Tree Improvement Program

January 1998

Minnesota Department of Natural Resources

Tree Improvement Program

Introduction

For the past twenty years the Minnesota Department of Natural Resources Tree Improvement Program has been based on genetic testing and the production of genetically improved seed. The program has been very successful. In certain species gains in height growth reach 13 percent. Combined with state nursery sales of more than 1.3 million improved seedlings in 1997 alone, this translates into remarkable gains in forest productivity.

For better or for worse, forest management is not the same as is was twenty years ago. Management objectives are no longer primarily directed at forest productivity. We are now planting fewer trees, instead relying on natural regeneration systems. Management budgets shrink annually. Although significant gains in productivity are realized through planting genetically improved seedlings, seed production is expensive and requires long term programs.

The production of genetically improved seed is not the only application of genetics principles in forest management. Seed source control is a direct application of population genetics and is the foundation of many tree improvement programs. Silvicultural systems have genetic implications and consequences. It is the responsibility of the tree improvement program to recognize all applications of genetic principles that contribute to forest productivity.

We do not need to change our program. Instead, we need to expand our program to utilize all applications of genetic principles that can contribute to forest productivity. We need to make sure natural resource managers and practitioners are aware of how genetics principles influence forest productivity. We need to be aware of how genetics principles fit into all objectives of natural resource management.

The tree improvement program will continue to pursue traditional genetic improvement by producing improved seed. However, the program will now place increased emphasis other applications of genetics, specifically seed source control and, integrating genetics principles into all natural resource management objectives.

This plan summarizes the tree improvement program and describes activities for the next five years.

Goal of Tree Improvement

- To increase productivity in managed systems by integrating genetics principles into natural resource management policies and practices

Benefits of Integrating Genetics Principles into Natural Resource Management

- maintenance of genetic diversity
- retention of native populations
- greater flexibility in natural resource management
- increased survival
- increased production
- reduced rotation length

Goals of Department of Natural Resources Tree Improvement Program

- employ comprehensive seed source control
- assist natural resource professionals integrate genetics principles into management planning and field practices
- produce improved seed sufficient to meet Minnesota reforestation program needs

Costs of Tree Improvement

• Tree Improvement Specialist Salary and Fringe	$42,000
• Travel	$5,700
• Equipment and Supplies	$10,000
• Minnesota Tree Improvement Cooperative	$15,000
Annual total budget	$72,700

Seed Source Control

Natural selection has produced species and populations within species that are well adapted to the environment in which they evolved. With few exceptions, seeds collected from a local source will survive and grow better than a non-local source. One exception would be the use of broadly adapted seed from a genetic improvement program. Most natural resource managers understand the importance of selecting an appropriate species for regeneration programs. They must also understand that the correct seed source must be used.

Seed source control is a direct application of population genetics and is the foundation of a tree improvement program. Bruce Zobel and John Talbert in their textbook, *Applied Forest Tree Improvement*, appreciate seed source control this way -

> No matter how sophisticated the breeding techniques, the *largest, cheapest, and fastest gains in most forest tree improvement programs can be made by assuring the use of the proper species and seed sources within species.*

Seed source control includes policies and operational guidelines for maintaining the source identity of seeds, seedlings, transplants and cuttings and their correct deployment. Guidelines cover all operational stages, from seed collection and transportation through all nursery practices, shipping and material deployment.

Seed source control guidelines also provide a base for introducing and explaining the application of genetic principles in natural resource management. These genetic principles are applicable to many aspects of resource management and field practices.

Several existing policies address seed source control. Division of Forestry Circular Letter #3421-2, *Nursery Seed Source Control*, (Attachment 1) promotes the practice of returning seeds and seedlings to their zone of origin and directs specific activities and responsibilities to DOF personnel. The Minnesota Crop Improvement Association certifies the origin of reproductive material and has operational policies and requirements for certification. Portions of these policies are in place and are working well. However, these policies need operational interpretation and must be combined to provide comprehensive, seed source control guidelines.

Preliminary comprehensive seed source control guidelines will be completed March 1998. Introduction and implementation will begin immediately and will take up to two years. The tree improvement specialist will work closely with natural resource managers, field practitioners and state forest nursery managers in explaining and implementing these guidelines.

Integrating Genetics Principles into Natural Resource Management

Although the tree improvement program has concentrated on the application of genetics principles to artificial regeneration, many aspects of natural resource management have genetic implications and consequences. Every time a tree is selected, a genetic decision is being made. Natural resource managers and practitioners will make better decisions when they are aware of genetic principles and how they are important in resource management.

The tree improvement specialist will assist managers and practioners, through training and direct assistance, understand the application of genetics principles to policy development, program planning and field practices. Training will introduce genetics principles and how they relate to natural resource management. The training will be both formal, in the classroom and, informal, in the field. This training will begin Fall 1998 and continue indefinitely. Genetics principles will be included in sections of the Forest Development Manual as appropriate.

An outline of training topics will be completed Summer 1998 and will include, but is not limited to, the following -

Seed Source Control

- DNR seed source control policies
- Minnesota Crop Improvement Association Reproductive Materials Certification
- Seed production and collection areas
- Verification in seed collection
- Cone and seed inspection, harvesting and, handling
- Seed and seedling deployment

Integrating Genetics Principles into Natural Resource Management

- Genetic and environmental components of tree phenotype
- Genetic relatedness
- Natural variation and adaptation
- Genetic implications of silvicultural systems and practices

Seed Production

- Seed orchards - improvement, diversity, seed production
- Plus tree selection criteria
- Test and orchard site selection criteria
- Test and orchard site maintenance and management

Seed Production

Significant gains in forest productivity can be achieved through the managed use of genetically improved stock that comes from tree breeding programs. Plus tree selection, selective breeding, progeny testing and establishment of seed orchards are necessary for developing broadly adapted, genetically superior seed. Tree breeding programs also conserve genetic resources in clone banks, seed orchards and genetic tests as well as create new genetic combinations.

Seed Orchards

A seed orchard is a plantation of selected clones or progenies which is isolated or managed to avoid or reduce pollination from outside sources, and managed to produce frequent, abundant, and easily harvested crops of seeds.

Trees selected for orchard establishment are chosen based on height, however, trees are selected only if they are straight and disease free. These selected individual trees are often called plus trees. Either seeds (for a seedling seed orchard) or cuttings (for a clonal seed orchard) are taken from these trees and planted together. The resulting plantation is used only for seed production.

The Division of Forestry has established seed orchards for seven important species; white pine, red pine, jack pine, black spruce, white spruce, black walnut and red oak. These species make up 80% of total state nursery sales. Division of Forestry seed orchards are listed in Table 1.

Seed orchards are expensive to establish and manage. Seed orchard management promotes the production of large quantities of genetically improved seed. Orchard management activities are prescribed keeping in mind that, all other factors being equal, large vigorous trees will produce seeds earlier and in greater quantities than small trees. Keeping orchards healthy insures regular cone crops. Keeping an orchard healthy prolongs its life. Fewer orchards can provide the desired amount of seed if they are kept healthy.

Ideally, seed orchard maintenance will be coordinated by an area forester with the tree improvement specialist. Area foresters work where seed orchards are located. They can inspect orchards from time to time and prescribe maintenance activities as needed. A maintenance checklist for each site will be developed by the area forester and the tree improvement specialist. The checklist will include activities such as vegetation management, pruning, removal of diseased or dead trees, and rodent and browse control. Checklist activities can be completed as needed and as time permits. Funding for orchard management and maintenance activities will be requested through the forest development annual work plan.

Table 1. Division of Forestry Tree Improvement Program Seed Orchards and Breeding Sublines. SO - seed orchard, SL - breeding subline, N/A - not applicable, a - acres

Species	Orchard/ Subline	Type	Families/ Clones	Planted	Trees	Area (a)	Region	Rogued
Black Spruce (*P.mariana*)	Eaglehead	half-sib seedling	128	1978	582	3	III	1986
	Split Rock	Imp 1st Clonal	20	1992	262	3	III	N/A
Jack Pine (*P.banksiana*)	Bemidji	half-sib seedling	125	1984	406	3	I	1991
	Nickerson	half-sib seedling	128	1984	403	3	III	1991
	Long Prairie	half-sib seedling	145	1984	495	4	III	1991
Red Pine (*P.resinosa*)	Cotton	half-sib seedling	17	1981	465	5	II	1991
	Eaglehead	half-sib seedling	42	1981	388	4	III	1991
White Pine (*P.strobus*)	St. Francis	clonal	15	1985	248	3	III	
White Spruce (*P.glauca*)	Cotton	clonal	26	1977	212	12	II	1997
Red Oak (*Q. rubra*)	GAN	SL	25	1992	104	1	III	N/A
	Booker Farm	SL	25	1993	82	1	III	N/A
	Rochester	SL	25	1990	49	1	V	N/A
	Gordon	SL	25	1990	73	1	V	N/A
	Split Rock	SO	38	1992	156	1	III	
	Faribault	SO	29	1992	273	3	V	
Black Walnut (*J. nigra*)	Delanie	SL	25	1990	107	1	V	N/A
	Wet Bark	SL	25	1988	107	1	V	N/A
	Geothite I	SL	25	1989	100	1	V	N/A
	Geothite II	SL	25	1989	59	1	V	N/A
	Rochester	SL	25	1990	75	1	V	N/A
	Chester Woods	SO	66	1989	185	2	V	
	Gordon	SO	65	1990	313	4	V	

Plans for Conifer Species

Genetic improvement programs and activities for conifer species are coordinated with the Minnesota Tree Improvement Cooperative. The cooperative has adopted an approach designed to produce large quantities of seed with a modest amount of genetic gain in as short a time as possible.

White Spruce

State nurseries sold more than 1.4 million white spruce seedlings in 1997, or 17% of total state nursery sales. Over 860,000 of white spruce seedlings sold were improved. Demand for white spruce seedlings is expected to increase slightly, mostly as a substitute for non-native species no longer produced by the state nursery program.

The Cotton white spruce seed orchard is a clonal orchard comprised of southeast Ontario origin material. A bumper crop of cones were harvested in 1996, with over 300 pounds of seed extracted. Orchard roguing was completed summer 1997.

A progeny test comprised of Ontario and Lake States material was established in 1986 and analyzed in 1995. From this analysis top performing clones and families were identified. Grafting of these clones and families began in 1995 and will continue for two or three more years, or until sufficient grafts are completed to establish an improved first generation clonal seed orchard. Site selection will begin spring 1999. Orchard establishment could be as soon as 2001.

The Cotton orchard and the planned improved first generation orchard will produce sufficient improved seed for the near future.

Control pollination breeding will be conducted with the eventual establishment of a second generation orchard. Control pollination breeding will begin spring 1998 or, when there is a sufficient flower crop. Second generation full-sib progeny tests could be established as early as 2001.

A white spruce comparison trial was established on five sites in spring 1993 to compare growth rates of four different genetic sources. The four sources are a woods-run local source, seed collection area, Cotton seed orchard of southeast Ontario origin and, seedling seed orchard of Minnesota origin. This test will be measured fall 1997.

Black Spruce

State nurseries sold 178,000 black spruce seedlings in 1997, or 2% of total state nursery sales. Over 106,000 of black spruce seedlings sold were improved. Planting programs for black spruce are expected to be small in the future.

Eaglehead first generation seedling seed orchard and Split Rock improved first generation clonal orchard will provide sufficient seed for the near future.

There are no long term plans for advanced generation tree improvement efforts in black spruce. Orchards will be maintained and seed will be collected as good cone crop years arise.

Red Pine

State nurseries sold nearly 3 million red pine seedlings in 1997, or 35% of total state nursery sales. Red pine is the most-planted species in the state. Planting programs for red pine are expected to remain steady in the future.

There are two red pine seed orchards. The Cotton and Eaglehead seedling seed orchards were planted in 1981 and are now starting to produce harvestable amounts of seed and should do so for 20 years. These two orchards will produce about one third of anticipated seed needs. Additional orchard acreage is necessary.

Although there is relatively little genetic variation in red pine, improvement efforts are cost effective, primarily because it is the most planted species in the state. Silvicultural systems for red pine have been fully developed providing high regeneration success.

In the next five years activities will concentrate on developing grafting protocols and the establishment of improved first generation orchards. Improvement activities will eventually lead to controlled breeding for the establishment of second generation seed orchards.

Jack Pine

State nurseries sold 645,000 jack pine seedlings in 1997, or 8% of total state nursery sales. Over 340,000 of jack pine seedlings sold were improved. Planting programs for jack pine are expected to remain steady.

There are currently three jack pine seed orchards; Long Prairie, Nickerson and Bemidji. The Bemidji orchard is seriously infected with a number of insect and disease problems. There are harvestable cones, although few. This orchard will eventually be abandoned. The other jack pine orchards are in excellent condition and are expected to provide the program with sufficient amounts of seed for the next ten to 15 years.

Controlled pollinations have been completed that will lead to the establishment of a second generation orchard. The orchard will be established and maintained cooperatively with Crow Wing County Land Department and costs will be shared. The orchard site has been selected. Planting will occur spring 1999. The second generation orchard, combined with existing jack pine orchards, will provide for improved seed needs well into the future.

White Pine

State nurseries sold 864,000 white pine seedlings in 1997, or 10% of total state nursery sales. Planting programs for white pine are expected to increase because of recent renewed interest in white pine and new legislatively appropriated monies specifically for white pine regeneration.

There is one white pine seed orchard. The St. Francis seed orchard contains material believed to have some degree of blister rust resistance however, none has been formally tested. This orchard should begin producing harvestable quantities of cones in the next few years. Orchard acreage will need to be doubled in order to produce anticipated seed needs.

This orchard will be expanded to include new clones believed to be blister rust resistant as well as having increased growth. Activities the next five years will be locating, collecting and grafting new clonal material for the St. Francis orchard.

Plans for Hardwood Species

Red oak and black walnut are under strong harvest pressure. In addition to increased gains in wood quality and volume, conservation of genetic resources is an important objective in the hardwood tree improvement program.

Red Oak

State nurseries sold 620,000 red oak seedlings in 1997, or 7% of total state nursery sales. Planting programs for red oak are expected to increase, in part as a result of increased funding assistance for private planting.

There are two red oak seed orchards. The Split Rock seed orchard is in poor condition and likely will be moved or abandoned. The poor condition of this orchard is primarily because of heavy, wet soils. The Faribault orchard is in good condition. These orchards will provide only a small fraction of anticipated seed needs.

Improvement activities the next five years will concentrate on developing and implementing orchard and subline management guidelines. Special emphasis will be placed on deer browse and rodent control. Orchard and subline surveys will be conducted fall 1997 and 1998. Survey results will be used to determine which clones are needed to fully stock subline and orchard plantings. Grafting replacement stock will begin in 2000. Once orchards are fully stocked and producing harvestable quantities of nuts, progeny tests will be established to evaluate orchard trees.

Black Walnut

State nurseries sold 131,800 black walnut seedlings in 1997, or 2% of total state nursery sales. Planting programs for black walnut are expected to increase, in part as a result of increased funding assistance for private planting.

There are two black walnut seed orchards. The Chester Woods and Gordon seed orchard are in very good condition. These orchards will provide only a small fraction of anticipated seed needs.

Improvement activities the next five years will concentrate on establishing and implementing orchard and subline management guidelines. Special emphasis will be placed on deer browse and rodent control. Orchard and subline surveys will be conducted fall 1997 and 1998. Survey results will be used to determine which clones are needed to fully stock subline and orchard plantings. Grafting replacement stock will begin in 2000. Once orchards are fully stocked and producing harvestable quantities of nuts, progeny tests will be established to evaluate orchard trees.

References and Suggested Reading

Wright, Jonathan. 1976. Introduction to Forest Genetics. Academic Press, Inc.

Zobel, Bruce T. and John Talbert. 1984. Applied Forest Tree Improvement. John Wiley & Sons, Inc.

Minnesota Department of Natural Resources
Division of Forestry

Circular Letter To: All Forestry Personnel
Subject: Nursery Seed Source Control
Date: January 9, 1996
File: #3421-2

(Replaces Circular Letter 3421-2 dated June 27, 1983)

Purpose

The goal of the DNR Nursery and Tree Improvement Program is to economically produce forest regeneration material of the highest genetic and biologic quality in the quantity needed for environmental programs. It has been recognized for many years that seed source control is the cornerstone of a successful reforestation program. The use of properly adapted seed sources is the necessary first step in establishing forest tree plantations. Usually, seed sources nearest the intended planting zone are best.

The purpose of this policy is to establish control of forest tree seed sources utilized by the state forest nurseries, such that identity of seed is maintained from collection through to redeployment as direct seedings or seedlings. This policy is intended to promote the practice of returning seed and seedlings back to their zone of origin.

Responsibilities

The Tree Improvement Program Coordinator directs the state Tree Improvement Program and suggests policies to the Directors Management Team. The Tree Improvement Coordinator, the Nursery Supervisors, Regional Silviculturalists, and Area Forest Supervisors share responsibilities for policy administration. Nursery personnel, Area Program Foresters, and Area Technicians are responsible for policy implementation.

Policies

Seed Zones

Based on prevailing climatic conditions, the State of Minnesota has been divided into six seed zones. These seed zones essentially follow administrative area boundaries existing on July 1, 1994 and are shown in Exhibit I. Because of documented poor performance, North Shore tree seed sources should be avoided for use in forest plantations. Other plants of significant interest from the shore zone will be processed.

Seed Source Control at the Point of Origin

Areas will be responsible for locating and recording forest tree stands having potential for good seed production, for species identified by the State Forest Nurseries. Seed collection and production areas should be located on state lands where possible. Formal cooperative agreements can be considered for other ownerships. These stands should be recorded by completing Form NA-02074-01, 'Seed Collection Stand Record', and submitted to the State Forest Nurseries for review and selection (see Exhibit II).

Seed collection and production areas should be reserved for seed production. The Area should prepare a management plan with cooperation from the Division Tree Improvement Specialist to indicate how the stand will be managed and how seeds or cones will be harvested. Each year, the Area will estimate the seed or cone crop in designated stands, reporting these estimates to the State Forest Nurseries no later than August 1.

Seed collection goals and prices to be paid will be set by the State Forest Nurseries with input from the local Area to reflect market prices. The area will be responsible for meeting assigned seed collection goals. Cone and seed collection should be directed toward seed collection and production areas previously determined. Cones and seed may be accepted from non-selected stands; however, the Area should inspect and approve these stands prior to accepting cones or seed. Cones and seed may be obtained by direct purchase from individuals, contracts awarded by competitive bidding, or collections by Division of Forestry personnel; but only from approved sites. Expanded contract purchasing and vendor development can be investigated through Nursery and Area cooperation.

If cones or seed are to obtained by direct purchase, the Area should advertize locally so that cones or seed will be purchased only from individuals registered to collect cones or seed from approved sites. Cones or seed collected in stands other than approved seed collection and production areas should only be purchased following inspection and approval by the Area.

The area should inspect samples of cones and seed for maturity and seed set. Immature seed, or cones with seed set below established standards for the species should not be purchased.

The area should measure, sack, and tag all seed and cones purchased in their area. At a minimum, tags should include the species name, the measured volume, the seed zone (Exhibit I) and the date collected (if known). If cones and seed cannot be shipped to the State Forest Nursery immediately, the Area should store cones and seed under conditions appropriate for each species to prevent molding, heating, rodent depredation, and other problems that may affect seed quality. If storage and hauling becomes a problem for the local Area, the Nursery should be contacted for pickup.

Seed Source Control at the State Forest Nurseries

Upon receipt at the State Forest Nurseries, an accurate record of cones and seed received will be maintained. Cones and seed should be properly stored until processing. Accurate and precise seed source records will be kept from extraction through storage of cleaned seed. Seed storage containers should contain both the Area name and seed zone number. Seed extraction, yield and quality reports will be forwarded to the Areas each year by April 1st.

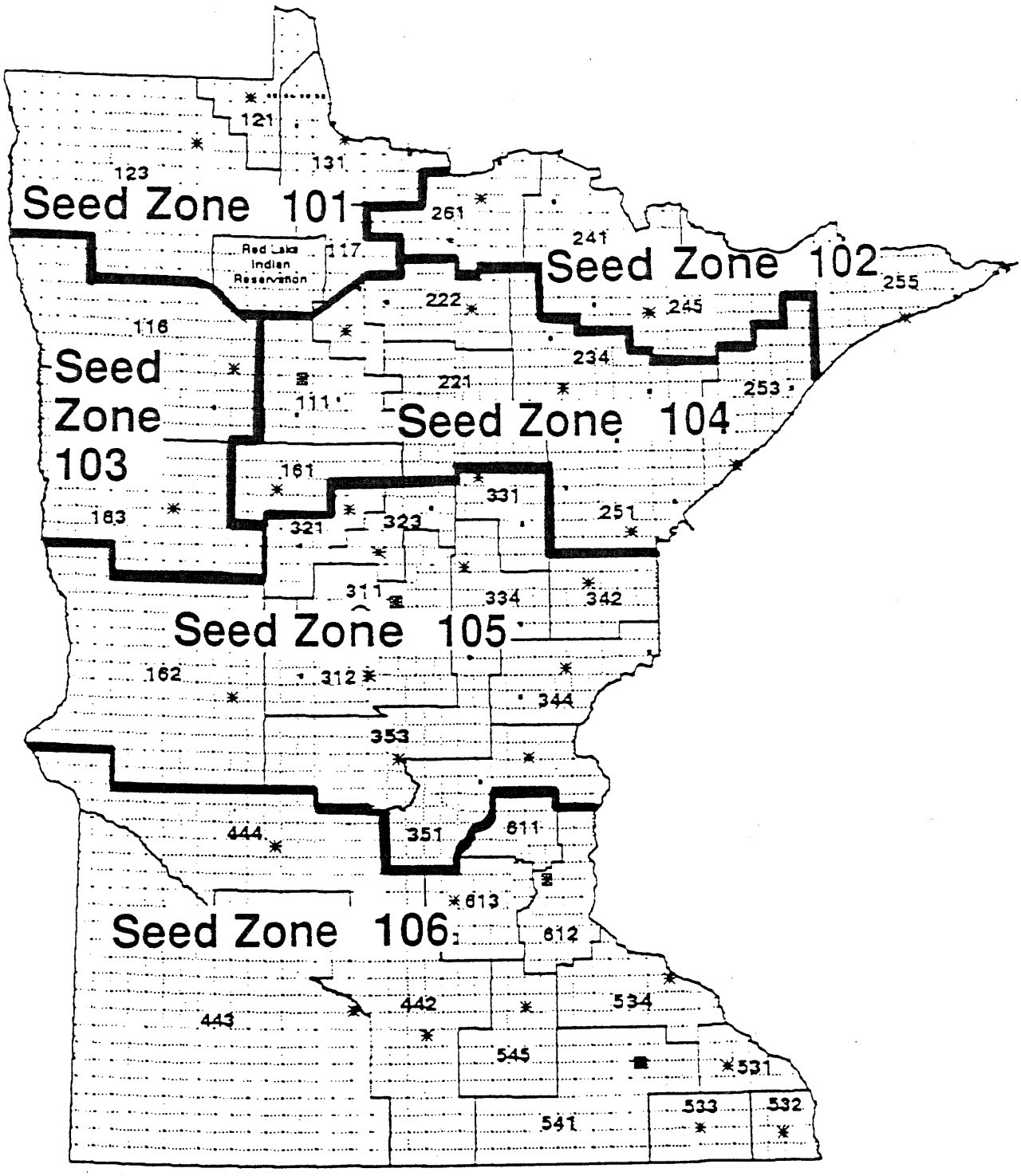
When seed is sown in the State Forest Nurseries, accurate and precise records will be kept including seed zone number, where it was sown in the nursery, and the date of sowing. Records should be sufficient so that any seedling can be identified by seed zone at all times.

When seedlings are lifted, sorted, packed, and shipped, they should be returned to their seed zone of origin whenever possible. If seedlings are requested for a seed zone from which no seed was either produced or available, an appropriate seed source may be substituted. Appropriate substitute seed sources should be determined prior to the packing season. To comply with plantation record-keeping in the Forest Development Module, seedlings shipped for state lands should include the seed zone number on the shipping container.

1-9-96
Date

/s/
Gerald A. Rose
Director, Division of Forestry

EXHIBIT I


Seed Zone 101
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Red Lake Indian Reservation
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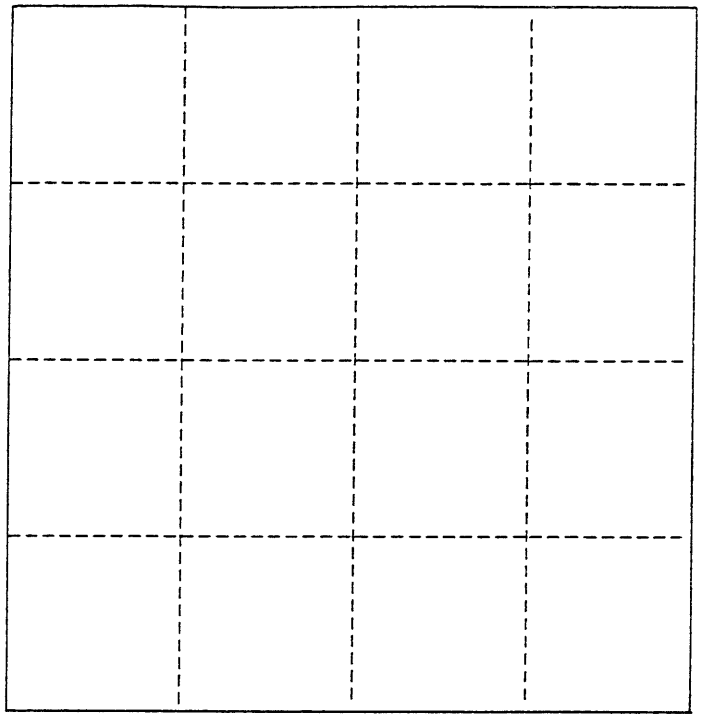
EXHIBIT II

NA-02074-01

DEPARTMENT OF NATURAL RESOURCES

SEED COLLECTION STAND RECORD

SCALE (Mark One) ☐ 4" to Mile ☐ 8" to Mile



Species				
Stand Number	R.A.D.	Section	Township	Range
Access				
Basal Area	Original Acres	Average Stems/Acres		Age
Site Index	Average Height	Year Selected		

GENERAL REMARKS:

MANAGEMENT PLANS AND SPECIAL CONDITIONS:

CONE COLLECTION RECORD

YEAR	* No. ACRES CUT	BUSHELS COLLECTED	SEED LOT No.	YEAR	* No. ACRES CUT	BUSHELS COLLECTED	SEED LOT No.

* ALTER MAP ACCORDINGLY