniques for population analysis of heterozygosity. The work is being done in cooperation with Dr. James King and Mr. Richard Jeffers of the USDA Forest Service, North Central Forest Experiment Station, Institute of Forest Genetics.

Soil Ecotypes of White Spruce

The natural occurence of white spruce in southeastern Ontario on soils of widely differing calcium content has prompted a study of potential ecotypic differentiation based on soil differences. Seeds from trees growing on five calcareous and five noncalcareous soils were provided by Mr. Mark Holst, Canadian Department of Fisheries and Forestry. The seedlings are being grown in hydroponic culture at three different levels of calcium concentration and two levels of acidity.

Response to cultural conditions will be measured by dimensional characters and by chemical analysis of foliage.

Pinus

Seedling Seed Orchards of Red Pine

A combined research and seed-orchard development project for the Wisconsin Department of Natural Resources was initiated with seed collections in 1963-65 from 310 trees throughout Wisconsin.[3] The sampling was designed to allow the estimation of how much variation in growth of red pine is attributable to maternal progenies within stands, to stands within climatic provinces, and to climatic provinces.

The seeds were sown in 1967 in a manner designed to minimize nursery site heterogeneity. A row of 5 seed spots was sown with 10 to 12 seeds in each of 35 randomized complete blocks. Border rows were also sown. The intent was to thin, by hand, each seed spot to one seedling soon after germination. Excellent germination was achieved but damping-off fungi assisted in the thinning despite seedbed fumigation and fungicide applications. Mechanical thinning was postponed until the end of the first growing season to minimize the amount of transplanting required. Plot mortality was then alleviated by transplanting seedlings from multiple seedling spots to empty ones. The overall result was adequate representation of seed lots in about 90 percent of the plots but seedling variability within plots was greater than intended.

Measurements of total height are currently in progress. The seedlings will be tagged by plot, lifted by replicate, and field planted at three locations in 1970. Field measurements will be made at plantation ages 8 and 15. Then the slowest growing 225 progenies will be rogued, as will all but the largest tree in each plot of each remaining progeny. The result will be about 800 trees per plantation to be used as sources of seed for the Wisconsin state nurseries.

The biological basis for an expected improvement of up to 5 percent in wood yield comes from progeny tests established in Wisconsin several years ago (Lester and Barr 1965). Whether significant improvement is achieved will depend on the variation pattern revealed and the success of relatively early selection. The latter will be resolved by juvenile-mature correlation studies (Lester and Barr 1966) before converting the progeny test to a seed orchard.

Interspecific Hybridization With Pitch Pine

Controlled pollinations have been made on pitch pine using pollen of sand pine and spruce pine. The objective of this study is to identify species combinations with a high growth potential for low quality sites. Seeds will be available for testing in 1970.

Genetics and Biochemistry of Variation in Needle Tip Burn of Eastern White Pine

Ninety trees from throughout southern Wisconsin have been phenotypically classed as resistant or susceptible to needle tip burn. Several grafts from each selection have been made and are being used in studies of response to ozone fumigation. Repeatability analysis of reaction to ozone fumigation will be used to estimate the extent of genetic control. A survey of possible biochemical differences between susceptible and resistant types will be made.

Ulmus

In 1957 Dr. Eugene Smalley, Department of Plant Pathology, began a program of screening world-wide seed collections of elms for resistance to the Dutch elm disease. About 400 collections have been screened and more than 1,000 resistant individuals representing 8 species and several putative natural hybrids are now growing in an elm arboretum near Madison. Many of these trees have begun flowering in the past few years and a program of genetics and breeding has been developed jointly between the Departments of Forestry and Plant Pathology to determine patterns of inheritance for disease resistance and for ornamental traits. At present our interest is concentrated on four species, American elm, Japanese elm, slippery elm, and Siberian elm.

Genetics of American Elm

Three crossing studies have been made with American elm. The first was an attempt to reduce

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3 *D. T. Lester. Proposal for genetic improvement of red pine in Wisconsin. 16 p. (Unpublished.)*

the chromosome number (56) to the same level as other species in the genus (28) so that transfer of disease resistance might be possible through interspecific hybridization. Pollinations with highly irradiated pollen and with pollen of species which rarely, if ever, cross with American elms resulted in production of a few seeds but all seedlings had the chromosome number of American elm. Self-fertility is the most likely cause of these results.[4]

The frequent assumption that elms are self-sterile as a consequence of early development of the stigma (protogyny) has been examined in selfing studies over a three-year period. Forty-seven out of 57 selfed trees have produced seed in one or more years. Unfortunately, several of the 10 trees which failed to produce seed after one selfing have been sacrificed to highway improvement. At present, I have no individual of American elm in which self-incompatibility is certain. These results raise doubts about reports of interspecific hybridization with American elm (Britwum 1961, Johnson 1946, Smucker 1944). The existence of one authentic hybrid between American and Siberian elm indicates that crossing can occur but self-fertility seems to be common.[5]

Our most recent crosses in American elm have the objective of determining general and specific combining ability for resistance to Dutch elm disease. The resistant trees are survivors of artificial inoculations on 10,000 seedlings contributed by private nurserymen. Six of the 36 survivors flowered in 1969 and were used in the crossing scheme shown in table 1. Excluding the selfed combinations, an adequate number of seedlings was obtained for all but two crosses. Analysis of variation in growth and morphology will be made after one growing season and disease resistance will be tested by artificial inoculation in the second growing season.

Genetics and Breeding of Diploid Elms

From our collections of resistant diploid individuals 15 trees have been selected as potentially useful ornamentals. These trees are being propagated by root-sprout cuttings for evaluation in landscape settings. Included among these selections are individuals of Japanese elm, Siberian X Japanese elm hybrids, Siberian X slippery elm hybrids, and multispecies hybrids of European origin.

In our diploid crosses we are presently concentrating on Japanese, slippery, and Siberian elms. Some Japanese elms have the desirable features of red autumn leaf color, open branching, and moderately large leaves. Disease resistance seems to be high but we have not tested large numbers of Japanese elms. Slippery elm has open branching, a large leaf, and is known to produce vigorous hybrids with Siberian elm. Disease resistance is thought to be low, but has not been adequately tested. Siberian elm has high disease resistance and drought tolerance. These species and some hybrids have been crossed using single tree pollens and pollen mixes (table 2). Hybrids, authenticated by morphological comparison of progenies from intra- and interspecific crosses are now one or two years old. Each tree will be artificially inoculated and scored for reaction to inoculation within the next 2 years. Survivors will be tested again and then selected for ornamental traits.

Dutch plant breeders have been highly successful in developing genetic resistance to Dutch elm disease, and we have evidence from open-pollinated progenies of our Siberian elm X Japanese elm hybrid family that resistance to the Dutch elm disease can be maintained through breeding. This result coupled with the apparent ease of crossing among the three diploid species of current interest suggests that a high degree of resistance to the Dutch elm disease can be maintained while a broad range of variation in ornamental traits is being developed.

[4] *Lester, D. T. Unpublished data.*

[5] *Personal correspondence with F. S. Santamour, Oct. 14, 1968.*

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Table 1.—Crossing scheme for disease-resistant and susceptible American elms (R = resistant, S = susceptible)

	R1	R2	S1	S2	R3	R4	S3	S4	R5	R6	S5	S6
R1	X	X	X	X								
R2	X	X	X	X								
S1	X	X	X	X								
S2	X	X	X	X								
R3					X	X	X	X				
R4					X	X	X	X				
S3					X	X	X	X				
S4					X	X	X	X				
R5									X	X	X	X
R6									X	X	X	X
S5									X	X	X	X
S6									X	X	X	X

Table 2.—Summary of elm families from crosses 1968-69

	U. japonica	*U. pumila*	*U. rubra*	*U. pumila* X *japonica*	*U. rubra* X *pumila*
U. japonica	X			X	
U. pumila	X	X	X	X	X
U. rubra	X	X	X	X	X
U. pumila X *japonica*	X	X	X	X	X
U. rubra X *pumila*		X	X	X	X

FOREST GENETIC RESEARCH AT THE INSTITUTE OF PAPER CHEMISTRY

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Forest genetics research is carried on in the Genetics and Physiology Group at The Institute of Paper Chemistry. The Institute is located in Appleton, Wisconsin, and has a staff of approximately 300 people. It is a nonprofit research and educational institution that was started in 1929 and is affiliated with Lawrence University. The Institute is a graduate school granting M.S. and Ph.D. degrees. Research at the Institute encompasses not only work in the area of pulp and paper technology but also includes studies in biology, chemistry, chemical engineering, mathematics, and environmental control.

Work in forest genetics began in 1954 under the direction of Dr. Philip Joranson and emphasizes poplar species, primarily aspens, and includes some studies involving cottonwood and closely related species. Several species of *Larix* have also been outplanted with the view to future work with this genus.

Predictions made by the USDA Forest Service indicate that pulpwood consumption is expected to increase from 50.7 million cords (1966) to 127 million cords in the year 2000. Loss of good quality forest land to agriculture, recreation, and urban and industrial development suggests increased production will need to be accomplished on less-productive lands. The magnitude of the increased production suggests several approaches will be required to prevent serious raw material shortages. The most promising include (1) improved utilization, (2) intensive forestry, and (3) forest genetics. Studies under way that speak to these problems include the following research projects.

1. *Aspen genetics and tree improvement project.* – The objectives of this long term investigation include (a) developing trees of exceptional growth rate and wood quality and (b) developing trees for several types of soils including those that will do well on sandy soils of low fertility and respond to such intensive forestry practices as fertilization and irrigation. Forest genetics procedures employed include selection, hybridization, and polyploidy. Naturally and artificially produced triploids have been obtained and show considerable promise in the area of improved wood quality and improved growth rates.

2. *Investigation of methods for the production of maximum growth in natural and improved aspen.* – This project has the overall objective of demonstrating the biological potential of aspen and aspen hybrids. More specifically, the program emphasizes the intensive aspects of forest management and has the goals of (a) exploiting presently available genetically improved species of *Populus*, (b) developing rotation age and harvesting system information, and (c) establishing the biological feasibility of such intensive forestry practices as fertilization and irrigation.

3. *Investigation of methods of separating chip and bark mixtures.* – Utilization of small-size trees and better utilization of the limbs and tops of trees hinges upon chipping in the woods, bulk handling of the chips, and separating chip/bark mixtures prior to pulping. The objective of this project is to develop chip/bark separation procedures.

4. *Tissue culture research.* – Research on the use of tissue culture in forest genetics began at the Institute in 1962 under the direction of Dr. Martin Mathes and was taken over in 1964 by Dr. Lawson Winton. The objectives of this work were to investigate the usefulness of tissue culture techniques in studying growth and differentiation with the ultimate objective of starting with a single cell and developing an intact, normally functioning tree. Several trees have been produced from callus tissue; this apparently is a "first" with woody plants. Dr. Winton acknowledges the assistance of Dr. Karl Wolter, of the Forest Products Laboratory, in suggesting several chemicals which have helped make this feat possible.

RESEARCH AT THE INSTITUTE OF FOREST GENETICS RHINELANDER, WISCONSIN

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The Institute of Forest Genetics at Rhinelander, Wisconsin, was formally opened June 6, 1957, by the North Central (then Lake States) Forest Experiment Station, USDA Forest Service.

Originally, only the Forest Genetics Project was located at the Institute. Today, there are in addition: Pioneering Research and Radiobiological Studies of Northern Forest Communities. Information presented here will pertain only to recent findings of the Forest Genetics Project. The objectives of this project are fourfold:

1. Increase knowledge of the genetic constitution and the variation in populations of several forest tree species through basic research.
2. Develop guidelines that will enable tree breeders to plan realistic and efficient tree breeding programs.
3. Breed trees for local use in pilot size operations.
4. Develop efficient means for vegetative propagation of forest trees.

The genetics project has concentrated most of its research efforts on white spruce (*Picea glauca*), jack pine (*Pinus banksiana*), red pine (*Pinus resinosa*), and yellow birch (*Betula alleghaniensis*). In addition, a large number of other native and exotic species such as tamarack, balsam fir, northern white-cedar, Norway spruce, Serbian spruce, Engelmann spruce, and eastern white pine are being studied less intensively.

Variation of White Spruce Seed Sources

To date, the Institute has established provenance tests for white spruce, jack pine, red pine, eastern white pine, tamarack, balsam fir, northern white-cedar, Engelmann spruce, Norway spruce, and yellow birch.

Results of a white spruce seed source test have been published recently by Nienstaedt (1969). White spruce (*Picea glauca* (Moench) Voss.) seed from 28 sources was collected over the entire range of the species from Alaska to Labrador and south to the limits of the species. They were field tested for 5 years in 14 field plantings in a region from 42° to 48° N. latitude from North Dakota to New Brunswick.

Survival exceeded 80 percent in all but three test locations. There were significant differences in seedling survival among seed sources. This was due largely to poor survival of seedlings from three Alaskan sources and one Yukon source. Seed from other sources showed only minor differences in seedling survival.

Seed-source differences in seedling height growth after 5 years were highly significant. The interaction between seed sources and plantation environment was also significant. A rank correlation analysis suggested that this significant genotype-environment interaction resulted mainly from the relative magnitude of response of seed from various sources to the changing environments and not to systematic changes in the ranking of seed sources.

An analysis suggested that the seed from the southeastern portion of the range of the species, including the Lake States, southern Ontario, and parts of Quebec and New England, were well adapted to all the test sites, and that some were growing better than the average for the plantations. Seedlings from sources on the Chippewa National Forest; McNally Lake, Quebec; and Ashley Mines and particularly Beachburg, Ontario, are among the 10 best in all 14 outplantings. Seedlings from some sources, particularly the northern ones, showed less than average adaptive stability and grew particularly poorly on the best sites. It is of interest to note that seedlings from a Douglas, Ontario, seed source still maintain a 22 percent superiority in height growth over those from seven other sources after 29 years in a plantation in northern Wisconsin. They are 17 percent taller than the local white spruce (King and Rudolf 1969).

The best individuals of the Beachburg source in four of the field plantings are being clonally propagated. Seed and seedlings from these grafts will be compared to seed and seedling progenies produced from white spruce seed orchards now being established in the Lake States area.

The data from this study suggest that individual tree selection, testing, and breeding of individuals from the southeastern portion of the species range may lead to improved new strains adapted to the test region used in this study. Selection in southeastern Ontario and adjacent areas in Quebec may yield particularly good genetic types.

Heritability Studies of White Spruce

Breeding for Delayed Budbreak

In the spring of 1958, 9 early-flushing and 16 late-flushing trees were selected in a white spruce plantation near Rhinelander, Wisconsin. These selections were cloned in 1962 and ultimately field planted in a replicated test in 1965.

Spring frost injury was recorded in the nursery in 1963 and again in the field in 1965. In 1963 an average of 80 percent of all buds on the early clones and 13 percent of the buds on the late clones were killed by frost. In 1965 the frost injury on these two types was 61 and 13 percent, respectively.

Flushing was recorded in the years without frost injury. On the average, the late clones were delayed 15 days in flushing compared to the early clones; the overall difference between the earliest and latest clones was 21 days.

Beginning in June 1968, terminal elongation of the clones was measured twice weekly until elongation ceased. Late clones completed 95 percent of their elongation 10 days later than the early clones. On the average, late-flushing parental trees were 42 percent taller than early-flushing parents at the end of the 1968 growing season. Total elongation of the late clones in 1968 exceeded that of the early clones by 25 percent. Since the average growth period was essentially the same for the early and late types (35.3 and 31.7 days, respectively), the superiority in total height elongation of the late clones resulted from a greater growth rate. The daily growth rate of the late clones was more than 50 percent greater than that of the early clones.

In 1967, early-flushing, late-flushing, and average individuals were crossed with 10 of the original and three additional selections (nine late-flushing and four early-flushing). The flushing and growth of the 27 progenies from the 9 late-flushing parents were studied in the greenhouse with day-night temperatures of 75°-65° F., and in growth rooms with temperatures of 65°-55° F., and 60°-50°F. The flushing differential was greatest in the greenhouse and flushing was delayed by lower temperatures. Heritability estimates (h^2) varied with growth conditions and reached 0.705 for flushing in the greenhouse. The heritability of height growth, based upon a combined analysis of all 3 growth conditions, was $h^2 = 0.445$.

In northern Wisconsin, selection and breeding of the two latest-flushing clones could increase frost avoidance by as much as 43 percent (Nienstaedt and King 1969). The data suggest that simultaneous selection for late-flushing and rapid growth is possible in white spruce.

Half-Sib Studies

Since 1957 over 100 individual white spruce trees have been selected throughout the Lake States of Michigan, Minnesota, and Wisconsin. Open-pollinated seed from 32 of the selections was sown in the nursery in the fall of 1963; resulting seedlings were transplanted in the fall of 1965 and field planted in 1968. In the nursery, the 2-2 seedlings were measured for total height and current height growth. Two of the parents from Menominee County, Wisconsin, produced seedlings that made 63 percent more growth in 1967 than all of the 28 progenies included in the 1967 measurements.

The average annual height growth of the parents was strongly correlated with the current annual growth and total height of their respective progenies ($r = .80$ and $.81$, respectively). When the progenies from the 11 parents of similar age (36 to 42-year-old) were compared, those from the 5 fastest growing parents were growing at a yearly rate (in 1967) nearly 21 percent better than the average for their age group. The data indicate the general feasibility of phenotypic selection in white spruce (Jeffers 1969).

To date, 103 white spruce half-sib families have been field planted near Rhinelander, Wisconsin. Included in these plantings are 31 selections from the Ottawa Valley in Ontario, Canada. Some of the same families have also been outplanted in three additional areas including one southeast of Rhinelander (39 families), one in the eastern Upper Peninsula of Michigan (55 families), and one in Ontario, Canada (25 families).

Disease and Insect Resistance Breeding in Jack Pine

In a number of studies at the Institute, observations have been made on the differential susceptibility of jack pine to a variety of insects and diseases. One study includes trees from 30 sources in Michigan, Minnesota, and Wisconsin that have been in the field for 15 years in 17 locations throughout the Lake States. During the first 10 years the trees in these plantings showed significant seed-source-related differences in susceptibility to white pine weevil, red-headed pine sawfly, needle rust, jack pine needle-cast, bark beetles, eastern pine shoot-borer, and eastern gall rust[1] (King and Nienstaedt 1965).

The general approach in the study of pest resistance at the Institute is as follows:

1. Parents are selected in the seed source studies from sources that have demonstrated variation in pest incidence. This should insure genetic variation in the progenies. Occasionally, parents are seleted within natural stands, provided that pest incidence has been severe enough to suggest that undamaged trees did not escape infection by accident.
2. Selection of parents is followed by grafting to establish breeding arboreta.
3. The selected clones are crossed with several pollen testor parents to produce full-sib families.
4. Resulting full-sib progenies will be tested for pest resistance.
5. On the basis of the testing in step 4, a new cycle of selection will begin.

Six seed sources were selected in a Lake States jack pine seed source test on the Argonne Experimental Forest, Hiles, Wisconsin, on the basis of white pine weevil incidence – three low incidence and three high incidence sources. Four individual trees within each of the six sources were selected on the basis of good form and growth in the resistant sources and poor form and growth in the susceptible sources. All 24 individuals were clonally propagated in 1965 and outplanted near Rhinelander in 1968. Six additional parents, one from each of the six original sources, were selected for use as pollen parents. Many of the grafts flowered in the same year they were field planted, and controlled pollinations were started. The goal is to cross the six pollen parents with all of the 24 white pine weevil selections. These 144 full-sib families will be used to study the inheritance of variation in white pine weevil resistance.

Trees selected in the Institute's seed source studies, on the basis of eastern pine-shoot borer were grafted in 1966 and were field planted in 1968. Individual jack pines have also been selected in natural stands for resistance to jack pine budworm and pine tortoise scale. They have been grafted, and all the clones will be used in controlled pollinations as soon as they begin to bear female strobili in abundance.

Birch Genetics

A rangewide study of natural variation in yellow birch including 55 seed sources has been underway at the Institute since 1963. Ten test plantings have been established in the Lake States, New York, and New England, and three plantings in Canada. Second- and third-year height growth in the Rhinelander nursery varied greatly and was essentially random. Total height was not correlated with latitude, longitude, length of growing season, annual precipitation, average January temperature, or average July temperature. Diameter was only weakly correlated with latitude and length of growing season.

In contrast to its random variation in height and diameter, yellow birch exhibits a gradual north-south trend or clinal variation in growth initiation and cessation. In general, more northern sources begin growing earlier and cease growth earlier than more southern sources.

To determine whether the height growth variability noted in the seed source study might be due to individual tree variability within the sources, a study of 199 individual tree progenies representing 20 of the original 55 seed sources plus one additional source is now in progress. At the end of the first growing season there were highly significant differences in seedling height among the sources and among the individuals within each source (Clausen and Garrett 1969).

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[1] *King, James P. Pest susceptibility variation in Lake States jack pine. (Manuscript in preparation.)*

Variation in DNA Content of Several Gymnosperms

A series of experiments has been conducted to determine the nuclear volumes and the amounts of DNA per cell in 13 coniferous species. The correlation between these two factors was determined, and the relationship between these factors and the distribution of the species was studies.

Slides of root meristems were prepared. The amount of DNA per cell was determined by Feulgen microspectrophotometry and biochemical analysis. The slides were also used to determine the nuclear volumes. Volumes were found to vary by a factor of 11.3 while DNA per cell varied among the 13 species by a mean value of 3.2. Red pine (*Pinus resinosa*) had the greatest nuclear volume and northern white-cedar the smallest. These two species also had the greatest and least amounts of DNA per cell.

The data suggest that nuclear size and DNA/cell may have an adaptive value. In the species studied, those with small nuclear volumes and less DNA/cell tend to have a wider distribution (Miksche 1967).

Intraspecific Variation of DNA per Cell in White Spruce and Jack Pine

The amount of DNA per cell was established chemically and cytophotometrically for 17 seed sources of *Picea glauca* and cytophotometrically for 11 sources of *Pinus banksiana*. DNA Feulgen absorption per cell varied from the lowest to the highest amount by factor of 1.6 and 1.5 for *P. glauca* and *P. banksiana*, respectively. Intraspecific variation of histone was similar to the observed DNA variation.

Intraspecific DNA also varied directly with intraspecific nuclear volumes; i.e., seedlings from sources with smaller nuclear volumes have less DNA per cell while seedlings from sources having larger nuclear volumes possess more DNA per cell.

A regression analysis between DNA per cell and latitude provided evidence that eastern and western population series of *P. glauca* exist in the seed sources studied. In the western series, DNA content per cell increased with increasing latitude. This relationship was not found for the eastern series. Two-year seedling height growth results also demonstrated that eastern sources are different from western sources. Seedling heights in the western provenances varied inversely with DNA content; i.e., seed from sources with small amounts of DNA per cell displayed greater growth. Seedlings from eastern sources, on the other hand, did not display the inverse relationship between DNA amount and 2-year growth (Miksche 1968).

Tree Improvement Opportunities in the North Central States Related to Economic Trends — A Problem Analysis

To determine the orientation and emphasis that tree improvement programs in the north-central States should take, a problem analysis exploring the economic needs for forest products has been developed by David H. Dawson of the Institute of Forest Genetics, and John A. Pitcher, Region 9, USDA Forest Service. The analysis indicates that most emphasis on tree improvement programs should be placed on *Populus* spp., white spruce, black spruce, *Betula* spp., *Larix* spp., shortleaf pine, jack pine, white pine, and black walnut. The analysis will be published soon by the North Central Forest Experiment Station, St. Paul, Minnesota (Dawson and Pitcher 1970).

Radiation Research

Until recently the radiation research at the Institute was conducted within the Forest Genetics Project. A significant portion of the research was devoted to the study of the relative radiosensitivity of various species of forest tree seed and seedlings. This type of research is being expanded to include a comprehensive study of the response of natural forest communities to gamma radiation. All radiation research is now under a new project entitled "Radiobiological Studies of Northern Forest Communities." Studies ranging from cell biology and genetics through general forest ecology will be conducted within the project. The program will include several seasonal exposures as well as a single long-term study of chronic irradiation. Support for this project will be provided by the Atomic Energy Commission as well as the USDA Forest Service. A wide variety of research in the program will be undertaken by University cooperators.

Leader of the new project is Dr. Thomas D. Rudolph, Principal Plant Geneticist, who has been on the Institute staff for more than 10 years.

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INTER- AND INTRASPECIFIC GRAFTING AND BREEDING OF FIVE-NEEDLE PINES

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Duluth, Minnesota

The forest tree improvement work at the Center was started in 1949 with the introduction of some of Dr. Riker's grafted eastern white pine selections. Subsequently a program of selecting, grafting, breeding and testing for resistance was begun. The work was initiated at Basswood Lake (15 miles NE of Ely, Minnesota) rather than elsewhere on a more accessible site for two main reasons. First, the high incidence of rust in the area along with large numbers of infected *Ribes* bushes affords good material for testing for resistance to blister rust. Secondly, the area is situated on a peninsula. The resultant cool, moist condition is conducive not only to graft survival but also to rust inoculation and infection.

In our first field grafting, Riker's white pine selections were grafted on 4- to 16-year-old native white pine rootstocks. The grafts produced conelets which were used in our breeding program. Many of the grafts have now grown beyond reach of ladders and are still too small for climbing for controlled pollination work. For these, a record of staminate and pistillate cone production is being kept, open-pollinated cones are gathered, and seeds are used in our resistance testing program.

An interspecific grafting program was begun involving all combinations of the rootstock species eastern white pine (*Pinus strobus* L.), red pine (*P. resinosa* Ait.), jack pine (*P. banksiana* Lamb.), mugho pine (P. *mugo* Turra), and Scotch pine (*P. sylvestris* L.); with scion species eastern white pine, Swiss stone pine (*P. cembra* L.), Korean pine (*P. koraiensis* Sieb. and Zucc.), Macedonian white pine (*P. peuce* Griseb.), and Himalayan pine (*P. graffithii* McClelland). Over a period of 17 years, about 2,000 grafts have been made, with a good sample of each scion-rootstock combination and about 65 percent total survival. These combinations were set up to investigate the possibility of using interspecific grafting to stimulate cone and pollen production and to provide breeding material low to the ground on hardy rootstocks.

Both staminate and pistillate cones are produced on most graft combinations. However, a difference in scion species response to rootstock species exists in some cases. For example, Korean pine grafted on red pine rootstocks produces only staminate cones and the graft combination is not too compatible. On eastern white pine rootstocks, grafts of this species are very compatible and both male and female cones are produced. However, Swiss stone pine tends to produce more pistillate cones on red pine than on white pine. Conelet production on other rootstock-scion species combinations also differs, but the grafts are still quite young. Differences in survival on various rootstock species also exist. In addition, time of pollen production is influenced by rootstock. We find, for example, that Swiss stone pine grafted on red pine produces pollen first each year, followed by Swiss stone pine on Scotch pine, mugho pine, and finally on white pine rootstocks. Differences in primary growth and needle length also exist among the various graft combinations.

Mugho pine shows promise as a rootstock species. It has the advantages of being low and convenient for work and of having numerous terminals for grafting. Consequently, many grafts can be made on one tree. To date, survival of all of the 5-needle pine species with which we are working is good on mugho pine. The grafts produce viable pollen and pistillate conelets. Controlled pollination of these have produced viable seed. Furthermore, we find that the rootstock on which the graft is growing tends to thicken and grow more or less in pace with the scion. Thus, a firm base develops which will support the normally more rapidly growing graft for some time. If such results are consistently obtained, mugho pine could serve as a very useful rootstock for experimental pine seed orchard work.

As the grafts produce staminate and pistillate conelets, both inter- and intraspecific pollinations are made. Every combination is repeated 3 years before it is abandoned as incompatible. Reciprocal crosses are made whenever possible. Seeds produced are grown in our nursery for resistance testing and outplanting.

Pollen is collected and kept separate by scion and rootstock species for determination of the effect of rootstock species on pollen viability. Each sample is tested for viability as soon as collected. Pollen is frozen over silica gel in a dessicator and sealed in a vacuum equivalent of 1 to 2 mm. mercury for one half hour. To date, we have been able to keep pollen viable for five years using this method.

The seeds are stratified and planted in nursery beds, grown for two summers and then inoculated. Best results have been obtained by wrapping the infected *Ribes* leaf around the needles of the seedling, thereby creating a miniature moisture chamber in which high infection results. If these *Ribes* leaves are too small – for example, when using *R. hirtellum* – a larger herbaceous leaf, such as one from *Rubus idaeus* is wrapped around the outside to provide pinning material and create the moist condition. Nursery boxes are covered with burlap and kept moist for 3 days. A consistent inoculation within each nursery box is indicated by the even distribution of yellow needle lesions found the next spring.

Some indication of variation in the rust is indicated by the differences in amount of infection obtained on identical samples of several white pine selections when inoculated separately using three different species of *Ribes* as inoculation sources. Also, a difference in lesion types is frequently observed. Both small discrete lesions and large coalescing lesions with some color differences are found.

Seedlings which survive inoculation in the nursery bed are transplanted into another bed for 1 year and then planted in the field test areas where rust infection is maintained at high levels by the cultivation of *Ribes* bushes.

TREE GENETIC AND IMPROVEMENT RESEARCH AT THE UNIVERSITY OF MINNESOTA

Scott S. Pauley
Professor [1]
Forest Genetics, University of Minnesota
St. Paul, Minnesota

The School of Forestry's Tree Improvement Research Project was initiated in 1955. Studies in this area during the past fourteen years have been designed to accumulate information on genetic diversity in native and exotic tree species and isolate genetically superior lines for direct use in Minnesota forest plantings or for further selective breeding. Nursery facilities and outplanting cooperation have been provided chiefly by the University's North Central Experiment Station and the Blandin Paper Company at Grand Rapids, the Cloquet Forest Research Center at Cloquet, and the USDA Forest Service Nursery at Eveleth, Minnesota. Indispensable cooperation has also been provided by the University's Departments of Horticulture, Plant Pathology, Entomology, Fisheries, and Wildlife; the North Central Forest Experiment Station of the USDA Forest Service; The Quetico-Superior Wilderness Research Center; the Minnesota Conservation Department, and other institutions.

Most of the studies carried on under the Tree Improvement Project are conducted by graduate student assistants as part of their graduate training program. In most cases the results obtained from these investigations are also used as the basis for their degree dissertations. Aside from purely research objectives, the Tree Improvement Project thus serves a useful graduate training and educational function. Twenty-nine graduate students have thus far participated in the Tree Improvement Project.

Major effort to this point has been directed to provenance experiments. During the past 10 years this work has been greatly facilitated by our participation in a cooperative Regional Research Project (NC-51: Forest tree improvement through selection and breeding) sponsored by the U.S. Department of Agriculture. Seed source experiments of 14 North Temperate Zone species have been established in more than 30 permanent outplantings throughout the State.

Results from the older experiments (e.g., white spruce, Scotch pine and Japanese larch) have provided information on the best adapted seed sources for direct use in various localities throughout Minnesota. Some of these species have now reached sexual maturity and our future research will be increasingly directed to selective breeding studies within and between the most promising sources.

Details regarding some of the studies are presented in the material describing the Conference Field Trip.

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1 *This was prepared by Professor Pauley prior to his death, April 18, 1970.*

D. M. Gunn Memorial Park

D. M. Gunn Memorial Park is located on the west side of Prairie Lake, about four miles north of Grand Rapids on State Highway 38. The park was established in 1956 by the Charles K. Blandin Foundation and was designed primarily for recreation. However, the north portion of the park was designated as a tree improvement research and demonstration area. The first outplantings were made in 1956.

Japanese Larch *(Larix Leptolepis)*

Seed Source Study

This outplanting of seven Japanese larch sources was established in cooperation with Michigan State University in 1960 as a part of the North Central Region Forest-tree Improvement Project (NC-51).

Initial mortality of the 2-0 seedlings was high (46 percent) necessitating replacements with 2-2 stock in 1962 which resulted in high survival. A single border row of European larch (*L. decidua*) surrounds the plantation and a number of failed spots have subsequently been replaced with sources of native tamarack (*L. laricina*).

Height measurements have indicated significant differences among sources but no apparent relationship between growth and latitute, longitude, or elevation of parent stands was found. Such a random pattern of geographic variation is not unexpected since the native range of the species is restricted to approximately 140 square miles on Honshu Island where it is found in small discontinuous populations.

Several trees were damaged or killed by sunscald in the winter of 1967-68 and Japanese larch is susceptible to the endemic larch sawfly (*Pristiphora erichsonii*) which was found and controlled in the plantation during the current season. In spite of these shortcomings the rapid growth of Japanese larch gives it considerable potential for use in Minnesota.

White Spruce Seed Source Study

This test plantation was established in 1962 in cooperation with the North Central Forest Experiment Station of the USDA Forest Service. The study consists of 25 white spruce seed sources and a single Itasca County black spruce source. The stock was 2-2 when planted. Mortality has been less than 1 percent.

Height growth of the sources represented clearly indicates that high latitude or high altitude short growing season sources (e.g., Alaska and Montana) are the slowest growing. Best growth has been made by an eastern Ontario source (Beachburg, Ontario) which was significantly better than the next best which are local (Itasca Co.) sources (table 1).

The plantation has been sprayed annually in late June or early July during the past several years to control the yellow-headed spruce sawfly (*Pikonema alaskensis*). This insect is a locally serious pest of open-grown white spruce in this area. A duplicate of this plantation established at Cloquet where no control was practiced indicated no apparent variation in susceptibility among the white spruce sources. The black spruce plots in this planting were, however, ignored by the sawfly.

Forest Tree Improvement Arboretum

During the period 1956-57 the School of Forestry established a Breeding Arboretum at Gunn Memorial Park. The collections consist chiefly of seed sources of *Populus* and *Betula* species, including varieties and hybrids and serve as a reservoir of potentially useful genes.

North Central Experiment Station Nursery University of Minnesota

A portion of the North Central Experiment Station Nursery has been used as the principal propagation area of the Tree Improvement Project since 1955. The Nursery is under the supervision of Professor William H. Cromell.

Dwarf Jack Pine *(Pinus banksiana)* and Eastern White Pine *(Pinus strobus)*

This study of seed-transmitted dwarfism in jack pine and white pine is being carried on in cooperation with Albert G. Johnson of the University's Horticulture Department, St. Paul Campus.

Table 1.—Gunn Park, Plantation B (1962) white spruce seed sources (ranking by Duncan's Multiple Range Test based on height in autumn 1966 at 9 years from seed)[1]

NCFES: Acq. No.	Seed Source Location	Height
		cm.
1663	Beachburg, Ontario	140
1647	Third River Rd.,Itasca Co.,Minnesota	127
3512	Itasca Co., Minnesota	125
1644	Adirondack Mountains, New York	119
1669	Grand Rapids, Minnesota	119
1662	Ashley Mines, Bannockburn, Ontario	117
1645	Monico, Wisconsin	116
1649	Coos County, New Hampshire	111
1655	Bangor, Maine	111
1660	Maniwaki, Quebec	111
1676	Huron National Forest, Michigan	110
3511	Itasca Co., Minnesota	105
1631	Spruce Woods Reserve, Manitoba	104
1659	Edmonston, New Brunswick	104
1661	Chicoutimi + St. Joan's City, Quebec	104
1687	Kakabeka Falls, Ontario	101
1664	Flin Flon, Manitoba	84
1628	Black Hills, South Dakota	83
1686	Moosonee, Ontario	83
1658	Lake Melville, Labrador	71
1665	Stony Rapids, Saskatchewan	66
1677	Summit Lake Region, Fort McLeod, B.C.	61
1657	Port Hope Simpson, Labrador	57
1654	Fort Yukon, Alaska	42
1653	Gerstle, Alaska	41
1630	Lewis & Clark National Forest, Montana	39

1/ All seed sources are white spruce except 3512 which is black spruce.

A normal-dwarf ratio of 1:1 characterizes the segregation ratio of plants grown from open pollinated witches' broom seed of jack pine and white pine (table 2). In the absence of any evidence that the witches' brooms tested were due to a pathogen, the conclusion has been made that the observed segregation was genetically determined since such a 1:1 segregation ratio was that to be expected from a simple Mendelian dominant gene for dwarfism when fertilization is accomplished by normal pollen. This hypothesis is supported by the observed total absence of male strobili on the brooms studied.

In all segregating populations the distinction between normal and dwarfed trees was sufficiently clear to permit classification during the first season of growth. Aside from the gross differences characterizing dwarf and normal seedlings, there is a distinct difference between the progeny of different brooms. These differences are reflected chiefly in the height and crown density of the seedlings.

Blackberry Experimental Area

This experimental area, established by the Blandin Paper Company in 1960, is located about 5 miles southeast of Grand Rapids on the south side of U.S. Highway 2.

Scotch Pine Seed Source Study

Scotch pine (*Pinus sylvestris*), a native tree of Europe and Asia, has the most extensive natural distribution of any pine species in the world. It is the most important pine species throughout most of its natural range, especially in northern Europe, where it is used chiefly for lumber, piling, and pulpwood. Scotch pine has been grown in Minnesota for many years as an ornamental and in recent years has gained wide acceptance as a Christmas tree.

The seed source outplanting at the Blackberry Experimental Area was established in 1962 with 2-1 stock supplied by Michigan State University. The planting represents one of the approximately 50 similar outplantings of Scotch pine seed sources in the North Central Region of the United States established under a Cooperative Regional Research Project (NC-51) sponsored by the U.S. Department of Agriculture. A summary of results based on measurements made in September 1966 (at which time the trees were eight years old from seed) is shown in table 3. The results may be briefly summarized

Table 2.—Chi-square tests of goodness of fit to a 1 : 1 ratio for normal - dwarf segregates of open-pollinated jack pine brooms

Broom No. - Year tested - Nursery (N) or Greenhouse (GH)	Survival	Normal 1-0 seedlings	Dwarf 1-0 seedlings	Chi-Square	Probability (1 d.f.) greater than:
	Percent	Number	Number		
1-1957-N	--	42	48	0.400	0.50
1-1961-N 1/	--	146	132	.705	.30
1-1962-GH	55	120	98	2.220	.10
2-1962-GH	75	73	77	.107	.70
3-1962-GH	70	81	59	3.457	.05
4-1962-GH	68	68	67	.007	.90
5-1962-GH	57	55	59	.140	.70
1-1962-N 1/	51	240	269	1.652	.15
2-1962-N	54	128	143	.830	.30
3-1962-N	52	125	133	.248	.50
4-1962-N	68	181	158	1.560	.20
5-1962-N	61	136	168	3.368	.05
All tests:	--	1,395	1,411	.091	.70

1/ Combined samples of seed from broom No. 1 collected in different years.

Table 3.—Relative height of Scotch pine varieties in autumn 1966 (8 years from seed) Blackberry Plantation A (1962)

Variety and seedlot numbers	Mean height 1/ in September 1966		Percent of Plantation mean	Origin
	Cm.	In.		
North European and Siberian varieties				
1. Altaica: 227	111	44	73	Altai Mts.,Siberian USSR
2. Rigensis: 223, 224,550,3513	154	61	101	Latvia, Sweden
3. Septentrionalis: 201,222,228, 230,273,274, 276,521,522, 543,544,545	126	50	82	Norway, Sweden, Finland
Central European varieties				
4. Borussica: 209	186	73	122	Northeast Germany
5. Haguenensis: 252, 253	179	71	117	West Germany
6. Hercynica: 203,208,248, 305,306,308, 312	187	74	122	Southwest Germany, Czechoslovakia
7. Polonica: 211, 317	198	78	130	Poland
South European varieties				
8. Iberica: 219	86	34	56	Spain

1/ Plantation mean = 153 cm. (60 inches)

by stating that in terms of growth rate and survival the best adapted sources for north central Minnesota are of Central European origin. Spanish sources are not frost hardy in this area. Extreme northern sources are slow growing and from the Christmas tree growers' standpoint are undesirable because of a foliage color change from green to various shades of yellow in autumn.

COMMON AND SCIENTIFIC NAMES OF WOODY SPECIES MENTIONED IN THE TEXT

Ash, white	*Fraxinus americana* L.
Aspen, bigtooth	*Populus grandidentata* Michx.
Aspen, quaking (trembling)	*P. tremuloides* Michx.
Aspen, Asian trembling	*P. tremula* var. *Davidiana* Schneid.
Basswood	*Tilia americana* L.
Birch, bog	*Betula pumila* L.
Birch, river	*B. nigra* L.
Birch, sweet	*B. lenta* L.
Birch, white	*B. papyrifera* Marsh
Birch, yellow	*B. alleghaniensis* Britton
Birch, yellow-bog birch hybrid	*B.* x *purpusii* Schneid.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Elm, American	*Ulmus americana* L.
Elm, Japanese	*U. japonica* (Rehd.) Sarg.
Elm, Siberian	*U. pumila* L.
Elm, slippery	*U. rubra* Muhl.
Fir, balsam	*Abies balsamea* (L.) Mill.
Fir, grand	*A. grandis* (Dougl.) Lindl.
Fir, white	*A. concolor* (Gord. &. Glend.) Lindl.
Hickory, pigment	*Carya glabra* (Mill.) Sweet
Larch, Dahurian	*Larix gmelini* (Rupr.) Litvin.
Larch, European	*L. decidua* Mill.
Larch, Japanese	*L. leptolepsis* (Sieb. & Zucc.) Gord.
Larch, Korean Dahurian	*L. gmelini olgensis* (Henry) (Ostenf. & Syrach)
Larch, Siberian	*L. sibirica* Ledeb.
Larch, western	*L. occidentalis* Nutt.
Larch, eastern	*L. laricina* (Du Roi) K. Koch
Maple, red	*Acer rubrum* L.
Maple, sugar	*A. saccharum* Marsh
Oak, red	*Quercus rubra* L.
Pine, Austrian	*Pinus nigra* Arnold
Pine, eastern white	*P. strobus* L.
Pine, Himalayan	*P. griffithii* McClelland
Pine, jack	*P. banksiana* Lamb.
Pine, Japanese red	*P. densiflora* Sieb. & Zucc.
Pine, Korean	*P. koraiensis* Sieb. & Zucc.
Pine, southwestern white	*P. strobiformis* Engelm.

Pine, limber	*P. flexilis* James
Pine, Macedonian white	*P. peuce* Griseb.
Pine, mugho	*P. mugo* Turra
Pine, pitch	*P. rigida* Mill.
Pine, ponderosa	*P. ponderosa* Laws
Pine, red	*P. resinosa* Ait.
Pine, sand	*P. clausa* (Chapm.) Vasey
Pine, Scotch	*P. sylvestris* L.
Pine, shortleaf	*P. echinata* Mill.
Pine, spruce	*P. glabra* Walt.
Pine, Swiss stone	*P. cembra* L.
Pine, western white	*P. monticola* Lamb.
Spruce, black	*Picea mariana* (Mill.) B.S.P.
Spruce, Engelmann	*P. engelmannii* Parry
Spruce, Norway	*P. abies* (L.) Karst.
Spruce, Serbian	*P. omorika* (Pancic) Purkyne
Spruce, white	*P. glauca* (Moench) Voss
Walnut, black	*Juglans nigra* L.
White-cedar, northern	*Thuja occidentalis* L.

BY-LAWS LAKE STATES FOREST TREE IMPROVEMENT COMMITTEE — 1968

I. *NAME OF ORGANIZATION*

The name of this organization shall be the Lake States Forest Tree Improvement Committee.[1]

II. *PURPOSE*

The purpose of the Lake States Forest Tree Improvement Committee shall be to encourage and coordinate forest tree improvement activities in Michigan, Minnesota, and Wisconsin.[1]

III. *MEMBERSHIP*

A. *Representation*

Membership in this Committee shall consist of representatives of:

1. Agencies within the Lake States that are conducting or strongly interested in tree improvement activities, and
2. Parties with bonafide interest in the subject matter with which the committee is concerned.

B. *Organizations Represented*

The number of committee members shall be limited to one from each of the following agencies or institutions: The University of Michigan, Michigan State University, The University of Minnesota, The University of Wisconsin, The Michigan Department of Conservation, The Minnesota Department of Conservation, The Wisconsin Department of Natural Resources. The Lake States Council of Industrial Foresters, The Institute of Paper Chemistry, The Northeastern Area State and Private Forestry, the U.S. Forest Service – Eastern Region, The Forest Products Laboratory, and the North Central Forest Experiment Station. (It is expected that these agency representatives normally will also represent the subject matter areas of silviculture, genetics, and wood technology.)

C. *Special Interest Membership*

Specific interest and subject matter areas will be represented by specialists in these areas. There shall be one member each representing the areas of forest entomology and forest pathology. Specialists in other subject matter areas shall be considered for membership at the discretion of the committee. Candidates for these positions shall be nominated by the Executive Committee and elected by the committee at large.

D. *Nominations*

Members of the Committee shall be nominated by the Head of the agency which they represent. The nominations will be called for by the Chairman at least 2 months before each Biennial Conference.

E. *Term of Membership*

Members shall serve for four years beginning January 1 following appointment and ending December 31 of the fourth year. Members may serve more than one consecutive term.

IV. *COMMITTEE OFFICERS*

A. *Officers*

The officers of the Lake States Forest Tree Improvement Committee shall be a Chairman, a Vice-Chairman and an Executive Secretary.

B. *Term of Office*

The term of office for the Chairman and Vice-Chairman shall be two years beginning January 1 following election. The Executive Secretary, who shall be the representative of the North Central Forest Experiment Station, shall serve a continuing term.

C. *Nominations for Office*

At least 2 months preceding each biennial conference, the Executive Secretary shall call for nominations from all members of the Lake States Forest Tree Improvement Committee for Chairman and Vice-Chairman candidates.

D. *Election*

The Committee shall elect a new Chairman and Vice-Chairman by majority vote on a written ballot at the Biennial Regional Conference or by mail immediately preceding this conference. Results will be announced at the conference.

V. *DUTIES OF COMMMITTEE OFFICERS*

A. *Chairman*

The Chairman shall preside over the meetings of the Lake States Forest Tree Improvement Committee. He shall appoint members to standing and special subcommittees.

B. *Vice-Chairman*

The Vice-Chairman shall preside in the absence of the Chairman and he shall be responsible for organizing the program of the Biennial Tree Improvement Conference during his term. He shall be selected from the State in which the Biennial Conference will be held.

C. *Executive Secretary*

The Executive Secretary shall keep the records of the Committee. He shall collect manuscripts of all papers on the Biennial Conference programs and help to prepare them for publication. He shall be the executive officer of the Committee.

VI. *MEETINGS*

A. *Committee*

The Lake States Forest Tree Improvement Committee shall meet in conjunction with the Biennial Lake States Forest Tree Improvement Conferences and at such other times and places as may be decided by the Committee or by the Executive Committee. Meetings other than those in conjunction with the Biennial Conference, shall be called by the Chairman. They shall be announced by mail to all members of the Committee.

B. *Conference*

The Biennial Tree Improvement Conference shall be held in odd-numbered years. The place of meeting shall rotate between the three states in this order: Michigan, Wisconsin, and Minnesota.

C. *Procedure*

Parliamentary procedures of all meetings shall be conducted in accordance with Robert's "Rules of Order."

VII. *COMMUNICATIONS*

A. *Newsletter*

At irregular times, but approximately annually, the Newsletter (Lake States Trebredinews) shall be issued. The various members of the Committee shall take turns in assembling, preparing, and issuing these Newsletters as arranged by the Executive Secretary.

B. *Proceedings*

Proceedings of the conferences and complete papers presented thereat shall be made available for publication.

C. *Special*

Announcements of conference meetings, dates, and places shall be sent to all committee members, and all attendees at previous conferences not less than 60 days before the conference is to be convened. The Executive Officers of the Committee may at any time issue communications of a general nature which they determine will be of interest to the membership of the LSFTIC and the Conference.

VIII. *COMMITTEES*

The terms of office for members of standing committees appointed by the Chairman shall be as specified in the appointment or for an indefinite period. The Chairman of a standing committee shall serve until a successor is appointed. Special subcommittees shall function and serve as directed by the Committee.

IX. *FINANCE*

A. *Non-profit Nature*

The LSFTIC is a non-profit organization, which collects no dues, maintains no treasury and issues no disbursements as a committee.

B. *Conferences*

Registration fees, not to exceed actual costs, may be collected in advance to cover incidental costs in connection with the Biennial Conferences.

C. *Communications*

Costs of special communications are borne by the supporting agencies. Publication of conference proceedings, correspondence, and minutes of committee meetings may be handled on a no-cost basis by one or more member agencies.

D. *Officers*

All expenses in connection with the duties of the LSFTIC committee shall be borne by the member's employer or by the member. The Committee shall make no reimbursement to the officers or members for expenses incurred in any regard.

X. *AMENDMENTS*

These by-laws may be amended by a majority vote of the members of the Lake States Forest Tree Improvement Committee voting at the time of any regular election of the Committee.

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1 See Proceedings, Lake States Forest Genetics Conference, March 20 - April 1, 1953. Lake States Forest Exp. Sta. Misc. Rep. 22, 1953, p. 81.

MEMBERSHIP LIST
LAKE STATES FOREST TREE IMPROVEMENT COMMITTEE

Name	*Address*	*Appointed Through*
Scott S. Pauley [1] CHAIRMAN	School of Forestry University of Minnesota St. Paul, Minnesota 55101	1971
Burton V. Barnes VICE CHAIRMAN	School of Natural Resources University of Michigan Ann Arbor, Michigan 48104	1973
Hans Nienstaedt EXECUTIVE SECRETARY	Institute of Forest Genetics North Central Forest Experiment Station Star Route #2 Rhinelander, Wisconsin 54501	
Dean Einspahr	Institute of Paper Chemistry Appleton, Wisconsin 54910	1971
Paul R. Flink	State of Michigan Forestry Division Department of Natural Resources Stevens T. Mason Building Lansing, Michigan 48926	1971
David W. French	Dept. of Plant Pathology and Botany University of Minnesota St. Paul, Minnesota 55101	1971
Clyde M. Hunt	USDA Forest Service, Northeastern Area State & Private Forestry 6816 Market St. Upper Darby, Pennsylvania 19082	1972
Erick Kurki	State of Minnesota Division of Lands & Forestry Dept. of Conservation St. Paul, Minnesota 55101	1973
Donald T. Lester	Department of Forestry University of Wisconsin Madison, Wisconsin 53706	1973
H. L. Mitchell	Forest Products Laboratory Madison, Wisconsin 53705	1971
John A. Pitcher	USDA Forest Service 633 W. Wisconsin Ave. Milwaukee, Wisconsin 53203	1971
Thomas J. Rausch	State of Wisconsin Dept. of Natural Resources Box 450 Madison, Wisconsin 53701	1972
Richard Schantz-Hansen	Lake States Council of Industrial Foresters The Northwest Paper Company Cloquet, Minnesota 55720	1973
Louis F. Wilson	North Central Forest Experiment Station 215 Natural Resources Building Michigan State University East Lansing, Michigan 48823	1971
Jonathan W. Wright	Department of Forestry Michigan State University East Lansing, Michigan 48824	1973

1 *Professor Pauley was Chairman until his death April 18, 1970.*