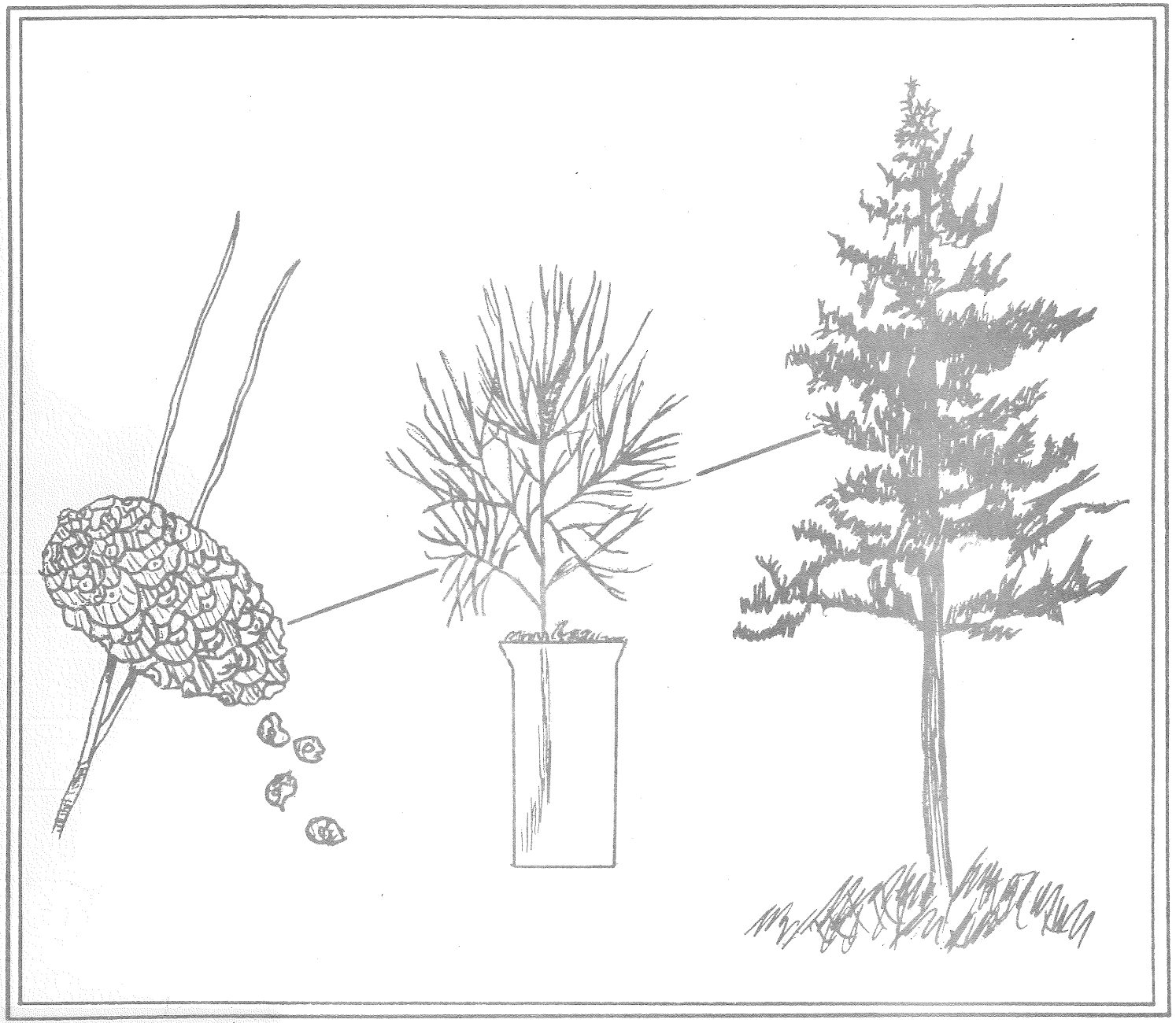
TREE IMPROVEMENT PLAN FOR MINNESOTA



DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FORESTRY

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TREE IMPROVEMENT PLAN FOR MINNESOTA

1981

This plan was prepared by Dr. Carl Mohn, College of Forestry, University of Minnesota and William Berndt, Department of Natural Resources, Division of Forestry.

The Division of Forestry greatfully acknowledges the time and assistance given by Dr. Mohn in the preparation of this plan.

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ABSTRACT - TREE IMPROVEMENT PLAN FOR MINNESOTA

DNR-Forestry provides the bulk of planting stock for all classes of land ownership in Minnesota. With emphasis placed on improved tree quality and production, it is imperative that the Division of Forestry establish a tree improvement plan. This plan was prepared for the following reasons:

1. To insure continuity of tree improvement efforts.
2. To define goals and priorities.
3. To outline specific activities.
4. To serve as a basis for financial planning.

The objective of a tree improvement program is to increase the productivity of public and private forest lands in Minnesota through the use of genetic principles. Emphasis in this program will be on softwoods which is consistent with the long-range plans of the Division. Improved traits will generally be limited to increased growth rate with the plan covering tree improvement activities through the year 2000. In general, tree improvement activities in this plan are:

1. Seed source selection and control of seedling distribution.
2. Seed production area development.
3. First generation seed orchard development.
4. Advance generation seed orchard development.

Priority listings of species included in this plan have been separated into four categories.

Category I - Highest priority, work to be initiated as soon as possible. Species are:

Red (Norway) pine
White Spruce
Jack Pine
Black Spruce

Category II - Work to begin after Category I has been started. Species are:

White pine
Black Walnut
Green Ash
Poplar
Scotch pine
Larch

Category III - For the purposes of this plan, seed origin only will be considered. Species are:

Red oak
White oak
Silver maple
Balsam Fir

Category IV - Lowest priority, work will be restricted to controlling seed source. Species are:

Colorado spruce	Honeysuckle
Black Hills spruce	Caragana
Northern White Cedar	Wild Plum
Eastern Red Cedar	Ginnala Maple
Russian Olive	

A brief description follows for the different species in each category.

Category I

1. Red (Norway) pine - This species should receive the major emphasis in the tree improvement program. It is the most widely planted species because of its products and favorable cultural characteristics. Growth rate is the single characteristic which will receive emphasis by establishing seed production areas and seedling seed orchards. Expected genetic gains range from 4% from seed production areas to 8% from seedling seed orchards. A minimum program is to establish 100 acres of seed production areas and 25 acres of seedling seed orchards. Work completed is a 36 acre seed production area and collection from over 200 trees growing in natural stands. Minimum program costs are estimated at $57,000.

2. White Spruce - This is the second most widely planted species in Minnesota and is suited for a variety of uses. Expected genetic gains in growth rate range from 8% for using Ontario seed source to as high as 17% from second generation open pollinated seedling seed orchards. A minimum program for white spruce is:

    a) 20 acres of clonal seed orchard (Ontario seed)
    b) 20 acres of second generation seedling seed orchards, open pollinated.
    c) 150 acres of plantation derived from clonal orchards used for seed production areas.

    Costs for the minimum program are estimated at $110,000. Work completed is 16 acres of clonal seed orchard established.

3. Jack Pine - This is the most common pine in the Lake States and is widely planted in Minnesota. The initial trait for improvement will be growth with later evaluation for improving form and other commercially important attributes. Expected genetic gains range from 3% for source identified seed to as high as 16% for 2nd generation controlled pollinated seedling seed orchards. The minimum program would be:

    a) 16 acres of first generation seedling seed orchard.
    b) 4 acres of cooperative project breeding populations.
    c) 20 acres of second generation seedling seed orchards open-pollinated.

    Minimum program costs are expected to be $54,000. Accomplishments to date include two outplantings of breeding populations totaling 3 acres and 18 acres of seed production area.

4. Black Spruce - This species is placed in Category I because of the abundance of sites suited to this species and its importance as a pulpwood species in Minnesota. The single trait concentration will be growth rate. The black spruce program is designed only to meet nursery seed requirements and not the large volume needs of direct seeding. Expected genetic gains are 3% from source identified seed to 14% or more for second generation open-pollinated seedling seed orchards. A minimum program is:

    a) 3 acres of first generation seedling seed orchard.
    b) 1 acre of first generation clonal seed orchard.
    c) 8 acres of second generation seedling seed orchards, open-pollinated.
    d) 200 acres of plantation managed for seed production.

    Expected costs are $148,000 for the minimum program. Accomplishments to date are a one acre clonal seed orchard and a 4 acre seedling seed orchard.

Category II

Species in this category will receive second priority and work should begin in the near future but not at the expense of work with higher priority species. Seed source control and development of seed orchards will be initiated at the first opportunity.

1. White Pine - This is one of the most valuable and rapid growing conifers found in Minnesota. The planting program is somewhat restricted because of concern for blister rust and white pine weevil. Efforts to improve white pine is hampered by a lack of genetic information and the biological characteristics of the species. Based on the current status of work with white pine, the following is planned:

    a) Seed source control
        1) Identify seed as to place of collection.
        2) Collect seed from disease free stands or trees.
        3) Distribute planting stock for use within 100 miles of seed origin.

    b) Seed Orchards
        1) Goal is to increase the resistance of planting stock to white pine blister rust.
        2) Obtain material from U.S. Forest Service and Wilderness Research Foundation and graft to nursery root stock.
        3) Establish 5 acres of grafted orchard.

    Efforts to deal with white pine weevil and increased growth rates will be considered during the later phases of the program.

2. Black Walnut - The restricted planting area of black walnut in Minnesota coincides with the natural distribution of walnut. Therefore zoning for seed collection and seedling distribution is not necessary. The two major objectives of black walnut improvement is to establish a seedling seed orchard and the preservation of outstanding walnut trees by establishing a breeding arboretum. These two installations will serve as a foundation for a continuing improvement program. Specific plans will be developed as the program progresses.

3. Green Ash - Current information regarding genetic variability justify some sort of improvement effort. However, it is advisable to wait a few years until experimental work in other parts of the U.S. become known. Current planting stock is generally satisfactory.

4. Poplar - The bulk of the materials now being produced represent selected hybrids obtained from an improvement program in the NE United States. The program planned for Minnesota is one of testing materials selected in improvement programs now being conducted by other organizations in the upper mid-west. The DNR is currently cooperating with the University of Minnesota in this type of program testing various poplar clones.

5. Scotch Pine - Scotch pine is planted mostly for Christmas tree production. However, because of prospects for significant genetic gains it is hoped that this species can be more widely used for timber purposes. Some strains of Scotch pine have shown a resistance to Schleroderris canker and this is an added incentive to increase planting for timber production. The genetic improvement of Scotch pine can be undertaken at relatively low cost. Course of action recommended is seed source control (two stages) and establishment of seed orchards to produce seed for both Christmas trees and timber production.

6. Larch - Productivity and resistance to virulent strains of Schleroderris have led to plans for the production of larch in DNR nurseries. However, there is little information available in making seed source recommendations or developing good seed orchards for Minnesota. For the immediate future, nursery production will focus on Japanese larch and European larch as these species are more productive than native tamarack on upland sites. Until more experience is obtained, it is recommended that the major proportion of stock produced be European larch.

Category III

In this plan, only seed origin control will be considered for species in this group. Intensive work should be delayed until the demand for planting stock increases and additional genetic information becomes available.

Category IV

Lowest priority; justification for intensive work with these species is weak. Either substitutes are available or problems ammenable to genetic solutions are not significant. Work with these species in the current plan should be restricted to controlling seed source.

I. INTRODUCTION

A. Background

The Minnesota Department of Natural Resources, Division of Forestry is one of the largest producers of tree and shrub seedlings in the Northeastern United States. They provide the bulk of the planting stock for all classes of land ownership in Minnesota.

In 1981 the state nurseries distributed more than 17 million trees which were planted on about 18,900 acres and provided seed for direct seeding of 4,000 acres.

Activities in this area are accelerating with the 1981-82 nursery seeding targeted for the output of 35 million seedlings in 1985. By the year 2000, the annual need for state produced planting stock is expected to reach 48 million seedlings with the potential for regenerating 53,000 acres. In addition, by 2000 the state is expected to be involved in the direct seeding of 15,000 acres annually.

DNR-Forestry, as the producer of the majority of the planting stock used in the state, has the responsibility of distributing the best possible materials to insure the effectiveness of planting programs. This will require an aggressive genetic improvement program. Genetic improvement of forest trees is a widely accepted, economical and effective tool for increasing the survival of seedlings and the productivity and quality of plantings. Large scale programs have been developed in many states and such a program would be of benefit to Minnesota.

B. Current Tree Improvement Activities

DNR foresters have been aware of the potential for genetic improvement over a considerable period of time. Despite a limited budget, the Department has initiated steps towards the production of genetically improved planting stock in cooperation with the University of Minnesota, College of Forestry; U.S.D.A. - Forest Service's North Central Experiment Station and private wood using industries. Encouragement for this work has come from State and Private Forestry of the U.S. Forest Service which has provided funding under Section 401, Title IV of the Agricultural Act of 1956, Public Law 540, 84th Congress (16 U.S.C. 568e). To date, DNR-Forestry has accomplished the following in their tree improvement program:

1. Red (Norway) pine

   a. Developed a 36 acre seed production area which is now yielding small quantities of seed.
   b. Selected and collected seed from approximately 200 trees growing in natural stands. This work is still in progress and eventually a seedling seed orchard will be established which should begin producing improved seed in the late 1990's.

2. White spruce

   Approximately 16 acres of seed orchard (12 acres at Cotton, St. Louis County and 4 acres at Sturgeon Lake, Pine County) have been established using grafts from selections made by the U.S. Forest Service, Forestry Sciences Laboratory, Rhinelander and the University of Minnesota. Site preparation and grafting for expansion of the second orchard has been completed and will be planted in the spring of 1981. Improved seed should be produced in the mid-1980's.

3. Black spruce

   a. A number of phenotypically superior trees were selected and grafted. The grafts have been planted in a one acre seed orchard near Sturgeon Lake.
   b. A four acre seedling seed orchard has been established near Duxbury in Pine County. This orchard contains 200 selected families. The first improved seed from this project should be available by 1990.

4. Jack pine

   A number of potentially superior stands to be used for seed collection areas have been identified. One of these stands is located in St. Croix State Park and some seed has been collected. In addition, the DNR has established two plantings of selected families provided by the U.S. Forest Service for use in future breeding work.

5. Poplar

   Selected hybrid clones have been obtained from the U.S. Forest Service's Northeast Forest Experiment Station and are being distributed by the Nurseries. Cooperative tests have been established with the University of Minnesota which lead to a first upgrading of the clone collection in 1979.

6. Black walnut

   Preliminary selection work has been done. Some stock from selected parents is now being produced in the nursery and some has been out-planted in seed production areas comprising seven acres.

C. Need for a long-term Tree Improvement Plan

While activities in the tree improvement area by the DNR have been productive and generally well conceived, a formal long-range plan has not been available. Over time the committment to tree improvement work has grown and the types of activities have become more complex, making planning more critical. This long-term plan was prepared for the following reasons:

1. To insure continuity of tree improvement efforts. Much tree improvement work is long-term in nature and production of improved materials may not begin until 20 years after the initial steps in a project. Programs can not be "personnel dependent" and a written plan will insure continuity regardless of transfers, retirements, etc.

2. To define goals and priorities. Given the variety of species the Division of Forestry grows in its nurseries, there is considerable opportunity to place emphasis on less productive phases of an improvement program. It is important to have stated program goals and priorities and to know how specific activities relate to these goals.

3. To outline specific activities. At present (1980) the DNR has no trained tree improvement specialist. It relies on individuals and agencies outside the Department for technical advice and direction. While considerable expertise is available, the DNR has overall responsibility for the program and needs the guidance provided by a plan to coordinate activities and to insure that action is taken on a timely basis.

4. To serve as a basis for financial planning. A long-term plan will enable the Department to anticipate what is needed to develop their genetic improvement program and make appropriate requests and allocations during the budgeting process.

II. GOAL AND SCOPE OF THE TREE IMPROVEMENT PROGRAM

A. Goal

The goal of this tree improvement program is to increase the productivity of public and private forest lands in Minnesota through the use of genetic principles. The program will result in the production or acquisition of genetically superior seeds or cuttings for use in the growing of planting stock or other regeneration activities. The target is the highest level of genetic improvement possible within the restrictions of available resources, current information and probable economic return.

It is important to recognize the continuous nature of genetic improvement and that many stages of a program can yield a degree of improvement.

In the near-term this plan concentrates on utilizing available information and materials to upgrade the genetic quality of nursery products. In many cases, the degree of improvement will not be the maximum of optimum level known to be attainable. However, these measures will yield substantial economic returns because they can be implemented promptly.

Providing for progressive genetic improvement of major forest tree species is consistent with the goal of the program. In developing the long-term plan, attention was given to providing a broad enough genetic base so that improvement work can be continued beyond the period it covers.

B. Scope of Program

1. Species

All species currently grown by DNR nurseries were considered in formulating the tree improvement program. However, all species were not treated equally for biological and economic reasons. In general, more effort was allocated to softwoods which are important for fiber and/or wood production. This is consistent with the emphasis in the long-range plans of the Division of Forestry.

2. Traits considered

Numerous characteristics of trees and shrubs can be modified by a genetic program. General catagories include growth rate, stem form, branching habit, climatic resistance, pest resistance, wood quality, chemical makeup and reproductive traits. Attempting to improve a large number of traits in a breeding program usually gives very limited results and most improvement programs concentrate on one or two characteristics. This principle was followed in developing the plan and emphasis was placed on those traits of a species which are most limiting to its usefulness and/or growth rate.

3. Duration of Program

This plan covers tree improvement activities through the year 2000. The plan only outlines the first phases of a tree improvement program. Periodic revision to account for changes in planting programs and technology will be needed and an extension of the plan will eventually be required. The time frame is consistent with current (1980) long-range plans of the Division of Forestry and is adequate to provide for substantial progress in the tree improvement area.

III. PROCEDURES USED IN THE PLAN -- GENERAL

A. Background

Major activities in the tree improvement program are summarized in this section. The elements as listed can be viewed as sequential steps in the program with each providing additional genetic gain. However, the progression is very much a generalization and species characteristics, current level of development or special circumstances have led to modifications at the species level.

B. Seed Source Selection and Control of Seedling Distribution

The DNR distributes planting stock throughout Minnesota, a large state with a diversity of environments. This diversity requires a variety of genetic materials for many species. The establishment of seed source zones coupled with the distribution of planting stock in a manner consistent with seed origin is a first step towards utilizing genetic variation. It is a relatively inexpensive measure which will reduce the probability of severe losses due to climatic extremes. It also can provide substantial improvement of the genetic quality of planting stock for many species. The basis for controlling seed origin can be of two types:

1. Selection of "most likely" geographic zones. This procedure is used in the absence of provenance test results. Seed collection is limited to areas with climatic and soil conditions similar to those of the prospective planting sites. For native species in Minnesota this would probably translate into the establishment of several seed collection zones using degree days or other measure of climatic conditions and then distributing planting stock on the basis of the particular zone it was derived from.

2. Use of tested seed sources.
There have been a number of provenance (seed source) tests carried out in Minnesota by research agencies. Results of these tests can be used as a basis for planning seed collections and seedling distribution. In some species, test results have indicated superiority of materials from populations some distance from the planting site, often from outside the state.

C. Seed Production Area Development

Seed production areas are natural stands or plantations managed for the production of seed. Heavy thinning, fertilization, insect control and other extraordinary measures are used to increase seed production. Natural stands used for seed production areas are located in preferred seed collection zones; plantations, if they are used, are derived from seed from such zones.

Genetic gain from seed production areas is comparable to that obtained from control of seed source. These areas should be viewed as a way to economically produce desirable seed rather than a primary means of increasing genetic gain. In the development of seed production areas, there is some possibility of additional genetic improvement by carefully selecting stands or plantations and the individual trees left to produce seed. Seed production areas can be developed with two types of emphasis:

1. Emphasis on seed production only.

   In this case, minimal attention is given to individual trees in the stand and emphasis is placed on total stand seed production. Thinning is carried out with proper spacing as the primary consideration. Genetic gain is a function of geographic (seed source) and stand-to-stand variation.

2. Emphasis on seed tree quality.

   Efforts are directed towards favoring outstanding individual trees and elimination of slow growing or poorly formed trees. Genetic gain is primarily a function of geographic and stand-to-stand variation but there is some gain from individual tree selection.

D. First Generation Seed Orchard Development

Seed orchards are plantings where selected materials are grown together so they interpollinate and produce genetically improved seed. It is in the seed orchard that favorable genetic characteristics are packaged for use and they are the production units of advance phases of tree improvement programs with sexually propagated species.

First generation orchards usually contain materials obtained directly from natural populations. These materials are normally selected on the basis of their phenotype. Orchards can be of several types. Many factors are considered, but the choice usually depends upon economics and the biology of the species. Classes of first generation orchards include:

1. Seedling seed orchards.

   These orchards are usually established using open-pollinated seeds collected from trees selected because of their favorable phenotype. Establishment cost of such orchards are low and the approach is favored in species which flower early when grown from seed.

   In establishing seedling seed orchards the option of using seed produced from controlled crosses among selected trees also exists. This increases the gain from field selection; however, the procedure is expensive and requires considerable time to implement.

Seed obtained from seedling seed orchards is of the following types:

a. Seed from first stage selection (unrogued orchard). Once seed is produced in the area planted with seedlings derived from selections, it can be used directly in the planting program. Gain at this stage is dependent on the effectiveness of field selection. Normally such seed is only used on a short-term basis with further development of the orchard planned.

b. Seed from second stage selection (rogued orchard). Seedling seed orchards are usually designed to allow additional selection. Often the stems in an orchard are reduced to 5 or 10 percent of the number planted. Trees retained for seed production are selected on the basis of their performance and the performance of their family (half-sibs or full-sibs) in the orchard and in other tests. Identification of all trees in the orchard is required. Selection should be carried out with restrictions to avoid inbreeding and to retain an adequate genetic base for further breeding. Seed produced incorporates the genetic gain from field selection and gain from selection using family information.

2. Clonal Seed Orchards.

These plantings are established using trees produced by vegetatively propagating selected trees. The most common means of propagation is grafting and each selected tree is represented in the orchard many times. The approach is normally tied to very intensive field selection and relatively small numbers of trees from natural populations are used in the orchards. It is most frequently used with species which can be grafted easily and whose grafts flower earlier than seedlings.

Establishment costs are moderate to high because of the propagation procedures. Seed produced can be classified as follows:

a. Seeds from first-stage selection. These seeds are obtained from clonal orchards once the grafts begin to flower. Gain at this stage is the result of the field selection and roughly twice that of an open-pollinated unrogued seedling seed orchard developed from the same selections.

b. Seed from second stage selection (rogued clonal orchard). Clonal seed orchards can also be rogued in order to achieve additional genetic gain. The procedure is essentially one of removing clones which produce less than outstanding offspring. Normally this selection can not be very intensive because of the limited number of clones in an orchard. It can, however, provide some gain beyond that obtained from field selection.

c. Second cycle seed. In programs in which multiple seed orchards containing different clones (original selections) have been established there is an opportunity for increasing the second-stage selection intensity. To do this a new grafted orchard is established using only the best clones, as indicated by progeny tests, from several different orchards. When several different agencies are conducting independent improvement programs with a species, this possibility can be exploited by exchanging clones.

E. Advanced Generation Seed Orchard Development

Once first generation seed orchards have begun to flower, efforts can be directed towards obtaining additional genetic gain by a new round of selection. Selection is carried out in populations derived from first generation programs and a new series of grafted or seedling seed orchards is established.

IV. RESOURCES AVAILABLE

A. Minnesota DNR-Forestry

1. Manpower

The Division of Forestry has adequate manpower and an appropriate organization for carrying out the physical activities of the proposed tree improvement program. Currently tree improvement work is recognized as one task of the Division's work plan and provisions can be made for increased activity in this area if funding is available. Responsibility for tree improvement work is assigned to the Nursery Coordinator. It is recommended that a tree improvement specialist with training and/or experience in forest genetics be added to the Division staff or some other provision be made to assist in the technical planning and coordination of tree improvement activities.

Nursery personnel carry out much of the work in the tree improvement area. The staff of the two active nurseries includes two Nursery Superintendents, two Assistant Nursery Superintendents, 12 full-time foremen and skilled workers and 4 seasonal monthly laborers. Field foresters are an additional resource, having contributed to tree improvement work in the past. The 90 District Foresters and 40 District Assistants are dispersed over the state which increases their value. In addition, Area and Regional Supervisors and their staff specialists serve a coordinating function and provide technical assistance.

2. Finances

Current Division of Forestry expenditures on tree improvement are approximately $40,000 per year. This expenditure is in excess of that required to match the $15,000 per year of Title IV funds received from the Federal Government. Any expansion of the program will require additional funding from the State Legislature, Federal Assistance Programs or both.

3. Facilities and Equipment

The Division of Forestry is now equipped to carry out the tree improvement program as proposed. The tree improvement program is intended to be supportative of and integrated with the nurseries and it relies heavily on nursery equipment and facilities. Certain specialized items will have to be acquired in the future. However, no major facility development or equipment purchases are anticipated before 1990. Facilities currently available for use in the tree improvement program are:

a. Nurseries. The three nurseries (one is inactive) maintained by the state have a gross area of over 600 acres. Developed bed space approaches ten million square feet. Nursery capacity is adequate for the production of the 48 million seedlings per year projected for 2000. Capacity of the nurseries should not be limiting to tree improvement work.

b. Greenhouses. There are two greenhouses available with a total of 2,200 square feet of floor space. The greenhouse at General Andrews Nursery has 1800 square feet and adequate temperature controls and air circulation. The older greenhouse at Badoura Nursery has 400 square feet of floor space and relatively primative controls. Little use of the greenhouses is made in normal nursery operations and they are available to the genetic program for grafting and propagation work.

c. Equipment storage and service space. Present facilities at the nurseries are adequate to meet program needs.

d. Cold Storage. A total of 8,800 square feet of root cellar and freezing rooms with the capacity for storing over 2 million seedlings is currently available at the nurseries. These facilities are used to capacity during parts of the year for nursery operations. The demands for cold storage for the tree improvement program should be small and sporatic. If conflicting needs for space arise, cold storage facilities available elsewhere in the state could be used on a temporary basis.

e. Lathhouse. A structure has been built at General Andrews Nursery which is suitable for conditioning containerized seedlings or for dormant season storage of potted grafting stock. Space is adequate for the proposed tree improvement program and could be expanded at a low cost, if necessary.

f. Cone storage building. Adequate facilities are presently available in the 5,040 square foot cone storage building at Badoura Nursery. This facility will have to be doubled in the future in order to provide necessary space to meet the anticipated demand of 48,000,000 seedlings in year 2000.

g. Propagation equipment. No special equipment other than expendable grafting tools has been acquired. As the tree improvement program progresses some specialized equipment for growing containerized seedlings may be required. These items should be modest in cost.

h. Seed harvesting and processing equipment. No special equipment is needed to handle the small amounts of seed used in developing seed orchards and tests. When seed production areas and seed orchards begin to produce seed on a regular basis the harvesting of seed will be a problem. Also, as the program moves to the stage where second generation orchards are being developed it will be necessary to work in the crowns of relatively large trees. The purchase, leasing or construction of specialized equipment to allow work in the tops of trees will eventually be necessary.

   Seed processing equipment is adequate for nursery operations and tree improvement work; however, provision to handle small lots of seed efficiently should be considered in the future.

i. Seed orchard site preparation and maintenance equipment. Currently equipment for maintenance work and site preparation is available from either the nurseries or at field stations. Major expenditures in this area are not anticipated and the use of private contractors can be considered, if problems of availability of heavy equipment arise.

4. Seed Orchard Test Sites

There is a total of 3 million acres of State Forest land under management of the Division of Forestry. These lands are distributed over a variety of sites in many parts of the state. The large acreage under state management should insure the availability of adequate space for seed orchards and tests. However, the concentration of seed orchards on two or three sites after the initial phases of the program are completed should be given strong

consideration. Establishment, maintenance and administrative costs will be reduced and, after the early phases of program development, these advantages will outweigh the biological consideration. Old field sites where cost of site preparation and problems with competing vegetation will be minimal are particularily attractive for seed orchard development. Steps to locate and, if necessary, acquire such sites should be given immediate consideration.

B. Technical Assistance - Outside Resources

Technical assistance and guidance for the DNR's tree improvement work is available from the following sources:

1. U.S.D.A., Forest Service - North Central Forest Experiment Station. There are several scientists specializing in forest tree genetics at the Forestry Sciences Laboratory, Rhinelander, Wisconsin. They have assisted in program developement in the past and this practice will be continued.

2. U.S.D.A., Forest Service - State and Private Forestry. A specialist trained in forest tree improvement is stationed in St. Paul. His assignment, in part, is to provide assistance to states in the tree improvement program.

3. University of Minnesota, College of Forestry. Very close cooperation in the genetics improvement area has taken place in the past. This cooperation is expected to continue in the future.

4. Technical Committees. There are three technical committees made up of specialists with interest in species covered in the Minnesota Tree Improvement Program. Members of these committees are a valuable source of technical information and plant materials. The committees are:

    a. G.P. - 13 Technical Committee (Great Plains Regional Tree Improvment Project). This committee is made up of representatives of the great plains states and is organized by the State Experiment Stations with some financial support from the U.S.D.A. Its function is sponsoring and coordinating cooperative research in tree improvement on the Great Plains.

b. N.C. - 99 Technical Committee (North Central Regional Tree Improvement Project). This is a North Central Region cooperative tree improvement research group which has been active since the early 1960's. Members of this group have considerable experience with species involved in the Minnesota Program.

c. North Central Tree Improvement Association. This is an association of foresters with an interest in tree improvement work. It is an outgrowth of the Lake States Forest Tree Improvement Committee and the Central States Forest Tree Improvement Committee. The DNR has a representative on this committee.

C. Cooperation - Other Programs and Interested Agencies

The Minnesota Tree Improvement Program should be coordinated with other interested parties and agencies that share this mutual concern. This will avoid duplication of effort and increase the resources available for the solution of particular problems. Much of the work to date in Minnesota has been cooperative in nature with exchanges of material and meetings to coordinate the efforts of state, federal and industrial foresters. It is expected that such cooperation will continue with the Division of Forestry participating. Prospective cooperators in tree improvement work include:

1. Other states - Wisconsin, Michigan and Iowa. These states share many of the same species and environmental conditions with Minnesota. Both Wisconsin and Michigan have active tree improvement programs.

2. U.S. Forest Service. The National Forest Administration has an improvement program with objectives which include the development of improved materials for the National Forests in Minnesota. In addition, foresters on the National Forests have provided assistance in plus tree selection and seed collection.

3. Soil Conservation Service. The state nurseries provide considerable planting stock to this organization and they have a vested interest in its genetic improvement. The agency could prove to be a source of improved plant materials and could provide assistance in locating potential seed production areas, plus trees, and seed collection.

4. Bureau of Indian Affairs. Foresters in this agency are currently cooperating in the red pine project. Continued cooperation will be encouraged.

5. Private Industries. Currently two Minnesota forest products corporations have initiated tree improvement work in support of their own nursery operations. They have been most interested in cooperating and their improvement work is closely coordinated with the DNR's.

V. PRIORITIES

A. General Considerations

The resources available for Minnesota's tree improvement program will not permit intensive work with all of the 20 plus species produced by the DNR nurseries. Even if funding were available, the advisability of such an extensive program in questionable. Tree improvement should be carried out within the context of the total forestry program and resources allocated to this type of work should be in proporation to the expected returns. With some species and traits the response to intensive improvement work may be so small or the value of gain so limited that the resources would be better directed to other aspects of the genetic improvement program or other forestry activities. Choices among species and traits are inevitable and priorities are needed to insure choices which provide the greatest long-term benefit to the forestry program.

The development of priorities for this program was a subjective process because of the large number of factors involved and limited knowledge. By drawing on the available data and the experience of a variety of specialists, a preliminary ranking suitable for planning was obtained. This ranking reflects the relative value of improved materials to the state's forestry program and the biological feasibility of achieving genetic improvement.

B. Value of Genetic Improvement

The initial step in establishing priorities was estimating the relative value of improving a species. the three major components in this estimate were:

1. Projected demand. Because of the time lag between the initiation of genetic improvement work and the production of improved stock, priorities must be based on future demand. The year 2000 was used because at that time a relatively stable level of regeneration activities is predicted. Projections are summarized in Table 1. They are based on information obtained from a draft copy of the Division of Forestry's long-range plan. Current nursery production levels and direct seeding activities are included in the table as a basis for comparisons. The total need for planting stock and direct seeding reflects the anticipated harvest and desirable level of artificial regeneration in the year 2000. Projections for species were made after reviewing past planting trends and examining probable trends in future forestry programs. The critical values in Table 1 are the number of acres to be regenerated annually with a species by the year 2000. These values share the defects of most

projections. Adjustments in the levels of nursery production are inevitable as planting practices change and reforestation objectives are modified. However, they do provide a general picture of the relative importance of the species in the future and are one measure of the value of improvement work.

2. Value-use ratings of species. While the acreage impacted by a species is significant in the establishment of priorities, the ultimate use of what is planted or sown should be considered. In general, the returns from improvement work with a species having a variety of uses are apt to be greater than for a species with limited uses. The values for major use catagories and the total value rating given in Table 2 are useful indicators of the value of genetic improvement. These values are subjective and represent a composite of opinions of DNR foresters, University of Minnesota faculty and extension foresters. They are based on the use of a species under Minnesota conditions.

3. Significance of improving specific traits. In the final analysis, the value of improvement work must be related to specific traits of a species. One to three traits per species were selected on the basis of the major use of the species and the reasonableness of their inclusion in a genetic improvement program. Rankings of very high, moderate or low were made as to the value to the forestry program of improving these traits. The rankings, given in Table 3, reflect the major use of the species (Table 2), extent to which a species is to be planted (Table 1) and problems or deficiencies observed in the planting stock now being distributed.

TABLE I

Summary of Current and Projected Artificial Regeneration Plans for State, County and Private Lands (1)

Species	Current Status - Annual Basis				Year 2000 - Annual Basis(5)			
	DNR Nursery Production(2) (M) Trees	Acres to be planted with DNR stock(3)	Acres to be direct seeded(4)	Total acres to be Regenerated	DNR Nursery Production (M) Trees	Acres to be planted with DNR stock	Acres to be direct seeded	Total acres to be Regenerated
	(species used primarily for forest plantings)							
Red (Norway) Pine	16,000	17,780	180	17,960	20,000	22,220	780	23,000
White Spruce	5,000	5,560	230	5,790	8,400	9,330	1,010	10,340
Black Spruce	350	390	1,890	2,280	1,000	1,110	8,550	9,660
Jack Pine	2,500	2,780	1,160	3,940	4,300	4,780	5,130	9,910
White Pine	750	830	20	850	2,200	2,440	80	2,520
Larch	-	-	-	-	5,000	5,550	-0-	5,550
Blk.Walnut	300	330	-	330	300	330	-	330
Red Oak	280	310	-	310	300	330	-	330
White Oak	-	-	-	-	100	110	-	110
Sub-Total	25,180	27,980	3,480	31,460	41,600	46,200	15,550	61,750
	(species used to some extent in forest plantings)							
Green Ash	450	500	-	500	750	830	-	830
Scotch Pine	250	280	-	280	400	440	-	440
Poplar	200	220	-	220	300	330	-	330
Soft Maple	300	330	-	330	300	330	-	330
Balsam Fir	-	-	-	-	100	110	-	110
Sub-Total	1,200	1,330	-	1,330	1,850	2,040	-	2,040

TABLE I (Cont.)

Species	Current Status - Annual Basis				Year 2000 - Annual Basis (5)			
	DNR Nursery Production(2) (M) Trees	Acres to be planted with DNR stock(3)	Acres to be direct seeded(4)	Total acres to be Regenerated	DNR Nursery Production (M) Trees	Acres to be planted with DNR stock	Acres to be direct seeded	Total acres to be Regenerated
	(species used primarily for shelter & wildlife plantings)							
Col.Spruce	1,000	1,110	-	1,110	1,600	1,780	-	1,780
Blk. Hills Spruce	300	330	-	330	500	560	-	560
White Cedar	300	330	-	330	300	330	-	330
E.Red Cedar	100	110	-	110	100	110	-	110
Russian Olive	300	330	-	330	500	560	-	560
Honeysuckle	500	560	-	560	800	890	-	890
Caragana	350	390	-	390	550	610	-	610
Wild Plum	100	110	-	110	150	170	-	170
Ginnala Maple	100	110	-	110	150	170	-	170
Sub-Total	3,100	3,440	-	3,380	4,650	5,180	-	5,180
Grand Total	29,480	32,750	3,480	36,170	48,100	53,420	15,550	68,970

(1) Does not include production of seedlings by private nurseries, acres planted with this stock or direct seeding on private lands
(2) Based on fiscal 1979 seeding plan
(3) Assumes 900 trees/acre
(4) Based on fiscal 1979 DNR plan
(5) Basis is review copy DNR Forest Management Program long range plan

TABLE 2

Value - Use Ratings of Species Produced in DNR Nurseries

Species	Value Rating by Use (1)						
	pulpwood	lumber	plywood & veneer	poles, posts and other wood products	Christmas trees	protection & wildlife	Total
Norway Pine	4	5	1	5	5	4	24
Jack Pine	5	4	1	5	1	2	18
White Pine	2	5	1	2	3	3	16
Scotch Pine	2	2	1	2	5	2	14
White Spruce	5	4	1	1	5	3	19
Black Spruce	5	1	1	2	4	2	15
Balsam Fir	3	1	1	1	5	3	14
Larch	3	2	1	2	0	3	11
Col. Spruce	1	1	1	0	4	4	11
Blk. Hills Spruce	1	1	1	2	4	4	13
N.White Cedar	1	3	0	3	0	4	11
E.Red Cedar	0	1	0	3	0	3	7
Green Ash	0	4	1	0	0	4	9
Poplar	1	2	1	0	0	4	8
Blk.Walnut	0	5	5	0	0	3	13
Red Oak	0	4	5	0	0	3	12
White Oak	0	4	5	2	0	3	14
Soft Maple	0	3	2	0	0	4	9
Honeysuckle	0	0	0	0	0	5	5
Russian Olive	0	0	0	0	0	5	5
Ginnala Maple	0	0	0	0	0	4	4
Caragana	0	0	0	0	0	5	5
Wild Plum	0	0	0	0	0	4	4

(1) 0=unsuited for use; 1=very limited value and potential for use; 2=used to limited extent or with potential for use; 3=used moderately or with high potential for use; 4=important species for use; 5=major species for use.

C. Feasibility of Genetic Improvement

Value of genetic improvement is only one aspect of the final priorities. The amount of genetic gain per unit of effort is also of prime consideration. There are two major considerations in assessing the prospects for gain: (1) the degree of difficulty of working with a species (its general biological characteristics) and (2) the expected response of a trait to improvement work (its genetic characteristics). The characteristics of species and species-trait combination are classified in Table 3 based on the following:

1. Biological Potential of Species for Improvement. The primary concern in this classification was the reproductive characteristics of species which would impact improvement work. Species which begin flowering at an advanced age and/or have infrequent seed crops were generally classified as having low potential for improvement work. Difficulties in propagating a species sexually or asexually also contributed to a low classification. Other factors considered included the availability of base populations on which to begin improvement work and the difficulty of producing seed on an operational scale. Species were classified as having low, moderate or high biological potential for improvement.

2. Expected Genetic Gain from Improvement Efforts. The extent of genetic variation and degree of genetic control varies considerably among species and traits. As a result the gain per unit of effort (or per dollar expended) is not a constant. In Table 3, estimates of the relative levels of response for various species-trait combinations are given. These estimates of low, moderate or high were obtained from a review of scientific literature and unpublished data.

TABLE 3

Biological Potential, Traits Selected, Value & Genetic Gain From Improvement Efforts

Species	Biological Potential of Species for Improvement (1)	Traits Selected for Improvement (2)	Value of Genetic Improvement to Forestry Program (3)	Expected Genetic Gain from (4) Improvement Efforts
Red (Norway) Pine	low	1. growth rate	1. very high	1. low-some gain from seed source control; 4-8% from orchard
		2. branching	2. moderate	2. unknown
White Spruce	moderate	1. growth rate	1. high	1. high (15-20%)
		2. branching	2. moderate	2. unknown
		3. frost resistance	3. moderate	3. high
Jack Pine	high	1. growth rate	1. high	1. moderate
		2. form	2. high	2. unknown
Black Spruce	high	1. growth rate	1. high	1. high
White Pine	moderate	1. blister rust resistance	1. high	1. low
		2. weevil resistance	2. moderate	2. low
		3. growth rate	3. moderate	3. moderate
Larch	high	1. growth rate	1. moderate	1. high
		2. pest resistance	2. high	2. low
Balsam Fir	moderate	1. growth rate	1. moderate	1. unknown
		2. climatic adaption	2. high	2. moderate
Soft Maple	high	1. climatic resistance	1. moderate	1. unknown
		2. growth rate	2. moderate	2. unknown

TABLE 3 (Cont.)

Species	Biological Potential of Species for Improvement (1)	Traits Selected for Improvement (2)	Value of Genetic Improvement to Forestry Program (3)	Expected Genetic Gain from (4) Improvement Efforts
Red Oak	low	1. growth rate 2. form	1. high 2. high	1. unknown 2. unknown
White Oak	low	1. growth rate 2. form	1. high 2. high	1. unknown 2. unknown
Col. Spruce	moderate	1. climatic resistance	1. low	1. moderate
Blk.Hills Spruce	low	1. climatic resistance	1. low	1. low
N.White Cedar	high	1. climatic resistance	1. low	1. unknown
E.Red Cedar	moderate	1. climatic resistance 2. growth rate	1. low 2. low	1. unknown 2. unknown
Russian Olive	unknown	1. climatic resistance	1. low	1. unknown
Honeysuckle	unknown	1. climatic resistance	1. low	1. unknown
Caragana	high	1. growth rate	1. low	1. high
Wild Plum	low	1. fruitfulness	1. low	1. unknown
Ginnala Maple	unknown	1. climatic resistance	1. low	1. unknown

(1) Biological potential for improvement based on reproductive characteristics of species, availability of plant materials, etc.
(2) Traits selected on the basis of species use.
(3) Value of genetic gain to forestry program reflects anticipated planting levels, value of products, limitations of current planting stock.
(4) Expected response to improvement efforts based on a review of literature.

D. Priority Listings

Estimates of the relative value of genetic improvement to the forestry program, the species biological potential for improvement and expected genetic response to improvement efforts were used to establish the following species priorities.

1. Category I.
Highest priority; work with these species should be initiated as soon as possible. Immediate control of seed origin is needed and provisions made to establish seed orchards as soon as practical.

a. Red (Norway) pine
b. White Spruce
c. Jack Pine
d. Black Spruce

2. Category II.
Second priority; intensive work with these species should be initiated in the near future but not at the expense of work with higher priority species. Seed source control should be initiated immediately and steps towards the development of seed orchards taken at the first opportunity.

a. White Pine
b. Black Walnut
c. Green Ash
d. Poplar
e. Scotch Pine
f. Larch

3. Category III.
Third priority; intensive work with these species should be delayed until either the demand for stock increases, additional genetic information becomes available or specific propagation problems are resolved. In the current plan only steps to control seed origin should be considered.

a. Red Oak
b. White Oak
c. Silver Maple
d. Balsam Fir

4. Category IV.
Lowest priority; justification for intensive work with these species is weak. Either substitutes are available or problems ammenable to genetic solutions are not significant. Work with these species in the current plan should be restricted to controlling seed source.

a. Colorado spruce
b. Black Hills spruce
c. Northern White Cedar
d. Eastern Red Cedar
e. Russian Olive
f. Honeysuckle
g. Caragana
h. Wild Plum
i. Ginnala Maple

Trait priorities within species are given in Section VII of the plan.

VI. PLANNING APPROACH

A. General Considerations

Specific plans were developed using the species priorities listed in the previous section and considering the following factors:

1. Benefits from tree improvement work can only be realized when improved seeds or cuttings are available for wide use. The goal of the DNR is to produce this material and all activities in the program are related to improvement--there is no research component.

2. The impact of genetic improvement is a function of both the amount of genetic gain and amount of improved material produced. Maximum benefit frequently can be achieved by producing large numbers of seedlings with a small genetic gain rather than small numbers of greatly improved seedlings.

3. The impact of genetic improvement on the productivity of forest plantings is also a function of time. Measures which can be implemented quickly, even if they provide relatively little gain, can have high economic value.

4. Tree improvement work is progressive in nature with improved materials produced at various stages. This offers flexibility which should be used in matching the improvement program to the needs of the planting program.

5. The same basic principles guide all genetic improvement work, but there are many alternative ways to apply these principles. In planning for each species the choice of methods depends upon the capacity of the organization, demands of the planting program and the reproductive biology of the species.

B. Financial Consideration

The plan was developed with three levels of program intensity for each of the high priority species. The minimal level assumes the maintenance of the current level of spending (in real dollars), the intermediate an increase of fifty percent and the intensive level a doubling of funding. In planning it was estimated that costs for record keeping, overhead, seed cost associated with source identification etc. would range from $20,000 per year in the minimum program to $32,000 per year in the intensive program. The remaining funds were allocated to the development and maintenance of seed production areas, seed orchards and other improvement related installations. If a tree improvement specialist were added to the Division staff, additional funding would be necessary.

C. Species Plans - Category I

Detailed plans were developed for the four Category I (highest priority) species. These plans are presented in Section VII-A and include the following:

1. A general discussion of the species' role in Minnesota forestry, the anticipated demand for seed and the current status of improvement work.

2. A brief summary of available information on seed production and projections of seed yield in the type(s) of orchard(s) proposed for the species.

3. A discussion of the traits to be considered in the improvement program.

4. A brief review of the elements of the improvement plan.

5. An outline of three alternative levels of the improvement program which includes:

    a. Program objectives in terms of the specific installations established to produce improved seed. These objectives were formulated using the best available estimates of the DNR's future need for seed and the value of improvement work. They should be reviewed periodically and modified to reflect trends in artificial regeneration in the state.

b. Estimates (in current dollars) of the physical costs of establishing and maintaining these facilities. These costs only include expenditures directly related to tree improvement. For example, they do not include the establishment costs of commercial plantations which are selected to be used as seed production areas but do include the costs of thinning etc. undertaken to increase seed production in these plantations. They are rough estimates based on the experience of other organizations, costs in the University of Minnesota research program and information from a variety of sources. They can only be used as approximations in planning.

c. Estimates of the degree of genetic gain (for growth rate in all cases) associated with various sources of improved seed. These values were derived from the literature and in most cases are based on small scale experiments. Because of the lack of actual improvement program experience, the estimates were made in a conservative manner.

d. A schedule for seed production which indicates the amount of seed expected to be produced by various components of the program during 5-year time periods--if the plans are followed.

e. Schedules for major activities. These are tentative and probably will be modified because of budget restrictions, seed crop failures and other factors. They are most useful as outlines of the sequence of activities which should be followed and can serve as a basis for annual plans.

D. Species Plans - Catagories II, III, & IV

Improvement plans for Category II species are presented in Section VII-B. Only minimal programs are presented for these species which were formulated to avoid conflicts with activities related to the improvement of higher priority species.

Category III and IV species are considered in Sections VII-C and VII-D. Specific plans are not presented for these species and discussions are limited to general remarks indicating potential seed sources or possible improvement approaches.

VII. SPECIES PLANS

A. Category I Species

1. Red (Norway) Pine

a. General

The current and projected role of this species in Minnesota suggests that it receive the major emphasis in the tree improvement program. It is the state's most widely planted species because of its products and its favorable cultural characteristics. The wood is suitable for pulp, lumber and poles; it is a popular Christmas tree and it can be used for protection plantings. The production of planting stock and field planting establishment is easy and plantations on good sites are productive and of high quality. The state has established one 36 acre seed production area with this species. A moderate approach to improvement work with this species has been adopted for two reasons. The first is the appearance of a virulent strain of Scleroderris in several eastern states. Westward spread of this pathogen could preclude the planting of red pine in Minnesota and improvement work would be of no benefit. The second reason is the limited genetic variation found in the species which means that gains will be relatively small. There is considerable disagreement as to the advisability of any sort of genetic work with red pine. Work can only be justified when it is associated with a large planting program, as it is in Minnesota, and small gains can be realized over large acreages. Currently red pine cones are purchased within the state and seed extracted at DNR facilities. Essentially all seed is from wild stands, but is identified as to origin (DNR region) in the nursery.

b. Seed production

Seed production is a major factor in the improvement of red pine and in nursery operations. Production is cyclical and procurement can be difficult. Fortunately, red pine seed can be easily stored and used in years when crops are light. However, the creation of a reliable seed supply and the reduction of costs of seed collection can be looked on as a major benefit of a genetic improvement program. Red pine can produce ovulate cones as early as age 5 and pollen as early as age 9. Significant cone production normally does not occur before age 15. Seed crops are erratic with heavy crops every 10 to 12 years, good crops every 3 to 7 years and light crops annually.

Actual studies of seed production are rare and little data has been reported for stands managed for that purpose. Average cone production in a good year is estimated to be about 200 cones per vigorous, mature, partly open-grown tree. In plantations, 104 cones per tree at 14' x 14' spacing and 326 cones per tree at 21' x 21' spacing were observed at age 18 during a good seed year by Stiell(1) in Ontario. Cones contain an average of 20 filled seeds each and there are approximately 52,000 seeds per pound. Estimated yields of seed for seedling seed orchards and seed production areas are:

Years from seed	Trees/Acre	Cones/Tree	Annual Seed Production Lbs./Acre
0-5	900	0	0
6-10	900	0	0
11-15	400	0	0
16-20	200	0	0
21-25	100	60	2.3
26-30	100	100	3.8
31-35	100	140	5.4

Asexual propagation of red pine by grafting is not particularily difficult. Grafting using scion wood from mature trees may reduce the time to flowering, however, results of experiments in this area are not clear and any reduction is not dramatic. In terms of seed production, no advantage is seen in a program utilizing grafting.

c. Traits to be improved

During the initial phases of the program with red pine, growth rate is the single characteristic which will receive emphasis.

d. Improvement Approach

The current situation and the characteristics of red pine demand a relatively extensive approach to improvement. Work is designed to control seed source and to produce large amounts of seed with modest costs. The plans combine the following elements:

1) Seed Source and Planting Stock Distribution Control. Evidence from provenance tests suggests that seed origin does impact survival and development of red pine.

(1) Stiell, W.M. 1971. Comparative Cone Production in young red pine planted at different spacings. Department of the Environment, Canadian Forestry Service. Publication 1306. 8 pp.

Wright et. al.(2), after reviewing data from 12 provenance test plantings, concluded that northern Minnesota may need a slightly different type of red pine than other regions of the North Central States. There apparently is a reasonable chance of gain in growth rate and/or reduction of climatic risk by controlling seed origin and it can be done at a low cost. For these reasons, a system of control should be adopted as soon as possible in Minnesota.

Pending further information, the Lake States Seed Collection Zones (3) based on "growth degrees" above 50°F and the distribution for stock now used by the state nurseries should be used to establish zones. Given the natural range of red pine in Minnesota only two collection zones, zones 3 and 4, of the Lake States scheme are significant. Evidence from other species indicates that the small segments of Zones 5 and 6 in Minnesota where red pine is found should be avoided entirely. Use of the Lake States sub-zones based on January temperatures does not appear necessary. All seed processed by the nurseries should be identified as coming from one of the following 4 zones (see figure 1):

a) Zone 3 west--area with 9,000 - 10,000 growth degrees above 50°F in the counties receiving planting stock from Badoura Nursery.

b) Zone 4 west--area with 8,000 - 9,000 growth degrees above 50°F in the counties receiving planting stock from Badoura Nursery.

c) Zone 3 east--area with 9,000 - 10,000 growth degrees above 50°F in the counties receiving planting stock from General Andrews Nursery.

d) Zone 4 east--area with 8,000 - 9,000 growth degrees above 50°F in the counties receiving planting stock from General Andrews Nursery.

(2) Wright, J.W.,R.A. Read, D.T. Lester, C. Merritt and C. Mohn, 1972. Geographic variation in red pine. Silvae Genetics 21:6:205-210.

(3) Rudolf, P.O., 1956. A Basis for forest tree seed collection zones in the Lake States. Minn. Acad. Sci. Proc. 24:21-28.

Seed from the two west zones should be used at Badoura Nursery which distributes stock to western Minnesota and seed from the two east zones should be used at General Andrews Nursery. Zones 3 and 4 seeds should be sown in separate beds and when the stock is lifted zone 3 material should be distributed to counties in zone 3 and south and zone 4 stock should go to the northern counties.

Use of zones of origin will be facilitated by the current practice of distributing stock beginning with the southern counties and ending with northern counties. Seed procurement and sowing should be planned to match the expected needs in the 4 zones. Unexpected shifts in demand and other complications may well result in the need to use stock outside its zone of origin. In these cases every effort should be made to minimize movement. For example, a shortage of zone 3 east stock should be met by using Zone 4 east stock in the northern part of zone 3.

Whatever system is adopted, less than complete control of seed source should be expected. The current practice of cone purchase from individual collectors will remain a practical necessity during the period covered by the plan and there is no assurance that all seed will come from native stands within seed zones. Both the large number of seed-bearing plantations of unknown origin in the state and the use of untrained collectors means that a proportion of seed will be misidentified. However, a reasonable degree of control should be obtained by educating collectors through local Foresters.

2) Seed Production Areas. Seed production areas will be used to provide stronger control of origin and to serve as a reliable source of seed. They will be developed with the objective of producing a large number of cones on individual stems to facilitate harvest.

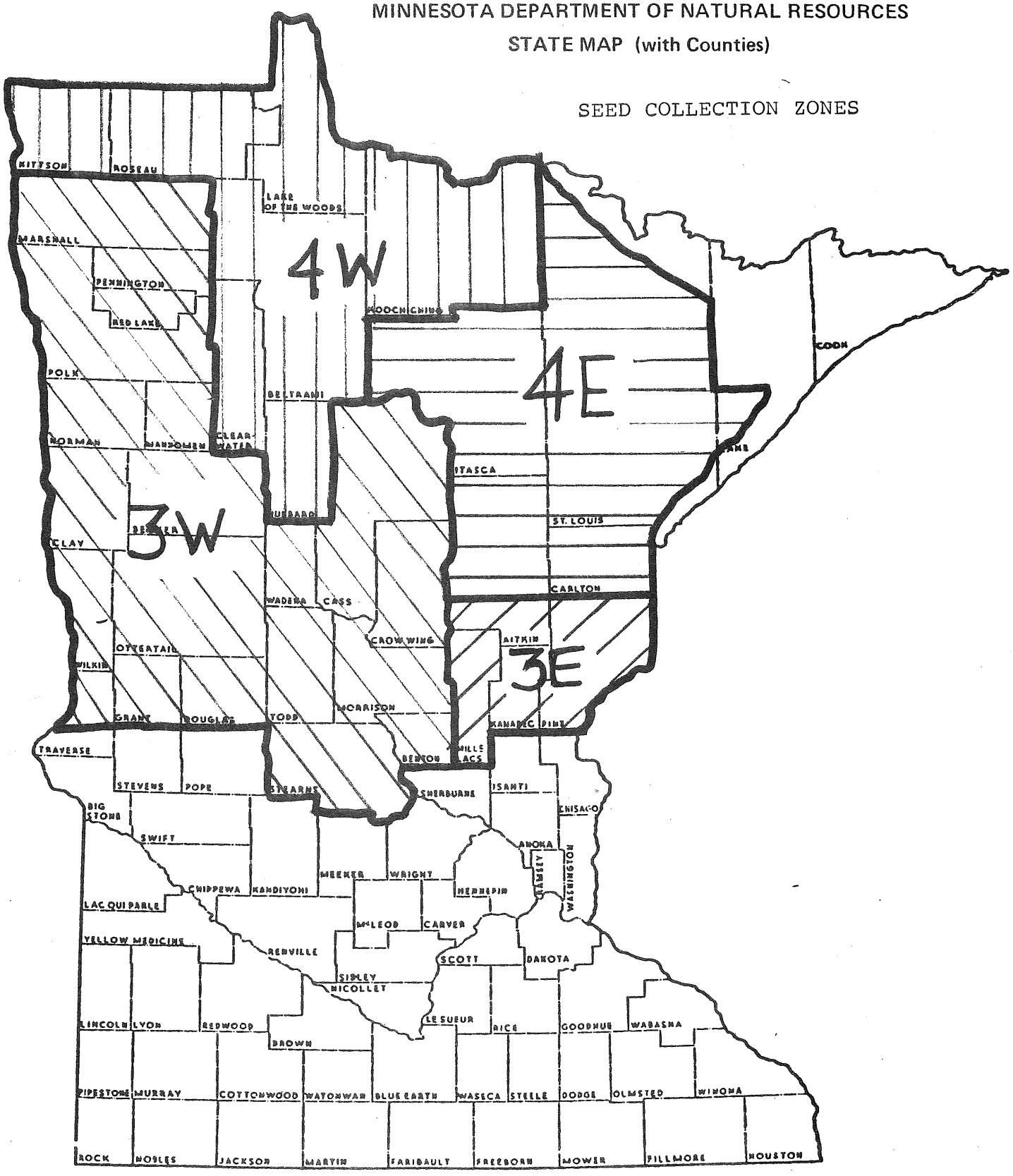
Work done in Michigan and Ontario indicates that seed production areas should be young (15-20 years) and on good sites. Selected natural stands should be thinned heavily, eventually reaching a point where there are less than 100 trees per acre.

Seed production areas should be located so as to have excellent all weather access. When possible they should be close to a nursery or other DNR station. Plantations can be used, if seed origin is documented. Seed production areas must be under control of the DNR and available for use for at least 25 years. In choosing stands seed zones should be considered and coordinated with the anticipated needs of the nurseries. Currently there are 36 acres of developed seed production area of Zone 4 east origin.

FIGURE 1

MINNESOTA DEPARTMENT OF NATURAL RESOURCES
STATE MAP (with Counties)

SEED COLLECTION ZONES



The extent to which seed production areas will be developed depends on the level of funding available to the tree improvement program.

3) Seedling Seed Orchards. This is the most intensive improvement work which can be justified with red pine. Establishment of this type of orchard is relatively inexpensive. It should provide a gain of from 4 to 8 percent in growth rate, insure control over seed origin and increase the dependability of seed supply. In addition, seedling seed orchards will serve as the basis for continued improvement work in the period beyond that covered by the plan.

Orchards will be designed to serve seed collection zones. Their design will permit intensive early selection and a spacing of around 200 trees per acre at the time of the first heavy seed production. The establishment and subsequent thinning of the orchards will be coordinated with programs being carried out by industrial forestry groups. This will permit evaluation of materials on several sites and be of mutual benefit.

Very little seed from seed orchards will be available before the year 2000. However, seedling seed orchards are included in all levels of planning because of their importance in establishing a continuing program and because they are the only practical means of obtaining any substantial genetic gain.

e. Red Pine Program Alternatives***

1) Goals - Year 2000

	Minimum Program	Intermediate Program	Intensive Program
Acres of Seed Production Areas*	100 (65 new)	100 (65 new)	170 (135 new)
Acres of Seedling Seed Orchard**	25	50	75

*3 new seed production areas, one in Zone 3 west, one in Zone 3 east and one in Zone 4 west in the minimum and intermediate programs. Seven new seed production areas in the intensive program, 2 per Zone except 1 in Zone 4 east.

**1 seedling seed orchard per zone in the minimum and intermediate programs, 2 per zone in the intensive program.

***It should be noted that the minimum program probably will not provide a broad enough genetic base for long-term improvement work. If a program at this level is adopted, eventually materials from similar programs in Michigan and Wisconsin may be needed to expand the genetic base.

2) Estimated costs of new installations: Minimum - $57,000, intermediate - $112,000, and intensive - $178,000.

3) Expected genetic gains:
- source identified seed = 1% gain growth rate
- seed production area seed = 2% gain in growth rate
- seedling seed orchards = 5% gain in growth rate

4) Schedule for seed production

Years	Pounds of Seed Needed Annually	Pounds of Seed Obtained Annually From:		
		Seed Orchards	Seed Production Areas	Natural Stands
	(Minimum Program)			
1981-1985	1100	---	130	970
1986-1990	1300	---	300	1000
1991-1995	1300	---	500	800
1996-2000	1300	---	500	800
2001-	1300	125	500	675
	(Intermediate Program)			
1981-1985	1100	---	130	970
1986-1990	1300	---	300	1000
1991-1995	1300	---	500	800
1996-2000	1300	---	500	800
2001-	1300	250	500	550
	(Intensive Program)			
1981-1985	1100	---	130	970
1986-1990	1300	---	300	1000
1991-1995	1300	---	650	650
1996-2000	1300	---	850	450
2001-	1300	375	850	75

5) Tentative Schedule of Major Activities

Year	Season	ACTIVITY		
		Minimum Program	Intermediate Program	Intensive Program
1980	Summer	a) Locate and prepare 5, 5-acre sites for seedling seed orchards	a) same as minimum	a) same as minimum
	Fall	a) Locate potential seed production areas in zones 3 east, 3 west, and 4 west select 65 acres, 1/zone	a) same as minimum	a) same as minimum except select a total of 135 acres, add zone 4 east.
		b) If seed crop available, select and collect seed in field for an additional 80 open-pollinated families (mostly from zone 3)	b) same as minimum	b) same as minimum except goal 400 additional (600 total) families
		c) Sow open-pollinated seed for 4 5-acre orchards in containers (200 families, 60 trees/family)*	c) same as minimum	c) same as minimum
	Winter	a) Thin ½ selected seed production areas to 200 or fewer stems/acre (about 35 acres)	a) same as minimum	a) same as minimum except about 70 acres
1981	Summer	a) Field plant 25 acres of seedling seed orchard	a) same as minimum	a) same as minimum
	Winter	a) Thin remaining portions of seed production areas about 30 acres	a) same as minimum	a) same as minimum except about 70 acres

Year	Season	Minimum Program	Intermediate Program	Intensive Program
1982	Summer		a) Locate and prepare site for additional 25 acres of seed orchard if seed will be available	a) same as intermediate
	Fall		a) If necessary and seed crop available, complete field selection and seed collection to bring total to 400 trees.	a) If seed crop available, complete field selection and collection to bring families to 600.
			b) Sow seed for an additional 25 acres of seedling seed orchard (200 family minimum)	b) same as intermediate
1983	Summer		a) Plant final 25 acres of seed orchard	a) Plant 25 acres of seedling orchard
1983	Fall			a) Sow seed for 25 acres of seedling seed orchard (200 family minimum)
1984	Summer			a) Plant final 25 acres of seedling seed orchard
1987 + 1990	All	a) Thin seed production areas to 100 stems/ acre	a) same as minimum	a) same as minimum
1991	Winter	a) Measure seed orchards planted in 1981.	a) same as minimum	a) same as minimum

Year	Season	Minimum Program	Intermediate Program	Intensive Program
1992	Winter	a) Measure seed orchards planted in 1982	a) same as minimum	a) same as minimum
		b) Thin 1981 orchards to 200 stems/acre	b) same as minimum	b) same as minimum
1993		a) Thin 1982 orchards to 200 stems/acre	a) same as minimum	a) same as minimum
			b) Measure 1983 orchards	b) same as intermediate
1994			a) Thin 1983 orchards to 200 stems/acre	a) same as intermediate
				b) Measure 1984 orchards
1995				a) Thin 1984 orchards to 200 stems/acre
2002-2005		a) Second measurement and thinning of seed orchards to 100 stems/acre	a) same as minimum	a) same as minimum

* Schedule for seed orchard establishment assume 9-month old containerized seedling used for field planting.

2. White Spruce

a. General - This is the second most widely planted species in Minnesota and it is suited for a variety of uses. The prospects of a substantial response to genetic improvement efforts with white spruce are excellent and this species has been allocated a high proportion of the resources available for genetic improvement. Currently 16 acres of clonal seed orchard have been planted (two sites, 12 acres and 4 acres) and a total of 20 acres to be established by 1981.

At present the state purchases cones within the state and seed is extracted at DNR facilities. All seed is essentially unimproved. It is estimated that 480 pounds of seed per year will be needed by 1990 with about 250 pounds to be used in direct seeding work.

b. Seed production - Seed production by white spruce is somewhat cyclical with good crops at 2 to 6 year intervals and light crops annually. Heavy seed crops have been observed in Minnesota plantations on excellent sites as early as 15 years after planting. Grafted materials flowers earlier and an average of 45 cones per graft was observed in one test six years after planting. Cone production in the test increased rapidly in subsequent years.

Evidence indicates that cone production can be increased substantially by fertilizers. For example, flowering of 10-year-old trees was reported to have been increased 15 fold by applications of ammonium nitrate.(1)

While cones can contain as many as 140 seeds, an average of 25 filled seeds per cone is a more realistic estimate. On the average, there are 226,000 seeds per pound.

In this plan the following estimates for production of seed in seedling and clonal orchards were used:

(1) Holst, M.J. 1959 Experiments with flower promotion in Picea Glauca (abstract) 9th Cong. International. Bot. 2:169

Grafted Orchards			
Years Since Grafted	Trees/Acre	Cones/Tree	Annual Seed Production Lbs./Acre
6-10	150	50	.8
10-15	150	100	1.6
15-20	150	150	2.5
20-25	100	250	2.8
25-30	100	300	3.3

Seedling Orchards			
Years From Seed	Trees/Acre	Cones/Tree	Annual Seed Production Lbs./Acre
6-10	1200	0	0
10-15	300	0	0
15-20	300	30	1.0
20-25	100	150	1.7
25-30	200	250	2.9

c. Traits to be improved. Trees of below average form, diseased trees or trees showing evidence of repeated frost injury will not be used as parents in the program. However, the trait given primary consideration in the early stages of improvement will be growth rate. In advanced generations characteristics other than growth may receive greater emphasis.

d. Improvement approach. Programs are designed to utilize existing seed source information as quickly as possible and to eventually provide nurseries with an adequate supply of improved seed from seed orchards. At the more intensive levels second generation orchards are planned to build on the improvement obtained in the first phase of the program. The following elements are utilized in the proposed program:

1) Purchase of Ottawa River Valley Seed. In the immediate future seed will have to be obtained from natural populations. Certain stands of white spruce in southeastern Ontario (Ottawa River Valley) have demonstrated their genetic potential for rapid growth over a wide geographic area.

Tests carried out by the U.S. Forest Service and University of Minnesota indicate that seed from these stands will give excellent results over the entire state. If possible, seed should be purchased directly from Canada and used by state nurseries.

There are major biological and administrative problems in obtaining seed from the specific stands in question. The Wisconsin Department of Natural Resources made an attempt in 1972 which was unsuccessful because of a poor seed crop and in 1973 there was no crop because of a spruce budworm outbreak. As far as is known, there have been no successful attempts to obtain large quantities of seed from the Canadian stands. The possibilities of obtaining and using this seed should be explored fully, despite the difficulties involved. Gains in growth rate associated with the use of such seed should be about 8 percent and is worth considerable effort.

2) Minnesota Seed Collection Zones. It will probably be necessary to continue to utilize considerable amounts of seed from Minnesota natural stands. Tests carried out by the University of Minnesota indicate that local sources can approach the Canadian sources in productivity. However, there is considerable variation in the Minnesota population and test results are not adequate for the establishment of detailed seed collection recommendations. Data indicates that Zones 5 and 6 of the Lake States Seed Zones (1) should be avoided and as an interium measure, a plan for seed collection and seedling distribution using the same zones as proposed for red pine should be adopted. These steps will reduce the frequency of planting failures, give control over seed source, and may give a small (3-5%) increment in growth rate.

3) Clonal Seed Orchards. Current emphasis in white spruce improvement is on the establishment of grafted orchards using scionwood from mature southeastern Ontario trees selected in existing provenance tests. This procedure will produce a breeding population of the favorable Ontario sources in Minnesota and provide a reliable source of superior seed.

(1) Rudolf, P.O. 1956. A basis for forest tree seed collection zones in the Lake States. Minn. Acad. Sci. Proc. 24:21-28.

Approximately 100 selections have been grafted and placed in seed orchards. Orchards are laid out at 15 foot x 20 foot spacing with clones arranged to insure effective cross pollination. These orchards may be thinned at approximately 20 years of age. This thinning will be proceeded by progeny tests which will provide the information needed to eliminate those clones which produce the least vigorous progeny.

Gain in growth rate obtained from these orchards should exceed that which would be obtained from the use of S.E. Ontario seed because of the selection of outstanding trees when establishing the orchards and the culling following progeny tests. It is expected to be between 10 and 20 percent. At the moderate and high program levels additional orchards of this type will be established by 1985.

4) Seed Production Areas. Plantations established with seed from clonal orchards between 1980 and 1985 will be used as seed production areas when they begin to flower (about 2000). Approximately 150 acres of successful plantations of this source should be managed for seed production by using fertilizers and thinning. Plantations used for seed production areas will be established with seed from a large number of the Ontario clones (100-150) and thinning will not be intensive. Thinning will begin at about age 20. These plantings will provide an inexpensive means of meeting the needs for seeds while orchards are being developed. Gains should be roughly the same as those from using Ontario sources.

5) Seedling Seed Orchards. These orchards will provide the basis for continuing improvement work beyond the period covered by the plan and a source of some improved seed. Two types of seedling seed orchard are proposed.

   a) Open-pollinated orchards. All levels of the plan call for four, 5 acre progeny test-seed orchards. One orchard will be located in each of the four seed zones and all will be close to a Division of Forestry facility. Progeny of clones in existing seed orchards and selections made in other tests will be included. A minimum of 50 progenies of selections of Minnesota origin will be tested. Data collected from the test-seed orchards will be used to cull the clonal

orchards. They also will be used to plan controlled pollinations for additional seedling orchards.

Seed will be assembled between 1981 and 1985 with care taken to sample several ramets per clone. Replicated nursery tests will be carried out and field planting will be completed between 1986 and 1990. Seedlings will be planted at 6 x 6 foot spacing with family identity maintained. Single-tree plots will be used to insure dispersion of family members over the orchard site. Plantings will be thinned to 300 stems per acre at age 10 on the basis of measurements made in the planting and other plantings of the same materials. A second thinning will be made at age 20. Seed should be produced by these orchards sometime after the year 2000. Gains of 5 to 10 percent above that obtained from clonal orchards are expected.

b) Controlled pollination orchards. At the moderate and intensive program levels the development of superior populations through controlled pollinations is planned. Selection will then be carried out in these plantations. Limited resources suggest that these crosses follow some form of testing and the 30 to 40 parent trees used in this phase of the program will be selected on the basis of the early performance of their progeny in the open-pollinated progeny tests (see above). These parents will be used to produce 250 to 300 families. The exact mating scheme to be used will depend on the results of the progeny tests. Families will be placed in test plantations, one in each seed collection zone, using a design which parallels that of the open-pollinated orchards. These tests will be converted to seed orchards by heavy thinning following measurements in the orchards and other tests. It is unlikely that these tests can be planted before 1990 and they will not be a factor in seed production before the 2005-2010 period. Gains in growth rate about 5 percent above that obtained in open-pollinated orchards are expected.

e. White Spruce Program Alternatives

1) Goals - Year 2000

	Minimum Program	Intermediate Program	Intensive Program
Acres of Clonal Seed Orchard (Ontario source)	20 (no additional)	30 (10 additional)	40 (20 additional)
Acres of 2nd Generation Seedling Seed Orchards -open pollinated	20 (4 locations)	20 (4 locations)	20 (4 locations)
Acres of 2nd Generation Seedling Orchards- controlled pollinations	0	20 (4 locations)	40 (4 locations)
Acres of Plantation derived from clonal orchards used for seed production areas	150	150	150

2) Estimated Costs of Installations (Establishment and Maintenance)

- Minimum Program = $110,000
- Intermediate Program = $180,000
- Intensive Program = $290,000

3) Expected Genetic Gains

- Purchase from seed zones in Minnesota - 3% gain in growth rate
- Purchase - Ontario seed = 8% gain in growth rate
- Seed production areas = 8% gain in growth rate
- Clonal seed orchards = 12% increase in growth rate
- 2nd Generation open-pollinated seedling seed orchards = 17% increase in growth rate
- 2nd Generation control-pollinated seedling seed orchards = 22% increase in growth rate

4) Schedule for seed production

Years	Pounds of Seed Needed Annually		Pounds of Seed Obtained Annually From:				
	Nurseries	Direct Seeding	Clonal Orchards	Open-Pollinated Seedling Orchards	Control Pollinated Seedling Orchards	Seed Production Areas	Purchase *
			(Minimum Program)				
1981-85	135	105	8	0	--	0	232
1986-90	160	240	24	0	--	0	376
1991-95	230	250	41	0	--	0	439
1996-2000	230	250	53	0	--	0	427
2000-2005	230	250	61	40	--	200	179
2006-2010	230	250	66	68	--	300	46
			(Intermediate Program)				
1981-85	135	105	8	0	0	0	232
1986-90	160	240	24	0	0	0	376
1991-95	230	250	49	0	0	0	431
1996-2000	230	250	69	0	0	0	411
2000-2005	230	250	86	40	0	200	154
2006-2010	230	250	94	68	20	296	0
			(Intensive Program)				
1981-85	135	105	8	0	0	0	232
1986-90	160	240	24	0	0	0	376
1991-95	230	250	57	0	0	0	423
1996-2000	230	250	85	0	0	0	395
2001-2005	230	250	111	40	0	200	129
2006-2010	230	250	122	68	40	250	0

*To the extent possible seed will be purchased from Ontario making sure the source is the selected stands which have performed well in tests.

5) Tentative Schedule of Major Activities

		ACTIVITY		
Year	Season	Minimum Program	Intermediate Program	Intensive Program
1981	spring	a) complete planting clonal orchard number 2	a) same as minimum b) graft 3000 scions	a) same as minimum b) same as intermediate
1982	spring		a) graft 3000 scions	a) same as intermediate
1983	spring			a) graft 3000 scions
	summer		a) select and prepare 10 acre orchard site	a) same as intermediate
	fall	a) collect seed from all grafts for O.P. orchard	a) same as minimum	a) same as minimum
	winter	a) sow seed in containers	a) same as minimum	a) same as minimum
1984	spring		a) plant clonal orchards number 3 (1500 grafts)	a) same as intermediate b) graft 3000 scions
	summer	a) establish replicated nursery tests with O.P. families, 220+ seedlings per family	a) same as minimum	a) same as minimum
1985				a) select and prepare 10 acre orchard site

Year	Season	Minimum Program	Intermediate Program	Intensive Program
1986	spring			a) plant clonal orchard number 4 (1500 grafts)
	summer	a) select and prepare seedling seed orchard sites (4,10-acre sites)	a) same as minimum	a) same as minimum
1987	spring	a) plant seedling seed orchards	a) same as minimum	a) same as minimum
1988	fall		a) evaluate progeny in O.P. orchards	a) same as minimum
1989	spring		a) begin controlled crossing	a) same as intermediate
1990	spring		a) continue crossing	a) continue crossing
1991	winter		a) grow seed from crossing in containers	a) same as intermediate (more seedlings required)
	summer		a) establish nursery tests with seed from crosses	a) same as intermediate
1993	summer		a) select and prepare 20 acres for seed orchards	a) select and prepare 40 acres for seed orchards
1994	spring		a) plant seed orchards	a) same as intermediate except additional acres

Year	Season	Minimum Program	Intermediate Program	Intensive Program
1996	fall	a) measure open-pollinated orchards	a) same as minimum	a) same as minimum
	winter	a) thin open-pollinated orchards	a) same as minimum	a) same as minimum
1999	winter	a) thin clonal orchards 1 and 2	a) same as minimum	a) same as minimum
2000	winter		a) thin clonal orchard 3	a) same as intermediate
2005	winter			a) thin clonal orchard 4

3. Black Spruce

a. General - Inclusion of black spruce as a first priority species reflects the abundance of sites suited to this species and its importance as a pulpwood species in Minnesota. Projections indicate that annual nursery production by the year 2000 will be 1 million seedlings, and that large acreages will be direct seeded with this species. The demand for seed will be large, 1350 pounds per year by the turn of the century. Only a small amount of this seed will be used by the nurseries. Currently cones are purchased within the state and seed extracted by the DNR. All seed is obtained from wild stands.

Tree improvement efforts have been initiated with this species. In 1978 a 3-acre black spruce seedling seed orchard was established near Duxbury by the DNR as part of a cooperative tree improvement project. In addition, approximately 1500 grafts were made from field selection and these were out-planted in 1979 near Sturgeon Lake. The two plantings should begin to yield useable amounts of seed in the middle 1980's.

Genetic information on black spruce is limited. Canadian tests suggest distinct variation patterns related to geographic origin and considerable variation within local populations. Tests have been recently established by the University of Minnesota which will provide additional information. It should be recognized that plans for the improvement of black spruce may require modification as these tests reach the stage where they can be confidently evaluated.

b. Seed Production - Information regarding seed production by this species under plantation or seed orchard conditions is also limited. It is known that black spruce flowers at a young age with moderate cone crops noted for plantations as young as 10 years. A Canadian report indicates that a seed orchard at age 10 produced an average of 171 cones each for trees in a control group and an average of 225 cones each for trees in a fertilized group. Beyond this report there is little information on the yield of young trees.

Cone crops are produced annually with complete failures being rare and heavy crops produced about every four years. The cones of black spruce are persistent and semi-serotinous. Most of the good seed is shed four years after it matures. Reports have indicated that first year cones contain as many as 50 seeds each. However, data based on seed extraction experience indicates that 10 seeds per cone is a more realistic value to use in projecting yields. The seeds are small, averaging about 400,000 seeds per pound.

Data has not been found to provide insight into the impact of grafting on seed production. Because of the early flowering age of seedlings, it is assumed that grafts and seedlings will behave similarily. The following estimates of yields from seed orchards were used in planning:

Years after field planting	Trees/Acre	Cones/Tree	Annual Seed Production Pounds/Acre
5 - 10	600	30	.50
11 - 15	300	100	.75
16 - 20	300	200	1.50
21 - 25	300	250	1.90

c. Traits to be improved - With black spruce, work will concentrate on a single trait--growth rate. This choice reflects the primary use of the species in Minnesota, which is for pulpwood.

d. Improvement Approach - The demand for large quantities of seed dictates that only a small proportion of the seed needed be obtained from seed orchards. The program is therefore designed only to meet nursery seed requirements with orchard material. These orchards will have a relatively short life and be replaced as soon as possible by orchards which produce seed with a higher genetic potential. In part the use of replacement orchards is aimed at reducing the cost of seed collection by confining it to relatively small trees. It is probable that the final harvest in orchards will involve the falling of trees following a heavy seed year to reduce seed collection costs. While small amounts of seed from orchards may be available for the direct seeding program, the bulk of the seed for direct seeding will come from collections made in natural stands and from plantations derived from seed obtained from first cycle seed orchards. Emphasis in the management of

these seed production areas will again be placed on reducing the cost of seed collection while obtaining a modest genetic gain.

Elements utilized in the proposed program are:

1) Source identification. Currently data relative to source effects as they apply to Minnesota are not available. As test results become available in the early 1980's modification of plans may become necessary. In the immediate future, a plan for seed collection and seedling distribution using the zones proposed for red pine should be adopted. Seed used in the nursery and in direct seeding should be subject to the same controls. Gain from source identification are estimated to be between 2 and 5%. Most seed collected will probably come from stands being harvested. For this reason, stands in which seed collection will be carried out repeatedly cannot be designated. However, whenever possible, field foresters should visit stands from which collections are to be made to insure their general vigor and the absence of disease.

2) First Generation Seed Orchard

   a) Seedling. Currently one 3-acre seedling seed orchard has been planted. The orchard contains 200 open-pollinated families selected for their vigor in 4 nurseries. It is designed to insure the identity of trees by family and individuals in the same family are dispersed over the orchard site. Initial spacing was 1200 stems per acre and will be thinned to 600 stems per acre using family and individual tree height measurements as a guide before seed production begins. Information from at least three other progeny test - seed orchards already established in Minnesota will also be available to help plan the thinning. A second thinning is planned 10 to 15 years after planting. This thinning will also be based on family and individual tree performance and follow a heavy seed year. Gains in growth from this type of progeny-test seed orchard are anticipated to be about 8 percent. No additional first generation seedling orchards are planned for the program.

b) Clonal orchard. The DNR has identified superior phenotypes and grafted material from these trees over several years. Parent trees were usually cut in the process of collecting scions. Currently approximately 1500 grafts have been out-planted. Each selection is represent by between 2 and 15 grafts. The value of field selection of black spruce is unknown and the limited number of ramets per clone precludes the development of a traditionally designed clonal orchard. Ramets from the same clone have been separated in the planting and all material has been carefully identified. These selections will serve as parents for second generation orchards and seed will be collected from this planting for nursery operations. Gain from the use of this seed cannot be estimated.

3) Open-pollination Advance Generation Seedling Seed Orchards. All levels of the plan call for the establishment of open-pollinated progeny test-seed orchards. These will range in size from 2 to 8 acres. Orchards will be located in each of the four seed zones outlined under red pine. Open-pollinated seed from the best 50-100 trees in the 1st generation seedling orchard and from as many of the grafted selections as practical will be utilized. The number of entries in these orchards, number of orchards, and the degree to which nursery selection will be used is dependent on the results on studies now being carried out by the University of Minnesota. Design and subsequent treatment of these tests will probably parallel that of first generation seed orchards and an additional gain of 5-10% are projected. The program will be coordinated with three other agencies in the state to insure that genotype - environmental interactions are accounted for.

4) Seed production areas. Beginning in the late 1980's seedlings should be produced in quantity using seed from orchards. Upland plantations established with these seedlings should begin flowering in the 1990's. Approximately 200 acres of these plantings should be managed as seed production areas and the products used in direct seeding programs.

5) Controlled pollination 2nd cycle orchards. At both the moderate and intensive program levels controlled pollinations to create superior populations in which to select should be initiated as soon as possible. Pollination work will be carried out in the seedling seed orchards in the late 1980's using the best unrelated 30-40 trees identified by early measurements for parents. At the moderate level about 150 full-

sib families will be produced and used to establish 8 acres of orchard (4 acres in each of two seed zones). At the intensive level, approximately 200 families would be produced. Crossing designs and planting details will be determined following the analysis of data from tests now in progress. It is projected that these plantings will be established and bearing seed by the late 90's.

e. Black Spruce Program Alternatives

1) Goals - Year 2000

	Minimum Program	Intermediate Program	Intensive Program
Acres of 1st generation seedling seed orchard	3 (no additional)	3 (no additional)	3 (no additional)
Acres of 1st generation clonal seed orchard	1 (grafting completed)	1 (grafting completed)	1 (grafting completed)
Acres of 2nd generation seedling seed orchards -open-pollinated	8 (4 locations)	16 (4 locations)	32 (4 locations)
Acres of 2nd generation seedling seed orchards -controlled pollinations	0	8	16
Acres of plantation managed for seed production	200	200	200

2) Estimated Costs of new installations and maintenance

- Minimum program = $38,000
- Intermediate program = $61,000
- Intensive program = $96,000

3) Expected Genetic Gains

- Source identified = 3% gain in growth rate
- Seed production areas = 6% gain in growth rate
- Seedling seed orchards: 1st generation open-pollinated = 8 percent gain in growth rate
- Clonal seed orchards; 1st generation=unknown
- 2nd generation open-pollinated seedling seed orchards = 14% gain in growth rate
- 2nd generation control-pollinated seedling seed orchards = 16% gain in growth rate

4) Schedule for seed production

Year	Pounds of Seed Needed Annually		Pounds Of Seed Obtained Annually From:				
	Nurseries	Direct Seeding	1st Generation Orchards	2nd Cycle Open-Pollinated Orchards	2nd Cycle Control-Pollinated Orchards	Seed Production Areas	Purchase*
			(Minimum Program)				
1981-85	9	556	0	0	0	0	565
1986-90	14	1265	2	0	0	0	1277
1991-95	25	1335	3	4	0	0	1353
1996-2000	25	1335	6	6	0	60	1288
2000-	25	1335	7	12	0	130	1211
			(Intermediate Program)				
1981-85	9	556	0	0	0	0	565
1986-90	14	1265	2	0	0	0	1277
1991-96	25	1335	3	8	0	0	1349
1996-2000	25	1335	6	12	0	60	1284
2000-	25	1335	7	24	4	130	1195
			(Intensive Program)				
1981-85	9	556	0	0	0	0	565
1986-90	14	1265	2	0	0	0	1277
1991-95	25	1335	3	16	0	0	1341
1996-2000	25	1335	6	24	0	60	1270
2000-	25	1335	7	48	8	130	1166

*Seed to be source identified

5) Tentative Schedule of Major Activities

		ACTIVITY		
Year	Season	Minimum program	Intermediate program	Intensive program
1983	fall	a) measure 1st generation seedling seed orchard	a) same as minimum	a) same as minimum
1984	winter	a) thin 1st generation seedling orchard to 600 stems/acre	a) same as minimum	a) same as minimum
1985	fall	a) collect seed for 2nd generation seedling seed orchards	a) same as minimum	a) same as minimum
1986	winter-spring	a) grow seedlings for orchards - containers first, then transplant to nursery	a) same as minimum	a) same as minimum
1987	summer	a) select and prepare sites for seedling seed orchards (one 2-acre site in each of 4 seed zones)	a) same as minimum (one 4-acre site in each of 4 seed zones)	a) same as minimum (two 4-acre sites in each of 4 seed zones)
	fall	a) measure seed orchard stock in nursery - select	a) same as minimum	a) same as minimum
1988	spring	a) plant seedling seed orchards	a) same as minimum	a) same as minimum
		b) begin planting seed production areas	b) same as minimum	b) same as minimum
			c) begin controlled pollinations	c) same as intermediate

		ACTIVITY		
Year	Season	Minimum Program	Intermediate Program	Intensive Program
1989	spring		a) complete pollinations	a) complete pollinations
	fall	a) thin 1st generation seed orchards to 300 stems/acre	a) same as minimum	a) same as minimum
1990	winter		a) begin growing seedlings for controlled pollination orchards	a) same as intermediate
1991			a) select and prepare site for control pollinated seedling orchard	a) same as intermediate
1992	spring		a) plant control pollinated orchard	a) same as intermediate
1993	fall	a) thin 2nd generation seedling orchards to 300 stems/acre	a) same as minimum	a) same as minimum
1998			a) thin control pollinated orchard to 600 stems/acre	a) same as intermediate

4. Jack Pine

a. General - This is the most common pine in the Lake States and is widely planted in Minnesota. It is well adapted to dry sandy soils, grows rapidly during its first 30 years and is particularily suitable to the Kraft pulping process. By the year 2000, the DNR's annual production of seedlings is estimated at 4.3 million and the direct seeding of over 5000 acres per year is anticipated. At current levels of use, 1,365 lbs. of seed will be required annually to meet these goals.

At this time the DNR's seed is obtained by purchasing cones within the state and extracting seed at their facilities. The bulk of the seed comes from natural stands and cones are usually collected from felled trees.

Tree improvement efforts by the DNR have been limited. Efforts have been made to have local foresters inspect stands from which seed is to be collected to insure that they are phenotypically satisfactory. There is no systematic control over the geographic origin of seed and the distribution of seedlings. One small seedling seed orchard has been established in Minnesota by private industry. This orchard is now producing seed and is a possible source of material for DNR improvement work.

Genetic research with jack pine has a relatively long history in Minnesota and elsewhere. Data indicate that substantial improvement in growth rate can be obtained from controlling provenance and selecting individual trees from outstanding geographic sources.

b. Seed Production - Jack pine flowers at a young age with regular seed production beginning as early as 5 years from seed. Cone crops are regular with very few failures. The cones are persistent and frequently serotinous. Cones may remain closed for as long as 25 years with the seed remaining viable. The persistence and serotinous cones of jack pine are a significant factor in program development. Cone collections need not be made annually and collection costs can be minimized by coordinating them with thinning or harvest operations.

Seed yield data are relatively scarce and frequently report several year's crops rather than one year's. Average annual production on mature trees in natural stands of 1000 - 2000 cones per tree has been reported, but 300 - 500 cones is a more frequently reported figure. In a 5-year-old provenance production of approximately 7 cones per tree was reported and comparable value were extrapolated from data from young jack pine plantations in northeastern and north central Minnesota. Cones contain an average of 30 seeds each and there are approximately 131,000 seeds per pound.

On the basis of the literature, the following yields are projected for well managed seedling seed orchards:

Years after Planting	Trees/Acre	Cones/Tree	Annual Seed Production Lbs./Acre
5 - 10	600	15	1.7
11 - 15	300	50	2.9
16 - 20	150	150	4.3
21 - 25	150	250	7.1

c. Traits to be improved - In the initial phase of the program primary consideration will be given to growth rate. However, at all stages of the program diseased and poorly formed trees will be avoided. As information becomes available the potential for improving form and other commercially important attributes will be evaluated and selection criteria modified if appropriate.

d. Improvement approach - The program with jack pine is designed to take immediate advantage of known variation associated with geographic origin. Seedling seed orchards will then be developed as quickly as possible. These orchards will meet the needs of the nurseries for seed.

The large amounts of seed needed for direct seeding precludes the use of orchards for this aspect of the program. Seed for this purpose will continue to come from natural stands but be source identified. Cost factors dictate that the large quantities of seed be collected from trees fallen in thinning or harvest operations and seed production areas are not appropriate. Elements of the program are:

1) Source identification. DNR seed procurement procedures and the distribution of seed and seedlings should be modified to reflect the finding of provenance tests which indicate that the best performing materials are often local. The four seed collection zones proposed for red pine appear to be a reasonable compromise between provenance test results and practical consideration and they should be adopted immediately. To the extent possible, District Foresters should designate stands within the zones from which collections are made. These stands should be relatively free of disease and have at least average growth rate and form.

2) Special Seed Collection. Meeting the nurseries need for seed is a more manageable problem than that of providing seed for direct seeding. By 1996 all seed used by the nurseries should come from orchards and collecting seed from about 12 acres of natural stand per year will meet the demand in the intervening period. Collections for the nurseries should be made with particular care using the results of provenance tests and guidance from the University of Minnesota and North Central Experiment Station. To the extent possible, collections should be made in the specific stands which have been identified as superior by provenance tests. In cases where this is not possible, suitable natural stands in the same locality as those performing well in the provenance tests should be used.

3) First Cycle Seedling Seed Orchards. Seedling seed orchards will be developed to provide seed for nursery operations. All levels of planning call for an orchard life of approximately 25 years. At that age trees will be cut to reduce the costs of final seed collection. Orchards will be established in each of the 4 seed zones and acreage adjusted to meet the anticipated distribution of nursery stock. At least two orchards will be established in a zone to provide some measure of evaluation in various environments.

All levels of planning call for the establishment of 16 acres of seedling seed orchard using open-pollinated families. In each of the 4 seed zones, 100 single-tree collections will be made from trees which are above average in vigor and form. Seedlings will be grown in replicated nursery tests and each orchard will contain 120 families including the most vigorous 60 families from the zone it is in and the 20 most vigorous families from each of the other 3 zones. Orchards will be planted at 6' x 6' spacing and thinned repeatedly beginning 5 years after planting. Thinnings will be made on the basis of family and individual tree performance. These plantings will provide seed from 1986 to 2005 and a 6 percent gain in growth is anticipated.

4) Advance Generation Seed Orchards. Steps to establish the next generation of orchard will be taken as soon as substantial flowering begins in existing orchards. The design and management of these orchards will be essentially the same as in first generation orchards. However, they will be established with either open-pollinated seed from selected trees in existing orchards or with seed obtained from controlled pollinations among selected trees in existing orchards. The minimum program calls for the exclusive use of open-pollinated seed which is less expensive and a gain of about 5 percent per generation is estimated. The intensive level calls for exclusive use of controlled pollinations which is a more expensive procedure with projected gains of 8 percent per generation. Orchards will contain a minimum of 100 families each and care will be taken to avoid excessive inbreeding. Measurements made in the first generation orchards will be evaluated to establish the validity of seed zones and formulate specific plans for these orchards.

5) Cooperative Improvement Project. The U.S. Forest Service's North Central Forest Experiment Station has proposed a cooperative regional jack pine improvement project and invited the Minnesota DNR to participate. They will supply the initial "breeding populations" derived from selections made over a wide geographic area to cooperators. These populations will be placed in plantings for evaluation and outstanding trees selected. Cooperators will exchange materials derived from selection and use them to develop seed orchards and use their own selection to produce the next generation's breeding population.

DNR participation in this project is recommended. It will provide access to a broader range of breeding materials for advanced generation orchards and a mechanism for cooperative work which may reduce future improvement program costs. The major benefits from the cooperative program will be realized when advanced generation orchards are established. In the immediate future it should be viewed as a supplement to the seedling seed orchard approach using Minnesota materials outlined previously. There should be no difficulty in combining materials from the basic Minnesota program and the cooperative project when advanced generation orchards are developed. Reasons for considering the cooperative project as supplementary are:

a) The design of the projects' planting limits the opportunity for obtaining genetic gain by using seed collected from "breeding populations."

b) There is a strong possibility that the production of useable seed from cooperative project plantings may take 10 years longer than it will for production by other phases of the program. The cooperative project is based on an assumption supported by a debateable interpretation of experimental data and the first seed produced may have little value. Benefits from the project would then not be realized until second generation orchards are established.

c) The initial phases of the cooperative project are limited in size. Availability of materials indicates that Minnesota will receive two or three breeding populations of 960 trees each (20 families of 48 seedling each per breeding population). Plantings established with these seedlings would cover a maximum of 4.2 acres. If these plantings are suitable for use as first generation orchards, their production would represent about 20 percent of that of the seedling seed orchards developed from Minnesota seed collections.

e. Jack Pine Program Alternatives

1) Goals - Year 2000

	Minimum Program	Intermediate Program	Intensive Program
Acres of 1st generation seedling seed orchard	16	16	16
Acres of cooperative project "breeding populations"	4	4	4
Acres of 2nd generation seedling seed orchards-open-pollinated	20	10	
Acres of 2nd generation seedling seed orchards-controlled pollinations (establishment year)		10	20

2) Estimated costs of new installations and maintenance:

- Minimum program = $56,000
- Intermediate program = $86,900
- Intensive program = $137,400

3) Expected Genetic Gains:

- Source identified seed (seed zone collections)= 3% gain in growth rate.
- Special stand collections = 5% gain in growth rate.
- 1st generation seedling seed orchards = 8% gain in growth rate.
- 2nd generation open-pollinated seedling seed orchards = 13% gain in growth rate.
- 2nd generation control pollinated seedling seed orchards = 16% gain in growth rate.

4) Schedule for seed production

Year	Pounds of Seed Needed Annually		Pounds of Seed Obtained Annually From:				
	Nurseries	Direct Seeding	1st Generation Orchards*	2nd Generation Open-Pollinated Orchards	2nd Generation Control-Pollinated Orchards	Collection Selected Stands**	Purchase***
			(Minimum Program)				
1981-85	50	535	0			50	535
1986-90	70	1215	27			53	1205
1991-95	86	1280	46			40	1280
1996-2000	86	1280	69	34			1263
2001-2005	86	1280	114	58			1184
			(Intermediate Program)				
1981-85	50	535	0			50	535
1986-90	70	1215	27			53	1205
1991-95	86	1280	46			40	1280
1996-2000	86	1280	69	17	17		1263
2001-2005	86	1280	114	29	29		1184
			(Intensive Program)				
1981-85	50	535	0				535
1986-90	70	1215	27				1205
1991-95	86	1280	46				1280
1996-2000	86	1280	69		34		1263
2001-2005	86	1280	114		58		1184

* Does not include possible production from "breeding populations."

**Stands will be those from which superior materials in provenance test were collected or stands in the same locality.

***Seed purchased from collectors working in specific seed zones and collecting from stands reviewed by DNR to the extent possible.

5) Tentative Schedule of Major Activities

		ACTIVITY		
Year	Season	Minimum Program	Intermediate Program	Intensive Program
1980	summer	a) identify selected stands and collect seed.	a) same as minimum	a) same as minimum
	fall	b) collect open-pollinated seed, 100 families each seed zone	b) same as minimum	b) same as minimum
1981	winter	a) sow open-pollinated seed in containers	a) same as minimum	a) same as minimum
	summer	a) move seedlings to replicated nursery tests	a) same as minimum	a) same as minimum
1982	summer	a) site preparation for 1st generation O.P. seedling seed orchard, 2, 2-acre sites in each of four seed collection zones	a) same as minimum	a) same as minimum
	fall	a) measure nursery tests	a) same as minimum	a) same as minimum
1983	spring	a) field plant O.P. orchards	a) same as minimum	a) same as minimum
1987	winter	a) thin O.P. orchards	a) same as minimum	a) same as minimum

		ACTIVITY		
Year	Season	Minimum Program	Intermediate Program	Intensive Program
1988	spring		a) control pollinations for 10 acres of seedling orchards	a) control pollinations for 20 acres of seedling orchards
	fall	a) collect seed for 2nd generation O.P. seedling orchard(20 acres)	a) same as minimum except smaller	
	winter	a) sow O.P. seed for 2nd generation orchard in containers	a) same as minimum	
1989	summer	a) move seedlings to nursery tests	a) same as minimum	
	fall		a) collect control pollinated seed	a) same as intermediate
	winter		a) sow control pollinated seed in containers	a) same as intermediate
1990	spring		a) move seedlings to replicated nursery tests	a) same as intermediate
	fall	a) site prep for 2nd generation O.P. seedling seed orchards (20 acres)	a) same as minimum (10 acres)	
		b) measure nursery tests	b) same as minimum	

		ACTIVITY		
Year	Season	Minimum Program	Intermediate Program	Intensive Program
1991	spring	a) plant 2nd generation O.P. seedling orchards (20 acres)	a) same as minimum (10 acres)	
	summer-fall		a) site preparation for 2nd generation control pollinated seedling orchard (10 acres)	a) same as intermediate (20 acres)
			b) measure nursery test	b) same as intermediate
1992	spring		a) plant C.P. seedling orchards (10 acres)	a) same as intermediate (20 acres)
	fall	a) second thinning 1st generation orchards	a) same as minimum	a) same as minimum
1995	fall	a) thin 2nd generation O.P. orchards (20 acres)	a) same as minimum (10 acres)	
1997	fall		a) thin 2nd generation C.P. orchards (10 acres)	a) same as intermediate (20 acres)
1998	spring		a) begin control pollinations for third generation orchards (20 acres)	a) same as intermediate
	fall	a) collect seed for 3rd generation O.P. seedling orchards	a) third thinning 1st generation orchards	a) third thinning 1st generation orchards
		b) third thinning 1st generation orchards		

B. Category II Species

1. White Pine

This is one of the most valuable and rapid growing conifers found in Minnesota. At this time, its role in the planting program is restricted because of the concern over white pine blister rust and the white pine weevil. However, planting of white pine may be stimulated by (1) the need for species to substitute for red pine as the virulent strain of Schleroderris moves westward and (2) a recognization that the risk from blister rust is relatively low on many sites in Minnesota.

Currently the DNR nurseries sow for the production of approximately 750,000 white pine seedlings per year. Seed is obtained from cones purchased within the State and identified as to area of collection. Projections call for the production of 2.2 million seedlings by the year 2000 and the requirements for seed will then exceed 100 pounds per year. These projections may be conservative and the current situation indicates that white pine improvement should receive prompt attention.

Efforts to improve white pine will be hampered by a lack of genetic information and the biological characteristics of the species. Feasible alternatives in developing improved materials are limited and any plan may well require modification as experience is gained. Based on the current status of work with the species, the following is planned:

a. Seed Source Control

There appears to be considerable opportunity to increase growth rate of white pine by using seed collected from specific stands. However, this approach would require a substantial collection and testing program and would not be completed before the mid-90's. In addition, such a program probably would not contribute greatly to increased pest resistance. For these reasons, only minimal control of seed source is being recommended for the immediate future. Resources will be primarily used to develop seed orchards rather than in working with natural stands.

There is very little basis for developing seed collection guidelines to be used until seed orchards are providing seed. The only existing seed source test in Minnesota is one near Cass Lake established by the U.S. Forest Service in 1962. Growth in this test suggests that seed for Minnesota should be collected where mean January temperatures are below 20°F. (this includes all of Minnesota).

The data also indicates that movement of seed should be restricted, at least until more information is available. Based on this limited testing, it is recommended that the following policy be adopted by the DNR nurseries:

1) Identification of seed as to place of collection be continued.
2) Seed collectors be instructed to obtain seed from disease free stands or individual trees.
3) To the extent possible, the nurseries distribute planting stock for use within 100 miles of the origin of the seed used to produce it or adopt the seed zones established for red pine.

b. Seed Orchards

The goal in establishing the first seed orchards is to increase the resistance of planting stock to white pine blister rust. Initially there will be no intensive effort to deal with white pine weevil or increase growth rate. These characteristics will be considered during later phases of the program. Products of the orchards will be used only where the risk of rust is high. The DNR is not in a position to begin the time consuming and complex process of selecting and screening materials for blister rust resistance. Fortunately, there are programs within the region which have been actively evaluating white pine blister rust resistance. In its orchard development, the DNR could utilize selections made in these programs. The two most likely sources of selections are the U.S.F.S. National Forest Administration program and the Wilderness Research Foundation's program. Both of these programs have collections of tested materials including selections made by the University of Wisconsin in the 1940's. Their materials would be hardy under Minnesota conditions and preliminary contacts have indicated that scions will be available. It should be recognized that a loss in growth rate may be experienced with these materials because of their origin. Scion wood obtained from agencies will be grafted onto "nursery-run" planting stock. If suitable white pine plantations between 3 and 5 years of age can be located, they will be converted into orchards by grafting in the field. Field grafting is preferred because it gives more normal growth than bench grafting and the losses associated with transplant shock are avoided. In the event that existing plantings suitable for conversion can't be located, grafting will be carried out on stock in containers in the greenhouse.

The goal will be to establish 5 acres of grafted orchard with approximately 100 grafts per acre. Establishment of the orchard (s) will require 500 successful grafts representing 30 to 40 trees whose progeny have shown above average rust resistance. Seed production data from grafted orchards is not available, but it is believed that 5 acres of orchard will meet the needs for rust resistant material by the year 2000. Seed production may begin in the grafted orchards within the first five years after establishment. However, production is expected to be very limited during the first 15 years. Establishment costs of the first phase orchards are estimated to be approximately $7,500. The costs of field and bench grafting are assumed to be roughly equal.

c. Tentative Schedules for the two alternative approaches are:

Field Grafting Approach

1) Summer 1980 - locate and initiate any treatment need in plantation to be converted to grafted orchards.
2) Spring 1981 - carry out small scale grafting trials to establish techniques and for training.
3) Springs 1982, 1983, 1984, 1985 - graft selections.
4) 1986 and following- maintain orchard.

Bench Grafting Approach

1) Summer 1980 - prepare root-stock for grafting trials and training.
2) Winter 1980-81 - carry out grafting trials to establish techniques.
3) Winters 1982, 1983, and 1984 graft selection- line out grafts in nursery following summer.
4) Summer 1983 - select and prepare orchard site.
5) Spring 1984, 1985, and 1986 - plant grafts in field.
6) 1986 and following - maintain orchard.

Subsequent development of orchards will depend upon research progress, the success of the initial program and planting levels.

2. Black Walnut

There is a modest, but consistent, demand for black walnut planting stock in Minnesota. The current production goal for the DNR nurseries is about 300,000 seedlings per year and it is expected to remain at this level through the year 2000. Planting is concentrated in southern Minnesota where a limited acreage of suitable site is found. Seed is purchased in the same area.

Given the restricted planting area and the fact that it coincides with the natural distribution of walnut, zoning for seed collection and seedling distribution is not necessary. Seed procurement procedures could be modified with efforts made to obtain seed from southern Wisconsin, southern Michigan and northern Iowa. A case for this procedure can be made using the results of a provenance test carried out by the DNR and U.S. Forest Service near Winona. Data from that test indicated that materials from south of the planting site (up to 200 miles south) grew more rapidly than local material. (1) However, these data are for six-year-old trees and subsequent mortality in the test has been very high. Until there is a more convincing demonstration of the advantage of non-local seed or seed orchards are developed, nurseries should continue to use seed collected in southern Minnesota from outstanding trees.

Selection and the development of seed orchards can provide substantial gains with walnut. This response from such efforts are promising from a biological viewpoint and the value of walnut makes such programs economically attractive. Orchard development is underway in neighboring states, however it is in its early stages and there is little opportunity for Minnesota to benefit from these efforts immediately. If a supply of genetically improved seed for use in Minnesota is to become available within a reasonable period of time, a program for genetic improvement should be initiated promptly by the DNR. This program, as outlined below, aims at the utilization of the genetic variation within the Minnesota population of walnut. Substantial genetic gain should be obtained and the risks of

(1) Bey, C.F. 1973. Growth of black walnut trees in eight mid-western states - a provenance test. U.S.D.A. Forest Service Research Paper NC-91. 7pp.

materials now being adapted to our climatic conditions are minimal. The program is of a modest size and there is the option of incorporating materials selected in other areas in the future. There are two major objectives. The first is the establishment of a seedling seed orchard which will produce seed by the mid 1990's. The second objective is the preservation of outstanding walnut trees found in Minnesota by establishing a breeding arboretum. This step is being taken because of the risk of losing high quality walnut as a result of harvest.

Activities related to these objectives are:

a. Establishment of seedling seed orchards - progeny test. This will require the planting of an orchard which contains at least 100 open-pollinated progenies with 30 seedlings per family. The orchard will cover a minimum of 4.5 acres. As trees develop the planting will be thinned with approximately 10 percent of the trees retained. These trees will be the best individuals in the best families. This orchard should begin to produce seed 10 to 15 years after planting. Genetic gain and seed production can't be predicted accurately. The best estimate is that the orchard will yield about 20 percent of the seed required by the nurseries and that gain in growth rate will approach 10 percent. The first step in the establishment of this orchard will be the selection of trees from which seed will be collected. Field selection will be intensive. Division of Forestry personnel within the natural range of black walnut will locate candidate trees and complete initial evaluations using a formal rating system which places emphasis on form. Final selection will be made after reviewing candidates. It is estimated that field selection can be completed in three years.

   Seed collections will be made in the first good seed year after 100 acceptable selections have been located. It is hoped that these collections can be made before 1984. A minimum of 100 nuts will be collected from each selection. To the extent possible, additional single-tree seed collections will be obtained from selections made in nearby states (Wisconsin, Iowa, and Michigan). Seeds will be sown at the General Andrews Nursery and 1-0 seedlings outplanted in an appropriate design at 8 x 8 foot spacing on a carefully selected and prepared site. Seed and seedlings will be identified as to mother tree at all stages.

The orchard planting will be managed intensively to maximize survival and growth. Thinnings will be carried out at frequent intervals to maintain large crowns for seed production and to remove the less valuable families and individuals. Once seed is produced by these trees, they will be collected and used in the nursery program.

b. Breeding arboretum

The breeding arboretum will contain from 4 to 5 ramets of each of the most highly rated selections. Although its purpose is to preserve germplasm, it also will produce seed which can be used in the nursery. A total of approximately 100 clones will be represented and it will cover approximately 1 acre. It should be located so as to facilitate future work including controlled pollinations.

To establish the arboretum, scions will be collected from selections during the dormant season and shipped to General Andrews Nursery for grafting in the greenhouse facility. The grafting work will be initiated as soon as selections have been made and continued until an adequate number of grafts are available. It is probable that grafting can be initiated in the winter of 1980-81. Each year scion wood will be obtained from approximately 25 selections and about 10 grafts will be attempted per selection. It should be possible to complete grafting by 1985. Successful grafts will be planted as soon as practical at 10 x 10 foot spacing with the individual ramets of a clone separated from each other. Grafts should flower between 5 and 10 years after planting and seed can be collected for nursery use.

Data collected from the seedling-seed orchard - progeny test can be used to evaluate trees in the clone bank and those whose progeny perform poorly will eventually be removed.

The two installations will serve as a foundation for a continuing improvement program. Specific plans can be developed as the program progresses and additional information becomes available and experience is obtained.

It is estimated that the costs of establishing the two installations described will be approximately $16,000.

3. Green Ash

The extent to which this species is planted in Minnesota and the available information concerning genetic variability justify some form of improvement effort. However, it seems advisable to wait a minimum of five years before formulating plans. Current planting stock is generally satisfactory and planning will be more effective after the results of experimental and applied work now being carried out in other parts of the United States are available.

4. Poplar

Approximately 150,000 rooted poplar cuttings are distributed by the DNR nurseries each year. These materials are primarily used in protection plantings, mine dump reclamation work and for wildlife habitat improvement. The bulk of the materials now being produced represent selected hybrids obtained from an improvement program centered in New England. These materials are not entirely suited for use in Minnesota. The stock is being distributed as a mixture of clones with diverse parentage which results in great variation in plantings. This variation is particularly objectionable in protection plantings. In addition, some clones are subject to winter damage in the northern part of Minnesota and subject to a variety of diseases. There is considerable opportunity for low cost genetic upgrading of the poplars being distributed. Poplars are almost exclusively propagated using hardwood cuttings and once superior trees (clones) are identified they can be quickly incorporated into the nursery program. With a minimum amount of effort the DNR can identify and promptly utilize materials shown to be superior under Minnesota conditions. The program planned for the DNR is essentially one of testing materials selected in improvement programs now being carried out by other organizations in the upper mid-west.

Currently the DNR is cooperating with the University of Minnesota in the testing of poplar clones. In 1979 the first results of these tests were used to upgrade the materials being produced by the nursery. Some clones being eliminated and the distribution of specific clones is being limited to certain parts of the state.

This type of testing should be continued and a systematic testing of clones identified as having potential in cold climates is recommended. Two sets of clonal tests are proposed, one in 1985 and the second in 1990. Each set of tests will involve about 30 clones and field plantings will cover approximately 1.5 acres on each of 6 sites. Tests will be at selected locations throughout the state. Planting design and the selection of clones to be tested will be carried out in consultation with University of Minnesota, College of Forestry. If possible these tests will be done in cooperation with other agencies who plant poplars and the DNR being responsible for only a portion of the tests. All tests will contain a sample of clones currently being distributed and candidate clones will be compared to them. Clones identified as superior to those currently being distributed will be multiplied and used for nursery production.

The total cost of the testing program should not exceed $15,000 and may be less if a high level of cooperation is obtained from other agencies.

5. Scotch Pine

Current production of Scotch pine seedlings by the DNR nurseries is approximately 250,000 per year and the projected production is 400,000 in the year 2000. Christmas tree growers are the major purchasers of this stock and relatively little is used for forest plantings. The lack of planting Scotch pine for wood or fiber purposes reflects a long-term bias against the species which developed with the use of genetically unsuited materials.

Despite the minor role of Scotch pine in Minnesota forestry, it has been placed in Category II because of the excellent prospects for significant gains and because it is hoped that the availability of suitable materials will stimulate greater use. More extensive planting of Scotch pine could help reduce the risk to plantations from pests by increasing the diversity of species. There is justificable concern over the extent to which our planting programs emphasize red pine (over 65 percent of the softwood seedlings produced by the DNR for forest planting are red pine) and Scotch pine is the "hard" pine with the greatest potential as a replacement. This need to consider species diversity is highlighted by the current threat to red pine from Schleroderris canker and the resistance of some Scotch pine to this disease is an added incentive to increasing its planting.

Extensive work has been carried out in Minnesota with Scotch pine and the diversity of the species is well documented. From 20 to 30 varieties have been defined and most of these are included in a series of provenance tests established in Minnesota in the early 1960's. Adequate information is available to take effective steps towards the genetic improvement of this species at a low cost. The following course of action is recommended:

a. Immediate seed source control (beginning in 1980). All Scotch pine produced in DNR nurseries should be carefully identified and distributed as varieties. This will provide the customer with a choice of material and improve feedback regarding performance. Considering the provenance test results and the commercial availability of seed the following three varieties should be considered:

   1) Riga (Rigensis). The growth of this variety is moderately fast in test plantings. Its stem form is the primary reason for its selection. The variety has straight stems and most of the older Scotch pine plantations in Minnesota with acceptable form are "Riga." It is not particularily well suited for Christmas tree production because of its poor fall color and narrow crowns. Distribution of this variety should be to the area north of General Andrews Nursery.

      Seed of this variety is usually available commercially. If supply problems are encountered arrangements should be made to obtain seed from good stands at the University of Minnesota's Cloquet Forestry Center or North Central Experiment Station (Grand Rapids).

   2) Scotch Highland (Scotica). Early growth of this variety in a single test in central Minnesota (near Rice) was satisfactory. The variety is also used extensively by Christmas tree growers in central and southern Minnesota. Stem form is satisfactory, although there is a tendency towards forking, and fall needle color is better than that of northern varieties. Stock of this variety should be used primarily for Christmas tree plantation in the central and southern parts of the state. Seed is available commercially.

3) Belgium (Haugenensis). This has been an exceptionally vigorous variety in all tests. The rapid growth is offset by less than desirable form and the variety is moderately useful for Christmas trees or for forest plantings which are carefully managed. The variety can be expected to do the best in areas south of General Andrews Nursery.

While this variety covers a large area in western Europe, seed collected from plantations near Campiegne, Belgium, has been the best performing in two central Minnesota provenance tests. Commercial seed dealers have has comparable seed on occasion and every effort to obtain it should be made by the DNR.

b. Second Stage Seed Source Control

The above recommendations must be viewed as having a limited life. Within the next two or three years additional information regarding Scotch Pine provenances will become available. The U.S. Forest Service is currently evaluating resistance to Schleroderris canker of the various varieties of the species and the results of these tests may well modify the variety recommendations. In addition to the disease resistance screening, six provenance tests within Minnesota are still being evaluated. In these test varieties growing between 48°and 55°N in western Europe are clearly the most vigorous. These include the following varieties (1) borussica (Northeastern German highlands), (2) Polanica (Poland), (3) Haugenensis (Western Germany, Eastern France and Belgium) and (4) hercynica (Southern and Central Germany and Central Austria). Large branches and crooked stems are common in these materials and an evaluation of the potential of specific seed lots for timber production must be completed before any recommendations can be made. Once screening for disease resistance and the evaluation of varieties for growth and form are completed, the question of the varieties or seed lots best suited for Minnesota plantings will be reviewed.

c. Seed Orchards

In the long run it is important that the DNR have a local supply of seed of the best varieties for use in Minnesota. In all probability, several seed producing units will be needed. These would include at least one orchard to produce seed of a

"timber type" variety and two or more orchards producing seed of Christmas tree varieties. In establishing seed orchards either seedlings or grafts could be utilized. Seedlings would be derived from tested European or North American stands or from seed obtained from controlled pollinations made in experimental plantings. Grafts would be made with scion wood collected from selected trees in experimental plantings. The literature indicates that one acre of plantation could provide seed for approximately 300,000 seedlings per year with significant production beginning somewhere between age 10 and 15. Grafting would probably result in significant seed production one or two years earlier than seedlings.

Steps toward the development of seed orchards will not be made until the specific origins and seed lots have been identified for use. At that time, probably in 1984 or 1985, steps should be taken to establish a seed orchard of approximately 2 acres for the production of stock to be used for forest plantings. Unless data from existing provenance test suggest otherwise, this will be a seedling seed orchard with young trees planted on a good site at moderate spacing. The planting would be maintained carefully and thinned periodically. Seedlings will originate from seed of those lots within provenances which have demonstrated superior growth and form. It will be necessary to contact European foresters to obtain seed from the desired stands (records are available). If seed of this type is not available, controlled pollinations among superior trees in the best seed lots in existing experimental plantings will be made.

Estimated costs of establishing the seed orchard for timber production are $3,000 if seed can be obtained from Europe and $3600 if controlled pollinations are made. Orchards for the production of seed for use in growing Christmas trees will be considered following the establishment of a timber production orchard. It is believed that satisfactory seed for Christmas tree planting stock can be obtained from commercial seed dealers and thus a lower priority is placed on this phase of the improvement program. Specific plans for work with Christmas tree types of Scotch pine will be developed at a later date.

6. Larch

DNR nurseries have produced and distributed larch planting stock in the past, however, no stock is being produced at this time. The great productivity and resistance to virulent strains of Schleroderris exhibited by this genus have led to the formulation of plans for the production and planting of substantial numbers of larch seedlings in the future (5 million/year by 2000). The scope of this proposed larch planting program means that a considerable effort should be made to upgrade the genetic quality of planting stock.

At this time, there is little information to use in making seed source recommendations or developing good seed orchards for Minnesota. The Institute of Paper Chemistry in Wisconsin has recently initiated a comprehensive study of the genetics of larch and several other groups in the upper Midwest have ongoing research programs with larch. However, until more information is available, no steps towards the development of seed orchards will be taken by the DNR. When information does become available, the potential for improving larch will be reviewed and an improvement program consistent with the level of planting in the state will be designed and initiated.

In the immediate future, nursery production of larch seedlings should focus on two species, Larix leptolepis (Japanese larch) and Larix decidua (European larch). Both of these species are more productive than our native tamarack on upland sites. Data which would permit choosing one of these two species on the basis of growth in Minnesota are not available. In experimental plantings, Japanese larch does appear to be more seriously impacted by the larch sawfly and it probably is more subject to frost damage than European larch. Until more experience is obtained, it is recommended that a major proportion of the larch stock produced be European larch and that any Japanese larch be distributed to the southern one-half of the state.

Japanese larch has a very limited range and the control of seed source is not as critical as it is with many other species. Provenance test results show differences among sources, however seed must be obtained from specific stands in order to utilize this variation. Given the difficulty of obtaining seeds from specific stands in Japan, the Division of Forestry will utilize the seed of this species which is

available commercially, whatever its source. Provenance tests of European larch have been carried out in Europe, northeastern United States, northern Wisconsin and northeastern Iowa. Results of these tests indicate that the most promising seed sources for Minnesota are low altitude stands (up to 450 meters) in Poland and Czechoslovica. Pending further study it is recommended that this variety be used in the DNR nurseries.

C. Category III Species

1. Oaks

Relatively little information related to the genetic variation of Minnesota oaks is available and the biological characteristics of the genus do not favor improvement work. No specific action related to their improvement is planned. Instruction to seed collectors will stress the importance of obtaining seed from good phenotypes and seed purchases will be concentrated in the areas where the bulk of the nursery production is planted.

2. Silver Maple

No formal work with this species is covered by this plan. The current practice of obtaining seed from local stands will be continued. A provenance test with this species has been initiated by the University of Minnesota and the results of this test will be examined in 1985 and seed procurement practices modified if it appears worthwhile.

3. Balsam Fir

Currently seedlings of this species are not being produced in the DNR nurseries, although they have been in the past. Should production of balsam fir seedlings be included in future plans, seed will be obtained from those areas identified as most promising by the two provenance tests being maintained by the University of Minnesota. A summary of 10 year development of balsam fir provenances in Minnesota should be available in 1980.

D. Category IV Species

Species in this category are planted either for protection purposes or for wildlife habitat improvement. Survival of materials in the field is the most critical factor for this group, although rapid growth is desirable. In the procurement of seed, the highest priority will be given to insuring hardiness. In those few cases where test results indicate the advisability of obtaining seed from a specific geographic area, every effort will be made to obtain these materials.

Species in this category are:

Colorado Spruce

Black Hills Spruce

Northern white cedar

Eastern red cedar

Russian olive

Honeysuckle

Caragana

Wild Plum

Ginnala Maple