

THE DOUGLAS-FIR BREEDING AND SEED ORCHARD PROGRAM FOR THE NORTHERN REGION, U.S. FOREST SERVICE

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INTRODUCTION

Objectives of the Program

The objective of the Douglas-fir breeding program for the Northern Region of the U.S. Forest Service is to provide site adapted seedlings selectively bred for improved hardiness, growth and wood quality for the Region's artificial reforestation program. An equally important goal will be to maintain genetic diversity in the species. The improved seedlings will come from intensively managed seed and hedge orchards made up of proven, genetically superior genotypes.

Projected Seedling Needs

The Region's anticipated annual Douglas-fir seedling needs for the first decade of the 21st Century are shown in Table 1.

Table 1. — Estimated annual Douglas-fir seedling needs by the Year 2000.

NF Area	Seedling Needs*
Central Montana	671.6M
Western Montana	2008.4M
North Idaho	2572.0M
Total	5252.0M

*1984 projections based on draft Forest plans

DOUGLAS-FIR BREEDING UNITS

Transfer Guidelines

Genecology studies have shown that interior Douglas-fir is narrowly adapted to increasing cold. A significant portion of a population moved very far up in elevation from its point of origin may be severely damaged by cold. Similar damage may occur to populations moved too far north of their latitude of origin.

Geographic Boundaries

Limitations on the movement of Douglas-fir have resulted in the establishment of eight geographic breeding unit boundaries. The geographic areas are as follows:

1. **Breeding Unit 12**—All of the Idaho Panhandle National Forest and the west half of the Kootenai National Forest.
2. **Breeding Unit 34**—All of the Clearwater and Nezperce National Forests.

3. **Breeding Unit NW**—The east half of the Kootenai National Forest and the northwest half of the Lolo National Forest.
4. **Breeding Unit SW**—All of the Bitterroot National Forest and the southwest one-quarter of the Lolo National Forest.
5. **Breeding Unit NE**—All of the Flathead National Forest and the east half of the Lolo National Forest.
6. **Breeding Unit 7**—Breeding Unit 7 is subdivided into two geographic areas identified as 7A and 7B. Breeding Unit 7B is described as those parts of the Lewis and Clark National Forest lying east of the Continental Divide and north of US Highway 12 and those portions of the Beaverhead and Deerlodge National Forests lying south and west of the Continental Divide.

Breeding Unit 7A includes all of the Helena, Gallatin National Forests, most of the Deerlodge National Forest, the west half of the Custer National Forest and small portions of the Beaverhead and Lewis and Clark National Forests.

Elevational Boundaries

The geographic areas described in the previous section have been further divided into elevational zones. These elevational zones are summarized in Table 2.

Table 2. — Douglas-fir breeding units and elevational zones.

Breeding Unit	Low	Mid	High
Idaho 12	<3099'	3100'–4099'	4100'+
Idaho 34	<3300'	3301'–4200'	4201'+
Montana NW	2500'–3999'	xxx	4000'+
Montana NE	3500'–4699'	xxx	4700'+
Montana SW	3500'–4999'	xxx	5000'+
Montana 7A	--- All Elevations ---		
Montana 7B	--- All Elevations ---		

The geographic boundaries and elevational zones for Douglas-fir are shown in Figure 1.

EARLY SELECTION TRIALS

To provide early and reliable growth information on all of the material to be tested in the Douglas-fir program, intensively managed early selection tests have been or will be established for each of the 14 Douglas-fir breeding units. The early selection tests are established on mild sites in developed tree improvement areas and are managed in a manner to minimize extraneous environmental effects.

Establishment and Design

The early selection test established, or to be established, in the Region's Douglas-fir program are planted with seedlings

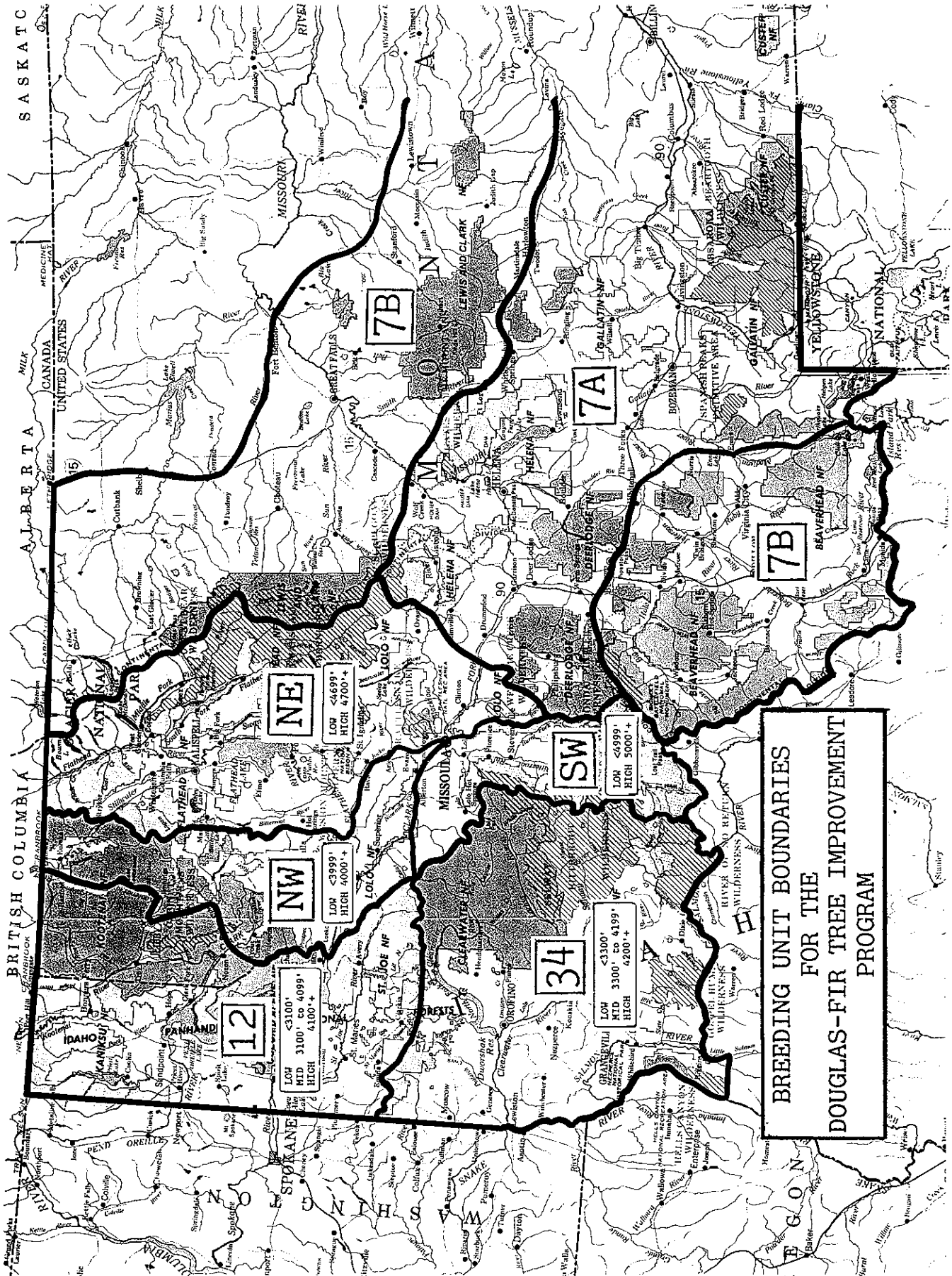


Figure 1. - Geographic boundaries and elevational zones for the Douglas-fir Tree Improvement Program.

grown from open pollinated seed collected from the wild parent plus-trees. They are shown in super cells and planted as 1-0 stock.

The early selection tests are planted in randomized complete blocks at a 2.85 X 2.85 foot spacing in 3 tree X 8 tree family plots. Each family plot is replicated 2 times for a total of 48 individuals per test. Only one test is established for each breeding unit. To minimize edge effect, each test is surrounded by two border rows of the same species.

Maintenance

The Douglas-fir early selection tests are intensively managed in a manner to prevent environmental stress. Uniform watering and fertilization are provided as necessary. Frost protection is provided as needed. The tests are weeded of competing vegetation and preventative measures are taken to avoid damage by insects and diseases.

Measurement and Analysis

Baseline height measurements are made in the Douglas-fir early selection tests at two years from seed (one growing season in the ground). The final measurement is made at five years from seed. The characteristics measured at the time of final measurement are total height and length of second flush.

Before analysis, baseline height is subtracted from final height and adjustments are made in the data for differences between replications. The data is then applied to a formula that provides a hardiness/growth index for each individual and family. The hardiness/growth index is used to rank families and individuals within families. Damaged individuals are excluded from the calculations. The formula for calculating the hardiness/growth index is:

$$H/G = (.2 \times \text{ad. ht.}) + (-18 \times \text{Prop. of 2nd Flush})$$

Elite Tree Selection

1. For Breeding Orchards. Using the hardiness/growth index ranking, the best five individuals in the best 50% of the families are identified for advanced generation breeding.
2. For Seed Orchards. Using the same hardiness/growth ranking, the best two individuals from the top 17 families and the best single individual in the next 16 families in each breeding unit are identified for seed orchard trees. The proportion of best individuals and best families may vary in order to provide a selection intensity (i) of at least 3.6
3. Genetic gain is calculated for selected seed orchard trees.

Disposition of the Tests

Trees in the Douglas-fir early selection test that are not selected for seed or breeding orchards or are not utilized for rootstock will be offered to other cooperators in the Douglas-fir Species Group of the Inland Empire Tree Improvement Cooperative.

ROOTED CUTTING PERFORMANCE TESTS

Long-term performance tests are established for each breeding unit to provide a measure of the fitness of selected elite trees

on natural sites over time. The performance tests will also provide data for advanced generation breeding. Information from the performance tests will be used to rogue poor genotypes from or add new genotypes to the seed orchards.

Establishment and Design

Rooted cutting performance tests are to be established for each breeding unit with sticklings from the best five individuals in the best 50% of the families in the early selection test. Open pollinated or controlled pollinated seedlings may be included in the performance tests for the purpose of providing gain estimates, for comparing selected material with ancestral or commercial checks, or for providing growth and yield estimates. These are described in more detail in the section on seedling field tests.

Rooted cuttings will provide a better estimate of the performance of selected individuals. If a better estimate of family means is needed, additional seedlings from those families may be included in the test.

The performance tests will be planted in 8 X 8 foot, non-contiguous, single tree plots. There will be 1 ramet per replication, 3 replications per test, 2 tests per breeding unit. If seedlings are also to be planted for the purpose of refining family means, they will be planted in the same manner but with 7 seedlings per family per replication.

The performance tests will be established on carefully selected and prepared sites. Test sites will be selected that are within the normal range of the species, in the appropriate geographic area and elevational range, and on a habitat type in which Douglas-fir is desirable or acceptable.

Maintenance

The Douglas-fir performance tests will be managed at the state-of-the-art to maximize survival. Guidelines for test plantation management are provided in Chapter 500 of the Tree Improvement Handbook and in "Installation, Maintenance & Measurement Guidelines for Genetic Tests" published by the Inland Empire Tree Improvement Cooperative (IETIC).

Measurement and Analysis

The Douglas-fir performance tests will be measured at five year intervals or as needed for up to one-half a rotation age. While hardiness and growth will continue to be characteristics of interest, the main purpose of the test will be to score individuals for general fitness on natural sites. The measurement of specific environmental factors on individuals and families in the test will be made as the opportunity presents itself.

The data from the performance tests will be used to measure family and individual performance for hardiness, growth, and response to other environmental factors and will provide an evaluation of material in seed orchards and breeding orchards.

Disposition of the Tests

The Douglas-fir long-term performance tests will be maintained for up to one-half a rotation age or for as long as useful

genetic data or material can be obtained from them. After that they will revert back to operational plantations. The tests may continue to serve as gene pools and may be used in the future to reconstitute the Douglas-fir breeding population.

CHECK POPULATIONS

Gain Estimate Plots

To provide a measure of genetic gain for the material in the Douglas-fir breeding program, gain estimate plots will be established in conjunction with selected performance tests. These plots will be established adjacent to the performance tests with seedlings from 50 randomly selected families from within the breeding unit. The trees will be planted at 5 X 10 foot spacing in 5 tree row plots, 10 individuals per replication (2 random family plots per rep), 3 reps per test. The gain estimate plots will be maintained and measured the same as the performance test. A gain plot will be established in conjunction with one performance test in BU 12-low & high, BU 34-low & high, BU NW-low, BU NE-high, BU 7A, and BU 7B.

Ancestral Populations

To provide a measure of how well selectively bred Douglas-fir material is performing compared to the original, unselected population, certain of the early selection tests and long-term performance tests will include plots with ancestral populations.

Ancestral seed lots will be collected from dedicated stands such as parks, recreation areas, buffer zones, wilderness areas, or general forest zones for which there is reasonable expectation that they will remain intact and therefore recollectable for a period of 50-60 years. As a hedge against the loss of some of the ancestral stands, sufficient seed from each will be maintained in the tree improvement seed bank to meet the needs of the program for the foreseeable future. The ancestral stands will be recollected periodically to assure a supply of seed with good germination.

Maintenance and measurement of the ancestral population plots will be the same as the early selection trial or performance test that they are planted with.

SEEDLING FIELD TESTS

In the Spring of 1982, nine Douglas-fir field tests were established in Breeding Unit 12. In the Spring of 1984, nine were established in Breeding Unit 34. In 1985, two were established in Breeding Unit SW-high and three in Breeding Unit NE-low. These seedling tests were established as part of the IETIC Douglas-fir plan with the primary purpose of providing family comparison. Nineteen of these tests are still viable tests and will continue to be a source of information for the Region One Douglas-fir breeding program.

Establishment and Design

The seedling field tests were planted with seedlings grown from open pollinated seed from wild parent plus-trees. They were planted at 5 X 5 foot spacing, 9 individuals per family per replication, 4 replications per test, 3 tests per breeding unit.

Maintenance

The seedling field tests were to be maintained at the-state-of-the-art as specified in the IETIC maintenance guidelines; however, because they are on many different ownerships maintenance has varied.

Measurement and Analysis

Baseline measurements have been made in most of the tests and additional measurements are being made at 5 year intervals from baseline. The data will be used to rank families for growth with the family mean for the difference between current height and baseline height as the ranking statistic.

Disposition of the Tests

As with the performance tests, the seedling field tests will continue to be maintained as a genetics test for up to one-half a rotation age or for as long as they yield useful data. They will also serve as a gene pool for advanced generation breeding.

SEED ORCHARD ESTABLISHMENT

First generation Douglas-fir seed orchards will be established at the Dry Creek Improvement Area for Breeding Units 12 and 34 and at the Bigfork Tree Improvement Area for Breeding Units NE, NW, SW, 7A and 7B. For most of the breeding units, the seed orchards will be established by converting early selection tests already on the site. Breeding Units NE-low and NE-high will be established vegetatively from an early selection test in Missoula (Figure 2).

Source of Material

First generation Douglas-fir seed orchards will be established for each breeding unit from the best two individuals from the top 17 families and the best single individuals from the next 16 best families in the early selection trials. Early selection trials at Dry Creek and Bigfork will be converted directly into seed orchards and selected trees will simply be moved to seed orchard coordinates. In addition, the selected genotypes will be multiplied in the seed orchard vegetatively by grafting with non-selected trees used as root stock. Scionwood may also be taken from truly outstanding individuals in field tests if it seems desirable to do so.

Design

The Douglas-fir first generation seed orchards will be planted at a 20 X 20 foot spacing. The SOMAD program will be utilized in the design of the orchard in order to maximize distance between related genotypes.

Management

The Douglas-fir seed orchards will be managed in a manner to promote early and abundant flowering. A management plan to accomplish this objective will be prepared for each seed orchard.

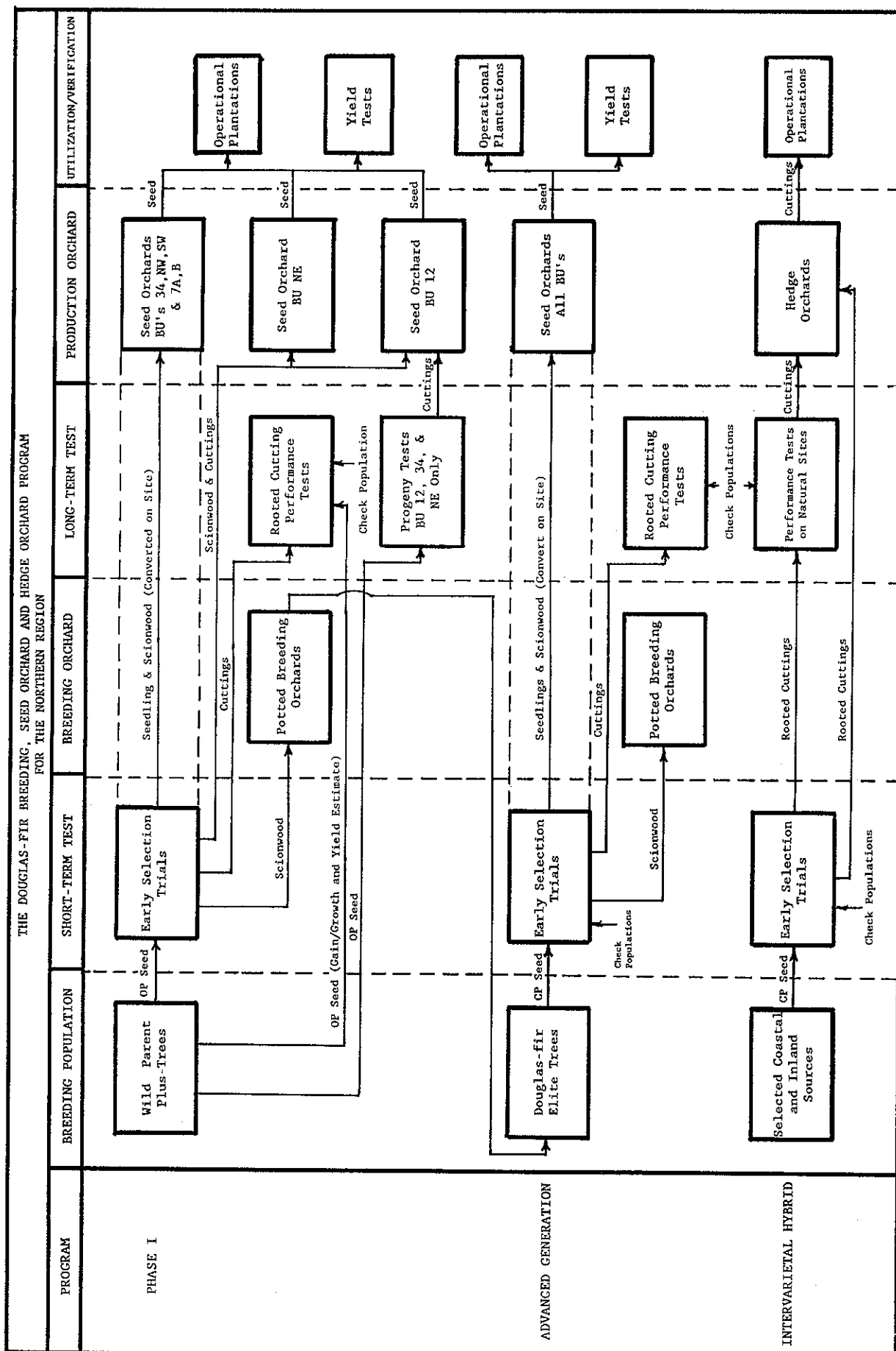


Figure 2.—The Douglas-fir Breeding, Seed Orchard and Hedge Program for the Northern Region.

Verification

As soon as the first generation Douglas-fir seed orchards become productive, yield tests will be established to verify the genetic worth of the seed coming from the orchard. The design of the yield tests has yet to be determined.

Disposition

The first generation seed orchards will serve as a source of seed for operational planting of Douglas-fir only until the advanced generation seed orchards become productive. When seed is no longer needed from the first generation seed orchards, the site will be used for some other tree improvement project.

BREEDING ORCHARDS

Advanced generation breeding in the Douglas-fir program will be done in potted breeding orchards to be established in special breeding houses at the Coeur d'Alene Nursery.

Source of Material

The Douglas-fir breeding orchards will be established vegetatively via grafting or rooting from the best five individuals in the best 50% of the families in each of the early selection trials. The genotypes are included in the long-term performance tests.

Management

Flower induction techniques will be utilized to promote flowering on the potted seed orchard trees.

Disposition

Once all of the desired crosses have been made and enough seed is on hand to establish advanced generation tests, the potted orchard trees will either be planted out on a tree improvement area as a gene bank or made available to another cooperator in the Douglas-fir species group for outplanting as a back-up orchard.

ADVANCED GENERATION BREEDING

Mating Design

Advanced generation material will be created by making controlled crosses among the potted breeding orchard trees using a four or five tree disconnected factorial mating scheme. Breeding orchards will be established by breeding unit and crossing will be done only among trees in each unit (Figure 2).

Testing Procedure

It is anticipated that advanced generation Douglas-fir material will be tested utilizing the same test design, test management, measurement schedule and data analysis as has been described above, (i.e., Early Selection Trials, Rooted Cutting Performance Tests, Seedling Field Tests, and Seed Orchard Establishment).

INTERVARIETAL HYBRIDS

In the late 60's and early 70's, scientists at INT made a series of controlled crosses: 20 inland Douglas-fir material sources and 25 coastal Douglas-fir pollen sources. From these crosses 91 full-sib hybrid families were created. These hybrid families are now represented in a single test plantation at 3400 feet in elevation in Green Creek on the Clearwater District of the Nezperce National Forest. (Figure 2).

Accomplishment to Date

The Green Creek intervarietal hybrid field test was measured in 1985 after ten years in the ground. The Douglas-fir hybrids were found to have almost equalled the survival of the inland parental lines and doubled their height growth. Both hybrids and inland lines surpassed the survival and height growth of the coastal parental lines. The performance of the hybrid families is felt to reflect high specific combining ability.

In 1984, cuttings were collected from 26 of the best looking hybrids in the Green Creek field test. These cuttings were rooted and planted in a 50 tree hedge orchard at the Dry Creek Tree Improvement Area. Rooted cuttings from the Dry Creek hedge orchard will be used in operational reforestation on selected sites in north Idaho. The selection of the 26 best trees and the establishment of the hedge orchard at Dry Creek is hereafter referred to as "Phase 1" of the Douglas-fir Intervarietal Hybrid program.

Generating New Material

Phase 1

When they become reproductive, the 26 best individuals in the Green Creek field test will be backcrossed with selected, interior Douglas-fir elite trees from the Region's selective breeding program.

Phase 2

As the seed orchards for each of the Douglas-fir breeding units become productive, crosses will be made between selected individuals in those seed orchards and selected individuals in coastal seed orchards. In so far as possible, crosses will be made between individuals from similar latitudes and elevations.

Testing Procedure

Material generated by both the Phase 1 and Phase 2 Douglas-fir Intervarietal Hybrid program will be tested in early selection trials. The material in the early selection trials will be scored and ranked for hardiness and growth using the hardiness/growth index. Representative seedlings from interior parents, and from coastal parents if appropriate, will be included in the test.

Rooted cuttings from selected individuals in the early selection trials will be outplanted in long-term performance tests on natural sites.

Hedge Orchard Establishment

Selected high ranking individuals in the Phase 1 and Phase 2 early selection trials will be used to establish "advanced generation" hedge orchards. Data from the long-term performance test will be used to rogue the hedge orchards. The early selection trials will be retained as breeding arboretums. Sticklings from the hedge orchard will be operationally planted on sites within the appropriate breeding units.

COOPERATION WITH THE IETIC

All activities in the Northern Region's Douglas-fir program will be coordinated with the Douglas-fir Species Group of the Inland Empire Tree Improvement Cooperative. Whenever possible, selective breeding work will be done cooperatively. This includes, but is not limited to, allowing field tests to be established on cooperator land, helping with the establishment and measurement of early selection tests and sharing data from genetic tests.

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