FOREST TREE IMPROVEMENT IN THE LAKE STATES 1953 - 1963

by

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Nineteen fifty-three represented a turning point in forest tree improvement activities in the Lake States. True, there had been activity in this field for a number of years by several agencies in the region. But, up to that time, there had been little formal recognition of forest tree improvement either by research or administrative agencies. Prior to 1953, a number of groups had carried on such work as seed-source studies, the planting of exotics, and other such activities as parts of regeneration or related work. Except for one unsuccessful controlled pollination series made by the Lake States Forest Experiment Station in 1928, only the University of Wisconsin had actually begun work directly aimed toward tree breeding activities.

In the early spring of 1953, the Lake States Forest Genetics Conference was held at Eagle River, Wis. This meeting, which was actually the first Lake States Forest Tree Improvement Conference, was planned and sponsored by the Lake States Forest Experiment Station, but the response indicated widespread interest in and awareness of the importance of forest tree improvement. All agencies within the region that were known to have some interest in tree improvement had been invited to attend, and there were representatives of the Universities of Michigan, Minnesota, Wisconsin; Michigan State University; Beloit College at Appleton, Wis.; the Conservation Departments of Michigan, Minnesota, and Wisconsin; several forest industries; the Forest Products Laboratory; the North Central Region of the U.S. Forest Service; and the Lake States Forest Experiment Station. In addition, there were a number of distinguished visitors from regions outside the Lake States. This group assembled, took a look at what had been done in the past in the general field of forest tree improvement in the Lake States, and then made suggestions for activities in the future.

SETTING THE STAGE - THE SITUATION IN 1953

Although the term had scarcely been heard in the region prior to 1953 a solid basis for advancement of forest tree improvement in the Lake States had been built. A brief rundown by agencies shapes up about like this:

1/ Research Forester, Lake States Forest Experiment Station, St. Paul, Minn., and Executive Secretary, Lake States Forest Tree Improvement Committee.

The Lake States Forest Experiment Station, under the leadership of Carlos Bates and the encouragement of its Director, Raphael Zon, began seed-source studies in 1928. Up to 1953 the Station had made seed-source studies of eight forest tree species and field tests of a score of exotic tree species. It had made some early attempts at breeding sugar maple, had field-planted 31 hybrid poplars, and had assembled 10 hybrid pines for field testing. These tests had demonstrated racial variations in red pine, Scotch pine, ponderosa pine, white spruce, Norway spruce, and green ash. They had illustrated the unsuitability of a number of hybrid poplars for the region, and they had emphasized the need for replication of field tests in a number of localities to avoid unpredictable losses. Results of the studies had been issued in 25 publications.

The University of Wisconsin began breeding forest trees for disease resistance under the direction of Dr. A.J. Riker in 1935 and started a program directed by R.A. Brink in the Genetics Department in 1948. Up to 1953 more than 220 eastern white pines had been selected and tested for blister rust resistance. In addition, more than 400 poplar selections were under test in various places for growth and resistance to diseases caused primarily by Septoria, Cytospora, and Hypoxylon. Several hundred additional trees had been selected to test the progeny for special traits and to build up breeding collections. Controlled pollination, particularly of red pine, had been undertaken, and specialized studies of vegetative propagation and flowering had been started preparatory to developing seed production areas and seed orchards in cooperation with the Wisconsin Conservation Department.

At the University of Minnesota, T. Schantz-Hansen in 1939 began a rangewide seed-source study of jack pine involving 38 sources. (Tests of exotic tree species had begun about 15 years earlier.) In 1947 work was started on poplars and involved about 150 selections, including a number of hybrids that were being field tested. Work was also underway to test various species and selections of elm for hardiness and resistance to the Dutch elm disease and phloem necrosis. Finally seed had been collected for a blue spruce seed-source study in the hope of finding trees hardy in Minnesota and resistant to Cytospora canker.

At Michigan State University Professor Bogue began testing exotic tree species about 1904. This was followed later on by trials of hybrid poplars, the breeding of nut-producing trees, and the study of variation in sap production by sugar maple trees.

The University of Michigan began a program of developing chestnuts resistant to the chestnut blight in 1930, under the direction of Dow V. Baxter. The testing of exotic tree species had begun under Filibert Roth in 1904. Studies that followed concerned the testing of ponderosa pine for resistance to a Cronartium rust, the development of a Norway spruce strain resistant to the spruce gall aphid, and the testing of various European strains of Scotch pine.

In 1948 the Nekoosa-Edwards Paper Company, under Robert Dosen's direction, began the cross-pollination of local central Wisconsin jack pines with lodgepole pine pollen from California and field-planted progeny in 1951-1953. In 1950, under B.L. Berklund's direction, they assembled seed of 25 sources each of red pine and jack pine for a regional seed-source study.

At Beloit College in Appleton, Wis., Philip N. Joranson in 1952 initiated a project for breeding native aspens. It was aimed primarily at locating and developing polyploid individuals of quaking aspen and bigtooth aspen in the hope that they would yield more and larger fibers than normal diploid trees.

Most of the research projects mentioned had been aided by cooperators such as the state conservation departments, some pulp and paper companies, and the National Forests.

FORMATION OF THE LAKE STATES FOREST TREE IMPROVEMENT COMMITTEE

The Lake States Forest Genetics Conference at its conclusion on April 1, 1953, unanimously adopted a set of resolutions, the first of which was as follows: "That there be established a Lake States Forest Tree Improvement Committee for the purpose of encouraging and coordinating forest genetics activities in this region. That a nominating committee, consisting of Messrs. M.B. Dickerman, R.A. Brink, E.J. Adams, and J.B. Millar, appoint a 6- to 10-man tree improvement committee representative of the interested agencies, geographical areas, and subject matter interests in the region."

The initial committee consisted of nine members representing three state conservation departments, four universities, forest industry, and the Lake States Forest Experiment Station. Two years later membership was enlarged to 14, at which number it has remained. The additional five members were representatives of the Forest Products Laboratory, the North Central Region of the U.S. Forest Service, the Institute of Paper Chemistry, and the fields of forest entomology and forest pathology (see Appendix I).

To carry out the mandates issued upon its inception, the Lake States Forest Tree Improvement Committee has operated on three broad fronts; preparation of guides, convening of regional conferences, and periodic dissemination of news (see Appendix II).

1. At the outset, there appeared to be a need for guides that might foster comparability in the conduct of certain tree improvement activities in the region. Accordingly several subcommittees were formed, each charged with a specific task. These groups prepared and had published an annotated bibliography of forest genetics in the Lake States, a guide for selecting superior trees and stands in the Lake States, a delineation of forest tree seed collection zones for the Lake States, a survey of forest tree improvement activities in the region, suggestions for registering and marking selections in the Lake States, and a survey of forest tree seed certification activities in the United States with suggestions for application in the Lake States.

2. Biennial tree improvement conferences have been held in 1955 at Wisconsin Rapids, Wis.; 1957 at Grand Rapids, Minn.; 1959 at Ann Arbor, Mich.; 1961 at Rhinelander, Wis.; and again at Grand Rapids, Minn. in 1963. These conferences have provided opportunities for those engaged in forest tree improvement research to report briefly on what they have done and what they have learned and to compare notes with other workers, and for those interested to learn the status of such research in the Lake States and to point out problems needing study. The conferences have been attended by from 60 to 150 people. In addition to work within the Lake States, tree improvement activities have been reported by speakers from the Northeast, California, the South, the Central States, the Pacific Northwest, and Canada.

3. A newsletter, Lake States Trebredinews, has been issued annually and now has a mailing list of about 300. It carries between-conferences news of tree improvement activities of all Lake States agencies, notices of important meetings, interim reports on subcommittee activities, and tree improvement items from other regions.

THE NC-51 COMMITTEE

In October 1958 representatives of several land grant colleges in the North Central Region met to discuss the advisability of developing a regional project in forest tree improvement. Such a project was subsequently formulated and approved.

The technical committee guiding the project (designated NC-51) operates under an organizational framework developed by the Cooperative State Experiment Station Service (CSESS) of the U.S. Department of Agriculture. One of the State Agricultural Experiment Station directors or assistant directors acts as advisor. In addition to the State Agricultural Experiment Station members, and the CSESS representative, a member of the U.S. Forest Service also is on the Committee (see Appendix III). Federal cooperative regional research funds are made available to the participating state experiment stations to supplement state funds in support of the work.

The Committee meets annually at which time it discusses and acts on studies proposed for inclusion in the regional project, hears progress reports from the various participants in the approved studies, and plans an annual report to the directors. Present approved studies all concern seed-source investigations. One station acts as a leader for a given study. Its representatives assemble seed, grow stock, prepare work plans, and distribute stock. Such other stations as wish to participate can obtain stock and can (but need not) follow the initiating station work plan. The initiating station is expected to take the lead in preparing regional reports, but other participating stations may make analyses and report upon their own data as they see fit.

Current (1963) approved racial variation studies under the regional tree improvement project are as follows, listing the initiating station first (* = poor survival; ** = failure); Scotch pine (Mich., Ill., Ind., Kans., LSFES, Minn., Mo., Nebr., Wis.), Austrian pine (Mich., Ind.*, Ia., Kans., Minn.**, Nebr., Wis.**), red pine (Mich., Ind., Kans., Minn., Nebr., Wis.), eastern white pine (Mich., Kans., Minn.), red oak (Ohio, Ill., Ind., Kans., Minn., Nebr., Wis.), Japanese larch (Mich., I11., Ia., LSFES, Minn., Nebr., Wis.), tamarack (Minn., LSFES, Mich., Wis.), Douglas-fir (Mich., Ind., Kans.**, Minn., Nebr., Wis.), grand fir (Mich., Ind., Kans.**, Minn., Wis.), and white fir (Mich., Ind., Kans.**, Minn., Wis.). Some of these cooperators are doing related work on other species or on material of the listed species that is in addition to the regional project material. In addition, studies have been approved for the following species, and seed collections for them have been started or arranged; balsam fir (Wis.), ponderosa pine (USFS, Nebr.), and eastern cottonwood (Ill.).

A DECADE'S DEVELOPMENT

Since 1953 there has been substantial progress in forest tree improvement in the Lake States. Most of the agencies that were engaged in such work they have increased their staffs, facilities, and projects, and some additional agencies have entered the field. Perhaps this can best be summarized first by agency and then by field of work.

The Agencies Doing Forest Tree Improvement Work in the Lake States

Lake States Forest Experiment Station.--In 1954 the Station received its first allotment of funds definitely earmarked for forest genetics research. The following year Hans Nienstaedt, a trained geneticist, joined the staff and has since become leader of the Station's genetics project. A field center was established adjacent to the Hugo Sauer State Nursery near Rhinelander, Wis., and the first building was dedicated in 1957. Facilities now available at the Institute of Forest Genetics at Rhinelander include two buildings with office space for a dozen scientists and their supporting personnel, several well-equipped laboratories, four growth control chambers, four greenhouse sections (20' x 50') with automatic controls and necessary headhouse facilities; a lath house; cold frames with bottom heating; and good nursery facilities. Reserved outplanting sites are available on the nearby Nicolet National Forest and on all the other National Forests of the Lake States. Within a few miles, trees of almost all species native to the northern Lake States are available for study and as a source of materials.

The Institute is responsible for the basic forest genetics research of the U.S. Forest Service in the northeastern quarter of the United States and for applied genetics research within the Lake States. First emphasis has been placed on improvement of the spruces, and similar work recently has been started on the birches.

The Institute has been given national responsibility for radiation-genetics studies to be conducted by the U.S. Forest Service and has prepared a site for a radiation facility to be established under the approved standards of the Atomic Energy Commission. Some radiation studies are already underway in cooperation with the Brookhaven National Laboratory.

In 1961 the second Pioneering Research Unit in the Forest Service was established at Rhinelander, with Philip R. Larson in charge. He will devote full time to physiological studies of wood formation.

In 1962 the Station assigned a full-time scientist (David Dawson) to tree improvement studies in the Northern Great Plains with headquarters at the Shelterbelt Laboratory in Bottineau, N. Dak. Initial studies largely concern variation in conifers of possible use in northern plains shelterbelts. Currently, the Station has six scientists assigned full time to tree improvement research.

University of Wisconsin-[2/].--The program at the University of Wisconsin was already well established in 1953 and was receiving substantial financial support from the Wisconsin Conservation Department. During the past decade, however, studies were expanded to search also for insect-resistant trees and for resistance to the cedar-apple rust, oak wilt, and maple blight. A summer field headquarters was established in 1954 near Sayner in northeastern Wisconsin with WCD support. Nursery facilities are available at Conservation Department Nurseries, particularly at Wisconsin Rapids and Trout Lake.

Currently, five scientists are devoting full or part time to tree improvement studies. Reduction in Conservation Department financial support has curtailed expansion of the work for the present.

University of Minnesota-.--In 1954 the School of Forestry made plans to add forest genetics to its curriculum, and in 1955 Scott Pauley came from Harvard University to head up the program. In 1955 also the Blandin Foundation gave the University a grant of funds for forest tree improvement work. The first formal course in forest genetics was offered in the fall of 1956. Nursery facilities were provided at the North Central Experiment Station and in the nursery of the Blandin Paper Company near Grand Rapids. Outplanting facilities were developed at the Gunn Memorial Park near Grand Rapids and on state-owned land near Grand Rapids, St. Paul, Rice Creek, and elsewhere.

Resources for the Future, Inc. made a grant to the University for the 1956-57 academic year to strengthen graduate training in forest genetics.

Beginning in 1956 staff members in entomology and plant pathology began to study variations in insect and disease development in jack pines of diverse seed origins.

Currently, one staff member is devoting full time to forest genetics work, and five graduate students are working on tree improvement problems in residence and five in absentia.

2/ A special function of the Universities is to train scientists, and the universities in the Lake States during the past decade have awarded a considerable number of M.S. and Ph.D. degrees to students specializing in forest genetics and in related fields. Because information from the various schools was given in varying ways, no attempt has been made here to present separate statistics for each one.

University of Michigan— .--In 1954 the School of Natural Resources initiated graduate training in forest genetics, with emphasis on the silvical aspects of tree improvement. The University added a course in forest genetics in 1959. They have developed outplanting sites at the University's Biological Station at Douglas Lake and on University properties near Ann Arbor. Currently, one staff member is devoting full time to tree improvement work and some graduate students are doing research in this area.

Michigan State University[3/] .--In 1957 Jonathan Wright came to Michigan State University from the Northeastern Forest Experiment Station and initiated both graduate and undergraduate courses in forest genetics. With his arrival the University launched an ambitious program concerned primarily with racial and individual tree variation and statistical bases for determining plot size for tree improvement research.

MSU has a nursery devoted primarily to growing tree improvement stock, has developed outplanting sites on college properties such as the Kellogg, Ruse, and Dunbar Forests, on several state forests, and on some National Forest land.

Currently, one professional staff member is devoting full time to tree improvement work, four others are devoting part time, and four graduate students are carrying on research in this field.

Institute of Paper Chemistry.--In 1954 the Institute initiated a forest tree improvement research program and brought in Philip N. Joranson to continue and expand the program he had started at Beloit College. Since then the Institute has added specialists in plant physiology and cytology to its staff, established laboratory and greenhouse facilities, and developed several outplanting sites on the lands of cooperating industries and of public agencies.

In 1961 Dr. Joranson left the Institute and Dean Einspahr assumed direction of the forest tree improvement program. Presently three full-time scientists are carrying out the research work dealing primarily with the aspens in the North and southern pines in the South.

3/ See footnote 2 on page 7.

Forest Products Laboratory.--Although the Laboratory planned a study on the causes of bird's-eye figure in sugar maple in cooperation with the Lake States Forest Experiment Station in 1928 (and since reactivated), its active tree improvement research program really began in 1958. Since the Laboratory is a national institution, much of its research concerns localities and species of no direct interest to many people in the Lake States. Some studies, however, deal with species native to the Lake States, and basic research on other species may have applicability here also. It initiated a program for obtaining wood quality data from Forest Survey plots as they are established.

The Laboratory has highly specialized facilities for studying wood structure, especially from small wood samples. Currently four scientists are spending full time on research related to tree improvement under the direction of Harold L. Mitchell.

Nekoosa-Edwards Paper Company.--In continuation of work started earlier, the company field-planted additional jack pine-lodgepole pine hybrids from its own pollinations in 1954 and established its own seed-source studies in 1954 and subsequent years. Currently one technical man devotes part time to these studies. The company has its own nursery and outplanting sites.

Consolidated Water Power and Paper Company.--Under John Macon's direction, the company in 1950 and again in 1956, made selections in white spruce transplant beds of the company nursery and field-tested the progeny on their own outplanting areas. Currently, one technical man spends part time on tree improvement work.

Quetico-Superior Wilderness Research Center.--Under C. E. Ahlgren's direction, the Center began a series of vegetative propagation tests in 1952 aimed specifically at tree improvement objectives. Since then it has also conducted work on flower stimulation, controlled pollination, blister rust resistance, and seed orchard development. The Center has its own outplanting areas and has made them available to cooperators. It has had the use of greenhouse facilities on the Duluth Campus of the University of Minnesota. Currently, one technical man spends part time on tree improvement projects.

Minnesota Conservation Department.--In 1962 the Forestry Division established, under Emil Kukachka's direction, a study of factors affecting cone production in white spruce and red pine; the Lake States Forest Experiment Station is a cooperator in this study. Currently, about four technical men spend part time on the project.

Tree Improvement Research Work by Subject Matter Categories

To give a bird's-eye view of tree improvement activities in the region since 1953, I have grouped them into five broad classes suggested by Scott Pauley several years ago. Needless to say, the coverage cannot be detailed or complete in the space available, but it should provide a reasonably accurate impression of what has been and is being done.

Selection and Testing of Variation.--Logically a high proportion of the tree improvement studies initiated in the Lake States since 1953 are concerned with selection and variation. Most numerous are studies of varying scope and intensity on natural variation within species. They concern such species as jack pine (LSFES, U. Minn., U. Mich., MSU, NEPCo, WCD, MPP, Mn CD, Mh CD).[4/] red pine (NEPCo, MSU, UW, U. Minn.), eastern white pine (LSFES, MSU), Scotch pine (LSFES, MSU, U. Mich., U. Minn., UW), ponderosa pine (LSFES, MSU), Austrian pine (MSU, U. Mich., U. Minn., UW), limber pine (MSU), Virginia pine (MSU), white spruce (LSFES, MSU, U. Minn., NEPCo, CWPP), black spruce (NEPCo), red spruce (LSFES), blue spruce (LSFES, U. Minn.), Siberian spruce (LSFES), balsam fir (UW), tamarack (U. Minn.), Japanese larch (LSFES, MSU, U. Mich., U. Minn., UW), Siberian larch (LSFES), European larch (IPC, MSU, U. Mich.), eastern hemlock (LSFES), Douglas-fir (MSU), paper birch (U. Minn.), and red oak (MSU, U. Minn., UW). A high proportion of this research involves racial variation or seed-source studies. An increasing number of studies, however, are designed to assess variation among individual trees within a species. This is a necessary forerunner to intelligent breeding work.

An increasing number of studies, however, concern variation induced by recombination or mutation. Included are a number of studies to locate and analyze natural hybrids and to develop interspecific hybrids. These involve several species of spruces (LSFES, U. Minn.), pines, both soft and hard (MSU, UW), birches (U. Minn., LSFES), aspens and other poplars (U. Minn., UW, IPC), and elms (U. Minn.). Some of the poplar trials have already yielded F_2 and F_3 generations. Other controlled pollinations have been made within species, primarily in white spruce (LSFES), black spruce (LSFES), Norway spruce (UW), red pine (UW), jack pine (LSFES), and eastern white pine (UW).' Included among these trials are a number of tests of selfing. Knowledge of self-compatibility or incompatibility is, of course, of prime value in such diverse activities as developing seed orchards and establishing pure lines for breeding purposes.

4/ Abbreviations for agencies are as follows: CWPP = Consolidated Water Power and Paper Co., FPL = Forest Products Laboratory, IPC = Institute of Paper Chemistry, LSFES = Lake States Forest Experiment Station, Mh CD = Michigan Conservation Dept., Mn CD = Minnesota Conservation Dept., MSU = Michigan State University, NEPCo = Nekoosa-Edwards Paper Co., QSWRC = Quetico-Superior Wilderness Research Center, USARS = U.S. Agricultural Research Service, U. Mich. = University of Michigan, U. Minn. = University of Minnesota, UW = University of Wisconsin, WCD = Wisconsin Conservation Dept.

The study of mutations is just getting underway in the region. The bulk of the work is being done with jack pine (LSFES). Involved so far are determinations of naturally occurring mutations among plants grown from seed (1) from untreated normal trees, (2) produced in witches brooms, and (3) subjected to X-rays. Other material is under study after exposure to Cobalt-60 irradiation. Related work includes controlled crosses between jack pines grown from X-rayed seed and the use of irradiated pollen in controlled pollinations on white spruce.

Utilization of Selected Variants for Planting.--A major practical application of tree improvement is to utilize selected and specially bred material in forestation work. This may involve either vegetatively propagated clones or seeds from specially treated and cultured areas or both. The practical use of clonal lines in this region is limited largely to aspens and poplars. Research in the use of such material is being pursued by several agencies (U. Mich., U. Minn., MSU, IPC, UW).

A highly encouraging development during the past few years has been the establishment of seed production areas by several agencies. In 1959 the Wisconsin Conservation Department began acquiring and setting aside superior red pine stands for seed production purposes, and shortly thereafter the U.S. Forest Service began similar activities. These selected stands have been cultured to remove undesirable trees and give the selected trees abundant growing space. Since then the Minnesota Conservation Department and several industries have followed suit. There are now in the Lake States 23 established seed production areas, involving about 900 acres of land and with a potential annual production of 3900 bushels of cones (see Appendix IV). The number of established and treated seed production areas includes 14 red pine, 7 white spruce, and 2 eastern white pine. In addition several other areas have been selected but have not yet been completely treated for seed production purposes; these include some for jack pine and black spruce.

The next step, the development of seed orchards, has also been initiated. The University of Wisconsin established a grafted red pine seed orchard for the Wisconsin Conservation Department in 1955 and has continued this activity in subsequent years. The U.S. Forest Service has also begun the development of grafted red pine, black spruce, and white spruce seed orchards, several of which will be established by 1967. Michigan State University has initiated the development of seedling red pine seed orchards in cooperation with the U.S. Forest Service and the Michigan Conservation Department (Appendix IV).

As increasing amounts of seed become available from seed production areas, seed orchards, and other sources where the ultimate geographic origin or the parentage are known, there will be more and more need to identify such seed. So long as the seed does not enter commerce, a records system that satisfies the needs of the producer-user is all that is necessary. If, however, the seed does enter commerce some method of certification by a reputable organization or a legally constituted agency may be required. For this reason the LSFTIC Seed Certification Subcommittee has been developing guidelines that will be available if and when forest tree seed certification is needed in the Lake States. It has been cooperating with a national committee of the Society of American Foresters in this endeavor.

Application of Genetics in Silviculture and Management of Naturally Reproduced Stands.--I am aware of no premeditated applications of genetics in the handling of naturally reproduced stands. The simplest and most direct applications obviously come through artificial regeneration. Nevertheless, I suspect that something hag rubbed off on the rather large number of forest managers in the region who have helped in the search for superior trees and who have marked and cut seed production areas. I would guess that closer attention is now given to such features as stem form, branch angle, branch thickness, and relative crown width (along with the standard features of size and vigor) in selecting crop trees or potential crop trees.

Fundamental Genetics Studies.--It is natural that the forest tree improvement work first initiated in the Lake States should emphasize variation and selection since they provide the basis for genetic improvement. Eventually, however, continued good progress requires that we know the "why" of the improvement we get or fail to get. We should know something about the mode of inheritance, the reaction range, the taxonomy, and the evolution of the species with which we deal.

Some of these fundamental studies have been started and have provided evidence of such facts as these: (1) the probable manner in which the closed-cone and open-cone character is inherited in jack pine (Univ. Minn.), (2) modes of inheritance of sex and photoperiodic response in Populus (Univ. Minn.), (3) the heritability of seed coat color in Austrian pine (Univ. Wis.), (4) the probable method of inheritance of resistance to winter injury in lodgepole pine-jack pine hybrids (LSFES), and (5) the heritability of forking in forest trees (Univ. Wis.).

Studies of natural hybrids between paper birch and bog birch and between black spruce and white spruce (Univ. Minn.) are yielding some information on experimental taxonomy. Furthermore, collections have been started of all spruce species (LSFES) and all elm species and varieties in the world (Univ. Wis.); this material should add information of taxonomic value. As progeny from recent controlled pollinations develop, more information on the nature of species will become available.

Current studies have not yet yielded much information concerning the evolution of our Lake States forest tree species. However, as comprehensive racial variation studies begin to provide data on the performance of sources within species, valuable clues to the migration history and evolution of several species should develop to supplement other data from pollen profile and geological research.

Supporting Sciences and Special Techniques.--Although genetics is the keystone of tree improvement, work in several other sciences also is required. Mostly involved are the botanical sciences, but zoology and biometry also make important contributions.

Many of the studies in this category undertaken during the past decade in the Lake States concern plant physiology. Among them are: (1) effects of photoperiod on springwood-summerwood growth of red pine (LSFES), fall grafting of spruce (LSFES), growth of northern conifers in southern and northern nurseries (LSFES, U. Minn.), breaking of bud dormancy in white spruce (LSFES), incidence of laminas growth and prolepsis in jack pine (U. Minn., LSFES), and response of paper' birch of various seed origins (U. Minn., LSFES); (2) effects of growth substances (such as gibberellic acid and auxins) on growth, wood properties, and flowering of some hardwoods and conifers (IPC, LSFES); (3) effects of chilling on fall grafting and breaking of bud dormancy in white spruce (LSFES); (4) the anatomical and biochemical changes related to rooting behavior of stem cuttings (IPC); (5) the effects of interspecific and intergeneric grafting, phloem inversion, and mechanical treatments on primary growth and flowering of forest trees (QSWRC, UW); (6) the effectiveness of vegetative propagation techniques such as grafting, budding, stem cuttings, stem splitting, root cuttings, and air layering for reproducing pines, elms, basswood, bird's-eye maple, hackberry, and aspens (MSU, U. Mich., U. Minn., UW, LSFES); (7) the phenology of white spruce from flower initiation to seed production (LSFES); and (8) a study of the physiological bases for vegetative reproduction (LSFES).

A number of cytological studies have been initiated. These have largely concerned the location of triploid aspens (IPC) and polyploid black and white spruces (U. Minn.), the determination of the probable makeup of natural birch hybrids (U. Minn.), and the relation of external appearance to meiotic stages in male spruce flowers (U. Minn.).

It is extremely important to know when the flower primordia are first formed, if treatments to stimulate flowering can be assured of success. (Obviously, treatments made after the die is cast can have little real influence.) Two studies of this nature are underway, one for red pine (UW, U. Minn., LSFES), and one for white spruce (LSFES).

The major end product of most forestry enterprises still is wood. Many tree improvement practices are aimed at increasing the quantity of wood produced. But wood quality also is highly important, and a variety of qualities are required for different products. A number of research projects concerning wood quality are active in the Lake States. They include studies to determine (1) the anatomical, chemical, and physical properties of aspen wood from small samples (IPC), (2) variation of wood qualities between and within aspen clones (IPC), (3) variation in and heritability of specific gravity and other wood characteristics according to seed origin in red pine, white ash, and various species and hybrids of poplars (FPL), (4) springwood-summerwood transition in red pine (LSFES), and (5) auxin-summerwood relationships in red pine (LSFES).

Disease resistance in forest tree species in the Lake States is also being studied. Included are artificial inoculation tests. The aim is to improve the resistance of the more important species to serious diseases. Studies underway concern resistance of white pine to the blister rust fungus (QSWRC, UW, LSFES), jack pine to the eastern gall rust and other rusts (U. Minn., UW), American elm to Dutch elm disease (U. Minn., UW), eastern redcedar to the cedar-apple rust (UW), poplars to Hypoxylon, Septoria, Dothichiza, and Napicladium cankers (UW), oaks to oak wilt (UW), and sugar maple to maple blight (UW). Many of these studies are aimed at screening young seedlings for resistance. A special study aims to determine racial variation within the blister rust fungus (LSFES).

Several other supporting studies are in the realm of ecology, entomology, and biometry. These include studies of (1) the relative effects of site and heredity on the volume and quality of wood produced by diploid and triploid aspens (IPC), (2) selection of poplars resistant to the poplar weevil (UW), (3) effect of fertilizers on the ability of pines to withstand insect attacks (LSFES), (4) effects of insects on cone production (LSFES), (5) variation in insect attacks according to seed origin in jack pine (U. Minn., UW, LSFES), and (6) the most efficient plot sizes and shapes for use in forest genetics field tests (MSU, U. Minn.).

Tree improvement work involves the use of many special techniques. A number of studies have been made in the Lake States during the past decade to test and improve such techniques. Included are tests of (1) various field and bench grafting techniques for conifers (QSWRC, LSFES, UW, U. Minn.), (2) vacuum and other methods of storing tree pollen (USARS, U. Minn.), (3) extended photoperiod to grow northern conifers in southern nurseries (LSFES, U. Minn.), (4) various types of bags for pollination use (LSFES), (5) seedling propagation methods for aspens (U. Minn.), (6) pine pollination techniques (UW), (7) methods of propagating conifers from cuttings and leaf bundles (LSFES, UW), (8) paper chromatography for sexing mature aspens (U. Minn.) (9) tissue culture of Lake States trees (LSFES, IPC), and (10) the development of a small aerial camera to take color photos to help delineate aspen clones (U. Minn.).

Activities of Action Agencies

In addition to the research activities in the region a number of agencies are applying tree improvement practices on their own lands or are facilitating research work by providing land, stands, planting stock, funds, or other materials to research agencies. Some examples of such activities are as follows:

1. The Wisconsin Conservation Department gave financial support to much of the tree improvement research conducted by the University of Wisconsin and also supplied land, stock, and nursery facilities, and built field stations to aid this work. It also provides nursery facilities to the Lake States Forest Experiment Station, and has assisted several agencies in obtaining tree seed.

2. The Michigan Conservation Department has provided outplanting sites and collected seed for Michigan State University and the Lake States Forest Experiment Station, and provided some financial support for genetics research at Michigan State University.

3. The Minnesota Conservation Department has provided outplanting sites to the University of Minnesota, and planting stock and seed to the University of Minnesota and the Lake States Forest Experiment Station. Many of its field men have been trained by Lake States Station specialists in selecting superior trees and have reported such trees.

4. The National Forests have provided outplanting sites, stock, and seed to the Lake States Station and Michigan State University and have given their men training in recognizing superior trees and stands and in tree climbing.

5. Several forest industries (Kimberly-Clark, Marathon Division of American Can Company, Mosinee Paper Co., Rhinelander Paper Co.) have provided plant material and outplanting sites to the Institute of Paper Chemistry, the University of Minnesota, and other agencies, and are cooperating in their field tests.

6. Most of the Lake States industries are getting their seed primarily from better-than-average stands or trees (Blandin Paper Co., Consolidated, Kimberly-Clark, Marathon Division of American Can Company, Northwest Paper Co., Rhinelander Paper Co.) or from specific districts (M&O, Kimberly-Clark), or are grafting their best trees (M&O).

7. The Blandin Paper Co. and the Diamond Match Division-Diamond Gardner Corporation cooperate with the University of Minnesota in field tests; Kimberly-Clark, Marathon Division of American Can Company, and Rhinelander Paper Co. do likewise with the University of Wisconsin; and Mosinee Paper Mills Co. and Nekoosa-Edwards Co. cooperate with the Lake States Station in a regional jack pine seed-source study.

LOOKING AHEAD

Tree improvement developments during the past decade in the Lake States have been noteworthy. Several research agencies now have the nucleus of strong programs, and increasingly valuable results can be expected. Throughout this period there has been a good spirit of cooperation among the agencies and individual workers involved in tree improvement in the region. This has helped provide good informal coordination of the work. Most action forestry agencies in the region have been interested in tree improvement work and have helped to advance it in several ways.

As programs expand, both in research and in application, there is a normal tendency for each group to become more self-sufficient and inward-looking. This tendency doubtless will appear in the Lake States. I hope and believe that the well-established background of cooperation among agencies in the Lake States will help to offset this tendency and that informal regional coordination will continue as in the past. I believe the Lake States Forest Tree Improvement Committee can continue to be a focal point for such regional cooperation.

With increasing staffs, greater numbers of specialists, and improved facilities, I look for the tree improvement research in the Lake States to make much more progress in the ensuing decade than it has in the past 10 years. By 1973, there should be much better evidence as to the extent and nature of variation among our important tree species; breeding possibilities for our principal species ought to be in clearer perspective; and there should be a considerable increase in emphasis on fundamental studies that will tell the "why" of the nature of our species, their reproduction both vegetatively and by seed, their resistance to several important insects and diseases, and the heritability of important traits. I would think, too, that there would be an increasing advance in applied tree improvement which might include almost exclusive use of selected stands for seed production, general establishment of seed orchards, and general consideration of genetic factors in marking and cutting natural stands.

Crystal ball gazing is fun, but only time can decide how good it is. Suffice it to say that Live improvement has made encouraging progress in the Lake States during the past 10 years, and I feel confident that we shall do even better in the future.