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**Timber
Management**

Progeny Testing

Proceedings of Servicewide Genetics Workshop Charleston, South Carolina December 5-9, 1983

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Dr. David Canavera, Westvaco, and his staff are recognized for their excellent job in hosting the field trip. Our thanks also go to Dr. Hans van Buijtenen for his involvement in the workshop. Finally, we appreciate the involvement and contributions of all participants who helped make this a most successful workshop.

Dick Miller
Genetics Section
Silviculture Group
Timber Management Staff
USDA Forest Service
Washington, DC.
March 1984

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Forest Genetics Workshop
December 5-9, 1983
Charleston, South Carolina

Monday

8:00 a.m.	Opening Remarks	
8:15 a.m.	Objectives of Workshop	Dick Miller
	I. Biological Limits of Seed/Breeding Zones	
	Moderator - LeRoy Johnson	
8:30 a.m.	Methods used to determine the biological limits of breeding zones in the Pacific Northwest.	Bob Campbell
9:00 a.m.	Methods used to determine seed transfer rules in the Inland Empire.	Jerry Rehfeldt
10:00 a.m.	Break	
10:15 a.m.	Seed/breeding zones and adaptation in the South.	Ozzie Wells
10:45 a.m.	Seed/breeding zones and adaptation in the Lake States.	Don Riemenschneider
11:15 a.m.	Evaluating breeding zones for ponderosa pine in California.	Tom Conkle
11:45 a.m.	Lunch	
	II. Progeny Testing--Objectives and Designs	
	Moderator - Ralph Lewis	
1:00 p.m.	Objectives for progeny testing.	John Kraus
1:30 p.m.	Statistical designs and how they relate to objectives and sites.	Floyd Bridgewater Steve McKeand
2:45 p.m.	Break	
3:00 p.m.	Short-term versus long-term progeny tests.	Jerry Rehfeldt and Earl Sluder
4:00 p.m.	Check lots--how many and genetic makeup.	John Brissette
4:30 p.m.	Converting progeny tests to seed orchards--pros and cons.	Ron Hamilton

Tuesday

8:00 a.m.	How many plantations should be established?	John Kraus
8:30 a.m.	Mating designs for genetic tests of forest trees.	Hans van Buijtenen
10:00 a.m.	Break	
10:15 a.m.	Round Table--Regional objectives and designs.	George Howe Jay Kitzmiller Janet Brotschol Jim McConnell John Murphy
11:45 a.m.	Lunch	

III. Progeny Testing--Nursery

Moderator - Clark Lantz

1:00 p.m.	Advantages and disadvantages of bare-root and container seedlings and of vegetatively propagated plant material.	Bill Randall
1:30 p.m.	Nursery Techniques--replication, sowing, culture, assessment, lifting, sorting, and packing.	Dave Van Haverbeke
2:15 p.m.	Comments from a Nursery Manager.	Frank Morby
2:45 p.m.	Experience with contract growing.	Pete Theisen
3:15 p.m.	Break	
3:30 p.m.	Round Table--Review of nursery techniques.	Joe Myers Gaylord Parks Jim Hamlin Jim Gates Dick Meier

Wednesday

IV. Progeny Testing--Field

Moderator - Dick Jeffers

8:00 a.m.	Site selection, site preparation, and test layout.	Jim Gates
8:30 a.m.	Progeny Test Management--animal control, release, and fertilization.	Carol Apruzzese

	Progeny Test Management--thinning and insect and disease control.	Sharon Friedman
9:15 a.m.	What is the influence of competition on selection of genotypes?	Carlyle Franklin
9:45 a.m.	Break	
10:00 a.m.	Round Table--Progeny test establishment and management including who performs tasks and training.	Jerry Franc Paul Stover Sheila Martinson Tim LaFarge Don Dorn
11:30 a.m.	Lunch	

V. Data Management

Moderator - Chuck Frank

12:30 p.m.	Round Table--Measurements--what, when, how, and why?	Jerry Franc Dick Jeffers Steve Grass Bill Randall Tim LaFarge Ross Melick

Moderator - Ron Overton

2:00 p.m.	Round Table--Computer systems for keeping track of plant materials and data analysis.	Jay Kitzmiller Sharon Friedman Ralph Lewis John Murphy

Thursday

Field Trip

Friday

8:00 a.m.	Comments from Deputy Director Timber Management	Dave Jolly

VI. Advanced Generation Strategies

Moderator - Janet Brotschol

8:15 a.m.	Strategies for maintaining the genetic base--how will advanced generation tests differ from first?	Hans van Buijtenen
9:30 a.m.	Break	

9:45 a.m.	Pest conditions in progeny test areas in the Southern Region.	Steve Oak
10:10 a.m.	Genetic mapping in the Pacific Northwest.	Roy Silen
10:25 a.m.	Progeny testing the pitch-lob hybrid.	Pete Garrett
10:40 a.m.	Reforestation Productivity Improvement Team recommendations and their impact on artificial regeneration programs.	Dick Shaffer
10:55 a.m.	Closing announcements	
11:00 a.m.	Adjourn	

GENETICIST WORKSHOP LIST OF ATTENDEES

Joe Myers	Horticulturist	R-1 Coeur d'Alene, ID
George Howe	Regional Geneticist	R-1 Missoula, MT
Jerry Franc	Breeding Specialist	R-1 Moscow, ID
Richard Jeffers	Regional Geneticist	R-2 Denver, CO
Kenneth Ready	Regional Geneticist	R-3 Albuquerque, NM
Ron Hamilton	Silviculturist	R-4 Ogden, UT
Jay Kitzmiller	Regional Geneticist	R-5 Chico, CA
Gaylord Parks	Zone Geneticist	R-5 Placerville, CA
Steve Grass	Geneticist	R-5 Placerville, CA
Wilbur Charter	Head Tim. Planning and Silvi.	R-5 San Francisco, CA
Chuck Frank	Zone Geneticist	R-5 Yreka, CA
Paul Stover	Geneticist	R-5 Yreka, CA
Frank Morby	Nursery Manager	R-6 Central Point, OR
Janet Brotschol	Forest Geneticist	R-6 Colville, WA
Bill Randall	Area Geneticist	R-6 Corvallis, OR
Sharon Friedman	Area Geneticist	R-6 Corvallis, OR
Barbara Bonefeld	Dorena Tree Improvement Center	R-6 Cottage Grove, OR
Charles Gansel	Dorena Tree Improvement Center	R-6 Cottage Grove, OR
Pete Theisen	Regional Geneticist	R-6 Portland, OR
Jim Hamlin	Area Geneticist	R-6 Roseburg, OR
Carol Apruzzese	Forest Geneticist	R-6 Seattle, WA
Sheila Martinson	Forest Geneticist	R-6 Vancouver, WA
Monte Bickford	Forest Silviculturist	R-6 Wenatchee, WA
Earl J. Rayburn	Silviculturist	R-8 Asheville, NC
Steve Oak	Pathologist	R-8 Asheville, NC
Walt Smith	Timber Management Staff	R-8 Asheville, NC
Bobby Kitchens	Regional Silviculturist	R-8 Atlanta, GA
Clark Lantz	Nursery Specialist	R-8 Atlanta, GA
Jim McConnell	Regional Geneticist	R-8 Atlanta, GA
Ralph Lewis	Zone Geneticist	R-8 Atlanta, GA
Tim LaFarge	Zone Geneticist	R-8 Atlanta, GA
Jerry Larson	Seed Orchard Manager	R-8 Brooklyn, MS
Charles B. Aulds	Forest Silviculturist	R-8 Cleveland, TN
Donald W. Peterson	Timber Management Staff	R-8 Columbia, SC
Jack Reichert	Forest Silviculturist	R-8 Hot Springs, AR
John Brissette	Nursery Specialist	R-8 Jackson, MS
Charles Studyvin	Seed Orchard Manager	R-8 Mt. Ida, AR
Whitney K. Lerer	District Ranger	R-8 Murphy, NC
Edwin H. Manchester	Seed Orchard Manager	R-8 Murphy, NC
Glen Beaver	Asst. Seed Orchard Manager	R-8 Murphy, NC
Jim Gates	Zone Geneticist	R-8 Pineville, LA
Robert Colona	Silviculturist	R-8 Roanoke, VA
Glenn Parham	Silviculturist	R-8 Tallahassee, FL
Leonard McNeal	Forester	R-8 Winchester, KY
John Murphy	Reginal Geneticist	R-9 Milwaukee, WI
Dick Meier	Zone Geneticist	R-9 Rhinelander, WI
Ross Melick	Zone Geneticist	R-9 Rolla, MO
Don Dorn	Zone Geneticist	R-9 Warren, PA
William H. Pawuk	Nursery Manager	R-10 Petersburg, AK
Gerald Rehfeldt	Research	INT Moscow, ID

GENETICIST WORKSHOP LIST OF ATTENDEES (cont'd)

LeRoy Johnson	Geneticist	NA S&PF St. Paul, MN
Ronald Overton	Geneticist	NA S&PF St. Paul, MN
Knud E. Clausen	Research	NC Carbondale, IL
George Rink	Research	NC Carbondale, IL
Ron Riemenschneider	Research	NC Rhinelander, WI
Pete Garrett	Research	NE Durham, NH
M. Thompson Conkle	Research	PNW Berkeley, CA
Bob Campbell	Research	PNW Corvallis, OR
Roy Silen	Research	PNW Corvallis, OR
David Van Haverbeke	Research	RM Lincoln, NE
Sam Gingrich	Research	SE Charleston, SC
Earl Sluder	Research	SE Dry Branch, GA
John Kraus	Research	SE Macon, GA
Osborn Wells	Research	SO Gulfport, MS
Ron Schmidtling	Research	SO Gulfport, MS
Dick Fitzgerald	Asst. Dir. TM, Silviculture	WO Washington, DC
Dick Miller	Forester/Geneticist	WO Washington, DC
Dick Shaffer	Forester	WO Washington, DC
Liang Hsin	Geneticist	BLM Portland, OR
Rod Stevens	Geneticist	BLM Roseburg, OR
Carlyle Franklin	Professor	NC State Univ., Raleigh, NC
Steve McKeand	Professor	NC State Univ., Raleigh, NC
Dr. Hans van Buijtenen	Professor	TX A&M, College Station, TX
Tom Blush	Research	WESTVACO, Summer, SC
David Canavera	Research	WESTVACO, Summer, SC

OBJECTIVES FOR THE SERVICEWIDE GENETICS WORKSHOP ON PROGENY TESTING

DICK MILLER

I would like to welcome you to Charleston and the Servicewide Genetics Workshop on Progeny Testing (evaluation plantations). I am especially pleased with the attendance from the National Forests, Research, and State and Private Forestry. Your attendance is a measure of the interest, commitment, and support of the tree improvement program.

Progress is being made on all phases of National Forest System tree improvement programs. Accomplishments are shown in Tables 1-4 for the major program areas for fiscal years 1980-1983. During 1983, we added over 12,000 selections (Table 1), 143 (86 net) acres of seed orchards and clone banks (Table 2), and 351 (302 net) acres of progeny tests (Table 3). Table 4 provides an overall view of where the seed used in our reforestation program is collected.

The primary objective of this workshop is to discuss in detail the state-of-the-art of progeny testing. All aspects, from setting objectives through data collection and analysis, will be covered. We all know progeny testing is a highly technical phase of our tree improvement programs. Each task is critical and must be performed accurately and within a prescribed time schedule. The work must be closely supervised and coordinated to ensure objectives are achieved and that the plantations are established correct the first time. Anything less than a first-class job will result in suspect data and questionable genetic information. Since many of the plantations will be used as a source for advanced generation selections and breeding, the selections and breeding work, if based on distorted genetic information, could result in significantly reduced gains in the future.

Progeny testing is also a high cost, labor intensive program. This creates a different series of problems in today's climate of budget reductions and reduced allocations of full-time equivalents (FTE's). A recent discussion with a Forest Supervisor brought these concerns into perspective. His major concern: the progeny test program has grown so large in dollar and labor needs that other programs are being negatively affected. New plantations are established each year and the maintenance, including data collection on both new and older plantations, has become an enormous job. We must be prepared to respond to these and similar concerns.

This workshop has been designed to focus our attention on new ideas, concepts, and techniques that will reduce the escalation of FTE and funding needs without inhibiting our ability to accomplish our goals. You, the participants, are the key to the success of this workshop. Time has been set aside for discussions following the presentations and the round tables. I encourage each of you to voice your ideas, experiences, and concerns. We must develop techniques that will streamline the progeny test phase of our tree improvement programs.

TABLE 1

TREE SELECTION

FY	Number of Selections	Goal
1983	89,560	138,506
1982	77,149	130,628
1981	67,860	136,777
1980	56,929	147,489

TABLE 2

SEED ORCHARDS/CLONE BANKS

	SEED ORCHARDS			CLONE BANKS		
FY	NUMBER	ACRES	FAMILIES	NUMBER	ACRES	FAMILIES
1983	101	2,143	7,970	35	229	5,029
1982	91	2,059	7,060	33	227	4,396
1981	80	1,947	5,846	31	209	3,655
1980	70	1,855	4,935	27	210	3,206

TABLE 3

EVALUATION PLANTATIONS

FY	NUMBER	ACRES	FAMILIES
1983	596	3,590	41,182
1982	554	3,288	35,815
1981	385	2,540	29,931
1980	223	1,921	24,753

TABLE 4

SEED PRODUCTION (Pounds)

FY	5 Selective Breeding	4 Seed Orchard	3 Select Trees	SPA	2 Seed Stand	1 Seed Zone	Other	Total
1983	0	6,527	4,038	484	12,978	18,476	3	42,506
1982	0	14,862	1,522	74	9,552	21,923	63	47,996
1981	1	6,682	1,581	131	32,583	19,386	174	60,538
1980	1	5,931	94	97	11,207	10,082	17	27,429

BIOLOGICAL LIMITS OF SEED ZONES AND BREEDING ZONES

LeRoy C. Johnson, Moderator, Seed/Breeding Zone Session
Area Geneticist, Northeastern Area
State and Private Forestry

The term "breeding zones" is commonly used in forest tree improvement. Some tree improvement specialists consider the term synonymous with seed zones (or seed collection zones); however, the two terms are not synonymous as we generally use them. "Seed collection zone" is defined by the Society of American Foresters' in Terminology of Forest Science, Technology, Practice and Products, addendum Number One as:

> The area covered by trees with relatively uniform genetic (racial) composition as determined by provenance-testing various seed sources. NOTE: The area usually has definite geographic bounds, climate, and growing conditions.

"Breeding zone" is not defined by the SAF.

The two objectives of this session are to:

1. Discuss seed collection zones and breeding zones and bring the participants of this workshop up-to-date on current research and,

2. Compile a list of seed zone and breeding zone references.

Objective one is an ongoing process. The papers presented by Drs. R. D Campbell, PNW; G. E. Rehfeldt, INT; O. O. Wells, SO; D. E Riemenschneider, NC; M. F. Conkle, PSW partially completes the first objective by bringing us up-to-date on current seed collection zone and breeding zone research. The interaction among those attending the workshop, in combination with the valuable updating of current research, helps us achieve the first objective. Technology transfer does not end with the publication of the workshop's papers--it just begins. We practitioners (Regional, Area, and Zone Geneticists) must apply the new knowledge and skills we've learned. Objective two is included in this paper.

SEED COLLECTION ZONES

The SAF definition of seed collection zones is not appropriate for our use because we seldom have enough provenance test data on hand to delineate zone boundaries prior to when we need them. Cunningham (1975) provides a clearer and more useful definition:

> Seed collection zones are subdivisions of land areas established to identify seed sources and to control the movement of seed and planting stock. Seed zones are needed for many species because of the genetic variation associated with their geographic distribution. Zone boundaries may be delineated from experimental data that identify genetic variation, or by analysis of the environmental factors that most likely acted as selective forces in creating such genotypic variation.

This definition more adequately reflects the 'real world' because seed zone boundaries are often drawn along physiographic, climatic, and political boundaries. For many species we are not able to delineate the zones on the basis of provenance data.

Nienstaedt and Snyder (1974) in their discussion on seed zones said, "A primary requirement of regeneration of forest land is planting stock from a seed source of proven adaptability to the planting site. To obtain maximum yields, seed from each source must be planted in an environment to which it is best adapted. Large losses in wood yields have resulted in the past from the planting of nonadapted seed." Stern and Roch, (1974) said, "The establishment of criteria governing the movement of seed and planting stock of a particular species is of major importance in programs of reforestation or afforestation, as it is the best way of insuring that the genetic potential of the species is correctly used by the silviculturist." These observations apply equally as well to breeding zones.

BREEDING ZONES

The Forest Service (FSM 2475.22) defines a breeding zone as a "geographical area based on anticipated adaptability of an improved population of trees. It may be larger than a seed collection zone." In 1976, Jay Kitzmiller defined a breeding zone as "an area in which an improved strain will be developed for reforestation." The N.C. State Cooperative calls similar areas "breeding regions." Breeding zones may be different for various species even though the species occupy the same natural range.

The final boundaries of breeding zones are delineated after provenance, family-field, or progeny tests are completed or when they are far enough along that reliable performance data is available. With seedling and tree performance data in hand, we can delineate zone boundaries. However, a tree improvement program is often started before we have sufficient information to adequately delineate the zones so we start with tentative breeding zones (cf. Kitzmiller 1976).

After the tentative breeding zones are delineated, we evaluate these zones by establishing tests with open or controlled pollinated seedlings. A problem with this approach is we are already committed to a seed orchard for a breeding zone by the time we gather sufficient information from our tests to more correctly delineate the zone's boundary. Fortunately we now have the technology to dismantle a seed orchard and rearrange it by transplanting the trees using tree spades, but this is expensive.

The following references on seed collection zones and breed zones were submitted by members of the panel and other participants in the workshop.

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Procedures for Determining the Biological Limits of Breeding Zones in the Pacific Northwest

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The first effort at delimiting breeding zones of forest trees usually must be subjective because pertinent biological and climatic information is lacking. Eventually, however, the breeder must decide whether to change the zones or continue with them as originally defined. If the decision is to refine the boundaries, how can it be done? This paper describes one approach to the problem. Questions about zones are likely to be tied to a species within a region; procedures presented here are based on experience with Douglas-fir in the Pacific Northwest, specifically western Washington and Oregon. To provide background, the conditions affecting decisions about breeding zones in the Pacific Northwest will first be described. Then some methods presently being used in cooperative studies[2/] by Regions 6 and 10, and the genetics research project of the Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, will be presented.

The Problem

Most of the questions about breeding zones in the Pacific Northwest arise because of complex environmental and genetic gradients within the region. Major temperature and precipitation gradients extend from the coastline to the crest of the Cascade Range, from south to north, and from low elevations to high. Gradients can be very steep. For example, a frost may occur only once in 10 years on the southern Oregon coast, but hardly a week passes without frost in some places just 150 km east in the Cascade Range. In even shorter east-west distances in several parts of the region, summer moisture may grade from abundant to barely enough to support Douglas-fir. Major trends are greatly modified by local conditions. In the Siskiyou Mountains, Coast Ranges, and Olympic Mountains (figure 1), a few kilometers may separate foggy, moist valleys from parched slopes in rain shadows. The extent of such conditions depends on height and configuration of local mountains and drainages. Mountain masses, watersheds, and temporary and permanent snowpacks also drastically modify local temperatures by radiation cooling and air drainage, especially in the Olympic Mountains and Cascade Range.

Source variation (genetic variation associated with local conditions) in Douglas-fir appears to mirror environmental gradients. In common-garden nursery studies designed to investigate patterns of source variation, the more intensive the sampling, the more complex the patterns that have been revealed (1, 4). Furthermore, the steeper the environmental gradient, the steeper the genetic gradient. One of the steepest genetic gradients so far shown is on the eastern slope of the Cascade Range where forest land grades into high desert (5). The most troublesome finding from the common-garden studies is that trends with major environmental gradients are so modified by local conditions that relationships of genetic variation with elevation, distance from the ocean or latitude cannot be generalized from one part of the region to another (1, 2, 3, 5, 6, 7).

1/Research Geneticist, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, USDA Forest Service, Corvallis, Oregon.

2/The methods described have been or are being used to suggest zone delineation in parts of the Pacific Northwest and Alaska for Douglas-fir, noble fir, lodgepole pine, Sitka spruce, and white pine.

The complex patterns of source variation revealed by seedling studies have caused considerable uncertainty in delimiting breeding zones. Also, because forested parts of the region are sampled poorly by long-term weather stations, the environmental dimensions of even the smallest zone are unknown and may encompass some troublesome diversity. Are these genetic and environmental differences large enough to expect that they will lead to genotype x environment (GE) interactions within present breeding units? If so, how should breeding zones be configured, considering the complexity of the genetic variation patterns? Because of these questions, the present breeding zones in the Pacific Northwest are geographically small and families are tested in 8 to 12 plantations in a zone at the expense of replication within plantations.

Risks in breeding can be minimized by testing families within small zones and in many plantations, but some problems still remain. If the present zones are too large this will become apparent in time--GE interaction will become significant, and average variation among families may decline. But if zones are too large, how can they be partitioned based on test results? Twelve plantations provide very few degrees of freedom for determining a relationship between environment and GE interaction and an even smaller resource for the drawing of boundaries during refinement of zones in an environmentally complex region. How does one decide if zones are too small and, if present zones are too small, how can results from present plantations be extrapolated beyond zone boundaries to enlarge the zones?

The Approach

One approach to the breeding zone problem that has been suggested in the Pacific Northwest is based on mapping patterns of genetic variation. In this approach, genetic clines are mapped in terms of topography and other indexes of environmental variation. The procedure involves estimating genotypic values of trees using open-pollinated progeny grown in common-garden nursery tests. There are three main assumptions: (1) a map of source variation is a map of environmental variation because source variation results from natural selection by the environments that are indirectly being mapped; (2) the greater the differences among environments, or the greater the difference in genotypes, the larger the potential GE interaction; and (3) genetic and environmental maps based on seedling data are appropriate to older trees.

Although assumptions (particularly 1 and 2) may seem logical, supporting evidence is fragmentary and indirect. The evidence has been discussed elsewhere[3/] and similar discussion here would require coverage not appropriate for this paper. The assumptions are presented here to emphasize that the following procedures are based on a model whose main aim is to demonstrate possibility. The danger is that people often take models too literally and without any formal evaluation. That is not likely in this case because using the model for the suggested purpose will automatically include tests of its validity.

3/Campbell, R. K. Mapped genetic variation to guide seed transfer in southwestern Oregon. In preparation.

Procedures

Genetic mapping can be briefly described in eight steps starting with the choice of a sample area.[4/] To enable extrapolation, the sample area should extend across two or more of the original breeding zones (figure 2). Size of sample area is limited to any area that can be sampled adequately with 150 to 250 locations. Usually this precludes sampling across extremely sharp changes in environmental gradients where there may be sharp breaks in the genetic gradients.

The scheme for sampling locations within the sample area is based on experience which indicates that most source variation of Douglas-fir is distributed in gradients and not in patches (1, 3, 4, 5, 6, 7). Mapping is therefore based on a regression model rather than a classification model. Experience also indicates very complex environmental and genetic gradients within small areas (1, 3). Collections at many locations are therefore needed to sample the several geographic and topographic variables required to index this variation. Sampling is done by collecting cones (and topographic data to describe locations) from one tree each at 100-150 locations. Collections are also made from two trees at another 50 or so locations to provide "repeats" for testing lack of fit to the regression equation in a later step. The importance of a representative sample of locations within the sample area cannot be overemphasized. Trees should be scattered widely to cover the potential range of geographic and topographic variables within the sample area (figure 2). To help minimize standard errors of regression coefficients, samples should be concentrated at extreme locations. Some collections from outside the sample area will help to increase precision of the model.

Seeds from cone collections are germinated in specified conditions and seedlings are grown in common-garden nursery tests to estimate the genotypic values of parent trees. The goal is to estimate a large fraction of the genotype in a 2- or 3-year-old test. As many traits as possible are therefore measured including, especially, aspects of vigor (e.g., height, diameter, and dry weight) and of growth rhythm (germination rate, bud burst and bud set date, second-flushing, frost resistance, and shoot-to-root ratio). To measure expression of genotypes as affected by environment, seedlings are grown in two or more contrasting environments. Environments are designed to create extremes in growth rhythm; i.e., short and long vegetative growing seasons. Such a test provides a genotypic value for every parent for several traits measured in two or more years and environments.

After obtaining genotypic values the next step is to simplify interpretation of the variation observed in the many traits. Because genotypic values for the different traits are correlated, this can be done by extracting principal components. Usually most of the variation among the set of genotypic values for all traits is dissociable into two or three principal components. In experience so far,[5/] a main principal component describes growth vigor and is highly correlated with height, diameter, and timing of bud set. A secondary principal component strongly correlates with growth rhythm, particularly with bud burst, but also partly with those aspects of bud-set

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4/ Ibid.

5/ From results of four independent experiments, sampling two areas each for Douglas-fir and noble fir. One experiment has been reported (1).

timing not correlated with growth. The principal components represent new variables that are uncorrelated with one another and that consolidate most of the variation in the original variables into fewer new variables.

The next step is to calculate genotypic values for each parent tree for each of the new variables. For each principal component that is significant, a factor score is calculated for each parent tree. The principal components represent independent parts of the parent tree's genotype and the factor scores are the phenotypic traits by which genotypic value is measured.

Describing the relationship of genotypic values to parent origin starts with a regression analysis of factor scores for each principal component. The goal is to describe the factor-score variation among locations using topographic and geographic indexes of environment. The descriptive model is selected from a preliminary model that includes polynomial and cross-products terms for the index variables. The objective is to build a regression equation to describe the source variation without lack of fit, while retaining only significant regression coefficients. A regression equation is selected for each principal component.

The final step in mapping starts with predictions of genotypic values within the sample area. For this, a multidimensional grid is constructed with dimensions for each of the significant topographic or geographic indexes (figure 3). Factor scores are predicted at intersections of the grid. Mapping is accomplished by choosing an appropriate interval between factor scores and then drawing isolines to contour the grid space at the chosen interval. One set of contours is constructed for each principal component.

The Application

The purposes for genetic mapping described here are: (1) to delimit zones incorporating sets of genotypes (and environments) that are relatively homogeneous, and (2) to make provisions for refining breeding zones by extrapolating from results in test plantations. Further explanations of mapping genetic variation may be helpful in conjunction with an illustration of the potential use of maps. For this, start with two hypothetical breeding zones with geographic boundaries as in figure 4. In each breeding zone, families are tested in eight plantation sites. The numbers given to sites reflect rank correlations of family means between plantations. For example, family means in plantations 1 and 2 are more highly correlated than in plantations 1 and 5, or 1 and 8. Low rank-correlations can mean large GE interactions. Assume that correlations of families in sites 1 and 2 with those in 7 and 8 are so poor that the breeder decides to divide the zone. Where is this to be done?

For ease in illustrating a concept, plantations are located in only two dimensions in figure 4, making the division of a zone relatively simple. A generally north-south line should suffice in either zone. But families tested in one zone are not tested in the other, so any division must stop at a present boundary. Furthermore, interactions may be a function of other environmental factors that are not indexed by the geographic dimensions. In the Pacific Northwest, source genotypes and environments vary in at least one other major dimension (elevation) and several minor ones. Extrapolating from test plantations may therefore be much more complicated than in this illustration.

Suppose genetic maps are available for the area. How might this help in using test results? The map of factor scores for the first principal component is given in figure 5. Genotypes for fast growth (and also the environments that have supported fast growth) grade from the west edge (factor score = 6) of breeding units to the east edge (factor score = 2). By hypothesis, therefore, the area extending across both breeding zones between isolines for factor scores 4 and 2 is a relatively homogeneous unit. Based on the first principal component of genotypes, it is more homogeneous than any other area of similar size within the sample area. In examining plantation results, however, we find that plantations 2 and 7 in the northern breeding zone, and 3 and 7 in the southern zone, are within this supposedly homogeneous area. Since we had previously decided that rank correlations between these plantations were too low to be acceptable, the problem of dividing the breeding zones has not been resolved. We conclude that interactions reflect differences in environment or genotypes that were not measured by the first principal component.

When a map of factor scores for the second principal component is superimposed on the sample area, the interactions become more interpretable (figure 6). Genetic variation grades from large values (factor score = 6) in the southwestern corners of the area to small values (factor score = 1) in the northeastern corner. A line drawn at factor score 2.4 divides the two zones into two units. Each is more homogeneous in respect to the second principal component than are either of the original breeding zones. The pattern of rank correlations of family means reflects this homogeneity. We conclude that interactions may be better indexed by the second principal component than by the first. Because these new units are common to both original breeding units, an objective basis exists for reconfiguring the old zones into two new ones, southwest and northeast of the line for factor score 2.4.

The hypothetical example given above is designed to indicate the flexibility of the procedure. Interactions can be examined in reference to different principal components of genotypic values, and although the example uses only two dimensions of an environmental index (latitude and east-west location), in an actual situation other significant dimensions may be helpful in explaining plantation results.

The best use of genetic mapping for delimiting breeding zones may be to sample a larger area and characterize zones before family testing starts. Homogeneous units and plantation sites could then be located efficiently based on gradient information (Figure 7). This possibility no longer exists for Douglas-fir in the Pacific Northwest because progeny-test plantations have been or are being installed for most breeding zones in the region.

Conclusions

Some possible advantages in making comprehensive maps of genetic variation patterns have been briefly described. The procedures for mapping and the uses of maps are based on assumptions; using the maps as suggested here is therefore a step in validating a model. Deviations from models are not uncommon--most biological models are oversimplifications. The main assumption here--that similarity among source genotypes reflects corresponding similarity in location environments--may be only partly correct. Or gradients of source variation may foretell GE interactions in the natural situation but not the

interactions expected under intensive culture. But, even if the mapping model is not complete, it does supply information about complex environmental gradients that apparently have been important in adaptation of Douglas-fir. Some aspects of gradients are likely to affect growth or survival even in the managed stand.

More to the point, perhaps, is the opportunity lost if the genetic variation patterns are not mapped now. There is currently a favorable economic climate in Region 6 for starting such efforts now, but this unusual situation may not last. Even more important, the native stands in the Pacific Northwest are disappearing. Provisions are being made to ensure conservation of the gene pool, but even so, there will soon be too few stands to provide for intensive sampling in many areas. Because the indispensible condition for describing source variation in complex environments is the careful allocation of many samples to many locations, the opportunity for mapping will pass quickly as remaining stands become separated by larger and larger cutover areas.

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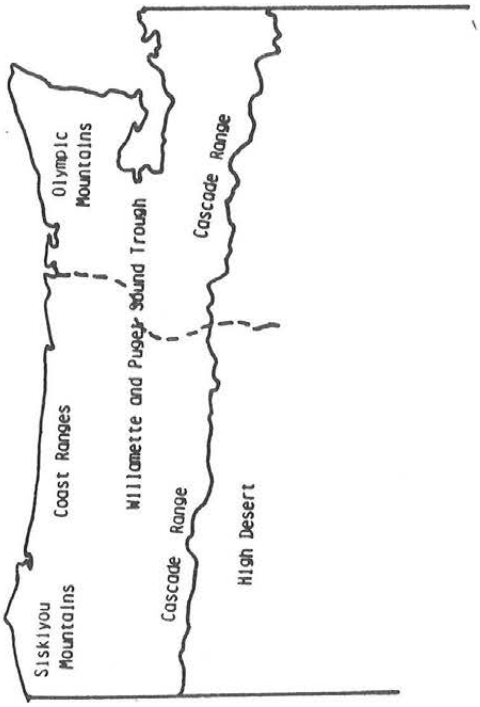


Figure 1.--The major physiographic features that affect precipitation and temperature gradients in the Douglas-fir region of western Washington and Oregon. East-west gradients are especially steep and variable because of the influence of the Pacific Ocean, the coastal mountain ranges, and the Cascade Range.

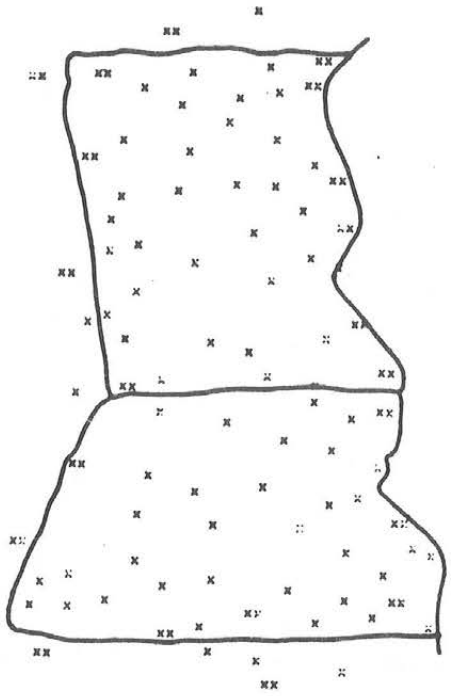


Figure 2. Sampling of the two "original" breeding zones that are to be the sample area for the hypothetical genetic mapping. Each x represents a collection of seeds from a single parent tree at a location. Double x's are samples from two trees at a location. This illustration shows the distribution of samples over two geographic indexes of environment; i.e., latitude and east-west direction. The eastern boundary represents a sharp division between two environmental gradients (e.g.; at the crest of the Cascade Range). Samples should be distributed to sample the extremes of any environmental gradients suspected as being associated with differences among sources. Environmental indexes that have helped explain genetic variation patterns in the Pacific Northwest are latitude, distance from the ocean, distance from the crest of the Cascades, elevation, duration of daily sun exposure, length of slope, aspect, soil type, and vegetational habitat type.

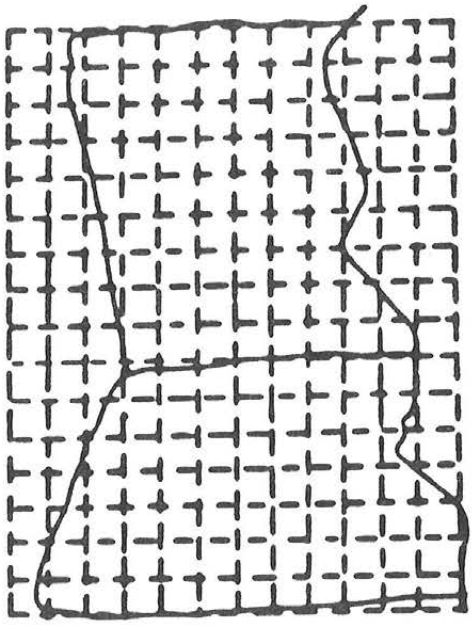


Figure 3.--Factor scores are predicted at intersections of the north-south and east-west grid superimposed on the sample area. If genetic variation is also significantly related to elevation (or other variables), a set of similar grids would be constructed for a graded series of elevations (or for other significant variables).

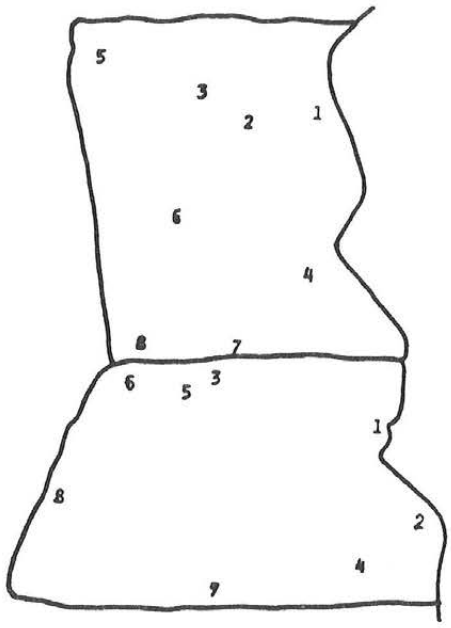


Figure 4.--In this hypothetical example, in each of the "original" breeding zones, a different set of families has been tested in eight plantations. The numbers 1 through 8 reflect rank correlations of family means between plantations. Family means in plantations 1 and 2 are more highly correlated than family means in plantations 1 and 8.

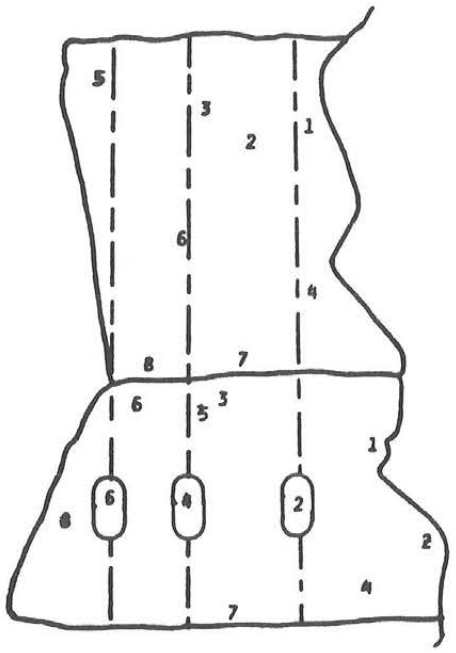


Figure 5.--Previous studies with Douglas-fir and noble fir indicate that factor scores for the first principal component may be patterned within a single area as illustrated in this figure. Dashed lines are isolines for the hypothetical factor scores given within the ovals along the lines. Genetic and environmental gradients are perpendicular to isolines.

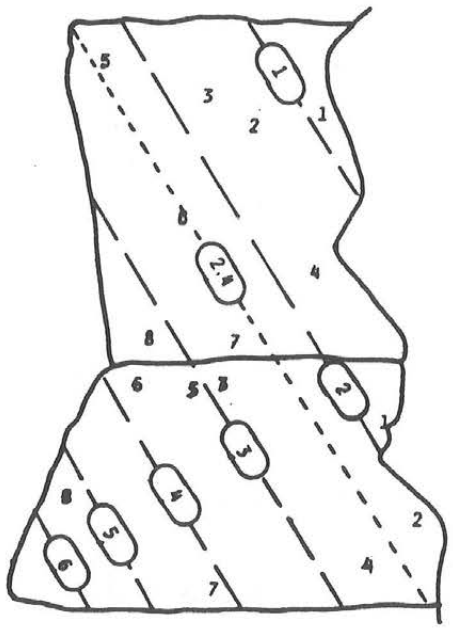


Figure 6.--The factor scores for a second principal component may indicate genetic and environmental gradients that are different from those for the first principal component. The illustration in this figure shows a gradient from the northeast (factor score 1 in the oval) to the southwest (factor score 6). In this example, isolines for factor score 2.4 divides the sample area into two relatively homogeneous breeding zones for minimizing GE interaction (see text).

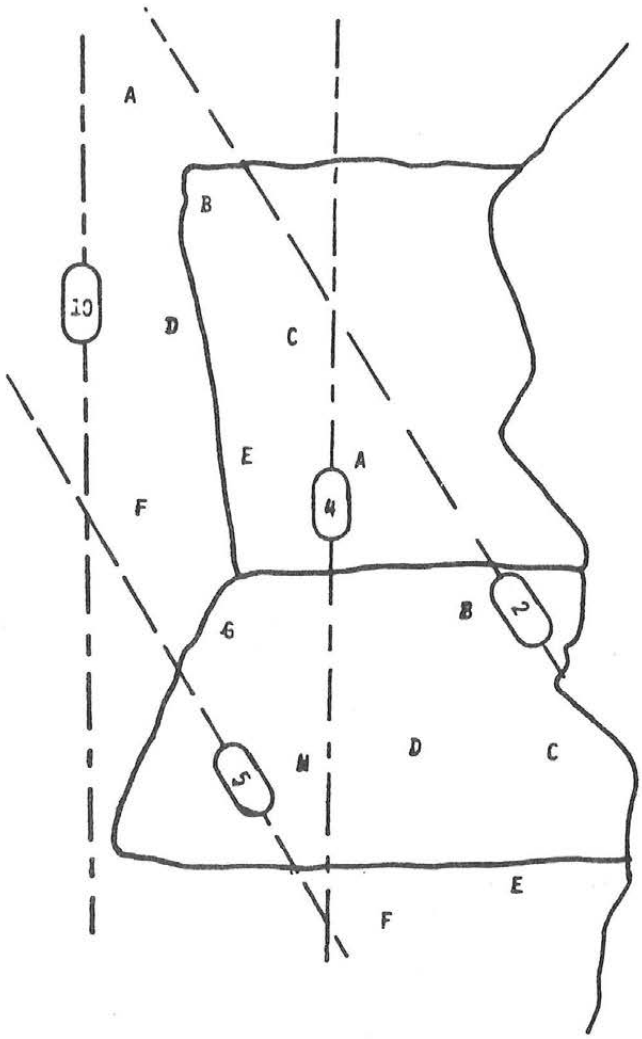


Figure 7.--In this example, a larger area than that shown in figure 2 has been sampled and two breeding zones have been delineated by genetic mapping before allocation of plantation sites (A through H) to locations within zones. If genetic gradients can be explained by only two environmental indexes (latitude and east-west direction), as in the illustration, fewer plantations than shown here would be needed. If the breeder decides to use four, they could be sited efficiently to sample genetic gradients, as in A, C, F, and H.

Seed Transfer in the Northern Rockies

by

Jerry Rehfeldt

Through the ages, natural selection has physiologically attuned populations to their environment. For each population there exists, therefore, an optimal range of environments for which individuals and their offspring are adapted (physiologically attuned). The movement of individuals beyond the optimal range results in maladaptation, the degree of which depends on the transfer distance in relation to the size of the optimal environment. Maladaptation can be expressed in responses that range from subtle losses in productivity to mortality. This means that optimal productivity from artificial reforestation requires the control of maladaptation. To accomplish this, the transfer of seeds must be limited.

BIOLOGICAL BASES FOR SEED TRANSFER GUIDELINES

Two principles control the establishment of biologically sound guidelines for limiting the transfer of seeds:

I. In order to limit maladaptation, the guidelines must be based on patterns of genetic variation among populations for traits that convey adaptation to natural environments.

II. Species have evolved under different environmental conditions, exhibit different patterns of adaptive variation and, therefore, require different seed transfer guidelines.

Seed transfer guidelines developed from these two principles are always administratively inconvenient. Inconvenience results from two sources. First, administrative boundaries are established long before biological principles become known. Implementation of new guidelines invariably requires coordination between administratively discrete units. Secondly, an inability to anticipate patterns of genetic variation appropriate to montane species has led to empirical seed zones that are biological failures. Implementation of new guidelines requires a change (often radical) in old procedures and, therefore, new guidelines meet strong resistance.

ADAPTATION TO HETEROGENEOUS ENVIRONMENTS

An understanding of the biological bases for seed transfer guidelines requires background on modes of adaptation. To survive, a species must be adapted to environments that vary in time as well as in space (see Roughgarden, 1979). Spatial environmental variability is easily visualized as the environmental gradients that occur in association with ecology, geography, or physiography. Temporal environmental heterogeneity involves the fluctuations from year to year, season to season, or day to day that occur at a given locality. Since forest trees are long-lived, sedate organisms that generally have broad geographic distributions, perpetuation of the species requires adaptation to environments that are extremely heterogeneous in both time and space. Adaptation to spatial and temporal variations can be achieved, however, according to contrasting modes. These modes can be visualized as alternative strategies.

One of the alternatives, specialization, develops from well-known Darwinian processes: natural selection in dissimilar environments alters gene frequencies to produce differentiated populations. Under the specialized mode, the genotype is expressed phenotypically, and, consequently, selection acts directly on the genotype. Populations are composed of individuals that are physiologically specialized for a particular segment of the environmental gradient. Thus, specialization is the primary mode for adapting populations to environments that vary in space. And from the experimental viewpoint, differentiation is easy to detect.

Phenotypic plasticity or genetic flexibility is the alternative mode to genetic specialization. Under this adaptive mode, natural selection produces homeostatic individuals that are capable of maintaining optimal physiological processes in a broad range of environments. Homeostasis develops from selection favoring (1) alleles with broad environmental tolerances and (2) high levels of genic heterozygosity. As a result, individuals are endowed with a complex system of alternative metabolic pathways. This means that a single genotype can produce a variety of phenotypes depending on the environment. The same phenotype can be produced by a variety of genotypes. The phenotype is more dependent on the environment than on the genotype. And, since genetic variability is poorly expressed phenotypically, genetic variability tends to be conserved. In consequence, individuals tend to be generalists; they are adapted to an extremely broad range of environmental conditions. From the experimental viewpoint, population differentiation is difficult to detect.

Unfortunately, the genetic mechanism conveying adaptation to spatial heterogeneity is somewhat antagonistic to the mechanism conveying adaptation to temporal heterogeneity. Antagonism between the flexible and specialized modes arises through the disposition of genetic variability. Under the specialized mode, selection discriminates against genetic variability within populations; under the flexible mode, genetic variability is at a premium. Yet, the degree that either adaptive mode develops is constrained biologically. On the one hand, there are environmental limits beyond which the plastic genome cannot function optimally; for a species to be adapted to environments beyond these limits requires some degree of specialization. On the other hand, populations cannot become specialized to environmental gradients so fine that the variability required to survive temporal environmental fluctuations is lost: temporal variances set the limits of specialization. This means that all species have been forced into an evolutionary compromise. For some, specialization has been sacrificed in favor of flexibility; for others, flexibility has been sacrificed; others exhibit intermediate levels of both modes. From the practical viewpoint, however, it is the result of this compromise on which limits of seed transfer as well as the breeding strategy must be based.

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Two centuries of provenance testing throughout the world have yielded a general axiom regarding seed transfer: local seed is best. Old tests, however, were usually established to locate provenances that outperformed the local. Consequently, the tests were generally composed of a few seed sources representing the entire botanical distribution of a species. Such tests are of insufficient power for determining desirable limits of seed transfer for relatively small geographic regions.

The modern synthesis of provenance testing is marked by tests designed to determine exactly how far seed can be transferred before maladaptation begins limiting productivity. The benchmark paper in the modern synthesis is Campbell's (1974) "A provenance-transfer model for boreal regions." In this paper, Campbell presents imaginative and unique techniques for attacking the limits and risks of seed transfer. Additional milestones in the modern synthesis include: the experimental approach of Clausen, Keck and Hiesey (see Heslop-Harrison, 1960); the trait selections and definition of maladaptation by Dietrichson (1964); the statistical interpretations of Morgenstern (1978); the presentation of results as contours by Squillace (1966); the concept of floating transfer guidelines of Langlet (1945; see Isaac, 1949) and the practical application of experimental results by Eriksson et al. (1980). It is the ingenuity of these researchers that is basic to the work on seed transfer being done in the northern Rockies.

Nevertheless, the general approach to developing modern seed transfer guidelines is very old. For 10,000 years man has been growing plants in common gardens in order to observe and select genetic variability. Thus, seeds are collected from a variety of populations; seedlings are grown in common environments; and genetic differentiation is observed for a variety of traits reflecting adaptation in natural environments.

The selection of provenances for testing in the northern Rockies is done in such a manner that geographic, physiographic, and ecologic characteristics of the seed sources are relatively independent of each other. Independence is accomplished by clustering selected populations within restricted geographic localities (usually relatively small drainages). Populations from the same cluster generally reflect a variety of habitats, elevations, or ecological settings. Cones from a random selection of at least ten phenotypes (squirrel caches are most preferred) generally constitute the sample within each population.

A series of three studies is used to assess adaptive variation among populations:

1. Studies of growth potential and phenology are made in short-term (3 to 5 years) field tests. Field environments are selected to represent operational ecological gradients. The environments that are most commonly used include: Moscow, elevation = 2,500 feet and frost-free period = 130 days; Priest River Experimental Forest, elevation = 2,200 feet and frost-free period = 90 days; and Tarlac, a high elevational site (5,000 feet) at Priest River where the last frost of spring and the first frost of fall often occur on consecutive nights. These contrasting environments provide ample opportunity for genetic differences among populations to be expressed. In the mild environments, differences in growth potential are maximized; at Tarlac, adaptation to short growing seasons can be expressed. Ready detection of differentiation requires intensive culture, including control of random extraneous environmental effects: competition, insects, diseases, and rodents.

2. Studies of periodicity of shoot elongation are held in the greenhouse where environmental fluctuations are not allowed to affect inherent patterns of shoot elongation. The periodicity of shoot elongation (the initiation, duration, rate, termination, and amount of elongation) is closely attuned to the length of the growing season to which each population is adapted. By studying elongation under controlled conditions, shoot elongation of single trees can be precisely expressed by mathematical models. Thus, the parameters that depict periodicity can be estimated precisely, and differentiation can be readily assessed.

3. Studies of cold hardiness are ordinarily carried out in the laboratory because environmental stresses sufficient to differentiate populations rarely occur while short-term field tests are in progress. Consequently, Levitt's (1972) laboratory tests for cold hardiness are used to differentiate populations early in September, a date when the first killing frosts of autumn can be expected.

From these studies, the degree of genetic differentiation among populations can be assessed by means of analyses of variance. Patterns of genetic variation are depicted by regression analyses. Rather than to test the influence of specific independent variables (precipitation, temperature, etc.), objectives of regression analyses are to develop models that account for large proportions of the variance among populations. While the results of such analyses must meet certain statistical criteria (significance, random relationships between residuals and independent variables, a lack of geographic pattern to residuals), the results must be sensible. When patterns of genetic variation can be reasonably related to environmental differences at the seed origin, one can be relatively certain that the observed differences are adaptive.

Then, limits to seed transfer can be defined as the smallest geographic or elevational interval across which differentiation of populations is detectable at a given level of probability (Rehfeldt 1979). This interval is calculated from the results of the analyses of variance and results of regression analyses. The former can provide a least significant difference that is necessary for detecting differences among populations. Regression coefficients quantify the differences among populations per unit change of the independent variables. The ratio of these statistics (lsd/b) provides the smallest distance along the independent variable that is required to detect differentiation at a given level of probability.

Adaptive traits tend to be intercorrelated. Thus, if populations of any species from the northern Rockies can be differentiated according to a single adaptive trait, correlated patterns of differentiation can be observed in several traits (Rehfeldt 1979, 1982a, 1982b, 1983a, 1983b). Species differ only in the ease that differentiation can be detected and, consequently, in the strength of the intercorrelations. Most importantly, the correlation of variables reflecting growth potential with those of cold hardiness is invariably negative. These negative correlations, moreover, have a strong genetic basis (Rehfeldt 1983c).

When compared in common gardens, populations adapted to relatively mild environments are the tallest, grow at the fastest rate, set buds the latest, and are most susceptible to fall (as well as spring and winter) cold injury. Populations from severe environments are short but extremely cold hardy. Adaptation in the northern Rockies results primarily from a balance between selection for high growth potential by mild environments and selection for high cold hardiness by severe environments.

Strong intercorrelations arise from the annual sequence of developmental events that woody plants from temperate climates must complete. This sequence begins with dehardening in the spring; it includes bud burst, shoot elongation, bud set, leaf elongation, lignification and bud development; and it terminates with cold acclimation. The entire sequence, however, must be completed within the frost-free period. Thus, as stresses by Dietrichson (1964), maladaptation will result from a lack of synchronization of the sequence of developmental events with the frost-free period.

Plants under stress, however, express maladaptation through a variety of agents besides cold injury and reduced growth. Thus, maladaptation can be expressed through agents such as insects or diseases. In fact, Hoff[1] has recently assessed the incidence of lodgepole pine needle cast (Lophodermella concolor) in a low elevational planting site in northern Idaho. He found that the incidence of the disease was significantly correlated ($r = .85$) with the elevation of the seed origin. If, however, seed transfer had been limited at this site by matching the annual developmental cycle with the growing season, only those trees originating from an elevation ±300 feet (Rehfeldt 1983a) from the site would have been planted. As a consequence, needle cast would have been incidental. Thus, maladaptation can be expressed by many distinct traits. But, since adaptive traits are intercorrelated, maladaption in general can be recognized as an incompatibility of individual traits with the physical environment.

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[1]R. J. Hoff, Forestry Sciences Laboratory, Moscow, Idaho, personal communication.

RISKS AND CONSEQUENCES OF SEED TRANSFER

Whenever trees are planted, there is a possibility that they will not be adapted to the planting site. Some of the risks and consequences of seed transfer become apparent from the negative relationship between cold hardiness and growth potential (for example, Rehfeldt 1981, 1983a, 1983d, 1983e). Experimental results predict losses in productivity from transfers of two types. First, when seed adapted to a mild environment is transferred to a severe environment, anticipated productivity can be offset by cold injuries. Second, when seed adapted to a severe environment is transferred to a mild environment, productivity can be lost because the growth potential of the transferred stock is less than that of local seed.

Expected losses from seed transfer can be quantified from regression models. For example, when either lodgepole pine or Douglas-fir seeds from northern Idaho are transferred 1,000 m upward in elevation, an injurious frost is expected to damage about 30% (of the mean damage) more of the transferred trees than the local. And, when seeds of the same species are transferred downward 1,000 m, 3-yr height of the transferred stock will be about 25% less than the local.

Estimates of productive losses for juvenile trees, however, cannot be transcribed accurately into productive losses of mature forests. On the one hand, reliable models are lacking; but on the other, additional maladaptive losses are expected in the future from such agents as insects, diseases, and snow breakage. Consequently, there is little doubt that the effects of seed transfer on productivity can be dramatic in the northern Rockies. The risks and consequences of seed transfer as estimated in juvenile trees portend even greater losses in future productivity. Juvenile estimates can only be considered as a minimum.

PATTERNS OF GENETIC VARIATION AND LIMITS TO SEED TRANSFER IN THE NORTHERN ROCKIES

In the discussion that follows, the terms "population differentiation" or "variation among populations" reference the entire intercorrelated system of developmental events that have been adapted to growing seasons of finite length.

For both Douglas-fir and lodgepole pine, differentiation of populations occurs across relatively small environmental gradients. Adaptation is of the specialized mode; differentiation is easy to detect and clines are steep (Table 1). Population differentiation can be detected across an elevational interval of only 600 feet, and, therefore, seed transfer should be limited to ±300 feet from the seed source. Since geographic transfers should also be restricted greatly ($\pm\frac{1}{2}^{\circ}$ latitude, for instance), seed zones should be relatively small geographically and narrow elevationally.

Ponderosa pine and western larch exhibit an intermediate mode of adaptation. Since differentiation occurs in response to relatively large environmental intervals, clines tend to be flat (Table 1); differentiation is difficult to detect. Consequently, seed transfer can be relatively broad, both geographically and elevationally.

Western white pine exhibits a flexible mode of adaptation. Differentiation of populations from the northern Rockies is nearly impossible to detect, and genetic variation cannot be related to environmental gradients. Thus, seed transfer can be essentially unlimited within the species ecological amplitude.

Table 1.--Genetic variation and limits to seed transfer in the Northern Rockies

Species	Adaptive Mode	Limits of seed transfer from a given source		References
		elevational (feet)	latitudinal (degrees)	
Douglas-fir	specialist	±300	±0.5	Rehfeldt 1979, 1982b, 1983b
Lodgepole pine	specialist	±300	Not known	Rehfeldt 1983a
Ponderosa pine	intermediate	±750	±0.75	Rehfeldt 1980
Western larch	intermediate	±750	±0.75 (about)	Rehfeldt 1982a
Western white pine	generalist	Unlimited within the ecological amplitude of the species		Steinhoff 1979 Rehfeldt et al. 1984

Seed zones and breeding zones are ordinarily considered as discrete parcels of land. Both, however, must reflect adaptive variation. Consequently, the biological constraints (risks) associated with seed transfer within either seed or breeding zones are exactly the same. From the biological viewpoint, therefore, seed zones and breeding zones should be identical.

Implementation of seed or breeding zones for species of the generalist mode pose few problems. Although sometimes incredulous, land managers readily accept liberal transfer guidelines. It should be remembered, however, the generalist owes its adaptive mode to high levels of genic variability. To constrain the breeding zone of the generalist is to breed in the direction of the specialist. Thus, the breeding strategy with plastic species must provide for maintenance of (excessive) variability within and among individuals.

The relatively small seed and breeding zones appropriate to species of the specialist mode are not, however, enthusiastically received. The cost of maintaining a large number of small seed inventories or the cost of establishing several seed orchards can easily eliminate anticipated economic gains. This problem is illustrated at a single district on the Payette National Forest in central Idaho: to establish discrete seed zones according to recommended limits of seed transfer for Douglas-fir, 14 seed zones would be required. Two solutions can be offered for such problems:

1. enlarge the recommended limits of seed transfer and accept lesser genetic gains and greater associated risks;

2. implement floating transfer guidelines rather than discrete seed zones.

The risks associated with stretching the limits of seed transfer were discussed earlier. In addition, to stretch the breeding zone of a specialist is to breed in the direction of the generalist. Although such a strategy may seem desirable economically and administratively, it is exceptionally risky biologically because it counters natural selection.

Floating transfer guidelines (Langlet 1945) rely on the relationship between geographic and elevational patterns of genetic variability (Rehfeldt 1983d, 1983e). Geographic patterns are also expressed elevationally. To traverse a geographic gradient from mild to severe is similar to traversing a gradient from low to high elevation within a geographic locality. Thus, when seed is transferred across such geographic gradients, it maintains a genetic similarity to geographically distant populations at ever lower elevation. This means that a single seed production area or seed orchard can serve several geographic zones, as long as the seed is used at slightly different elevations within each zone. Such floating transfer guidelines provide the silviculturist and tree improver with a flexibility not available with discrete seed zones.

The existence of variable adaptive modes allows comparison of the relative evolutionary success of the specialist and generalist. If success is defined in terms of acres occupied, there is little doubt that specialization leads to the greatest success. Douglas-fir and lodgepole pine have larger geographic distributions and greater ecological amplitudes than any other western species. But, in the event of a genetic catastrophy, rapid evolution is not possible. The incorporation of single genes within adaptive complexes (specialized populations) requires linkage equilibrium, a process that tends to be slow. By contrast, the flow of a favorable allele throughout the genetic system of a flexible species can be quite rapid. This, in fact, is currently happening with western white pine. Resistances to blister rust (Cronartium ribicola) are rapidly spreading throughout natural populations of the species (Hoff et al. 1973). The genetic system of the generalist, therefore, is the most resilient; it responds readily to changing conditions.

There is little doubt, therefore, that both the specialist and plastic modes provide for effective perpetuation of species. While such a discussion may seem academic, the application to tree breeding is direct. There is little doubt that techniques of tree improvement will be more simple, more straightforward, and less expensive for species of the flexible mode than for those of the specialized.

SUMMARY

1. In order to limit maladaptation, seed transfer guidelines must be based on genetic variation among populations for traits that convey adaptation to natural environments.

2. Species have evolved under different environmental conditions, exhibit different patterns of adaptive variation and, therefore, need different transfer guidelines.

3. Seed transfer guidelines for the northern Rockies are based on a series of common garden studies involving (1) growth and phenology in field environments, (2) cold hardiness in the laboratory, and (3) periodicity of shoot elongation in the greenhouse. Limits of seed transfer have been defined as the smallest geographic, ecologic, or physiographic distance across which differentiation can be detected at a given level of probability.

4. Traits that key adaptation in the northern Rockies tend to be intercorrelated. In particular, traits conveying a high growth potential are negatively associated with those determining cold hardiness. This means that productivity is lost (maladaptation is increased) whenever (1) populations adapted to a mild environment are transferred to a severe environment, and (2) populations from a severe environment are moved to mild conditions.

5. Floating transfer guidelines provide a flexibility to seed transfer that is lacking with discrete seed or breeding zones.

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BREEDING POPULATIONS IN THE R-8 TREE IMPROVEMENT PROGRAM

O. O. Wells and J. L. McConnell[1/]

Breeding populations in the Southeast are based upon seed movement and planting zones which have been defined by experimentation, mainly provenance testing. Such testing is fairly well advanced for most species. Only in a few cases has it been necessary to combine populations out of administrative necessity or bridge gaps in the areas covered by tests by intuitive leaps. Most of the breeding zones are large by western United States standards, but this merely reflects the climatic uniformity of the southern coastal plain. Actually, the Forest Service has chosen a relatively conservative seed movement policy compared to forest industry in the South. In this paper I will describe the breeding zones which have been delineated for the seven species in which R-8 Tree Improvement programs are being conducted and will explain the rationale behind them. Some loblolly pine seed movements which southern forest industry has recently undertaken for anticipated gains in rust resistance or increased growth rate will also be discussed.

Loblolly pine.--Loblolly is divided into six breeding populations (BPs) each with from 50 to 150 clones (Fig. 1). There are two western BPs (one

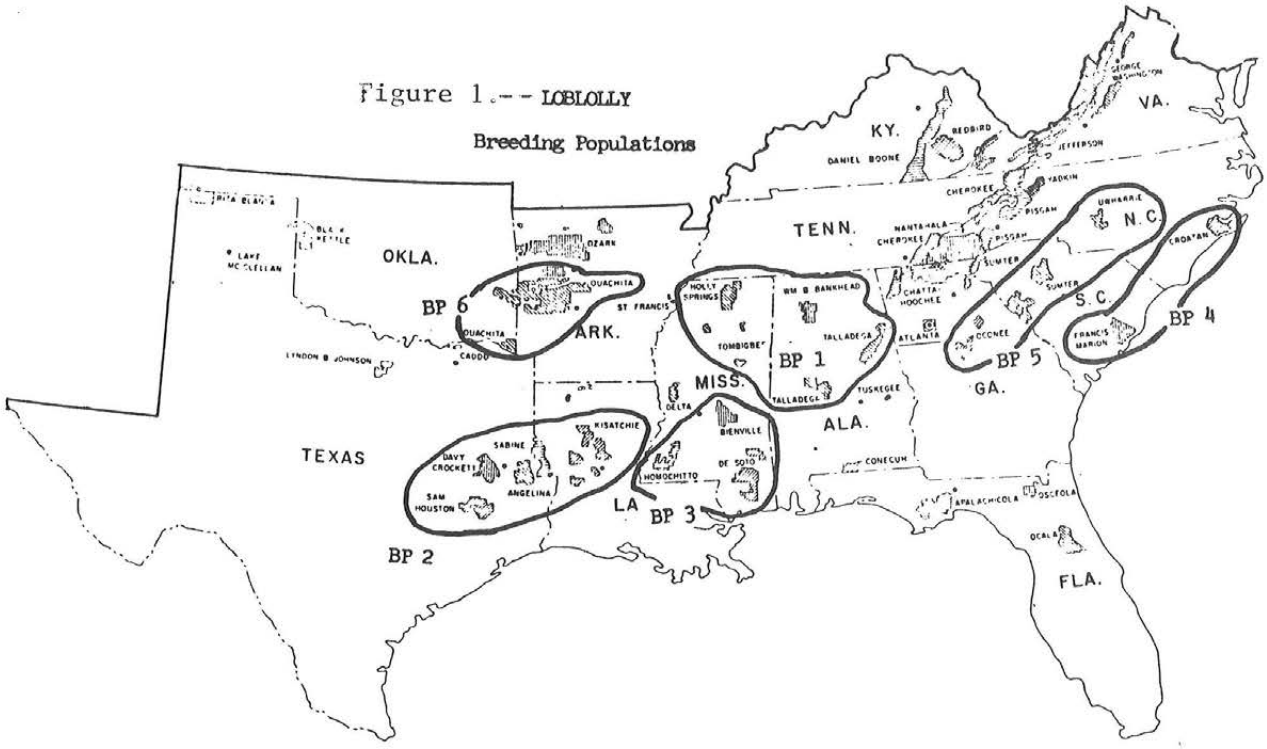


Figure 1.--LOBLOLLY Breeding Populations

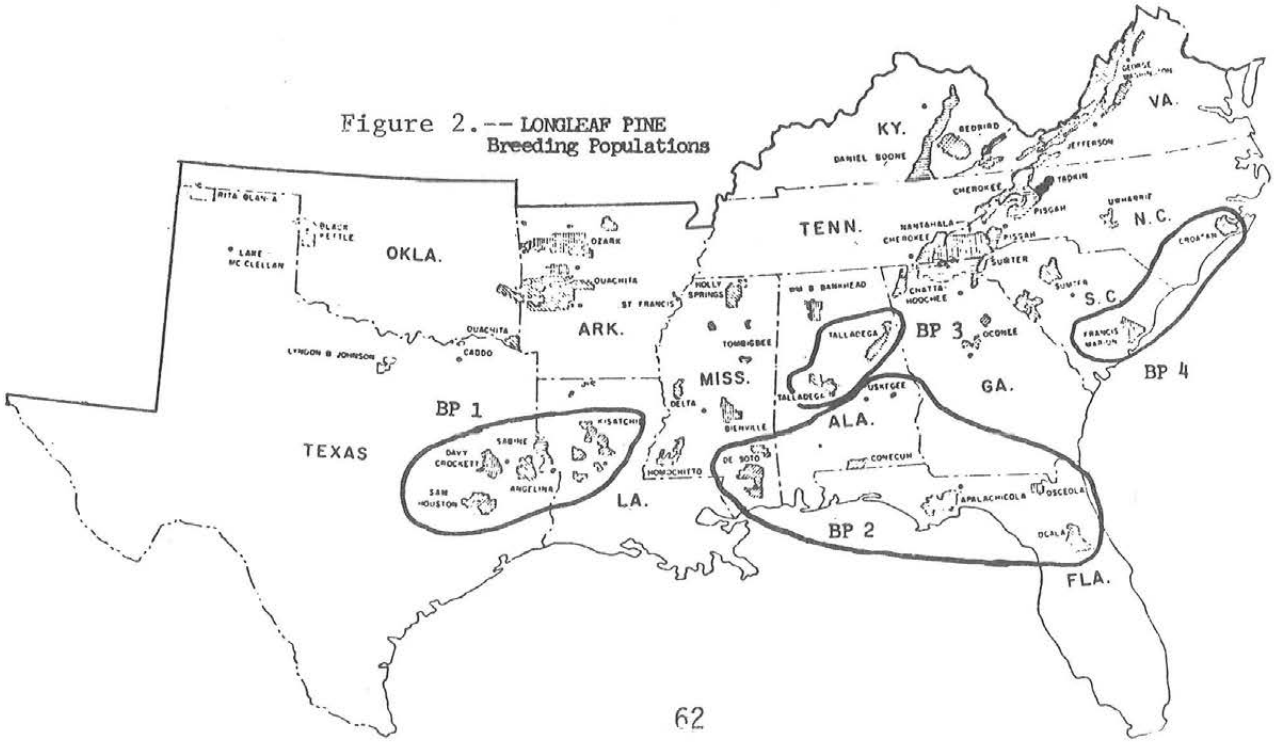
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northern and one southern), one for southern Mississippi, a northern Mississippi-northern Alabama BP, and one each for the Piedmont and Coastal Plain of the Carolinas. This division is based on the major geographic patterns of variation in the species (Wells and Lambeth 1983). Loblolly west of the Mississippi River is inherently slower growing, more drought resistant, and more rust resistant than loblolly east of the River. There is also latitudinal or coastal-continental variation of commercial importance in loblolly both east and west of the Mississippi River. This is the basis of separation of BPs 2 and 6, and of all BPs east of the Mississippi River. BP3 consists of selections from the southern half of Mississippi and BP1 covers the northern halves of Mississippi and Alabama. The 25-year results of the loblolly phase of the Southwide Pine Seed Source Study (SPSSS) show that seed can be moved from the Gulf Coast north to the latitude of Starkville, Mississippi (33° 30') without signs of maladaptation and the division of BP1 and 3 was based on this result. Compared to BP1, BP3 selections can be expected to be less drought resistant and to be faster growing, more frost tender and more susceptible to snow and ice breakage. In addition, many of the selections from the Homochitto National Forest can be expected to be quite rust resistant.

The best evidence for separating BPs 4 and 5 comes from tests that show Atlantic Coastal loblolly to be inherently faster growing than loblolly from the Piedmont of the Carolinas (Lantz and Hoffman 1969). BP4 represents the seed source that is being widely used by some forest industries in the Ouachitas, Northeast Texas, northern Louisiana, and in parts of northern Alabama and Mississippi. It grows considerably faster than the local sources in these areas and has been well-adapted for over 25 years in tests there. Region 8 plans to test progenies from BPs 1, 4, and 5 in the Ouchitas to take advantage of this effect.

Longleaf pine.--Longleaf pine has been divided into four BPs: a population west of the Mississippi River, a central Gulf Coast population, the Alabama mountains, and a coastal Carolina population (Fig.2).

Figure 2.-- LONGLEAF PINE
Breeding Populations



The population west of the Mississippi River has been shown to be slower growing and more brown spot (Scirrhia acicola (Dearn.) Siggers) susceptible than longleaf from the central Gulf Coast in two provenance tests (Henry and Wells 1967, Wells and Wakeley 1970, and Derr 1971). The SPSSS tests were conducted in a number of plantings located along a east-west transect from Georgia to near the Texas-Louisiana line and the central Gulf Coast seed source outperformed the western seed sources in all of these plantings except the most western one. As the Davey Crockett and Sam Houston National Forests are considerably farther west than any of the provenance tests and as the frequency and intensity of drought increases rapidly to the west in that area conservatism dictates that only longleaf from west of the Mississippi River be planted on the Texas and Louisiana National Forests.

The Alabama mountain population of longleaf has been shown to be more suitable for planting on the Talladega National Forest than longleaf from the central Gulf Coast (Wells and Wakeley 1970, Snyder and Allen 1968) so BP3 has been separated from BP2. BP4 in the Carolinas has been delineated as a separate entity as provenance tests show it to be somewhat slower growing than BP2.

Slash pine.--Slash pine has been divided into two BPs, western and eastern, with the dividing line at the Mississippi-Alabama border (Fig. 3). Provenance testing has shown that slash pine from the western part of the natural range (Mississippi and Louisiana) is more drought and cold resistant than slash pine from north Florida-South Georgia and therefore a better choice for planting on the National Forests in Louisiana and Texas where drought is more frequent than farther east (Snyder et al. 1967). This would seem a straightforward reason for having two BPs but the situation is complicated by

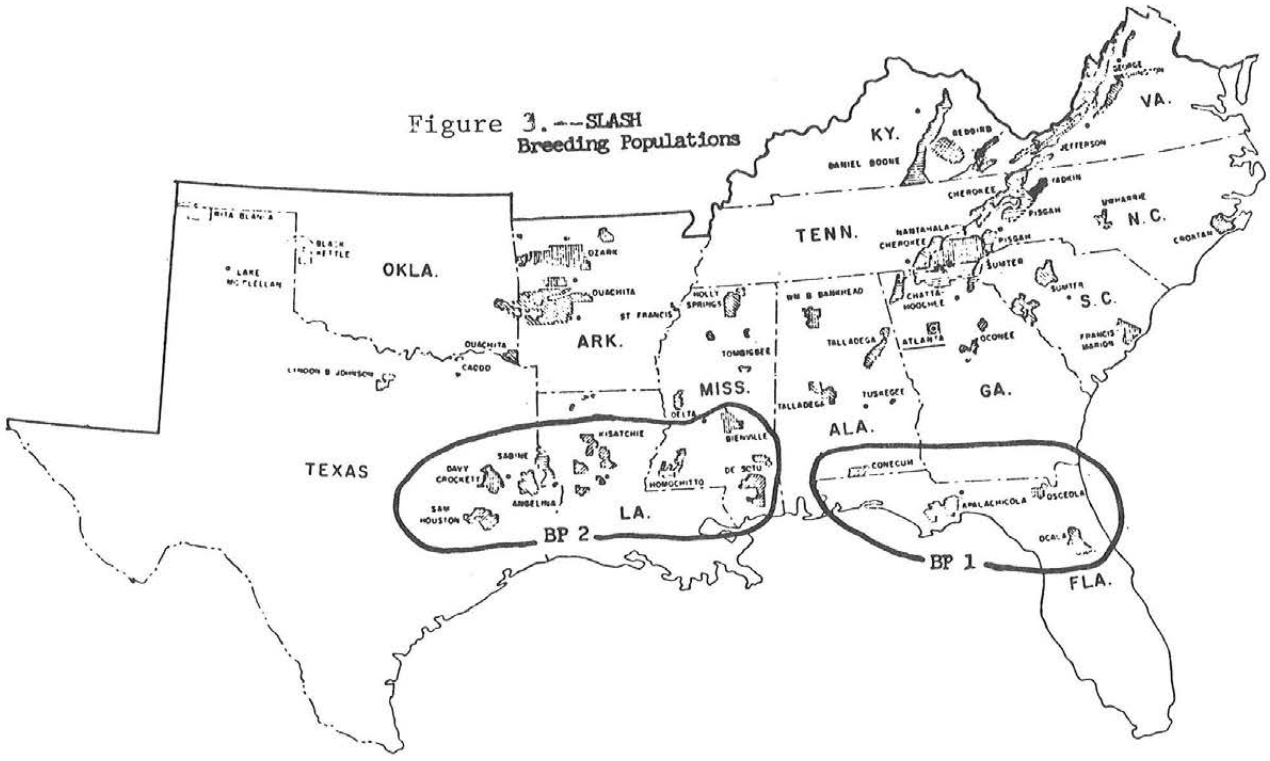


Figure 3.--SLASH Breeding Populations

the fact that all of the first generation selections from the National Forests of Louisiana were made in plantations rather than natural stands and slash pine plantations in that particular age class invariably were of north Florida-South Georgia origin. Thus BP2 is composed of 50 natural stand selections from the DeSoto National Forest and 50 plantation selections from the Kisatchie. This would have the effect of diluting the inherent drought resistance of the Mississippi slash pine or the reverse, enhancing the drought resistance of the plantation selections of North Florida-South Georgia provenance from the Kisatchie.

BP1 consists of slash pines from the National Forests in Alabama and Florida. Provenance testing has shown this to be a homogenous area without commercially important geographic variations in either growth rate or rust resistance.

Shortleaf pine.--Shortleaf pine is divided into five BPs (Fig. 4). BPs 1 and 2 divide shortleaf west of the Mississippi River into northern and southern groups; BPs 4 and 5 divide Appalachian Mountain shortleaf into northern and southern groups. BP3 combines shortleaf from both southern and northern Mississippi and thus is one of the very few cases where trees with proven differences in growth potential have had to be combined in a single BP. Division of Mississippi shortleaf into northern and southern BPs would have meant less than 25 trees in each BP. The other alternative would have been to combine northern Mississippi and Ouachita shortleaf and southern Mississippi shortleaf with the Texas-Louisiana BP. This alternative was rejected because provenance tests have provided some evidence that shortleaf from west of the Mississippi River has inherently faster growth than eastern shortleaf and also because of the possibility that western shortleaf may be better adapted to the droughty conditions of East Texas and western Louisiana (Wells 1979).

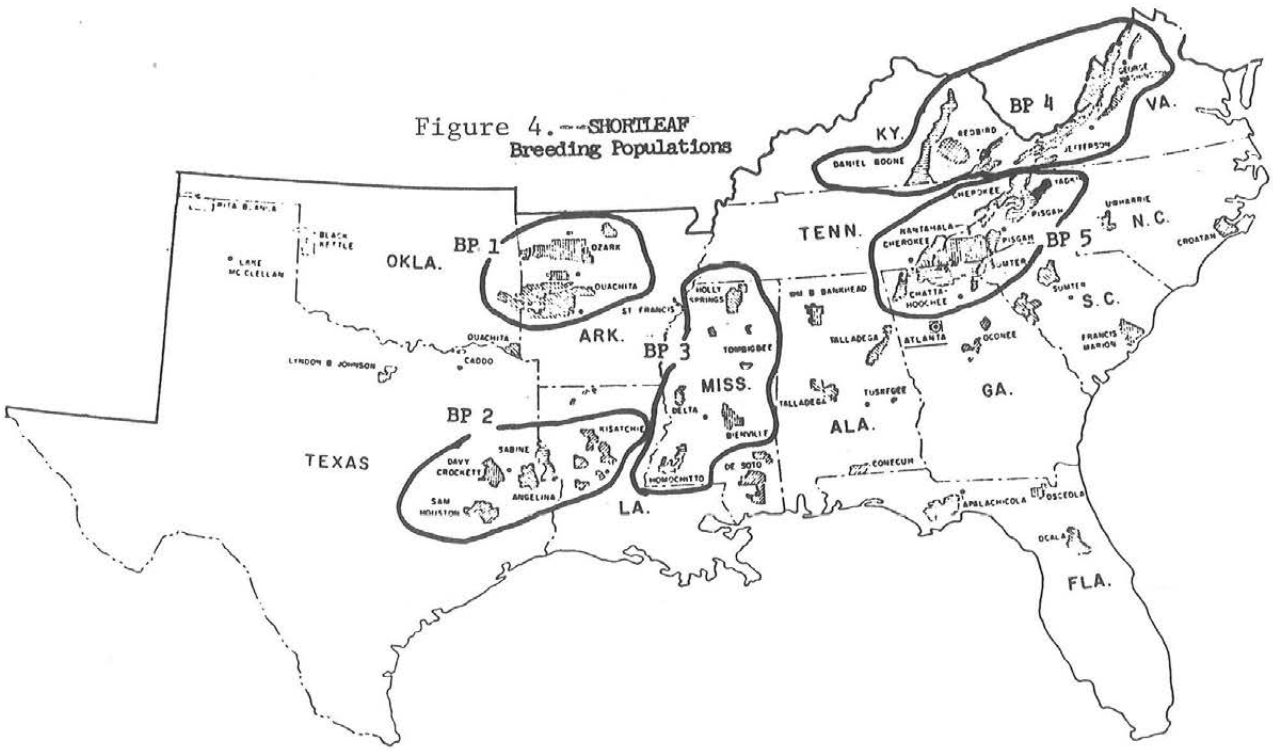


Figure 4.--SHORTLEAF Breeding Populations

BPs 4 and 5 were separated because provenance tests showed a distinct difference between them in adaptability when planted near the latitude and elevation of the Kentucky and Virginia National Forests. These National Forests are near the northern limit of the natural range of shortleaf pine and our tests clearly show that only local seed performs satisfactorily under such conditions.

Virginia and white pines.--Single BPs of 150 selections each have been delineated for Virginia pine and white pine (Fig. 5) of the Appalachian Mountains. The National Forests in the southern and central Appalachians extend over 4-1/2 degrees of latitude (270 miles) so a justifiable concern is whether or not trees from the southernmost National Forest in this area, the Chattahoochee, will be cold hardy in northern Virginia. Pertinent information from provenance tests is available for white pine but not for Virginia pine. In a range-wide Forest Service study, white pine from the southern Appalachians has been frost hardy and has grown well for at least 11 years in three plantings that span the National Forests from Virginia to Georgia (Wright 1970). A single breeding population thus seems justified for white pine.

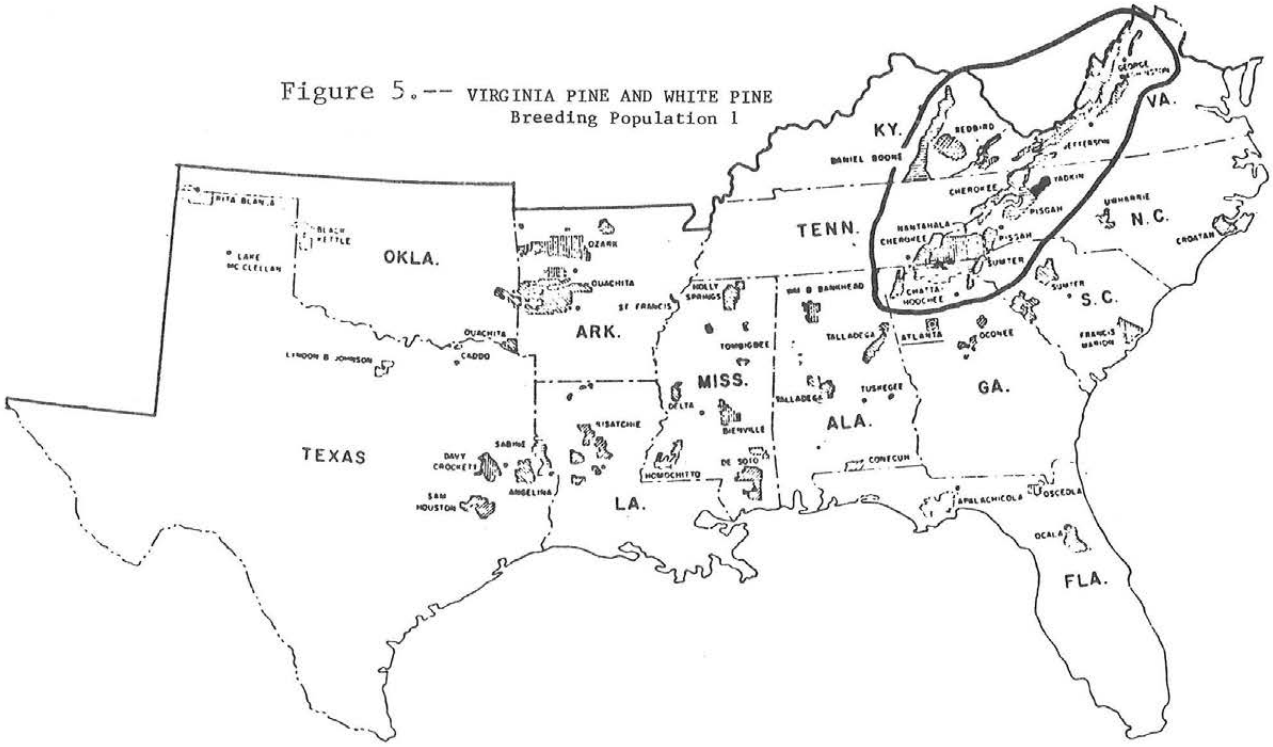


Figure 5.-- VIRGINIA PINE AND WHITE PINE
Breeding Population 1

We have no comparable data for Virginia pine. We can speculate or perhaps rationalize, that as the National Forests sample roughly the central part of the Virginia pine range, progenies involving the Georgia trees will not be tested at the northern extremity of the range where they would be at maximum risk. Breeding work has not begun on Virginia pine and we may want to divide this BP on a north-south basis before we begin to combine Georgia trees with those from Virginia and Kentucky.

Sand pine.--The Ocala population of sand pine has been designated as the only BP in this species (Fig. 6). As the Ocala National Forest is the only place the Forest Service plants sand pine, the Choctawhatchee race of western Florida was not included in the program.

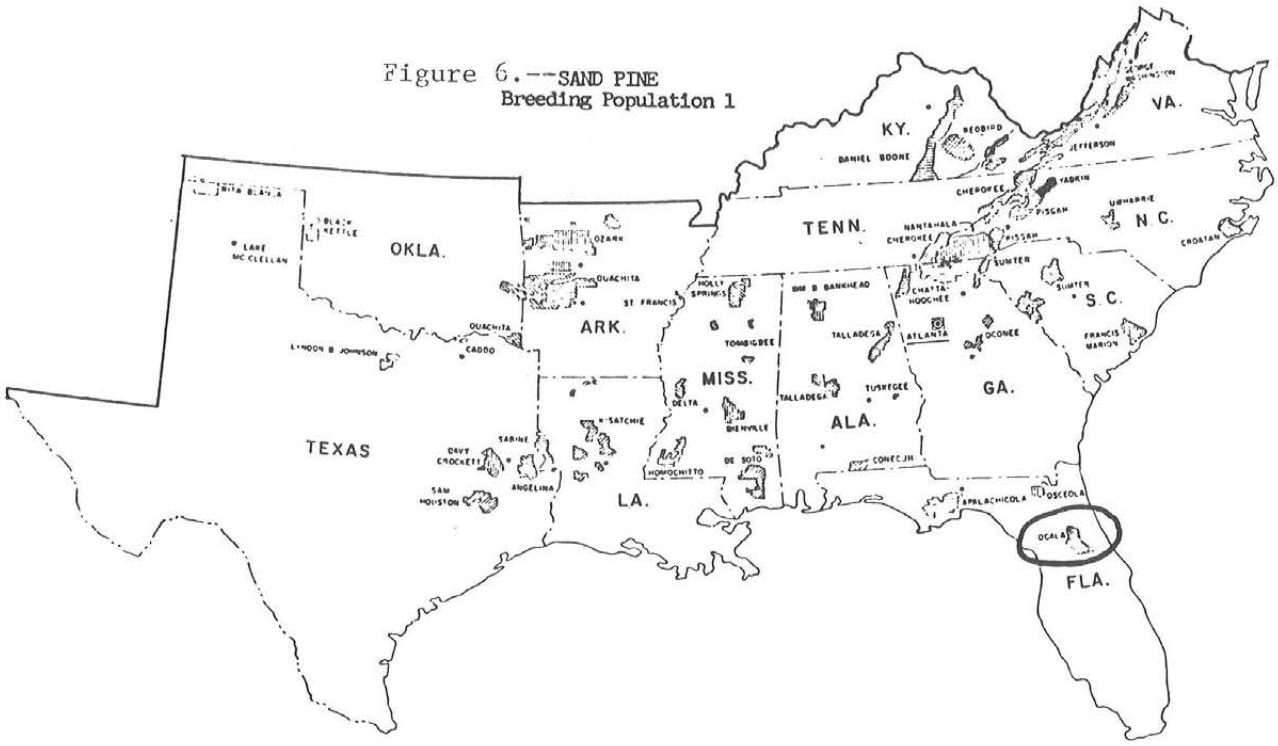


Figure 6.--SAND PINE
Breeding Population 1

The philosophy underlying sub-division of the seven species into BPs is one of maintaining populations that have distinct characteristics as identifiable genetic entities. Adaptability has been the most important characteristic used as a criterion for population distinctness. In the provenance tests which have been our principal data base, growth rate and ability to survive planting have been the principal indicators of adaptability. Outright injury by ice, snow, and freezing temperatures has also been noted but has not occurred often enough in our provenance tests to be of universal value. Poor adaptation under our test conditions for about the first 20 years has been manifested mainly by relatively slow growth and slightly higher proportions of poorly formed trees. After 20-25 years under test, some poorly adapted sources exhibit increased susceptibility to pests, principally bark beetles. This has been the case when loblolly from near the Gulf Coast has been moved too far north (Wells and Lambeth 1983). The phenomena has not been well-studied in the tests in other species.

At some point it may be desirable to combine breeding populations. This will probably be done after two or three generations of crossing within BPs. By that time research should have provided a better idea of the consequences of such combination.

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ABSTRACT

Riemenschneider, Don E. Adaptive variation and seed zones in the Lake States.

The general concept of adaptive zones and a logical process for delineating them are discussed. Adaptive zones were delineated on the basis of 1) biological criteria, i.e., the magnitude of the genotype x environment interaction and the ease with which it may be interpreted in relation to geographic subdivisions, and 2) economic or operational criteria.

The pattern of racial variation in Lake States jack pine was used to illustrate how adaptive zones may be established. Data on mean annual volume increment of 26 jack pine seed sources tested at 8 locations suggested that there may be several adaptive groups based on the response to local climate. Except for a northeastern Minnesota population, these groups are not strongly associated geographically and I suggest that adaptive zones are more properly based on actual climatic data rather than on geography.

ADAPTIVE VARIATION AND SEED ZONES IN THE LAKE STATES

by

Don E. Riemenschneider[1]

The terms seed zone, breeding zone, adaptive zone, etc., have been used by tree breeders for many years. The terms all have a common conceptual basis, but the choice of the specific term depends on a particular activity, i.e., limits on the transfer of seed collected from native stands (seed zone), establishing breeding populations (breeding zone), or moving improved seed (adaptive zone). The common basis is the problem associated with maximizing genetic gain when important genotype x environment interactions are present. In selecting the 'best' population from a set of populations, the selection is straightforward if one population is superior in all environments. If a significant amount of genotype x environment interaction exists, however, the choice is more difficult. To gain the most in this situation it is often desirable to subdivide the environment and then select the best population for each subdivision. The topic of seed, breeding, or adaptive zones is one that deals with the mechanics of how the range of environments is subdivided.

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A LOGICAL PROCESS FOR ESTABLISHING ADAPTIVE ZONES

I will use 'adaptive zone' as a generic term that includes others such as 'seed zone' or 'breeding zone'. The populations specifically adapted to conditions within any zone will be referred to as an 'adapted group'. I define an adaptive zone as follows: a delineated geographic area within which it is biologically and economically feasible to restrict the choice of available populations to a single adapted group.

In my opinion, two major criteria are used in subdividing the environment into a set of zones. The first is biological and the second is operational or economic. The first important criteria, is the previously mentioned relative magnitudes of the genetic and genotype x environment interaction effects. Adaptive zones are established where the interaction is both significant and interpretable based on a set of some easily observed environmental factors. For example, if we know that one population does best on high elevation sites and another population does best on low elevation sites, we have an easily interpretable environmental factor that may serve as the basis for environmental subdivision. Alternatively, genotype x environment interaction may be significant but not well related to any enironmental factor. In this case establishing adaptive zones is impossible and the interaction must be accepted as a limit to breeding progress.

The second important criterion is operational or economic acceptability. Clearly, with easily interpretable environmental gradients and a related genotype x environment interaction it would be possible to delineate an infinite number of adaptive zones. Although this would reduce within-zone interaction to nonsignificant levels, it would also require the establishment of an infinite number of seed collection stands or breeding programs. The obvious goal in subdividing the total environmental range into zones, therefore is some level of compromise between reducing the genotype x environment interaction and the cost

associated with such a reduction. Whether in the form of an explicit analysis or via intuition, this type of compromise always is made when establishing adaptive zones.

The first step associated with making environmental subdivisions for delineating adaptive zones is testing of the appropriate population and estimating genetic main effects versus the genotype x environment interaction (fig. 1). If the interaction is unimportant, there is no problem because only one adaptive group exists. If the interaction is important but not interpretable in relation to environmental factors, adaptive zones and groups are not identifiable and there is no solution to the problem. The limit to breeding progress must be accepted. If the interaction is interpretable, environmental subdivision and delineated zones are created followed by economic or operational feasibility evaluations of such zones. The subdivision is repeated until either the interaction is no longer interpretable or further subdivision is precluded by economic or operational considerations.

In the following, I will discuss how an evaluation of biological criteria can be applied to a Lake States conifer, jack pine. Although other conifer species also are important in the region and evaluating biological factors may lead to much different conclusions for other species, the process will be similar for arriving at delineated zones. I will not judge the economic or operational viability of any zones proposed here.

RACIAL DIFFERENTIATION IN JACK PINE

Reference populations.

In discussing racial differentiation, adapted populations and adaptive zone delineation it is important to explicitly state the reference populations of both genotypes and environments. I will refer to experimental data derived from the Lake States jack pine seed source test. Conclusions will be drawn from the

performance of 26 seed sources from Minnesota, Wisconsin, and Michigan at 8 test locations (tables 1 and 2). The characteristic used for evaluation will be mean annual volume increment after 30 years growth.

The eight sites represent the range of jack pine in the Lake States except for the Lower Peninsula of Michigan. The reference population of genotypes is jack pine of natural stand origin from the entire three-State area whereas the reference population of environments is Minnesota, Wisconsin, and the Upper Peninsula of Michigan.

The major limit imposed by this population of genotypes is its restriction to natural populations that have not been exposed to artificial selection. Results from improved populations may or may not be different but additional testing of a new reference population would be required.

Previous Work.

In 1954, 2-year-old seedlings from 29 jack pine stands in Minnesota, Wisconsin, and Michigan were used to establish 17 test plantations throughout the three States. The experimental design at each location was 4 replications of a randomized complete block design with 64-tree, square plots. The tests have been evaluated periodically and seed collection zones have been recommended (King 1966, Jeffers and Jensen 1980). On the basis of 20-year volume yield, Jeffers and Jensen (1980) suggested that the sources could be classified into three broad adaptive groups representing three zones corresponding to latitudinal bands. Group 1 was five sources from northeastern Minnesota and northern Wisconsin, group 2 was a large central group from central Minnesota to the Upper Peninsula of Michigan, and group 3 was six sources from southern Wisconsin and the Lower Peninsula of Michigan.

Current evaluation.

We obtained height, diameter, and survival measurements from eight selected locations in the fall of 1983. From these data we calculated individual tree volume using Alban's (1978) equation for plantation-grown red and jack pine. Per acre volume for each plot was calculated from individual tree volume based on original planting density and current survival. The per acre volume, as mean annual increment (cubic feet per acre per year), was used to re-examine Jeffers and Jensen's (1980) seed zone recommendations based on 20 year data. Compared to previous work that used bivariate correlation analysis of seed source means between different locations, I used a form of multivariate analysis, principal components, to examine possible racial variation. The procedures used for the mutivariate analysis are those outlined by Isebrands and Crow (1975). I used mean annual increment at each location as a variable and obtained ordination of the seed sources based on the two most significant components.

Patterns of adaptation.

In the previous evaluation of volume growth at the eight locations, significant differences were found between sources at all 8 locations (Jeffers and Jensen 1980). In my analysis, significant differences were found between sources at only six locations (table 3). This may be due to differences in replication. At both of the locations where differences were not significant two of the four replications were used for a crop tree thinning experiment and thus were not included in this analysis.

A combined analysis showed significant variance due to locations, sources, and location x source interaction (table 4). Estimates of variance components showed that the main effect for sources constituted only 31% of the sum of the source and interaction components while the interaction component made up 69% of the sum. Thus, in terms of our flow chart (figure 1) for establishing seed

zones, the first question, 'is genotype x environment interaction important?', can be answered yes. The next step is to attempt a geographical interpretation.

DELINEATING ADAPTIVE ZONES

Principal component analysis yielded two vectors (linear combinations of the original variables) that accounted for 64% of the original variation (table 5). When seed sources are ordinated based on these two principal components, some groupings are clear (figure 2). Notably, the 'northern group' (sources 1592, 1593, 1594, 1602, from northeastern Minnesota, and x source 1610 from northern Wisconsin) appears to constitute an adaptive group. Likewise, the 'southeastern group' (sources 1616, 1617, and 1618 from the Lower Peninsula of Michigan) separates well. Other groups that I have arbitrarily identified separate less well. This is especially true of the 'fringe group' (sources 1600, 1609, 1611, and 1595), which are all from the southern border of the range of jack pine in Minnesota and Wisconsin.

Analysis of variance showed significant differences between groups at all locations. In mean performance, the northern group appears to be responsible for a large amount of genotype x environment interaction (table 6). This group ranked number one at the Superior test site in northeastern Minnesota but ranked low at all other sites. Indeed, if a combined analysis of variance is done omitting data from the northeastern Minnesota location, the genetic main effect variance is increased in relation to the genotype x environment variance (table 7).

In terms of our model for establishing zones, the second question 'is the genotype x environment interaction interpretable?', can also be answered yes. Local sources appear to be best adapted to conditions in northeastern Minnesota. An identifiale adaptive group performs best in a readily delineated geographic area. This area should be considered separate for transferring of seed collected from natural stands.

The balance of the data is more difficult to interpret. Although each site had one of the principal component adaptive groups that performed well, these groups are difficult to delineate geographically. For example, the fringe group, which is superior at the Pillsbury and Mosinee sites, is intermixed geographically with the central (a) group (figure 3) which performed poorly at these two locations (table 6). Likewise, the northeastern group, which grew well at the Argonne and Ottawa sites, includes sources from the eastern Upper Peninsula (which are geographically separate) but also one source from Northern Wisconsin (which is geographically mixed with sources from several other groups) (figure 3).

The reason for the poor relation between groups based on observed performance and groups based on geographic origin is probably due to a lack of correspondence between climatic conditions and latitudinal or longitudinal gradients (table 8). Component 1 is highly correlated with growing degree days at the test site but more weakly correlated with latitude and longitude. This indicates that although jack pine seed sources may be adapted to cimatic conditions, this adaptation is less predictable on the basis of latitude. The first principal component is also well correlated with several edaphic parameters. The significance of this oservation is doubtful because these variables are also well correlated with growing degree days. The second principal component vector is correlated with mean January temperature at the test locations and in this case the climatic factor is more definable geographically, i.e., the principal component and the important climatic gradient are well correlated with longitude. This second component, however, only accounts for about 50% of the variation of the first component and thus is much less important as a classification variable.

Jeffers and Jensen (1980) divided 26 seed sources into three adapted groups. These three groups remain basically valid and, in fact are supersets of the six groups identified by principal component analysis. Jeffers and Jensen's group 1 contains only the northern group. Group 2 contains the two central groups and the northeastern group and group 3 contains the southeastern and fringe groups. Jeffers and Jensen's three groups separate sources only on the basis of the first principal component and do not interpret variation due to the second axis (figure 2). Also, note that division on the basis of the first component is difficult to delineate geographically because the component is more cloely related to actual variation in growing degree days than to latitude. This difficulty was noted previously by Jeffers and Jensen (1980) who recommended that growing degree days at the planting site be considered when selecting seed sources for Wisconsin.

A system has been proposed for delineating adapted groups and their appropriate planting environments based on growing degree days and mean January temperature (table 9). Average growing degree days and average January temperature for each of the six adapted groups are calculated from the data in table 1. When these groups are matched to the eight planting sites evaluated in this study using the matrix in table 9, it is possible to select the best performing group in seven out of eight cases. The two central groups do not differentiate on the basis of the climatic factors but this causes only a slight loss at one planting where both the number 1 and number 3 ranked adapted groups are selected. Interpretation based on climate rather than geographic boundaries seems to be the only method whereby the data may be extended to stands other than those actually tested and I would recommend this system, or some refinement of it, delineating adaptive zones in the Lake States.

Table 1. Locations at which Jack pine seed was collected

Seed source	County	Latitude	Longitude	Growing degree days[2]	Average January temperature
No.		°N	°W		°F
MINNESOTA					
1589	Cass	47.4	94.4	9,200	5
1590	Cass	47.0	94.6	9,400	7
1591	Itasca	47.5	94.1	9,100	5
1592	Lake	47.7	91.2	7,400	10
1593	Cook	48.0	90.3	6,700	14
1594	St. Louis	48.1	92.4	8,500	5
1595	Pine	46.0	92.6	9,500	10
1596	Pine	46.4	92.8	9,000	9
1597	Becker	47.1	95.4	8,900	4
1600	Cass	46.8	94.4	9,400	6
1601	Beltrami	47.5	95.0	8,600	5
1602	Itasca	47.8	93.3	8,800	6
WISCONSIN					
1605	Bayfield	46.7	91.0	9,000	13
1606	Forest	46.0	88.9	8,500	12
1608	Burnett[3]	45.9	92.1	10,000	10
1609	Marinette	45.2	88.3	9,600	14
1610	Oneida	45.8	89.8	9,000	10
1611	Wood	44.4	89.7	10,000	13
MICHIGAN (Upper Peninsula)					
1612	Gogebic	46.2	89.2	8,500	12
1613	Ontonagon	46.6	89.0	8,800	15
1614	Alger	46.3	86.7	8,100	15
1615	Chippewa	46.3	84.8	8,000	15
1621	Luce	46.6	85.4	7,900	16
MICHIGAN (Lower Peninsula)					
1616	Manistee	44.2	86.2	10,100	22
1617	Ogemaw	44.2	84.1	9,600	19
1618	Alpena	45.0	83.5	9,000	19

[1]Data from Stoeckeler and Rudolf (1956).

[2]Normal annual sum of average daily temperatures of 50°F or above.

[3]Not planted at University of Minnesota CFC (Plantation 6).

Table 2.--Location of jack pine planttins.[1/]

Forest	State	County	Latitude	Longitude	Growing degree days	Mean Jan. Temp.
					No.	°F
Superior NF	Minnesota	Lake	47.6	91.1	7,400	10
Pillsbury SF	Minnesota	Cass	46.4	94.5	9,400	6
General Andrews EF	Minnesota	Pine	46.4	92.8	8,700	9
Mosinee IF	Wisconsin	Washburn	46.2	92.0	10,000	10
Chequamegon NF	Wisconsin	Bayfield	46.3	91.4	9,000	13
Argonne EF	Wisconsin	Forest	45.8	89.0	8,500	12
Marinette CF	Wisconsin	Marinette	45.7	88.0	9,600	14
Ottawa NF	Michigan	Ontonagon	46.3	89.2	8,500	12

1/ Data from Jeffers and Jensen (1980).

Table 4.--Combined analysis of variance results for mean annual volume increment of 26 sed sources at eight locations.

Variation	SS	df	MS	F-ratio	Variance component
Location	305,691	7	43,670	48.23**	563.96
Source	66,858	25	2,674	2.95**	72.84
Loc x Source	158,458	175	905	2.15**	163.98
Error	173,457	411	422		422.04

1. ** = differences significant at the 0.01 probability level.

Table 5.--Principal component analysis results of mean annual volume increment for jack pine grown at eight locations.

Location	Eigenvector 1	Eigenvector 2
Superior	0.379	0.185
Pillsbury	-.354	0.364
General Andrews	-.185	0.462
Mosinee	-.514	0.082
Chequamegon	-.494	-.090
Argonne	0.104	-.504
Marinette	-.399	-.318
Ottawa	-.134	-.499
Variation (percent)	42%	22%

Table 6.--Mean annual volume increment (cubic feet/acre/year) of seed source groups determined by ordination of seed sources after principal component analysis.

Group	Location							
	Superior	Pillsubry	Andrews	Mosinee	Chequamegon	Argonne	Marinette	Ottawa
Northern	90.9	90.7	86.1	18.1	57.4	109.8	77.1	87.2
Central (a)	83.7	112.2	115.2	47.6	86.2	98.8	74.6	111.4
Central (b)	88.2	118.7	92.0	46.5	88.4	124.7	93.0	121.3
North-eastern	82.3	69.9	84.8	33.3	76.6	131.9	87.7	131.7
South-eastern	65.7	111.9	87.9	66.5	108.8	110.1	122.4	127.5
Fringe	76.9	140.3	107.2	70.1	99.9	94.6	99.6	91.5
F-ratio Groups	4.88 **	7.70 **	5.56 **	29.83 **	13.82 **	3.25 *	27.62 *	4.37 *

1. ** = differences significant at the 0.01 probability level.

2. ** = differences significant at the 0.05 probability level.

Table 7.--Combined analysis of variance results for mean annual volume increment of 26 seed sources at seven locations. The superior plantation is excluded.

Variation	SS	df	MS	F-ratio	Variance component
Location	303,059	6	50,509	53.11 **	623.66
Source	77,380	25	3,091	3.25 **	96.47
Loc x Source	142,648	150	951	2.16 **	165.44
Error	169,675	386	440		439.57

1. ** = differences significant at the 0.01 probability level.

Table 8. Correlations between the first two principal component analysis eigenvectors and several climatic and edaphic characteristics at the test locations.

Variable	Eigenvector 1	Eigenvector 2
ph	0.381 ns	0.443 ns
% silt + clay	0.566 ns	-.030 ns
% organic matter	0.746 *	-.260 ns
Exchange capacity	0.622 ns	-.341 ns
Soil nitrogen	0.705 ns	-.345 ns
Soil phosphorus	-.242 ns	0.655 ns
Soil potassium	0.966 **	0.042 ns
Exchangeable calcium	0.555 ns	0.365 ns
Exchangeable magnessium	0.742 **	0.281 ns
Latitude	0.587 ns	0.509 ns
Longitude	-.214 ns	0.883 **
Growing degree days	-.913 **	0.032 ns
Mean January temperature	-.061 ns	-.781 *

ns = not significant
* = differences significant at the 0.05 probability level.
** = differences significant at the 0.01 probability level.

Table 9. A system for matching adapted groups of seed sources to planting location based on growing degree days and average January temperature of the adapted group and the location.

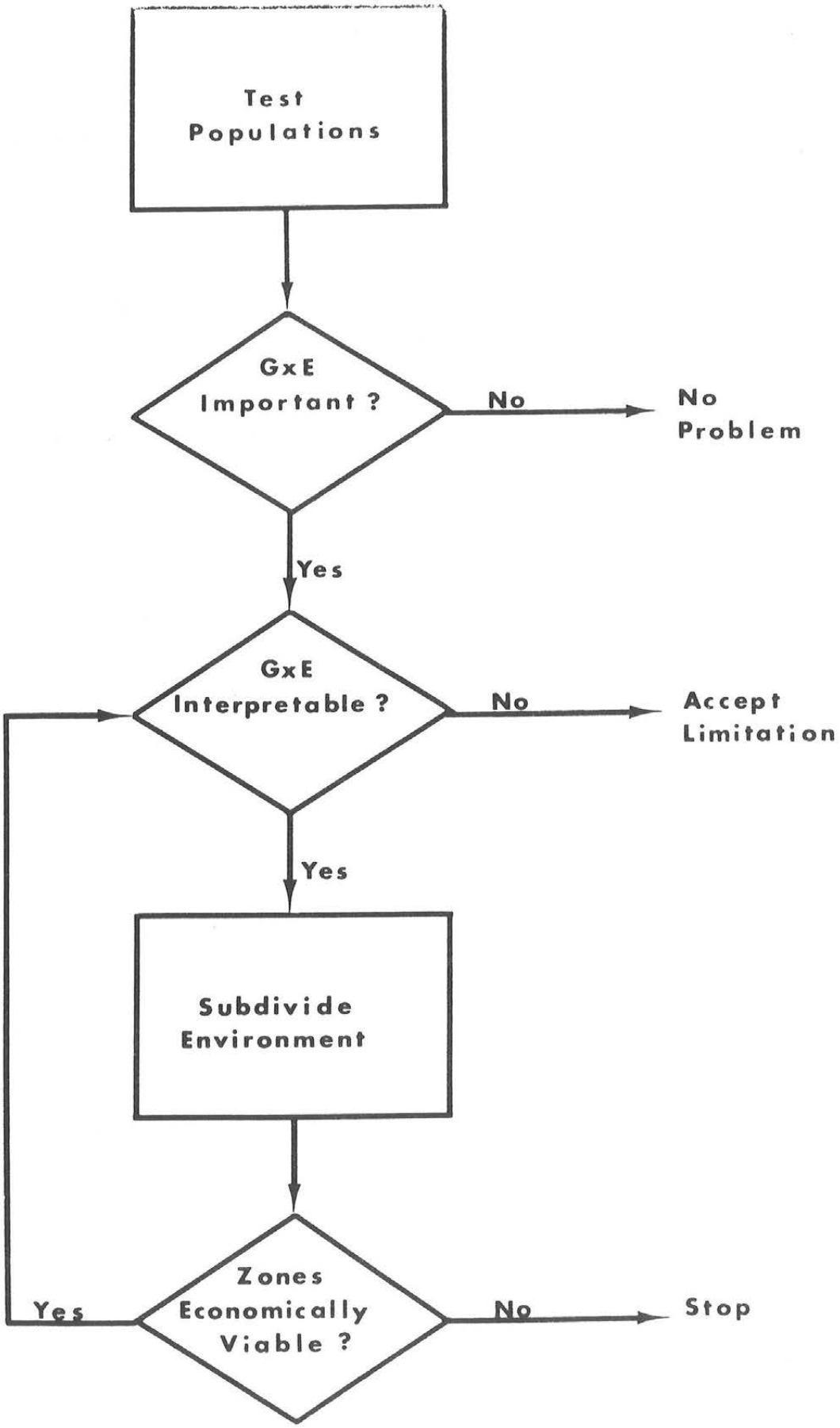
Growing Degree Days	Average January Temperature: (°F) < 11°F	> 11°F
< 8,100	Group: Northern Location: Superior	No data in this combination.
8,100 - 8,600	No data in this combination.	Group: Northeastern Location: Argonne, Ottawa
8,600 - 9,100	Group: Central (a) Central (b) Location: Gen.Andrews	Group: Southeastern Location: Chequamegon, Marinette
> 9,100	Group: Fringe Location: Pillsbury, Mosinee	

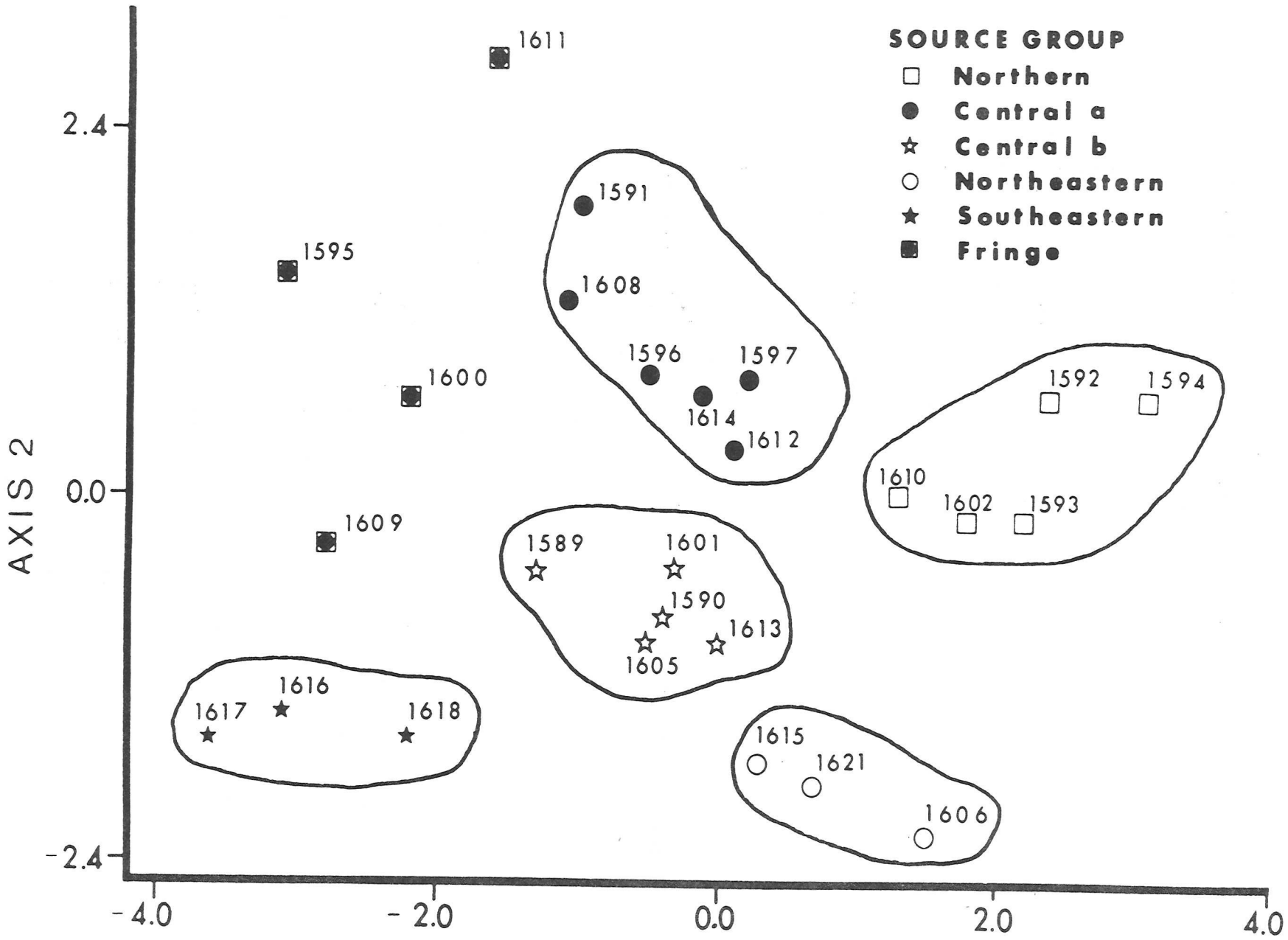
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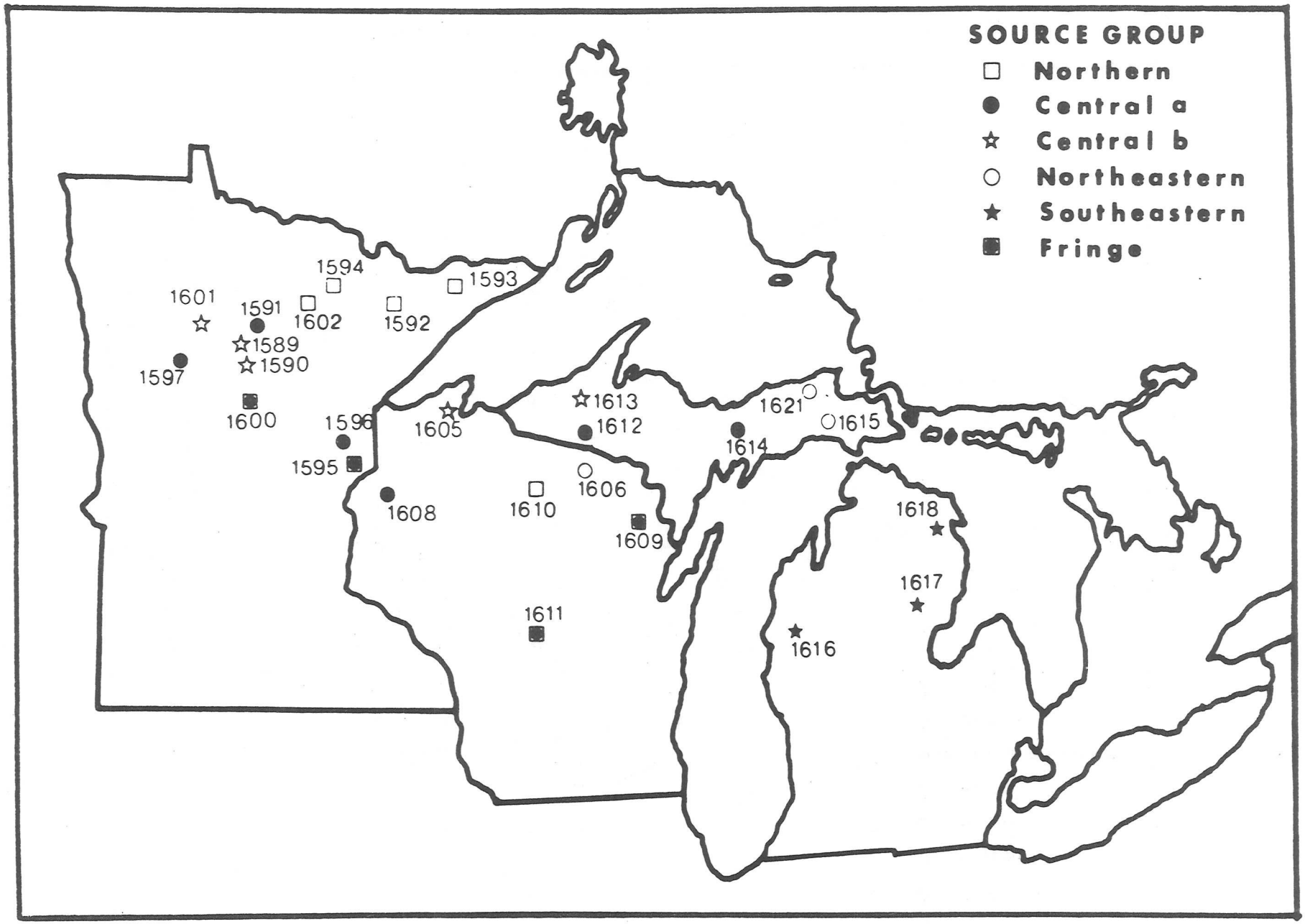
Figure 1. Flowchart outlining the progression of steps used in delineating adaptive zones.

Figure 2. Ordination of seed sources obtained from a plot of the first two principal components of an analysis of the performance (mean annual volume increment) of 26 seed sources at eight locations in the Lake States. There appear to be six groups: The northern group, two central groups, a northeastern and southeastern group, and a fringe group. The last group separates well on the basis of the first component but is dispersed with regard to the second.

Figure 3. Geographic locations of the 26 seed sources and their principal component groupings.


Test Populations
GxE Important ?
No
No Problem
Yes
GxE Interpretable ?
No
Accept Limitation
Yes
Subdivide Environment
Zones Economically Viable ?
Yes
No
Stop


SOURCE GROUP
Northern
Central a
Central b
Northeastern
Southeastern
Fringe
1611
1595
1591
1608
1596
1597
1600
1614
1612
1592
1594
1610
1602
1593
1609
1589
1601
1590
1613
1605
1616
1617
1618
1615
1621
1606
AXIS 2
2.4
0.0
-2.4
-4.0
-2.0
0.0
2.0
4.0


SOURCE GROUP
Northern
Central a
Central b
Northeastern
Southeastern
Fringe
1594
1593
1601
1591
1602
1592
1589
1590
1597
1600
1596
1605
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1612
1621
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1611
1616

Evaluating Breeding Zones for Ponderosa Pine in California[1]

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INTRODUCTION

Tree species range from the least to the most genetically variable of organisms, and knowledge of the amount and geographic distribution of variation is prerequisite for efficient design of breeding programs. Genetic variation has been demonstrated in progeny tests (for example, Campbell 1979; Rehfeldt 1983a, 1983b) and in biochemical analyses of allelic gene products (Gansel and Squillace 1976, Squillace and others 1980).

At the Institute of Forest Genetics, we are using progeny tests and enzyme analyses in a large-scale study of ponderosa pine in California's Sierra Nevada. There, ponderosa is phenotypically variable, widely planted, intensively managed, and a principal species in the Forest Service Pacific Southwest Region's high level breeding program. Breeding zones are being established, superior trees are being selected, and seed orchards are being grafted. Nursery tests are nearing completion, and field tests are being established on sites with high growth potential for ponderosa pines.

This paper reports an analysis of enzyme variation in ponderosa pine in California and provides information useful in evaluating tree breeding zones.

BREEDING ZONES

Forest Service policy for artificial regeneration requires planting seedlings from local seed sources. Seed zones define local sources by setting seed collection boundaries related to physiographic features and elevation. In California, tree improvement planners assumed that ponderosa pine breeding zones could include plus-trees from several seed zones. They did so for these reasons: some environments and species associations are common to several seed zones; progeny tests will evaluate plus-tree breeding values over a wide range of locations, enabling progeny that perform well throughout the breeding zone to be selected--that is, those for which genotype X environment interactions are negligible.

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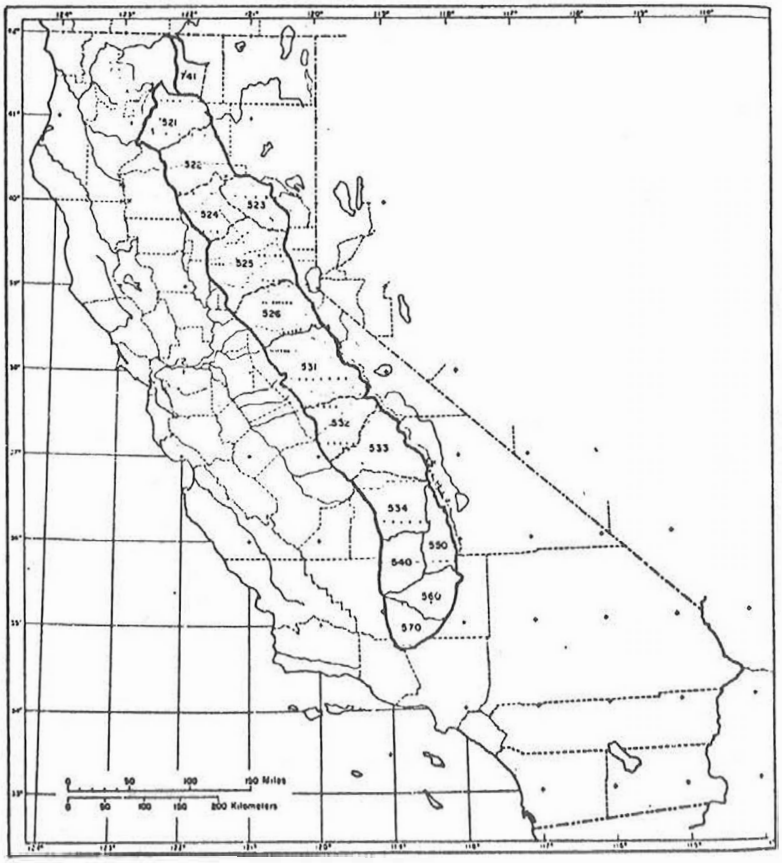
1 Presented at USDA Forest Service, Forest Genetics Workshop on Progeny Testing, December 5-9, 1983, Charleston, South Carolina.

But decisions regarding boundaries of breeding zones and the size of the breeding populations for ponderosa pine are difficult because few test results are available to evaluate genetic variation over the entire targeted area. A long-term progeny trial from an elevation transect demonstrated that ponderosa pines were strongly adapted to different elevations at latitudes near Placerville (Callaham and Liddicoet 1961, Conkle 1973, Echols and Conkle 1971, Mirov and others 1952). In another study, geographic samples of Sierra Nevada ponderosa pines did not differ significantly in composition of resins (Smith 1977). In a third study, geographic samples differed significantly in seedling root growth characteristics related to winter dormancy and the length of cold storage after nursery lifting (Jenkinson 1980).

METHODS

Open pollinated seed from 524 plus-trees from seed zones north of Mount Shasta south to the Greenhorn Mountains were selected for this study (figure 1). A complete designation of a seed zone, for seed collection purposes, consists of the number and a code for the appropriate 500-foot-elevation band. In this report a "seed zone" means the combination of geographic zone and elevational band.

Figure 1. Geographic location of seed zones of the southern Cascades and west slope Sierra Nevada of California.



Ponderosa seeds were analyzed by starch gel electrophoresis (Conkle and others 1982) and multilocus (specifically 30 loci) enzyme genotypes were determined for each plus-tree. The genetic interpretation of enzyme band patterns (isozymes) were based on segregation of alleles in haploid seed tissues of heterozygous seed trees (Conkle 1981).

We analyzed large numbers of enzyme loci to gain knowledge about the relative amounts and geographic distribution of variation. Just as it is difficult to find single genes controlling growth, it is difficult to find alleles of a single enzyme locus related to specific phenotypic responses. But multilocus analyses of enzyme variation provide useful information that correlates with greenhouse, nursery, and field trials.

GENETIC DIVERSITY

The literature suggests that species with low genetic diversity--few alleles per locus, many monomorphic loci, and average heterozygosity values equal to or near 0.0--are difficult to modify by artificial selection. Red pine was the first conifer found with no diversity (Fowler and Morris 1977). It is a species well known for high self-fertility, no inbreeding depression, and no measurable response to selection. Two other North American conifers have since been found lacking diversity: western redcedar, found throughout northwestern forests (Copes 1981), and Torrey pine, a California endemic surviving in two small and geographically isolated habitats (Ledig and Conkle 1983).

Species with high genetic diversity are those in which most loci are polymorphic in populations and single trees are heterozygotes at about 30 percent of loci. They include loblolly pine, Douglas-fir, and Norway spruce (Hamrick and others, 1981). These species, in contrast with red pine, are self-incompatible, have strong inbreeding depression, and show significant improvement with artificial selection.

The analyses yielded diversity estimates about two-thirds of those of species with the highest values. Three measures of genetic diversity for individual seed zones were analyzed: mean number of alleles per locus, proportions of polymorphic loci, and expected heterozygosity (table 1). Actual counts of heterozygous loci per tree corresponded to Hardy-Weinberg expected values and only the expected values are listed in the table.

The ponderosa pines studied averaged three alleles per locus, 89 percent of the loci had allelic variation, and a tree, on the average, was heterozygous for 21 percent of all loci (table 1) . These values are higher than those reported for ponderosa pines from the northern Rocky Mountains (O'Malley and others 1979). This difference could reflect true population differences or could arise from analyzing different loci, from using different laboratory techniques, and from occasional differences in interpretation of isozyme bands. Our averages for alleles per locus and percent of polymorphic loci are higher than the average of 20 conifers reported by Hamrick and others (1981), but average heterozygosity equals the conifer species average.

Seed zone values clustered closely about mean values, and no north-south trend in diversities is suggested. These diversity values indicate that ponderosa pines have significant amounts of variation well distributed throughout seed zones.

Table 1. Genetic diversity of ponderosa pine from 12 seed zones of the Sierra Nevada of California.

Seed zone	Sample size	Alleles per locus	Polymorphic loci	Expected heterozygosity
	Number		Percent	
741	38	2.8	90	23
521	22	2.4	83	22
522	48	3.0	80	20
523	49	3.3	100	22
524	62	3.4	97	20
525	61	3.2	87	20
526	47	3.3	93	20
531	51	3.1	93	21
532	41	2.9	80	21
533	53	3.2	87	19
534	28	2.7	90	19
540	40	3.1	87	22
Unweighted mean	45	3.0	89	21
SE mean	3.5	0.1	2	0.3

MULTILOCUS CLASSIFICATION

Can underlying genetic associations be determined, using the ponderosa pine genotypes arrayed across the geographic area? To suggest aggregations, we used individual tree multilocus genotypes to develop new groups based on genetic similarities. The trees are fixed point samples where longitude, latitude, and elevation mark their physical locations, and subsequent aggregations must make geographic sense. Nearby trees should be in the same group if their genotypes are similar and the process should maximize genetic distances among the new groups. The groups will have identifiable geographic boundaries. We do not view the number or the size of groups as rigidly fixed, but our experience indicates that iterations stabilize within a limited range of values. Further increases or decreases in the number of groups lower the amount of variation accounted for by the classification.

We used discriminant analyses for classification and canonical analyses (multivariate analogues of one-way analyses of variance) for hypothesis testing, determining associations among original variables and canonical vectors (associations are based on matrices of simple correlations between the original variables and the appropriate canonical vectors), and examining spatial distributions of groups (Williams 1983). The matrix equation for distance in discriminant analyses is analogous to the t-statistic and was useful for testing pairwise differences among groups. Because the classification results use the data to compute group means, we plan for a future paper to estimate unbiased classification error rates by a cross-validatory procedure (Smouse and others 1982). Statistical analyses were made by appropriate SAS procedures; DISCRIM for discriminant analysis, CANDISC for canonical analysis, and CANCORR for canonical correlation analysis (SAS Institute Inc. 1982).

Allelic data for each tree were transformed to genotype scores (Spielman and Smouse 1976). Although variation in these scores are individually binomial, linear combinations of scores approximate multivariate normality. To examine the degree of geographic differentiation in the allelic data, the scores were then regressed against data on latitude, longitude, and elevation, using canonical correlation analysis. A combination of linear, quadratic, and crossed variates (latitude, longitude, latitude X longitude, elevation, elevation squared, elevation X latitude, and elevation squared X latitude) were maximally correlated with the allozyme variables. The first two canonical vectors were highly significant and accounted for 35 and 29 percent of genotypic variation, respectively--49 percent when combined. The first vector was associated with latitude and longitude and genetic scores for alleles at 13 loci. The second vector was associated with elevation variables and scores for a different combination of alleles at 14 loci.

Trees were divided into seed zone and elevation-within-zone classes, and class means were computed and plotted for the first two canonical variables. From groups found in the plots of class means, candidate groups were developed. Then candidate groups were examined by canonical analysis. Mahalanobis distances and plots of the canonical scores were used to develop aggregate groups.

Groups formed in this manner plot in strata directly related to seed zones and elevations (table 2). The average Mahalanobis distance was 3.3, and the predicted probability of correctly allocating trees to groups (Smouse and others 1982) was 51 percent (the random probability of allocation is 6 percent). The first three canonical vectors were significant, accounting for 46, 37, and 34 percent of the variation, respectively. Combined, they account for 65 percent of the total variation.

Table 2. Groups, signified by letters, arrayed by seed zone and elevation in seed zone.

Seed zone	Elevation (feet X 100)								
	<24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	>60
741	B	B	B	B	A	A	A	A	A
521	C	C	C	C	D	D	D		
522	E	G	B	F	J	C	C	C	
523		E	F	F	F	F	F	F	
524	E	E	G	G	I	J	J		
525	E	E	G	G	I	J	R		
526			G	G	I	R	M		
531		E	N	O	N	R	R	M	
532			N	R	Q	R	P		
533			N	O	R	R	R	R	
534				S			S	R	R
540					T	S	T	P	Q

Individual trees were then allocated to groups by discriminant analysis. This allocation used the original multilocus genotype for each plus-tree. Each tree's genotype resulted in an array of probabilities for membership in the entire array of groups (table 3).

Table 3. Classification probabilities of five trees for membership in 17 groups.

Tree from group	Post-classification membership in groups...																
	A	B	C	D	E	F	G	I	J	M	N	O	P	Q	R	S	T
P													1.0				
P									.02	.04	.08	.02	.45	.39			
C		.16	.11		.40		.01		.12			.18					
F			.02	.49		.48		.01									
C		.01	.19		.02	.38	.11	.04	.20		.01	.02	.02				

The probability is 1.0 that the first tree listed in table 3 belongs in group P. The first column indicates the tree, in fact, came from the seed zone and elevation class of group P. This tree's genotype indicates a total match with P group characteristics--the tree has no significant probability of belonging to any other group. The second tree listed in table 3 is likewise from the area of group P. Its highest probability for membership is in group P. But this tree also has a high probability of membership in group Q and minor probabilities for membership in J, M, N, and O. The third example is one for a tree from the C area, which has, however, a genotype more closely related to those of group E. The fourth example is one with equal probabilities of belonging to two groups. The final tree has significant affinity with groups C, F, G, and J and minor affinity with six others.

About 53 percent of all trees were reallocated to the group representing their original area (table 4). The number counts of these trees by actual and new assignment groups are diagonal values within the table. Across the first row of data, a total of 13 trees were included in the analysis and 11 were assigned correctly to group A. In the second row, 17 of 30 trees were assigned correctly to group B.

Group R, which included the largest number of trees, is centered in seed zones of the 530 series and includes trees from the middle of ponderosa's elevational distribution (table 2). Other groups that also include large numbers of trees--F, G, and I--are centered in zones of the 520 series and, like R, include elevational groups from the middle of ponderosa's elevational distribution.

Table 4. Allocation of trees into groups on the basis of tree genotypes and multivariate classification equations.

Tree's actual group	New assignment group (based on genotype)																	
	A	B	C	D	E	F	G	I	J	M	N	O	P	Q	R	S	T	Total
A	11					1		1										13
B	2	17		2	1	1					3		1		1	2		30
C			21	1		1	2	1		1	2				1	1		31
D				5											1			6
E			1		8	3	2	1			1				1		1	18
F		3	3			32	1		4	1	5				3	2	1	55
G		2	4	3	3	3	23	4	7		6		2	1	7		4	69
I		1	1	1	1		5	20	3	3		1			3	1	2	42
J		1	4				1	1	15		2				3	1	1	29
M					1	1			1	9					1	1		14
N	2	1	1								11				3			18
O							1			1	2	9					2	15
P	1	1	2	1									13	2	3			23
Q					1		2	2	2					12		1		20
R	2	5	7	6	4	7	5	2	5	3	4	4	1	4	58	4	3	124
S				1												6		7
T								1				2					7	10
Total	18	31	44	20	19	50	41	33	37	18	36	16	17	20	84	19	21	524

Groups from central elevations of the northern and southern Sierra Nevada have about 50 percent of trees correctly assigned. The other 50 percent of trees have genotypes that assign them to diverse groups throughout the entire range. In contrast, trees in groups from low and high elevations and trees from far northern areas in seed zones 741 and 521 and central areas in seed zones 526 and 531 are well classified--65 to 85 percent of trees are correctly reassigned to original groups.

DISCUSSION AND CONCLUSIONS

Isozyme variation in ponderosa pines correlates with geographic origin. The equations developed define groups where trees in groups share genetic similarities and where genetic distances between groups is maximum. They incorporate allelic information from 30 loci and the classification reflects the distribution of polygenic variation over the area. As expected, the variation within some loci was distributed randomly over latitudes, longitudes, and elevations. But differences among loci that vary in relation to geographic location were sufficient to assign individual trees to correct groups with high precision.

The groups defined by multivariate analysis consist of trees drawn mainly from contiguous seed zones and elevations. Groups tend to include trees from lower elevations in one seed zone with trees from higher elevations in a more southern seed zone. The results further suggest that ponderosa pine in the Sierra Nevada has a significant genetic subdivision that corresponds closely with the change from the 520 to the 530 series seed zones. Trees from the middle elevations of the species distribution in the northern Sierra Nevada (groups F, G, and I) and in the southern Sierra Nevada (group R) are variable--about 50 percent have genotypes with affinity to locations from throughout the distribution. But trees in groups from far northern and central Sierra Nevada locations and those from the lower and upper elevations contain from 65 to 85 percent with strong genetic affinity for their groups.

These enzymes provide information about the relative amount of variation in taxa and thus estimate the potential for genetic change. The enzymes are also highly useful for charting geographic patterns of genetic variation in a variable taxon--ponderosa pine of the Sierra Nevada. They are a means of subdividing natural populations into biologically significant groups which may, for practical purposes, be equated to breeding zones.

Details of this analysis and of improvements to the classification now under way will be reported in the future. The further work includes a tree-by-tree assessment of class assignments, and an examination of the probabilities for post-classification membership in groups (as in table 3), reassignment of trees when probabilities permit, and computing new classification formulas. This iterative procedure promises to improve the classification scheme by further reducing the proportion of misclassified trees. Future analyses are being designed to compare isozyme classifications with those based on growth in nurseries and plantations of offspring of the 524 plus-trees.

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The Objectives of Progeny Testing

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Abstract. The objectives of progeny testing are usually one or more of the following:

1) evaluate genotype of parents,
2) estimate genetic parameters,
3) provide a source of trees for another cycle of selection,
4) obtain data for certification of improved seed,
5) develop a seedling seed orchard.

Keywords: Progeny testing, selection, genotypic evaluation

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I'm tempted, and I've learned there is nothing more futile than the memory of a temptation resisted, to list the first objective of progeny testing as an attempt to disprove the validity of Murphy's laws. Unfortunately I have never seen a progeny test that met this objective, and Murphy's laws remain valid.

Actually, the first objective that we usually think of when we speak of a progeny test relates not to the progeny themselves but to their parents. In this sense, we are not actually testing the progeny but using the performance of the progeny to evaluate the genotypic worth, or breeding value, of the parent trees from which the seed were obtained. It is important in this kind of progeny test that we clearly keep in mind the traits which are being evaluated, because even though the objectives of the test may be to evaluate the parents, the design, length of time of the test, and analysis may be quite different if we are evaluating parents for resistance to fusiform rust disease or if we are looking for parents with desirable long-rotation timber traits. In some cases, where the progeny will be used to evaluate parent trees already in established seed orchards, the objectives will be to identify parent trees for removal from the seed orchard as poor breeding material. It may not neccessarily be the case, but often is, that these tests are used to identify the best parents for use in advanced generation breeding programs. At the risk of infringing on someone else's presentation, I should add that progeny tests with the objective of parent evaluation can be conducted by using seed from relatively simple mating systems such as from wind pollination or from polycross controlled pollination,

or by using more sophisticated systems such as diallel crosses.

Often when working with a new species, a new group of trees, or beginning work on a new trait, progeny tests are conducted with the primary objective of obtaining estimates of genetic parameters. Most commonly, variance components are used to obtain estimates of general combining ability, specific combining ability, and heritability. Reliable estimates of heritability can be used to make estimates of the genetic gains being obtained from the breeding system and population under study. Progeny tests designed to obtain these estimates of genetic values can also be used as the basis for seed orchard roguing and selection of parents for advanced generation breeding, but the mating systems necessary to obtain these estimates are often too expensive to use for evaluating large numbers of selected trees.

Another objective of progeny testing can be to provide a source of trees growing under reasonably uniform conditions from which new selections can be made. Common practice is to analyze assessment data, identify the outstanding family or families for the trait or traits under consideration, and then to select from those families individual trees that exhibit the desired phenotypic characteristics. Progeny tests to determine a source of material for selection must be carefully designed to provide reasonably accurate estimates of family performance plus a sufficient number of trees in each family from which to make individual tree selections.

Data from progeny tests are also used to obtain certification of improved seed produced in seed orchards. To my knowledge very few tests have been established with this objective in mind. This is surprising

because, for most seed certification programs, a relatively simple test that compares a commercial or unimproved seed lot with a sample from a bulked lot of seed orchard seed can be used to provide data for certification of an orchard which is in production.

Last but not least would be, or could be, progeny testing in the early phases of the establishment of seedling seed orchards. Under these circumstances, the test is truly of the progeny involved and the objective is to identify families that are performing so far below standard that the removal of the entire family from the seedling seed orchard is justified. In most seedling seed orchards, this progeny test information will have to be obtained by the time the trees are approximately 5 years old, depending somewhat on the species involved and the traits being evaluated. Once the initial thinning of the seedling seed orchard has been done, little valid information can be obtained on a family basis and most further thinning is conducted on the basis of individual tree performance.

EXPERIMENTAL DESIGN AND HOW IT RELATES TO TEST OBJECTIVES AND SITES

By

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INTRODUCTION

The basic aim of all genetic testing is to determine inherent differences among entries. Each tree is the product of its genetic potential and the environment affecting its expression. Since genotypes cannot be observed directly, environmental effects that mask genetic differences must be controlled, removed, or estimated. It is often practically impossible to control environment in genetic tests of forest trees because the effects of environmental factors are often poorly understood; the organisms and populations are large; and the effects of environment are exerted on forest trees over many years. All these factors mitigate against using controlled environments in genetic tests.

Environmental variations within tests can be minimized by the uniform application of all site treatments that affect tree performance. The impact of environmental variations can be further reduced by grouping genetic entries among which comparisons are planned so that the environmental differences within the area occupied by the grouping are small. Thus, the differences among entries that are due to non-genetic factors are minimized. It is also possible to reduce this same kind of error by replicating the comparisons

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among genetic entries to sample the differences induced by environmental factors. Growing the same genetic entries in many plots (and ensuring that none is favored by randomly assigning the entries to positions within plots) means that differences among the entries that are due to environment within each replication will cancel out in the average effects among entries over the entire experiment. Increasing the numbers of replications in an experiment means that size (and cost) will be greater.

The challenge is to meet the test objective(s) within some size or cost constraint by artful arrangement of genetic materials. Many considerations are implicit in this brief statement. This paper discusses several of these considerations and how they impact field designs for genetic tests.

THE IMPACT OF ENVIRONMENTAL VARIATION ON CHOICE OF EXPERIMENTAL DESIGN

The discussion of factors influencing the manner in which genetic entries are distributed in tests is much more easily done in the context of a particular experimental design. The choice of experimental design for field testing of forest trees is fairly straightfoward. The choice dépends primarily on three factors. These are 1) the site variability and 2) the size and 3) number of plots.

There are three types of experimental designs generally considered for genetic tests. In order of increasing complexity, these are 1) completely random, 2) randomized complete block, and 3) incomplete block designs (on which there are many variations).

Completely Random Design

In this design, replicates of genetic entries are assigned to positions within the test area at random. If there are many large plots to be planted

on a variable site, the experimental error will be increased because the environmental differences among plots of the same genetic entry will be large. Thus, this design is most useful when numbers of genetic entries are small, and the site is uniform. The completely random design is infrequently used in genetic tests of forest trees because these conditions are rarely met. Further, the next level of complexity in experimental design, the randomized complete block, is still very simple and offers some security against confounding genetic and environmental effects.

Randomized Complete Block Design

In this design, genetic entries are assigned to positions within blocks at random. There are several blocks, each shaped to minimize known or suspected environmental variation within its boundaries. Thus, much of the environmental variation is partitioned among blocks and comparisons among entries within each block are relatively free of the environmental effects that might mask the genetic potential. As the number of genetic entries increases, so must the block size. When the block size becomes large enough that the environmental variation within blocks may mask genetic differences, the next level of complexity of experimental design must be considered.

Incomplete Block Designs

This class of experimental design seeks to accommodate larger numbers of genetic entries while keeping block sizes small enough to minimize the effects of confounding environmental variation within blocks. The basic concept is that all planned comparisons among genetic entries can be made but not all comparisons can be made in every block. Thus, the numbers of genetic entries (and thus block size) is reduced for every block, but not for the experiment as a whole. Incomplete block designs may be constructed so that there are

unequal numbers of comparisons among entries as in split-plot or in factorial experiments which confound some of the interaction effects to keep precision up while reducing block size. Balanced incomplete block designs ensure that genetic entries are assigned to incomplete blocks so that every pair of entries is compared within the same number of blocks, i.e. that each comparison has equal precision. Lattice designs are examples of balanced incomplete block designs that are useful in genetic tests of forest trees.

Incomplete block designs are more efficient than complete block designs; they give grater precision than randomized complete block designs with the same number of blocks. Thus, incomplete block designs may be a better choice when the amount of experimental material is limited or when the number of blocks cannot be increased for other reasons. If it is practical to increase the numbers of blocks, the randomized complete block design may be a better choice than a more complex design. The greater complexity implies more effort and expense in laying out, mapping, measuring, and data processing.

There are many specific examples of experimental designs that may be useful for particular situations. However, the majority of genetic tests of forest trees are established using randomized complete block designs because of their simplicity. Incomplete block designs (usually split-plot or lattice designs) have also been used, but infrequently.

CONSIDERATIONS IN DETERMINING EXPERIMENTAL DESIGN PARAMETERS

The discussion to this point has attempted to show the relationship among block numbers, block size, site heterogeneity and choice of experimental design. The discussion will now turn to a consideration of the factors that influence block size and the distribution of experimental materials among plots and blocks. Designs that do not incorporate blocking will not be

considered nor will the distribution of test material over locations or years since these considerations are made elsewhere in these proceedings.

The basic determinants of block size are: 1) the numbers of genetic entries to be tested, 2) the numbers of trees required per block per entry (i.e. per plot), and 3) the spacing between trees. There are many considerations in deciding upon these three design parameters. These are discussed below.

CONSIDERATIONS IN DETERMINING PLOT CONFIGURATION

Intergenotypic Competition Effects

Part of the environmental variation in genetic tests is that which arises from competition with adjacent genotypes. Specifically, a genotype evaluated in competition with different genotypes might perform differently if it had been competing with similar genotypes. Intergenotypic competitive effects have been demonstrated in several species of forest trees (Adams et al. 1973) Pinus taeda L., (Snyder and Allen 1971) Pinus elliotti Englm., (Sakai et al. 1968) Cryptomeria japonica D. Don, and (Tauer 1975) Populus trichocarpa Torr. and Gray). If these effects are an important source of variation, they must be taken into consideration when choosing a plot configuration.

The important point is that trees should be tested in competition with genotypes similar to those they will compete with in operational plantations. Operational plantings may be made with single provenance, seed orchard bulk mixtures, half-or full-sib families, or even single clones. A genetic entry evaluated in competition with one of these types may perform differently when evaluated in competition with another. For example, half-sib families evaluated in genetic tests using row-plots are competing with half-sibs on two sides and non-sibs on two others (the two end trees are competing with

non-sibs on three sides). A family selected in such a test might not perform the same if every individual in the stand competes only with half-sibs or if each competes only with non-sibs (Williams et al. 1983).

If genetic entries are to be planted operationally as bulked mixtures of seeds from seed orchards, perhaps genetic tests should utilize some type of single-tree or at least few-tree plots of each half-or full-sib family to promote competition among all entries. If plantations are to be made of single families, some type of block plot may be best.

Border Rows

If border trees are required simply to ensure that each tree in the test has the same level of inter-tree competition, one or two border rows surrounding an entire test should suffice. However, if intergenotypic competition effects are thought to be important, border rows will be required around each measurement plot. Furthermore, the border row for each measurement plot must be of the correct genotype to provide the desired competition effect. Practically, this means that at least the outer row of each genetic entry may not be used to assess genetic performance. For example, a 100-tree square plot would provide only 64 measurement trees. Such a requirement not only increases plot and block sizes without increasing the numbers of measureable trees per entry, but more genetic material must be acquired to adequately test each entry.

The need for such border rows is exemplified in provenance tests where radical differences in height growth may occur at early ages. These early differences would be exaggerated in later measurements since entries overtopped early would have little chance to express the potential for later growth. The use of border rows of the same provenance surrounding each

measurement plot would limit these exaggerated differences to the border trees.

Within-Block Variability

Blocking implies environmental differences are negligibly small within blocks. In practice, these often may be reason to suspect some environmental variation within blocks that must be considered when choosing a plot configuration. If variations in slope, drainage, or other observable features of the planting environment were not apparent or suspected, square plots would be best because they are the most compact shape. Thus, square plots would be most likely to minimize unseen variation in soil fertility, etc.

Most often, blocking is done perpendicular to an observable gradient like slope or drainage. In such cases, row plots should be arranged parallel to the gradient so that the individuals comprising each genetic entry (e.g. family) will sample the within-block variation.

Non-contiguous arrangements randomize several individuals of each genetic entry throughout each block. Entry means are not confounded with within-block environmental variation and are more efficient for detecting differences among entry means (Lambeth, et al. 1983). However, if the best individuals within families are to be selected in such tests, the individual-within-family variation is now confounded with intra-block environmental variation. That is, family selection is made more precise at the cost of less precision in selecting the best individual within each select family.

CONSIDERATIONS IN DETERMINING THE NUMBER OF TREES PER PLOT

What Traits Will Be Measured?

Different traits are affected to different degrees by environment, i.e. they have different heritabilities. Traits with lower heritability will have

higher error variance in the same genetic test since they are affected more by the environment. Genetic tests should be designed to detect differences at the desired level of precision for the most variable trait of interest.

At What Age(s) Will Genetic Tests Be Evaluated?

The patterns of genetic and environmental variation also change over time (Franklin 1979). Thus, the most variable trait of interest at its most variable age should be used as a design criterion. This will ensure that at least the desired level of precision will be had for all traits of interest.

Interaction Between Numbers of Plots and Trees Per Plot

The numbers of blocks and numbers of trees per plot interact at a given level of precision. For example, in a randomized complete block design with 6 blocks to test for differences among f families each represented by n individuals per plot, the error variance of a family mean (V_{eF} on an individual-tree basis) would be:

$$V_{eF} = \frac{\sigma^2_w}{bn} + \frac{\sigma^2_{BF}}{b}$$

where σ^2_w = the component of variance among trees within plots,

and σ^2_{BF} = the component of variance due to plot-to-plot variance.

Examination of the formula shows that adding either blocks or trees per plot reduces the error variance and increases the precision of the estimate of differences among family means. If more trees are added to each plot to reduce V_{eF}, the addition of more blocks has less impact on V_{eF}. Conversely, adding more blocks makes larger increases in plot size to increase precision superfluous. Where more trees should be added depends upon the relative sizes

of σ^2_w and σ^2_{BF}. Case studies of the procedure to determine the optimum allocation of plants within experiments may be found in Jones et al. (1959) and Bridgwater, et al. (1983). This type of determination requires a priori estimates of variances which may be had most often from the literature. If they are unavailable, information from other crops or simply experience must serve.

Once optimum allocations of plants have been determined, there are several other considerations that will impact plot and block sizes.

Spacing

Spacing among individual trees should be such that inter-tree competition begins when desired. The onset and degree of inter-tree competition affects the expression of several traits. For example, if initial spacing was very narrow, volume growth rate would be depressed at an earlier age than with wider spacings. If intergenotypic competition effects were important, the timing of the onset of competition would be even more important.

Most experimenters choose to plant genetic tests at operational plantation spacings so that stand development in the test will approximate that used in forestry practice. Using operational spacing in genetic tests may be very important in some species. Full-sib families of Douglas-fir interacted with spacings in a Nelder's design (Stonecypher and McCullough 1981). Thus, families tested at one spacing and operationally planted at another might not perform as expected.

There is some evidence that patterns of variation in very close ($\leq$ 1 m) spacings may mimic those in mature tests of loblolly pine (Franklin 1983). Thus, selection for some traits may be done at early ages. However, such

closely spaced entries may not permit the expression of other traits like pruning ability.

Mortality

Initial numbers of trees per entry should be increased by a factor that takes mortality into consideration. Often this is guesswork. However, if inter-tree competition is an important factor in the test, it may be advisable to plant considerably more trees than needed at the planned measurement age(s). If expected motality does not occur, trees must be removed to avoid stand stagnation.

Thinning

Planting more trees than needed implies that thinning is necessary to promote normal stand development. The need for thinning depends upon the test objective(s), the trait(s) of interest, and the species. Thinning, like other forestry practices, is most often done in genetic tests in a manner similar to that used in operational forestry programs. However, if estimating variance components is one objective of the test, thinning may best be done systematically, not silviculturally, as is forest practice. Thus, estimates of within and among family variance should not be biased. If traits like resistance to disease are to be assessed, infected trees cannot be selectively removed.

CONSIDERATIONS IN DETERMINING THE NUMBER OF GENETIC ENTRIES

Provenance And Genetic Gain Tests

Both of these test objectives present special problems in test design. Large block plots are required to determine how either of these types of genetic entries will develop under stand conditions. Both types of test are

usually carried for long periods up to the full rotation age. Thus, enough trees to allow for mortality and thinning and still have sufficient trees for measurement at rotation demand large numbers of trees per plot initially. If several seedlots are being tested, the large plots required imply large block sizes. Thus, the alternatives are to use more complex incomplete block designs and/or more blocks to achieve the desired level of precision.

Progeny Testing

Progeny testing specifically means that the parental genotypes that produced the genetic test materials are under evaluation. There are usually relatively few entries in such tests since they are most often established to select (or reselect) among seed orchard entries as for rogueing. Thus, the primary design criterion is to accurately assess differences among family means. This implies that relatively many individuals (each a sample of the family mean) should be used to represent the parent(s). The experimenter must then decide how best to distribute these individuals among plots and blocks. This is simply done using a priori information and techniques described earlier.

Tests In Which Selections Will be Made

Genetic tests designed to be base populations for further cycles of selection and genetic improvment require that sufficient numbers be tested to provide satisfactory selection differentials among and within families. The numbers of entries required for breeding populations of forest trees are much too large to consider including in a single test. In practice, different subsets of families from the breeding population are tested as units. Selections are made within each test (or test series) and subsequently pooled to form the mating population for the next cycle. This implies that some

standard(s) be planted in each test for comparison or that sufficiently large numbers of entries be included in each test so each subset may be considered a sufficient sample of the breeding population. In the former case, entries from different subsets are compared on the basis of a common standard checklot(s); in the latter case on the basis of the test average. If the latter course is followed, the numbers of families in each test (or test series) must be large enough to be a representative sample of the breeding population. Thus, block sizes can be quite large.

Each family must be represented by sufficient numbers of individuals to achieve a desired level of precision in estimating differences among family means. This is important since a substantial portion of genetic gains will come from selecting among families. There must also be sufficient numbers of individuals per family to capitalize on within family genetic variation. These are best compared within plots to minimize environmental variation among individuals. This implies large numbers of individuals per entry in each block and thus larger block sizes.

Estimating Variance Components

It is often a goal of genetic testing to estimate variance components that may be used to refine selection procedures, estimate genetic gains, and evaluate breeding strategies. The numbers of families and individuals required to precisely estimate variance components depends upon the heritability of the trait(s) of interest (Falconer 1960). When the heritability is unknown, Robertson (1959) suggested using 20 to 30 individuals per family in half-sib analyses. Fifty crosses (full-sibs) in factorial or diallel mating designs may provide acceptable estimates of variance components

with at least 6 parents of either sex and up to equal allocations of males and females (Namkoong and Roberds 1974).

If interactions with years and locations are not large, variance components may be pooled over separate tests of subsets of the breeding population, thus large numbers of families each represented by many individuals may be avoided.

Check Lots

The addition of check lots increases the size of blocks simply by adding more seedlots to be tested. Often, it may be desirable to include more than one check lot in each test to serve more than a single objective. For example, the North Carolina State University-Industry Cooperative Tree Improvement Program plans to include four separate check lots in every second-generation genetic test of loblolly pine. Each test will include: 1) a seed orchard bulk mixture representing the breeding region under test to measure genetic gains over first-generation seed orchards, 2) an unimproved bulk collection from the region under test to be used as a standard for comparison among families in different tests, and 3) two check lots from each of two neighboring testing areas to measure the potential for movement of improved seeds and breeding stocks among testing areas.

The numbers of plots of each check lot will also depend upon the statistical procedures used to detect differences among genetic entries and check lots, and the level of precision desired for the test. For example, Dunnett's statistic requires the same numbers of plots for check lots as for genetic entries to ensure a desired level of precision (Dunnett 1955). The aim in the N. C. State Program is to test for significant differences among a group of half-sib families and a standard with Dunnett's procedure. Since

each half-sib family mean will be represented by 5 plots of full-sib families in that program (Talbert 1979), five plots of each check lot would be required to ensure that differences were real at the 95% confidence level. Including that number of check lots was impractical, therefore some confidence was sacrificed, and two plots of each check lot were included in each test.

CONCLUSION

Several factors that influence plot and block sizes, configurations, and numbers and, therefore, experimental design considerations were discussed. The myriad of considerations must be made with a knowledge of the biology of the test species, experimental design, and forest management practices to arrive at a design that will accomplish the objectives of the test. These considerations should be made in concert with those who can provide professional assistance in each area.

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Veracity of Short-term Testing

by

Jerry Rehfeldt

INTRODUCTION

According to common usage, short-term describes a test from which quasi-final decisions are made within 10 years. But, trees are long-lived sedentary organisms that must face extremely variable environments throughout their life. Thus, as argued from the intuitive viewpoint, it seems extremely unlikely that short-term tests can earmark those trees capable of maintaining a superiority in growth for a full rotation. Critics of short-term testing, however, can marshall only two arguments for invalidating juvenile selections:

(1) Genotype-environment interactions can be assessed only after full exposure to the vicissitudes of environment, and

(2) Juvenile-mature correlations involving allometric traits are demonstrably weak.

Anticipated genetic gains from intensive tree improvement will not accrue without first reconciling adaptation. Thus, tree improvement will take place within biologically sound breeding zones, which will greatly limit genotype-environment interactions. This means that criticism of the first type is applicable to early results from provenance tests. Moreover, improved races must occupy natural

environments during their juvenile years. Therefore, possible genotype-age interactions are inconsequential in interpreting juvenile results of progeny tests. Thus, criticism of the second type applies to individual tree selections from progeny tests and evaluation trials.

Interactions of genotype and environment (gxe) can be represented by three general classes (fig. 1). When assessed across an environmental gradient, genetic variation for traits involving growth potential and those involving cold hardiness reflect types I and II, respectively. Type III will follow only after the joint occurrence of the first two. This is because the type III interaction involves general performance rather than individual traits. To tree improvers, it is the type III interaction that is most feared: early selections may prove to be non-adapted when infrequent environmental stresses occur. To limit the effects of possible type III interactions, breeding zones are constructed.

The validity of juvenile progeny tests depends, consequently, on accurate estimates of gxe from young trees. The type I interaction is common in tests at all ages. [Note that the type I interaction is expressed by main effects of genotypes; the ranking of genotypes does not change across the environmental gradient.] Thus, the major obstacle in early assessment of gxe is that the type II interaction depends on natural environmental stresses that occur infrequently at intensities sufficient for differentiating populations. For many stresses (particularly cold), the type II interaction, can be observed in both the greenhouse and laboratory. Extrapolation to natural conditions seems direct. For instance, a greenhouse study of the periodicity of shoot elongation (Rehfeldt, 1984b) and field performance after 16 years

(Rehfeldt, 1980) both provided estimates for the elevational limits of seed transfer for ponderosa pine in central Idaho to be ±750 feet of the seed origin. The correlation between fall frost injury in field tests of Douglas-fir populations from north Idaho shows a correlation of r = .67 with freezing injury from laboratory tests (Rehfeldt, 1979a). The cessation of shoot elongation of western white pine populations shows a correlation of r = .69 between field and greenhouse estimates (Rehfeldt et al. 1984). And the correlation of 2-year elongation of Utah sources of lodgepole pine grown in the greenhouse and 3-year field height was r = .76 (Rehfeldt 1984a).

When interactions of types I and II can be demonstrated, the type III interaction can be predicted with confidence. After observing type I in the field and type II in the greenhouse, it is not necessary to witness the expression of type III in field performance. It will occur soon after field expression of type II. [It is when types I and II are not observed, as with western white pine, that one has cause for concern.]

It is possible, however, that traits other than those studied in juvenile tests will be important to adaptation at older ages. Indeed, not all stresses can be simulated in the laboratory, greenhouse, or field. Dietrichson (1964), however, showed that maladaptation in temperate climates can be recognized by a lack of synchronization of an annual sequence of developmental events with the climate. Thus, maladaptation can be recognized in juvenile studies as a lack of such synchronization, but can find alternative expressions in long-term tests, including, for example, expression via insects and diseases.

Thus, 4-year data from a lodgepole pine provenance test provided elevational limits to seed transfer (±100 m) that are based on growth potential (type I) and cold hardiness (type II interactions) (Rehfeldt, 1983a). In a long-term evaluation trial, Hoff (1984) found the incidence of needle cast (Lophodermella concolor) to be closely related ($r = 0.85$) to the elevation of the seed origin. If elevational transfers of seed had been limited according to juvenile results of provenance tests, needle cast would have been incidental.

In contrast to short-term provenance tests, long-term tests are usually maintained under conditions that differ little from those routinely applied to artificial regeneration. Thus, measurements involve performance rather than individual traits. In such tests, the occurrence of type III interactions confounds the assessment of adaptive variation and, consequently, confounds estimated limits to seed transfer. For instance, populations from high elevations have a low growth potential and are, therefore, small in all test environments. On all sites except the mildest, populations from low elevations tend to suffer cold injuries and are, therefore, small. This means that correlations of performance with elevation of the seed origin approach zero. In reality, however, the phenotypic expression of two very strong but conflicting correlations has been obscured.

Thus, an accurate assessment of adaptive variation requires a quantitative evaluation of individual traits. Such an evaluation is prerequisite to (1) establishing the appropriate biological limits to seed transfer, and (2) calculating the genetic correlations needed to estimate the tradeoffs among traits that are available to the silviculturist. For yielding this type of information, well-conceived, short-term tests are far superior to the common long-term test. In juvenile tests, extraneous random environmental effects can be controlled. Detection of differentiation becomes easier. And traits that are components of future performance can be attacked directly.

Under long-term testing, components of performance become confounded and random environmental effects tend to overwhelm differences among families or populations. Even though the ultimate risks involved in seed transfer can only be assessed over the long term, valid results must await full expression of the type II and, subsequently, type III interactions. The common long-term test will yield reliable data on adaptive vatiation only after expiration of the long term.

Proponents of long-term testing argue (largely verbally) that individual trees exhibit greatly different inherent growth patterns (fig. 2). It is the alleged inability to distinguish among patterns during juvenile years that (1) relegates juvenile-mature correlations to insignificance, and (2) invalidates juvenile selections from progeny tests. One can argue, however, that the hypothesized growth curves of figure 2 belong to forest mythology; when trees of the same (biologically sound) breeding zone are compared, the shape of inherent growth curves can be represented by the same family of curves (fig. 3). The patterns of figure 2 can develop from those of figure 3 only after the accumulation of extremely severe random environmental effects.

A discussion of tree growth cannot ensue without consulting the specialist. Mensurationists (Wykoff[1]) note that site index curves will cross only under extreme conditions, such as suppression (Stage 1963). Moreover, silvicultural activities at nearly all stand ages evoke the greatest and fastest responses from the largest trees (Wykoff et al. 1982). Thus, trees of growth curves C and D (fig. 2) do not seem to be hidden beneath dominant trees. Nevertheless, it is the data on which yield tables are developed that is most pertinent. Monserud (1984) recently compiled stem analyses of three dominant Douglas-firs within 135 natural stands from northern Idaho and western Montana. Of the stands sampled, 43 were even-aged (the age of all sampled trees varied by less than 5 years at bh, breast height). Growth curves of individual trees within 67% of the even-aged stands were similar to those of figure 4; once divergence occurred, it was maintained. In 19% of these stands, identical growth curves were evident (fig. 5). And, for 14% of the even-aged stands, the trees that were tallest late in life were not the tallest early; figure 6 illustrates the most extreme examples of flip-flops that were available from Monserud's data.

[1]W. R. Wykoff, Forestry Sciences Laboratory, Moscow, Idaho. Personal communication.

The growth curves illustrated for wild trees in natural stands (figs. 4, 5, and 6) quite obviously do not support the hypothetical curves illustrated in figure 2. In fact, Monserud believes that differences in the shape of the curves (figures 4, 5, and 6) are small and insignificant. To him, these data represent a single underlying growth curve which is modified by the main effects of environment (fig. 7). Fluctuations in the growth curve of individual trees at a given site reflect microenvironment and genetics. Consequently, with environmental control, genetic differences should be detectable early. This conclusion is supported by Sorensen and Miles (1982) who showed that selfed and outcrossed progenies were following similar growth curves, but at different rates (trees reached the same point on the curve at different ages).

One can argue, however, that the curves observed by mensurationists are biased. By the time mensurationists sample, growth curves of types B, D, and perhaps C (fig. 2) have been lost through natural selection. The argument, itself, mitigates against developing improved races from genotypes other than type A. If natural selection has eliminated certain genotypes, they certainly should not be represented in breeding programs; tree improvement must be consistent with natural selection. And, if long-term testing is necessary to fully differentiate curve type A from C, only a portion of the individuals from only half of the families need be carried through long-term testing. Regardless, mensurational data suggest that the parameters controlling the shape of the growth curve of select trees are expressed early in the life of the tree.

The word "early", however, means something quite different to a mensurationist than to a geneticist. Monserud's data begin at the age when trees reached breast height. In the northern Rockies, it may take 10 to 15 years for trees to reach breast height under natural conditions. Thus, flip-flops in growth curves could occur before trees reach breast height. Silviculturists, however, believe that dominance is expressed before age 10. Not only is this true for ponderosa pine in California (Oliver and Powers, 1971) and lodgepole pine in southeast Idaho (see Rehfeldt et al., 1980), but tends to be true for nearly all species in the northern Rockies (Wellner[2]). In fact, the phenotypic correlation between the height of individual western larch trees at age 9 in a thinning trial with height at age 29 averaged $r = 0.75$ at close spacings (Schmidt[3]). [Incidentally, the size of phenotypic correlations was negatively related to spacing.] Thus, silviculturists believe that the future dominant and codominant trees in natural stands can be recognized before age 10.

[2]C. A. Wellner, Forestry Sciences Laboratory, Moscow, Idaho, personal communication.

[3]W. A. Schmidt, Forestry Sciences Laboratory, Missoula, Montana, personal communications.

Consequently, if major flip-flops are common, they must occur before age 10. This possibility, however, is certainly not the case with lodgepole pine in natural stands; dominance is readily expressed between ages 5 and 25 (Rehfeldt et al., 1980). Moreover, with short-term studies maintained under intensive cultural levels, age-age correlations of the height of individual trees, families or provenances of Douglas-fir (Rehfeldt 1979a, 1983b), white pine (Rehfeldt 1979b; Rehfeldt et al. 1984), lodgepole pine (Rehfeldt 1983a) and ponderosa pine (Rehfeldt 1984b) tend to be extremely high ($r = .8$ to $.9$) from ages 3 to 5.

Thus, genetic data indicate no major flip-flops before age 5. Silviculturists believe that dominance is expressed before age 10. Mensurationists show that a growth curve of a single form characterizes tree growth beyond ages 10 to 15. None of these data substantiate the existence of innate growth curves that could be responsible for major flip-flops in the performance of families and individual trees. This suggests that only with severe environmental events are the innate curves disrupted greatly. Therefore, the parameters controlling specific curves should be recognized early in the life of a tree if environmental factors are controlled.

Why then, are most genetic data inconsistent with the foregoing? Why are juvenile-mature and parent-offspring correlations generally weak? Why do variance trends depict a reversal of patterns near age 15? And, why are tree improvers generally obsessed with the notion that family performances will flip-flop in time? One must carefully examine the quality of the data available for such comparisons. Long-term tests tend to be riddled with random environmental effects, and studies of suitable age tend to be hopelessly confounded with interactions of genotype and environment. Both of these effects have the same consequence: error variances obliterate the genotypic value of growth potential. The phenotype is determined more by the environment than by the genotype.

To obtain reliable data, random environmental variances (associated with insects, diseases, rodents, cattle, and big game) must be controlled, particularly during the early years. Common sense dictates that trees with tops broken at any age should be purged from data sets used for age-age correlations, progeny comparisons or family evaluations. During the juvenile years random environmental events are most disastrous: trees are overcoming transplanting; growth is relatively slow; and a small stature increases the likelihood of injury and hampers recovery. As a consequence, environmental variances are not only high but also accumulate exponentially. Genetic effects are easily inundated by environmental effects until that time (teens?) when tree height and growth are large enough to allow phenotypic expression of the genotype. It is not surprising, therefore, that most of the flip-flops in family performance, such as those observed by Samuel and Johnstone (1979), occur soon after planting; nor is it surprising that differences among families tend to stabilize during the teenage years when growth is increasing exponentially.

When the juvenile environment has been controlled and maimed trees have been purged from data sets, relatively strong relationships have been observed. Franklin and Squillace (1973) presented a parent-offspring correlation of r = .56 for slash pine. Steinhoff[4] presented a phenotypic correlation of r = .65 relating height of individual trees at plantation age 3 with that at age 12 for western white pines growing at Ida Creek; in fact, if the shortest 65% of the families had been culled at plantation age 3, none of the top 10% at age 12 would have been lost. These same data also provide genetic age-age correlations of essentially 1.0 (range = .80 to 1.06) for all age combinations between plantation ages of 3 and 12.

[4]R. J. Steinhoff, Forestry Sciences Laboratory, Moscow, Idaho, personal communication on genetic variation at Ida Creek.

Reliable data must also be free of the effects of gxe. Stated or implied objectives of studies established 20 to 30 years ago generally involved combined provenance and progeny tests. Such tests, in their entirety, generally confound studies of juvenile-mature correlations, variance trends or family evaluations. This is because age-age correlations relate performance (the integration of all traits) at one age with performance at another. When maladaptation is expressed, the growth potential of all trees not adapted to the planting site is obscured. The value of a particular correlation depends on the plantation age at which environmental stresses occurred. Since juvenile-mature correlations are intended to elucidate basic principles of genetic control of tree growth, assessment should be made among only those trees adapted to the planting locality.

Western white pine, however, expresses essentially no population differentiation in the northern Rockies. Consequently, genotype-environment interactions do not occur (except as experimental errors). Therefore, an old test, the vigor-quality plots established by Bingham and Squillace between 1956 and 1959, contains full-sib families suitable for analyses of age-age correlations and variance trends. Phenotypic correlations of height of individual trees at plantation age 7 with height at age 17 amounted to $r = 0.71$ (Steinhoff 1974), a value that was influenced, unfortunately, by random environmental variances. Regardless, if the shortest 50% of the families had been eliminated at age 7, none of the top 25% would have been lost at age 17 (Steinhoff[5]). Figure 8 presents growth curves of several families that illustrate the

[5]R. J. Steinhoff, Forestry Sciences Laboratory, Moscow, Idaho. Personal communication on genetic variation at the vigor-quality plots.

greatest differences in mean height at 17 years. Quite obviously, differences in height not only were observed early, but also, early differences have increased, particularly after age 7.

Variance trends (fig. 9) however, do not follow patterns suggested by the growth curves of individual families (Rehfeldt[6]). At age 17, when differences in height of among families were the greatest (fig. 7), estimates of additive genetic variances had declined to zero. Although these variance trends are similar to those reported for other species (see Franklin 1979), environmental effects are largely responsible. According to figure 8, 10 years were required for trees to average 5 feet in height! [Intensive culture in natural environments can produce trees of a similar height in 4 years (Rehfeldt 1979b).] Variance within family plots has increased exponentially (fig. 8) and has obliterated family variances.

Because of these environmental variances, the same data were analyzed by using 5-year height as a covariate to adjust the height of all trees to a common height at age 5. As a consequence, all genetic and environmental effects that had accrued before age 5, including transplanting shock, were removed from the data. Associated variance trends (fig. 8) are much different than those derived from height alone; beyond age 12, estimates of additive genetic variance increase. This suggests that variance trends in total height were overwhelmed by environmental effects, some of which (about 1/3 of the variance) could be accounted by the covariate. Regardless, the matrix of genetic

[6]G. E. Rehfeldt. Unpublished data.

correlations associated with variance trends for both height and adjusted height are higher than the phenotypic correlations for all age-age combinations for which additive genetic variances were positive. In fact, the genetic correlations varied between 0.8 and 1.2. Thus, the correlated responses from juvenile selections should be substantial.

These two studies with western white pine show that juvenile selections can be reliable when random environmental variances are controlled and gxe do not confound the results. This means that genetic, silvicultural and mensurational data can be summoned to validate short-term results of progeny tests and evaluation trials.

FINALE

The objective of any testing program is to differentiate genotypes. Therefore, it would be most desirable to differentiate (or select) according to the genotypic value rather than the phenotypic value. Since this is not yet possible, the most desirable alternative is to test under conditions in which the phenotype is more a function of the genotype than of the environment. This means that reliable results will require an alteration in testing procedures:

1. Intensive culture to control extraneous environmental variation (Woollons 1980). Where practical, site preparation should include stump removal and tilling. Environmental effects can be controlled by cultivating, spraying, poisoning and fencing.

2. Establish tests at relatively close spacings such that crowns are closing at the end of the first cycle of measurements (5-6 yrs). This will:

   a. provide for a large number of observations per family.

   b. facilitate control of the environment.

   c. maintain tests under a relatively low level of inter-tree competition for stimulating the expression of growth potential.

3. Accumulate data suitable for attacking individual traits rather than relying on performance, the integration of all traits.

4. Purge data of all observations that confound assessment of the traits under study. Trees that have broken tops at any ages should not be allowed to confound progeny tests or evaluation trials.

The appropriate duration of a testing program is dependent more on the precision by which differences can be detected than on age alone. Selections can be made as soon as the results become valid. Consequently, duration depends on tree size in relation to random environmental effects. Differences must be large enough to overcome error variances. This means that the age suitable for making selections

depends on species, growth rates, objectives and cultural techniques as well as on genetic variability. For instance, differences among provenances are usually larger than differences among families within provenances, and, therefore, results of provenance tests are generally available at an earlier age than those of progeny tests or evaluation trials. Tests conducted in mild climates generally yield results earlier than those conducted in severe environments. Intensive culture controls random environmental effects, and, thereby, yield results earlier than those maintained under the philosophy of "let nature take its course." In the northern Rockies, short-term provenance tests can be completed within 3 to 4 years; progeny tests and evaluation trials can be terminated after 5 to 8 years.

Still, as stressed by Franklin (1979), the debate of short-term vs. long-term testing cannot be resolved until age-age genetic correlations are available in studies maintained under intensive culture. The need for genetic correlations is emphasized; the effectiveness of early selections can be measured only in terms of genetic gains derived from the correlated responses associated with juvenile selections.

ACKNOWLEDGMENT

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Figure 1. Portrayal of interactions of genotype and environment.

Figure 2. Hypothetical illustration of inheritable patterns of tree growth.

Figure 3. An alternative to figure 2.

Figure 4. Growth curves from 4 even-aged stands of Douglas-fir illustrating the maintenance of differences in height of individual trees throughout their life (from Monserud 1984).

Figure 5. Growth patterns illustrating essentially no differences in growth patterns of individual trees (from Monserud 1984).

Figure 6. Growth curves illustrating flip-flops in the performance of individual trees (from Monserud 1984).

Figure 7. Site index curves for inland Douglas-fir (from Monserud 1984).

Figure 8. Growth of selected western white pine families (from Steinhoff[5]).

Figure 9. Variance trends for western white pine. σ^2_W = component for the variance within family plots; σ^2_A = additive genetic variance; and h^2 = heritability.

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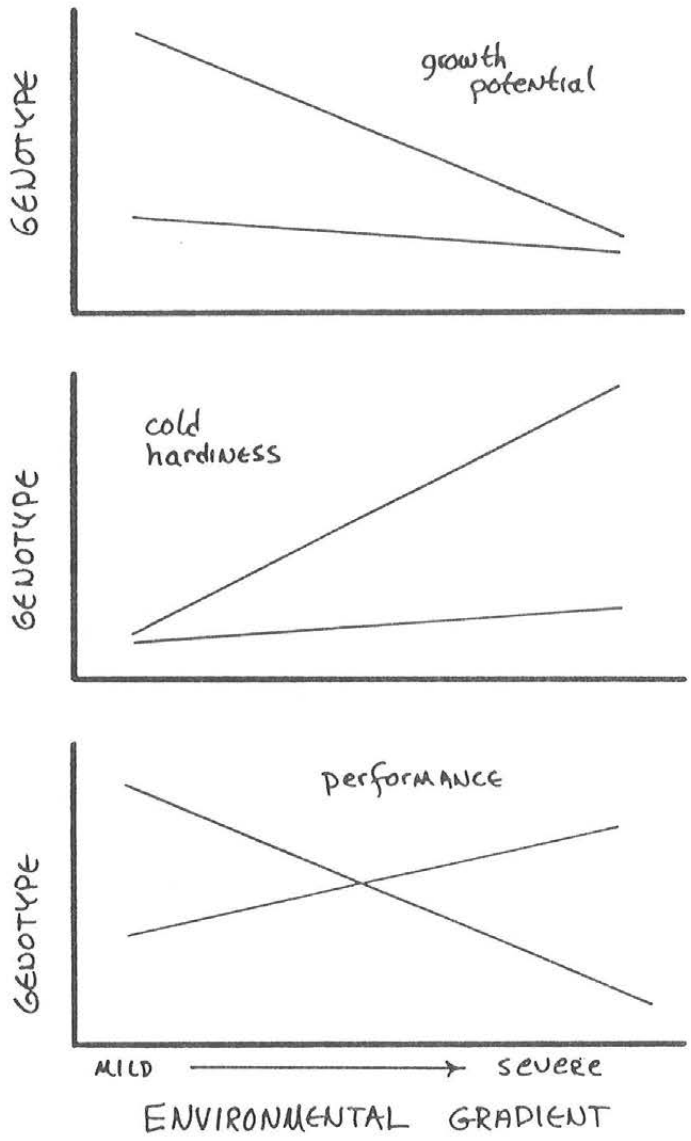

GENOTYPE
growth potential
GENOTYPE
cold hardiness
GENOTYPE
performance
MILD
SEVERE
ENVIRONMENTAL GRADIENT

Figure 1

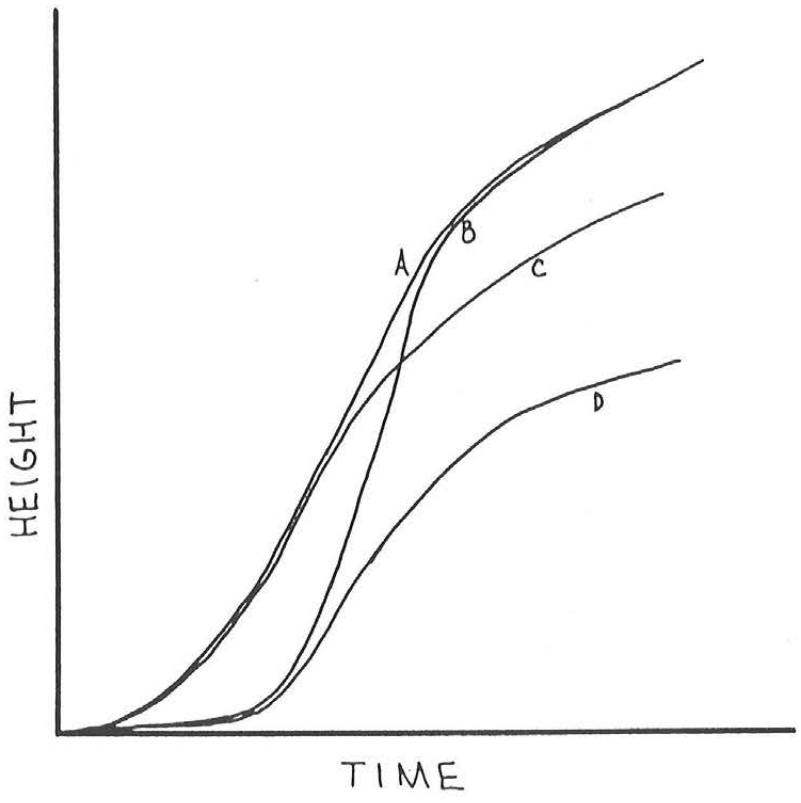


Figure 2

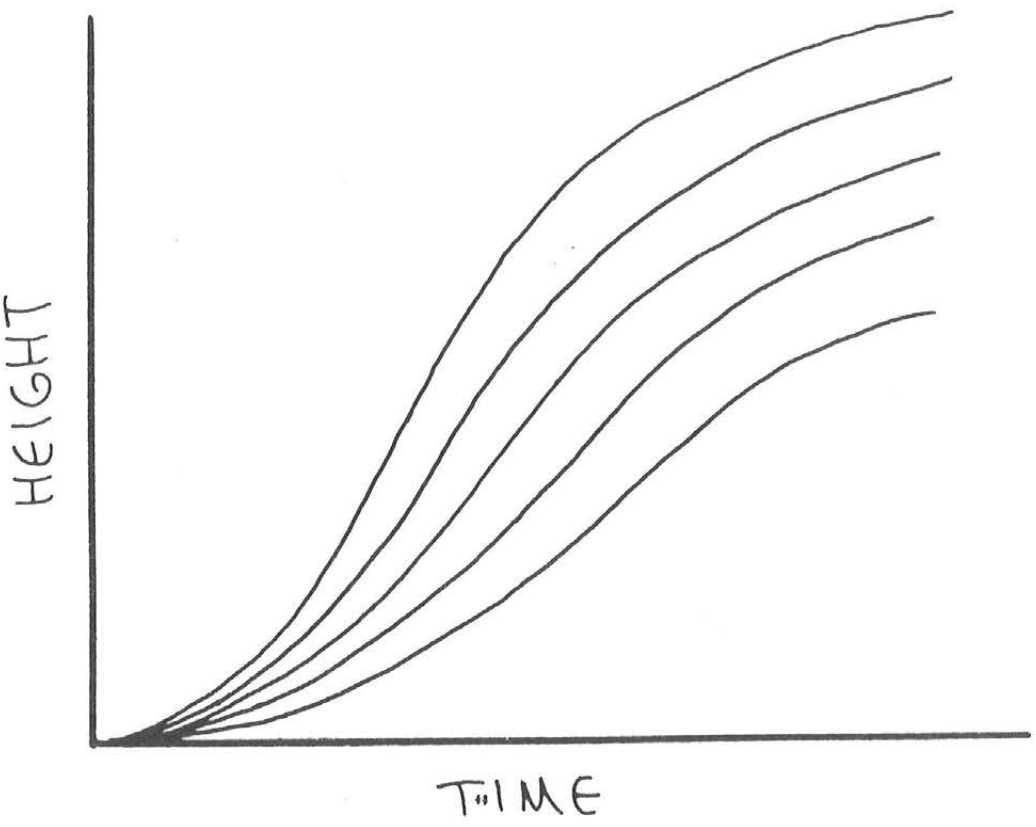


Figure 3

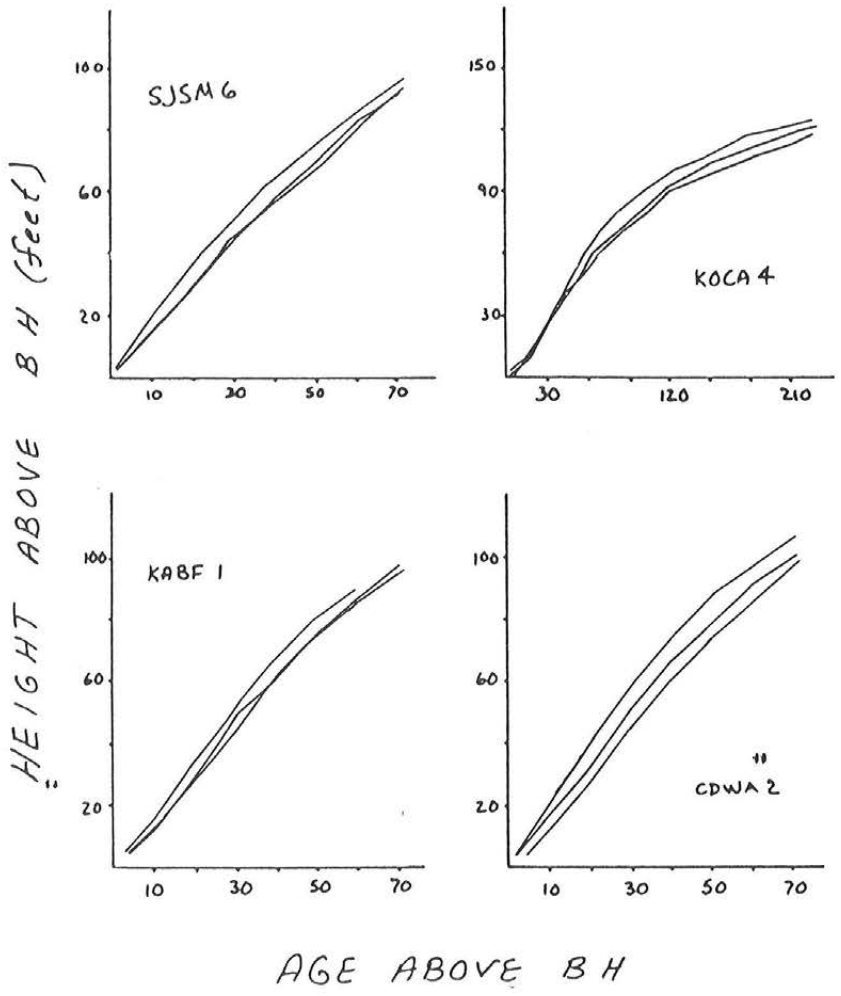


Figure 4

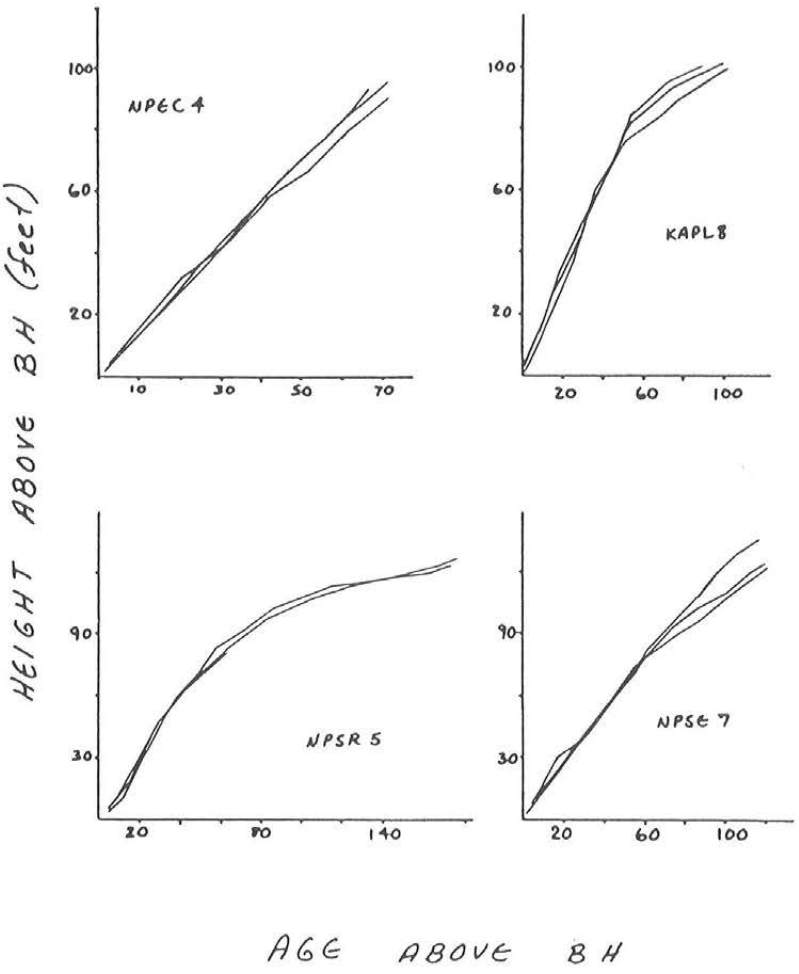


Figure 5

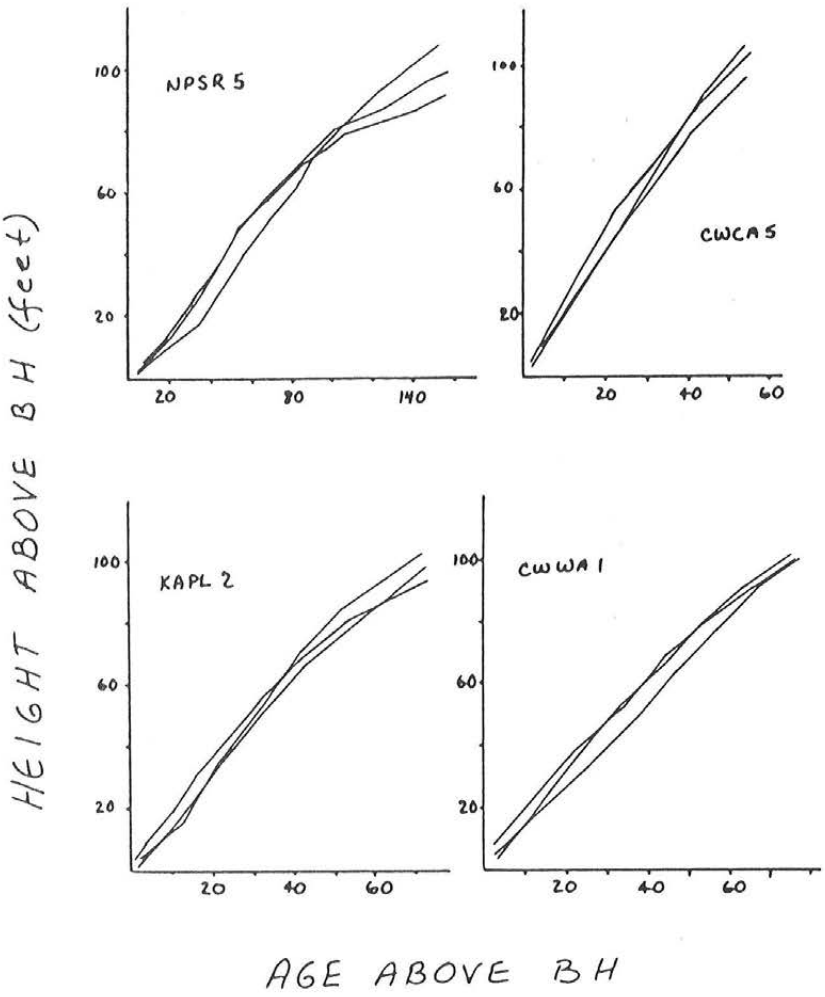

HEIGHT ABOVE BH (feet)
NPSR 5
CWCA 5
KAPL 2
CWWA 1
100
60
20
20
80
140
40
AGE ABOVE BH

Figure 6

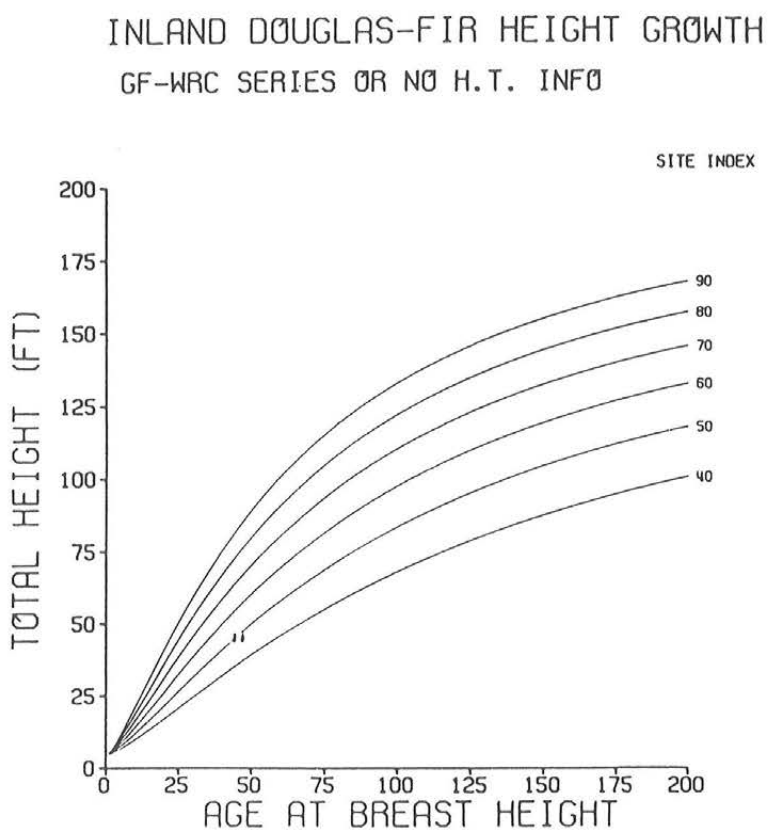

INLAND DOUGLAS-FIR HEIGHT GROWTH
GF-WRC SERIES OR NO H.T. INFO
SITE INDEX
90
80
70
60
50
40
TOTAL HEIGHT (FT)
200
175
150
125
100
75
50
25
0
0
25
50
75
100
125
150
175
200
AGE AT BREAST HEIGHT

Figure 7

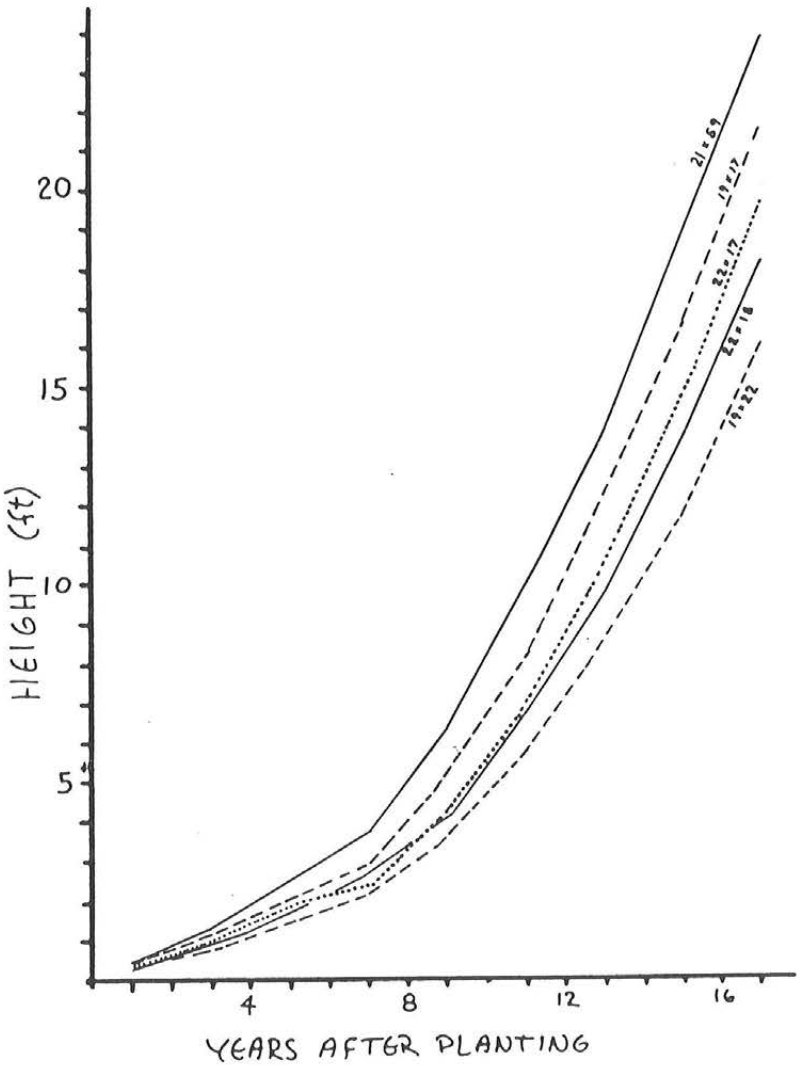


Figure 8

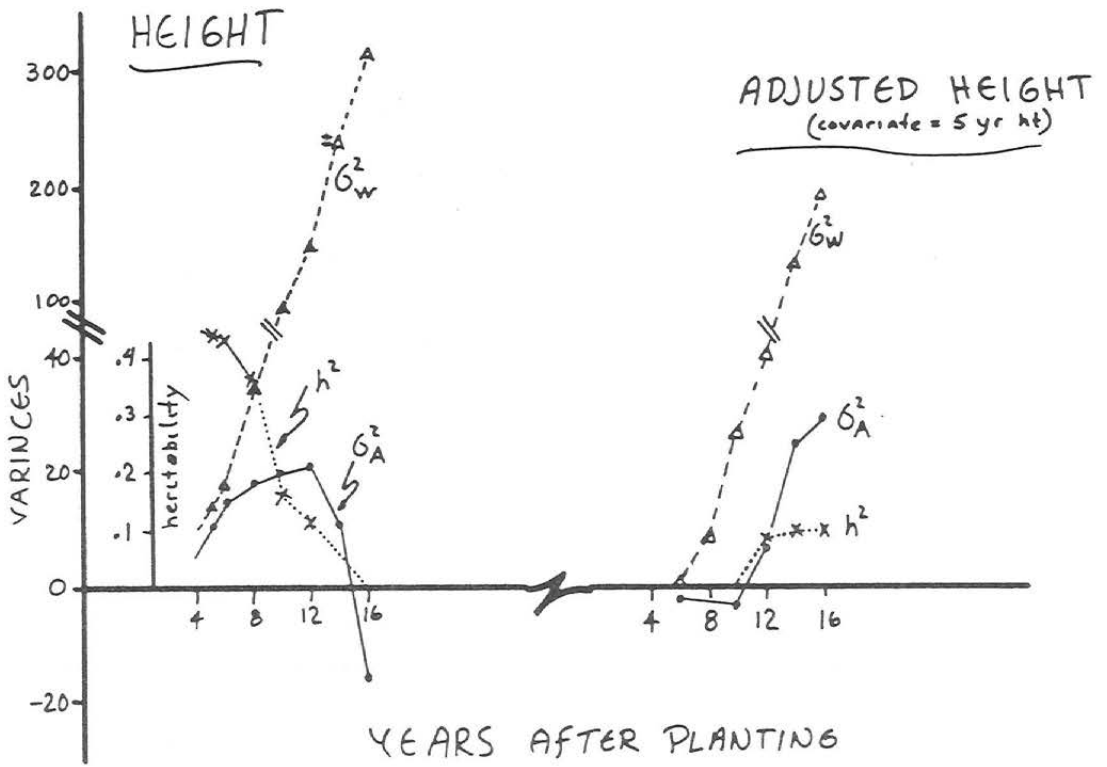

HEIGHT
ADJUSTED HEIGHT
(covariate = 5 yr ht)
VARIANCES
heritability
σ^2_W
h^2
σ^2_A
300
200
100
40
20
0
-20
.4
.3
.2
.1
4
8
12
16
YEARS AFTER PLANTING

Figure 9

A LOOK AT SHORT-TERM PROGENY TESTS

by

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Abstract. Although gain per generation is less with early selection, selection on the basis of early progeny tests normally yields greater gain per year than selection at maturity. For some traits, generations can by cycled rapidly if early flowering can be achieved. Selection for growth traits before age 5 years will be risky. Sampling variation is a source of serious error and needs to be controlled.

Additional Keywords: Juvenile-mature correlation, genetic correlation, genetic gain, correlated gain, selection.

INTRODUCTION

Timber tree species require 20 to 60 or more years to reach harvest size, depending upon species, end product, and location. These long generations pose a serious problem for tree breeders because progeny tests take so long to reach an age at which final evaluations can be made. Slow generation turnover results in slow genetic progress and delayed return on investments in a breeding program. Consequently, there is much interest in shortening the length of progeny tests.

LITERATURE REVIEW

Nursery Selection

Perhaps the first work related to early evaluation of progeny tests was very high intensity selection of seedlings for height in commercial nursery beds. The selected seedlings and some average checks were planted in the field and their growth rates over time compared.

Results from a few such studies have been reported. Select loblolly seedlings were 25 percent larger than average seedlings after 5 years in the field in Texas (Zobel and others, 1957). In a similar test of slash pine, select seedlings were 23 percent taller than average stock after 8 years in the field (Bengston, 1963). Zarger (1965) selected outstanding seedlings of loblolly, shortleaf, and eastern white pines at TVA's Clinton Nursery. Ten-year data from field plantings showed that 65 percent of the selections maintained greater height and 78 percent maintained greater diameter and volume than did nursery run seedlings.

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Slash and loblolly pine seedlings selected in a Georgia nursery were 19 and 16 percent taller, respectively, than controls at age 4 years (Barber and Van Haverbeke, 1961). At age 9 years the same selections were, respectively, 22 and 20 percent greater in volume than controls (Hunt, 1967). In another study, select loblolly pine seedlings were 126 percent taller than controls at outplanting and 45 percent taller at age 10; select slash pines with an initial height superiority over controls of 104 percent were 20 percent superior at age 10 (Hatchell and others, 1972).

These studies indicate that selection of individuals at a very early age can be effective in producing gains in height. But mass selection of individuals is not the same as selection among families as practiced in progeny tests. LaFarge (1975) studied the correlation between family mean heights after one season in the nursery and after five seasons in the field for slash and loblolly pines. Correlations were mostly very weak for the 15 study plantations, only two being statistically significant. Differences among nursery heights of progenies were significant for all the studies and among field heights for 13 of the 15 studies, so weak nursery-field correlations were not caused by lack of variation among the progenies.

Seed and Seedling Size Effects

One source of variation in seedling size in the nursery is variation in seed size, which functions as an environmental effect to mask variation in inherent vigor. The effects of seed and seedling size on growth over time have been studied seperately and in combination. Good reviews of the early literature were provided by Righter (1945) and Fowells (1953).

From his studies, Righter (1945) concluded that seed weight is correlated positively with seedling size but not with inherent vigor. The seedling possessing the greatest inherent vigor is just as likely to be a runt that originated from a very small seed as a giant that originated from a large one. If seedlings from small seed are larger than those from large seed, inherent vigor is involved. Early differences in size among progenies from different parents may be largely due to differences in seed size, which is a type of environmental effect.

From a detailed study with ponderosa and Jeffrey pines conducted 2 years in the nursery and 9 years in the field, Fowells (1953) concluded that seed size had an effect on germination but not on transplanting survival and on seedling height but not on root weight. The effect of seed size was evident for 3 years after field planting. Seedling size had an effect all the way through the study, with the larger seedlings generally surviving and growing better than the smaller ones. However, small seedlings did produce some large trees in the field.

In a study of selection intensity in the nursery bed, Callaham and Duffield (1962) found that low intensity selection among ponderosa pine seedlings from average-sized seeds produced no effect on tree size at age 20, but moderate intensity selection among 2-year-old seedlings

from ungraded seeds did affect tree size at age 15. In a 6-year-old study with medium and large seed and medium and large seedlings of south Florida slash pine, medium seeds and large seedlings survived best and large seedlings grew the fastest (Bethune and Langdon, 1966). In a 2x2 factorial study of the effects of seed and seedling size on loblolly pine, Sluder (1979) found that at age 3 years in the field, seed and seedling size each had a positive effect on tree size; at age 15, trees from large seeds were shorter than those from medium seeds and trees from large seedlings had survived better and were taller than average seedlings. Seed and seedling size effects tended not to combine additively. Seed weight but not seedling height was significantly correlated with tree volume at age 15 in a loblolly pine study in Texas (Robinson and van Buijtenen, 1979). Five seed traits including weight accounted for 20 percent of the variation in initial seedling size and growth rate among loblolly pine progenies, but after 2 years they acccounted for only 7 percent of seedling size (Perry and Hafley, 1981).

These studies show that, generally, seed size variation will affect seedling size for several years, after which variation in inherent vigor of the trees will emerge from the early masking effect of seed size. So selection for vigor at very early ages will suffer some degree of imprecision from this early environmental effect.

Juvenile Traits and Screening

Of course, some econonmically important traits are expressed very early in the life of the tree. Such traits can readily be evaluated in short-term tests.

Loblolly pine seedlings were found to vary by family in ability to withstand transplanting shock (Beineke and Perry, 1966). Time of bud set in Douglas-fir seedlings varies by family, affecting their fall frost hardiness and 4-year heights (Rehfeldt, 1983). Sap sugar content is reliably expressed in sugar maple by the time seedlings are 3 cm in diameter at ground line (Kriebel, 1960).

Susceptible pine seedlings can be infected by fusiform rust in the nursery or any time after outplanting if rust inoculum is present. For early evaluation or screening for rust resistance, artificial inoculation procedures were developed (Jewell, 1960; Matthews and Rowan, 1972) and refined (Walkinshaw and others, 1980; Lundquist and others, 1982; Frampton and others, 1983).

Results from artificial inoculation have been compared with field infection results. The correlation has been variable, but the screening method predicts field performance reasonably well, particularly for slash pine (Jewell and Mallett, 1967; Goddard and Schmidt, 1971; Goddard, 1972; Miller and Powers, 1981; Sluder and Powers, 1982). For a good test, field infection percentages need to average 60 to 70 (Sohn and Goddard, 1979).

One problem affecting correlation between screening and field results is variation in pathogenicity of the rust fungus (Powers and others, 1977; Powers, 1980; Walkinshaw and Bey, 1981; Powers and Zoerb, 1983). Biochemical indicators might be another way of determining rust resistance of young seedlings (von Weissenberg, 1971; Lewis, 1975; Rockwood, 1973; Rockwood, 1974). Seedlings from eastern white pine can be inoculated for early testing for blister rust resistance. They can also be screened for resistance to injury by air polutants by subjecting them to fumigation procedures (Kriebel, 1983).

Biochemicals produced by seedlings and young trees may be useful in early screening and selection. The terpene makeup of oleoresin is strongly inherited. Relative proportions did not vary with tree age over a range from 2 to 20 years (Squillace, 1971). White pine seedlings resistant to weevil attacks had high concentrations of alpha-pinene and low concentrations of limonene (Kriebel, 1983). Extracts from the inner bark of American chestnut show promise for selection for resistance to the chesnut blight (Samman and Barnett, 1973). Poplar ramets and sugar maple seedlings responded to partial defoliation with increased rates of synthesis and concentrations of phenolic compounds (Baldwin and Schultz, 1983). A fast- and a slow-growing red pine showed large differences in growth substance, peroxidase, and ascorbic acid in extracts from terminal shoots (Westing, 1962). Tanksley and others (1981) found isozymes to be very effective in determining genotype of backcross seedlings of tomato. Hanover (1983) discussed the theory and practice of using molecular markers, terpenes, and isozymes for measurement of geneitc variability and other purposes including increasing selection efficiency.

Juvenile-Mature Correlation

Some traits vary with age of the tree. Selection among young progenies and trees for these traits could be risky, depending upon the correlations between measurements of the traits at juvenile and mature ages.

Considerable study on juvenile-mature correlation has been done. In slash pine, 25-year-old parents and their 3-year-old offspring showed moderate to strong correlation in height and other traits (Franklin and Squillace, 1973). In another slash pine progeny test there was very strong correlation between heights of 5-year-old full sib progenies and the mean height superiority of their parents (Webb and Barber, 1965). Such parent-offspring correlations indicate that selection in progeny tests could be done at an early age, but correlations between measurements at juvenile and mature ages on the same progenies need to be studied because choices often are made among the progenies themselves rather than the parents.

Perhaps one of the most convenient traits to compare at the juvenile and mature stages is specific gravity. This correlation has proven to be

very strong for loblolly pine (Zobel, 1956; Zobel and Rhodes, 1956; Talbert and others, 1983), strong for yellow-popler (Thorbjornsen, 1961), but only moderate for cottonwood (Farmer and Wilcox, 1966).

A number of studies have provided long-term data on juvenile-mature correlations in height and other traits. Wakeley (1971) studied the relation of 30th-year to earlier measurements of individual trees of southern pines. He found that choices before age 20 were subject to considerable error in predicting the best ones at age 30. The main problem with choices at age 10 or 15, however, was that of missing some individuals which became superior later on. Ponderosa pines observed from age 2 to age 20 showed moderate correlation between ages 5 and 20 and good correlation between ages 12 and 20 for height (Callaham and Duffield, 1962). In a study with slash pine progenies, Squillace and Gansel (1974) found little correlation between ages 3 and 25 years for height, but beginning at age 8 the correlations with age 25 improved rapidly with age of younger measurement. Selection at about age 10 years gave the greatest genetic gain per year. In longleaf pine, the correlation between ages 8 and 15 years was a moderate 0.57 for progeny mean heights (Snyder, 1973). Third-year survival, height, and rust-free percentage data from wind-pollinated progenies of slash pine had high mulitple correlation coefficients with volume per plot at ages 8 (R=0.89) and 15 (R=0.83) years (Sluder, 1972). Phenotypic correlations for mean heights of wind-pollinated progenies of loblolly pine were 0.73 between ages 3 and 15 and 0.80 between ages 5 and 15. The same correlations on an individual tree basis were, respectively, 0.53 and 0.60. Genetic correlations for progeny mean heights were even greater than the phenotypic correlations and genetic correlations for rust-free percentages were about as high as those for height (LaFarge, 1972). Stem straightness is a trait for which choices can be made very early in the life of slash pines (Goddard and Strickland, 1964). Baradat (1976) found that the progenies of maritime pine had reached mature physiological behavior for most important traits by the time they reached 7 years of age. When correlated with tree volume at age 30 years, various early measurements on black walnut showed the height correlation to reach a plateau by age 3, d.i.b. at 3.5 feet by age 4 or 5, and tree volume by age 12 (Kung, 1973). Preliminary results from another study of black walnut indicate that parents with the highest breeding values for height and volume can be selected reliably when their progenies reach 4 to 6 years of age (McKeand and others, 1979). Webb (1963) reviewed the earlier literature on juvenile-mature tree relationships and concluded that some traits can be evaluated at an early age but others will require observation over a longer period of time.

Correlations in Provenance Studies

Wide-ranging tree species differ widely in their physiological adaptation to environment. These differences should be expressed at an early age in provenance study plantations. Adaptations affecting spring and fall frost injury and lignification of summer wood affect growth and form of Scots pine provenances (Dietrichson, 1964). Differences in catalase enzyme activity in seeds and respiratory intensity in seedlings could be

used to differentiate between and predict growth of provenances of spruce (Schmidt, 1972). Eastern white pine provenances differed in isozyme variables, three of which were correlated with height growth (Ryu, 1982). Elevation zonal differences were established at an early age in a ponderosa pine seed source study (Namkoong and Conkle, 1976). Height of sugar maple provenances at ages 2 and 9 years were significantly correlated, but considerable switching in rank did occur between the two ages (Kriebel, 1962). Steinhoff (1974) concluded that final evaluation of provenance tests of ponderosa and western white pines should not be done before ages 15 or 20, based upon data from plantations up to 50 years of age. In a study of loblolly pine in Georgia, the correlations of seed source mean heights were 0.92 between ages 10 and 20 when data were averaged over 10 plantations. However, within some plantations the high age-age correlations were somewhat disrupted by local conditions such as ice storms (Sluder, 1980). In the southwide seed source study of loblolly pine, the large east-west and coastal-continental differences evident at ages 5 and 10 years have persisted to age 25. Minor switching within these wider groupings has occurred in later years, however (Wells, 1983).

Early Selection and Culling

Several studies have yielded data for estimating heritabilities and efficiency of selection in the juvenile or very young stage. Many of 116 half-sib progenies of Sitka spruce planted in Scotland changed rank in mean height during the first 6 years and family heritability had increased only to 0.25 by ages 5 and 6 (Samuel and Johnstone, 1979). Several clonal tests of hybrid poplar were measured at ages 1, 4, 9, and 15 years and the seven tallest selected at each age. Selection differential increased with age at selection and selection efficiency was generally better at age 9 than at ages 1 or 4. Heritability was greatest at nine years and selection at that age was highly efficient in all plantations (Wilkinson, 1974). In a study with cottonwood, performance of "blue tag" clones selected at age 5 and planted commercially was good, but a group of clones selected at age 14 showed from two to three times as much improvement in height and diameter as the group selected at age 5. Furthermore, the best clone at age 14 was not outstanding at age 1 and a clone which looked good at 1 was doing poorly by age 14 due to its susceptibility to foliar disease (Cooper and Ferguson, 1979). Selecting the top 10 percent of full-sib families produced 15 to 18 percent genetic gain in 5-year height of yellow-poplar, but correlations between heights at 1 or 2 years and heights at 5 were not strong enough to have produced such gains in 5-year heights if selection had been done at age 1 or 2 (Farmer and others, 1983). Data from half-sib progenies of sycamore taken at ages 1, 2, and 4 years showed heritabilities for height and volume increased with age of the trees. Genetic correlations between traits at different ages were generally higher than phenotypic correlations. Selection on root collar diameter at age 2 for gain in volume at age 4 would require a much larger progeny test to get the same gain that could be obtained by selecting directly for volume at age 4, even though the genetic correlation between the two

traits was 0.92 (Land, 1981). Heritability of growth in eastern white pine full-sib progenies increased between ages 4 and 6, reversing a decline evident during the first 3 years. Maternal effects were much larger than additive effects at age 4, but by age 6 that relationship had reversed (Kriebel and others, 1972). In a study with black walnut, Kung (1973) found that by using closer spacings and higher selection intensities for earlier ages of selection, he could get more gain with early selection than with selection at age 20. Best gain came with selection at age 6. He used the product of the juvenile-mature correlation and the selection differential to determine the best selection age. If large populations can be handled in the juvenile stage, correlated variable or isozyme screening could be used for culling in the juvenile stage with selection to be completed on morphological traits at a later age or ages and on a much-reduced population (Brown, 1967; Tanksley and others, 1981).

Pattern of Variance

If patterns of variation change with age of a progeny test, accuracy of selection at early ages likely will be affected. In some studies already cited, heritability did change with age of the trees. In a Douglas-fir provenance study, development of genetic variances in height growth over a 53-year span fell into three periods: (1) juvenile--environmental error variance increased logarithmically, genetic variance within populations was moderate, and variation among populations was low but increasing; (2) early reproductive--environmental variance was restricted, genetic variance within populations disappeared, and variation among populations increased but not as much as expected; and (3) late--environmental variance increased rapidly, genetic variation within populations did not reappear, and variation among populations remained at about the same level as in (2) (Namkoong and others, 1972). In ponderosa pine, elevation zone seed sources and families within sources were evaluated periodically from age three to 29 years. Again, there were three growth phases: (1) exponential, ages 3-8; (2) steady, ages 8-20; and (3) declining, ages 20-29. Switching of family rank occured in (1) not in (2), and some in (3). The authors concluded that if the management system will include a long period of phase 3, selections should be delayed until that phase can be adequately observed (Namkoong and Conkle, 1976). Franklin (1979) studied the variances over time in the two studies just cited and found that they too formed a pattern which could be divided into the three phases indicated above. He called them (1) juvenile genotypic, (2) mature genotypic, and (3) codominance suppression phases. Heritability was highest during the mature genotypic phase. Variance patterns for a slash and a loblolly pine study were similar to the patterns for the two western species. Franklin recommends that selection for height and volume be deferred until half the rotation age. He has attempted to compress the three growth phases into a shorter time span by planting progenies at close spacing.

The study has been evaluated up to age 5 and variance patterns suggest that the phases are indeed being compressed, although the codominance suppression phase has not yet been reached (Franklin, 1983).

Response to Early Selection

In a mature trait the correlated response to selection applied at some younger age to the same trait fits the same pattern as that for correlated traits as presented by Falconer (1960). The response, or gain, formula, with different subscript symbols than those used by Falconer, is

$G_{M/J} = i_J h_J h_m r_G \sigma_{PM}$, where

$G_{M/J}$ = gain in mature trait from selection in juvenile trait,

i_J = selection intensity used on juvenile trait,

h_J, h_m = square root of heritability of juvenile and mature trait,

r_G = genetic correlation between juvenile and mature trait, and

σ_{PM} = phenotypic standard deviation of mature trait.

The formula looks simple and neat, but getting at the numbers is another matter. For example, for any particular progeny test in which selection in the juvenile stage is to be performed, data from the mature phase will not be available when selection is done. Response can't really be predicted unless information is available from other sources, such as previous experience or research. The tree breeder has some control over two factors of the formula, i_J and r_G. Control over r_G is determined by how early or how late juvenile selection is done. So we need to know how the factors work together, how variation in one or more affects $G_{M/J}$ and what the most favorable combinations of values are for the factors over which the breeder has some control.

When breeding material is held to a mature age, selection can be done both at the juvenile and mature stages. This will normally be done in seedling seed orchards where initial spacing is too close for mature trees. In such early truncated selection, the lower the juvenile-mature correlations, the lower the juvenile selection intensity should be to avoid high risk of misjudgement (Kung, 1974). By computer simulation, Riemenschneider (1979) studied the effects of early culling in a white spruce seedling seed orchard in north-central Minnesota. With culling done at age 15 years, gain in volume at age 30 years increases as the phenotypic correlation between the trait at the two ages increases.

Gain at 30 decreases little with increasing culling at 15 unless the correlation is low. With a juvenile-mature correlation of 0.5, gain at 30 years decreases rapidly as culling level at 15 increases above 60 percent, for a given final percentage retained. Considering all factors, such as genetic gain at age 30, seed production, growing space requirements, and cost per unit gain, the optimum culling level for age 15 was about 60 percent.

Baradat (1976) approached the juvenile-mature correlation problem by measuring clones in a seed orchard as the mature stage and their young progenies as the juvenile stage for maritime pine. For clonal data,

$$A_i = \frac{(\bar{x}_i - u)\ VA}{VG + VE/n_i}, \text{ where}$$

A_i = estimated additive genetic deviation of clone i,

$\bar{x}_i$ = mean of the ramets of clone i,

u = clonal orchard mean,

VA = additive variance among the clones,

VG = total genetic variance among the clones,

VE = random variance, and

n_i = number of ramets in the clone.

For selection among clones, using data from juvenile progenies,

$$A_{iM} = \frac{\text{Cov}\ (A_J, A_M)\ (\bar{x}_{iJ} - u_J)}{VG_J + VE_J}, \text{ where}$$

A_{iM} = estimated additive genetic deviation of mature clone i,

$\text{Cov}\ (A_J, A_M)$ = covariance between additive genetic values of the juvenile progenies and their mature conal parents,

$\bar{x}_{iJ}$ = mean of juvenile progeny i,

u_J = overall mean of the juvenile progeny test,

VG_J = total genetic variation in the juvenile progeny test, and

VE_J = random variation in the juvenile progeny test.

A coefficient analagous to the heritability coefficient is

$$CGP = \frac{Cov(A_J, A_M)}{\sigma_{PJ}\sigma_{PM}}, \text{ where}$$

CGP = coeffecient of genetic prediction,

$Cov(A_J, A_M)$ = as defined above, and

σ_{PJ}, σ_{PM} = phenotypic standard deviation for the juvenile and mature stages.

Height growth at 5 to 10 years was found to be a good predictor of total wood production at 25-60 years for 13 older provenance and progeny tests in western Europe ($0.64 < r_{PMJ} < 0.94$) (Nanson, 1976). Nanson concluded that, if $i_J h_{GJ} r_{GJM} > i_M h_{GM}$, gain from early selection will be greater than that from late selection (G=genetic). The age of optimal early selection is the age at which the trait is best expressed and/or reaches a high heritability. Furthermore, multitrait selection may best be done sequentially, not at one specified age.

Lambeth, (1980) after studying juvenile-mature correlations and the efficiency of early selection in eight species, concluded that the optimum selection age increases somewhat with rotation age, but ranges from 5 to 10 years for rotation ages of 20-25 years. He measured efficiency with the formula,

$$E = \frac{r_{JM} T_M}{T_J}, \text{ where}$$

E = efficiency of early selection,

r_{JM} = the juvenile-mature phenotypic correlation,

T_M = generation time in years for mature selection, and

T_J = generation time in years for juvenile selection.

Selection intensities and heritabilities are assumed to be the same at both ages. His estimate for r_{JM} was based on the combined data from 14 studies and eight species, which produced a very high coefficient of 0.964. However, data from ages 1 through 3 years were omitted from the estimate because such early data did not fit the pattern shown by data from age 4 onward.

In an overview of the subject, Lambeth (1983) concluded that early testing in the nursery, greenhouse, or phytotron for growth rate has the potential for reducing the generation cycle by 4 to 8 years. Hindrances

to such early selection are seed size effects, sampling variation, and lack of research data. He goes on to say, however, that enough positive results have been obtained to warrant establishment of experimental populations to be cycled through several short generations to determine the validity of the procedures. In further discussion of the efficiency of early selection, he points out that when comparing 7-year vs. 35-year cycles, r_{JM} need be only 0.20 for E to = 1.0. However, for selection at age 2 vs. age 8, r_{JM} must be 0.54 for E to = 1.0.

EXPERIMENTAL RESULTS

A number of tests were established in central Georgia by the Southeastern Forest Experiment Station and have been measured periodically up to ages 20 to 22. Simple correlations among progeny mean heights at the different ages were calculated for 10 of the plantations (table 1). A pattern of decreasing correlation with increasing difference in age at measurement is clear for all the plantations. Generally, correlations between progeny mean heights at age 20 to 22 and mean heights at ages below 8 or 10 years were low. In fact, correlations with age 8 or 10 were so low in some plantations that selection among families at that age appears to be risky.

Plantation 38 contained 27 wind-pollinated progenies. Data from this plantation were used for a more detailed study of the utility of early selection. Results are presented in the following discussion.

Genetic correlations between progeny mean heights at the different ages were in all cases greater than the simple correlations shown in table 1:

	Genetic correlation with older age		
Younger age	8 years	15 years	22 years
3	0.88	0.54	0.93
8		.58	1.18
15			.84

For progeny mean height in plantation 38, heritability decreased steadily with age as the phenotypic standard deviation increased:

	Age			
Parameter	3 years	8 years	15 years	22 years
h^2	0.85	0.69	0.42	0.19
σ_p (feet)	.59	1.31	1.90	2.47

Table 1.--Simple correlations among progeny mean heights at different ages in ten study plantations. a/

Plantation 38

Age	8	15	22
3	0.83	.41	.45
8		.43	.52
15			.76

Plantation 39

Age	8	15	22
3	0.94	.88	.72
8		.94	.79
15			.93

Plantation 40

Age	5	10	15	22
3	0.54	.48	.42	.34
5		.67	.70	.54
10			.65	.52
15				.92

Plantation 49

Age	10	21
5	0.34	-.05
10		.60

Plantation 41

Age	10	15	22
5	0.72	.46	.22
10		.74	.42
15			.76

Plantation 45

Age	5	15	21
3	0.78	.30	-.21
5		.73	.23
15			.72

Plantation 46

Age	10	15	21
5	0.60	.44	.59
10		.71	.63
15			.83

Plantation 50

Age	5	10	21
2	0.86	.63	.33
5		.90	.60
10			.77

Plantation 51

Age	5	10	15	21
3	0.89	.73	.62	.56
5		.90	.80	.76
10			.94	.84
15				.91

Plantation 56

Age	10	20
5	0.43	.60
10		.97

a/ Plantations 38, 39, 46, 50, and 51 are slash pine; Plantations 40, 45, and 56 are loblolly pine; and Plantations 41 and 49 are longeleaf pine.

Predicted genetic gains in progeny mean heights were calculated for all combination of selection age and response age. For example, the best five families were selected at age 3 (S.I. = 1.388) and their superiority to the plantation mean calculated for ages 8, 15, and 22 years, using the gain formula shown earlier. This same procedure was used for the other measurement ages. Because of the low heritability of progeny mean height at age 22, predictions of gain at age 22 were lower when selection was done at that age than when it was done at any of the younger ages. For ages 8 and 15, however, selection at those ages gave better predicted gain than selection at earlier ages:

	Predicted genetic gain at age			
Selection age	3 years	8 years	15 years	22 years
		feet		
3	0.71	1.23	0.86	1.30
8		1.26	0.83	1.26
15			1.12	0.83
22				0.67

For a look at actual gains, I selected the tallest five progenies at age 3 and followed those five to age 22, comparing their mean height with the plantation mean height at each measurement age. I did the same for the other ages. At no response age did selection at an earlier age give greater actual gain than selection at that age:

	Actual gain at age			
Selection age	3 years	8 years	15 years	22 years
		feet		
3	0.93	1.56	1.19	1.87
8		1.58	2.09	2.40
15			2.54	2.13
22				3.56

Selection efficiencies for the various selection and response ages were calculated according to Lambeth (1980). Whether based on predicted gentic or actual gains, it is more efficient on a gain per years basis to select at age 3 than at age 22:

	Efficiency at response age		
Selection age	8 years	15 years	22 years
	Based on predicted gain		
3	1.59	1.92	6.55
8		1.14	3.91
15			1.67
	Based on actual gain		
3	1.60	1.17	1.77
8		1.27	1.40
15			0.81

DISCUSSION

In plantation 38, some change in rank of family mean heights occurred over time. Jones 18, for example, ranked 18.5 in height at age 3, then ranked sixth, fourth, and second at ages 8, 15, and 22, respectively. It has proven to be a very desirable progeny in other traits as well. Had final choices been made at age 3, Jones 18 probably would have been rejected because of mediocre height growth to that age.

An ice storm struck plantation 38 immediately after the 8-year measurement. Top breakage probably accounts for poor correlations between heights at 15 and the other ages. By age 22, the earlier height relationships appear to have been largley restored.

It appears from these study results and the literature review that early progeny test evaluation followed by early selection definitely has a place in breeding programs. The main questions are how early to select and which trait or combination of traits to use for selection.

Some traits are expressed in the early juvenile stage and change little over time. Progeny or screening tests for such traits can be designed to handle such large numbers of progenies and trees within progenies that high intensities of selection can be performed at very young ages. In this way, generations can by cycled rapidly if improvement in juvenile traits is the primary objective.

Growth traits, however, need more time before final evaluation so early effects of such environmental factors as seed size can run their course. Age 5 years probably is the earliest that selection for height should be done under usual field conditions. This also is usually the age at which reliable evaluation for field infection by fusiform rust can be done. Thus, unless special screening or other testing environments are used, final evaluations of progeny tests should not be done before age 5. For growth traits, age 10 would be even better for final evaluation of field tests.

Progeny tests could be arranged for some form of tandem selection, and each trait could be evaluated when it is best expressed. Height and d.b.h. probably would be the last traits selected. By then, many progenies and trees would have been dropped from consideration, lightening the measurement load.

If the primary objective of a progeny testing program is to establish an advanced-generation clonal seed orchard, then there may be time to carry progeny tests for 10 or more years because there may be no big rush to dismantle the previous-generation seed orchard. It takes time and a large investment to get one going, so the turnover rate for seed orchards likely will be slow. So either take your time with progeny tests or cycle two or three generations between seed orchards. The latter course should give the greatest gain for the next seed orchard.

Perhaps the best use of early progeny testing would be to single out a few of the most important traits and breed for each one seperately, cycling generations at a pace best suited for each trait. After a few

generations, and the number probably would vary by trait, the different lines could be control-crossed among each other for another seed orchard and another round of generation cycling with selection. All this assumes, of course, that age to flowering can be drastically decreased under controlled conditions.

Lambeth (1983), in discussing early testing, talks about the difficulties caused by sampling variation when one sample of a progeny is used for early testing and a separate sample of the same progeny is used for the mature field test. Sampling variation tends to mask correlations that are real. If both the juvenile and mature measurements are made on the same material in the field test, however, such sampling variation effects are not present. For this reason, juvenile-mature correlations for data taken on field-planted materials likely will be higher than those for data from juvenile tests in the greenhouse and mature tests in the field.

It seems reasonable to conduct progeny tests quickly, controlling or avoiding environmental extremes. However, when grown to rotation age as a crop, the genotypes thus chosen still will face these extremes. Ability to withstand or recover from environmentally caused damage, such as ice breakage, will not have been measured in early tests.

The choice between early and mature tests is ultimately one of economics: how quickly do you want progress and how much are you willing to pay for it. There likely always will be some risk of making wrong choices with early progeny tests, but the error will be in failing to choose good progenies more often than in choosing poor ones. Progress per generation will be less with early progeny testing, but progress per year potentially is greater.

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CONTROLS IN PROGENY TESTING OF FOREST TREES

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Abstract.--Controls provide a standard for comparison and are needed in most progeny tests, but not all. The need for controls is determined by the objectives of the test and the genetic makeup of the parents. These same factors also determine the desired genetic composition of the controls. The control material must be treated as an integral part of the progeny test, from planning through seed handling and nursery practice, to seedling care and outplanting procedures.

INTRODUCTION

Progeny testing is an experiment in which the offspring of various parents are the treatments under study. Control treatments are included in many experiments as a standard for comparing the test conditions and the effectiveness of the treatments under study. The need for a control can be characterized into three cases (Cochran and Cox 1957, p. 13): (1) if the effectiveness of the type of treatment, or of one of the treatments being studied, has been consistently demonstrated previously, there is no need for a control; (2) if the type of treatment has been shown to be generally effective but not consistent under all conditions, a control is needed to describe the test conditions; and (3) if the effectiveness of the type of treatment is not known, a control is needed to measure the performance of the treatments. Examples of progeny tests can be found that fit each of the above cases and some tests fit more than one.

The purpose of this paper is to discuss the use of controls or check lots in testing the progeny of forest trees. Some of the questions considered are (1) when should controls be used, (2) what constitutes a good control, and (3) how should controls be incorporated into the test? Information was taken from the literature and also from conversations with several forest geneticists throughout the United States.

WHEN TO USE CONTROLS

Check lots can serve many purposes, including: (1) measuring the effectiveness of the parental selection method, (2) providing a standard for roguing an orchard, (3) tying together incomplete tests over locales or time, (4) providing a basis for estimating realized genetic gains, and (5) proving genetic superiority for seed certification (which is required in many states and for "Tested Reproductive Material" certified by the Organization for Economic Cooperation and Development).

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The use of check lots in progeny tests largely depends on the objectives of the test. The primary objective of any progeny test is to provide a genetic evaluation of the parents by examining the offspring. Parental evaluation can be used to define seed zones, rogue seed orchards, or select genotypes for advanced generation populations (McKinley 1983). Controls may be important or merely useful, depending on the objectives of the progeny test. McKinley also discussed some secondary objectives for progeny tests, including: selection among and within families as a source of future generations, estimation of genetic parameters, estimation or direct demonstration of realized genetic gain, and production of seeds. Among these secondary objectives, controls are most important to estimate or demonstrate realized gains. Of course, having estimates of realized gain and being able to show differences in the field can be extremely important when working with non-geneticists.

The genetic character of the tested trees also affects the need for check lots. A random collection of open-pollinated seeds provides an estimate of the natural population in the collection area. The means of the traits measured on the test trees estimate the means of those traits in the natural population and are the standards for comparing the parents. Therefore, no control is needed. However, phenotypic selection results in new populations often better for the selected traits than the natural population. The degree of improvement is unknown and can only be determined by comparison with a control.

GENETIC COMPOSITION OF CONTROLS

Just as the progeny test objectives and genetic makeup of the parents determine the need for controls, they also dictate the genetic composition of the check lots. In tests designed to measure the performance of individual parents, the optimum control is one which represents the best genetic alternative to the tested material. If first generation progeny testing was preceded by provenance testing, then controls taken from superior geographic seed sources are appropriate. For example, Livingston Parish, Louisiana loblolly pine (Pinus taeda), when planted throughout most of the range of the species, has exhibited both superior growth and resistance to fusiform rust (Cronartium fusiforme). It is often included as a control to evaluate both growth rate and rust resistance in loblolly pine progeny tests. Seeds collected in seed production areas also make good check lots for first generation tests. It is very important in such evaluations that control seedlings represent what should be planted, not necessarily what is commonly planted. Commercial checks or nursery run seedlings may represent anything from source identified seed to seeds collected in response to newspaper ads.

If evaluation of the effectiveness of the parental selection method or determination of realized genetic gain is the objective of a progeny test, controls should be grown from seeds collected from the comparison trees or from non-selected trees in the stands where the parents were selected. These check lots may not represent the best genetic alternative to the tested material, but because of the objectives of the progeny test, are a better comparison.

Progeny tests of hybrids should include as controls both parent species, preferably produced by the same crossing method. For example, the pitch pine (P. rigida) x loblolly pine hybrid has great potential in the mid-Atlantic and northeastern states. To determine if the hybrid is truely superior, it should be compared to the best local pitch pine and the loblolly pine source proven best adapted to the area. Also, because the hybrid is produced by controlled pollination, the check lots should also be from controlled crosses.

Controls made up of the best genetic material from the previous generation are appropriate for advanced generation tests. It may also be desirable to include check lots representing the natural population and successive cycles of improvement for demonstration purposes and for estimating overall gains.

Progeny tests are usually replicated on several sites so that genotype-environment interactions can be evaluated. Because the same controls must be used in all replicates, performance of the controls should not fluctuate widely from site to site relative to the select families. Bulking check lots into a control mix will give a more consistent performance because of the number of genotypes involved.

Genetic checks are a type of control used to tie together incomplete tests by adjusting family performance for scale effects, e.g. site quality or planting year differences. Such checks are common in full-sib family progeny tests where not all the crosses can be made in one year, or when seeds must be collected in successive years to provide sufficient quantity. The same full-sib genetic checks are used in all the tests within a breeding population, regardless of test location or year of planting. Thus, they not only provide a common comparison but they also provide a full-sib control for the full-sib test.

As with all progeny test controls, it is important that genetic checks be stable across sites. However, at the beginning of a controlled pollination program there will be no genotype-environment interaction data available for selecting genetic checks. Since bulking would eliminate the full-sib value of genetic checks, increasing the number of checks is the only way to overcome the problems of interactions. In succeeding generations data will be available for selecting good general purpose genetic checks.

The mating design will influence the importance of genetic checks in a test. In the tester polycross design, relatively few pollen parents are used resulting in relatively few half-sib families among the crosses. The same half-sib families will occur on each site or in each planting year, thus reducing the importance of genetic checks. However, in partial and disconnected diallel schemes, there may be no half-sib relatedness among the sets of crosses, and genetic checks are needed to tie together the various sets.

OPERATIONAL USE OF CONTROLS

Controls are an integral part of the experiment and must receive treatment identical to the experimental units so the results will be directly comparable (Cochran and Cox 1957, p. 14). Therefore, the genetic composition of progeny test controls and the number needed must be determined

when planning the test. As previously discussed, the genetic composition of the check lots will depend on the genetic makeup of the parents and the objectives of the test.

The number of controls used will depend on both statistical and operational considerations. The kinds of comparisons to be made should largely determine the number of controls needed. To establish that any individual parent is superior to the control, only one control plot per replication is needed. However, if the performance of the parents as a group is of interest, the control plot would have to be represented several times in each replication for the comparison to be meaningful. Statistically, the number of control plots should equal the number of plots making up the treatment mean to be evaluated (McKeand 1983). For example, in a full-sib progeny test the general combining ability of the parents is evaluated based on a number of full-sib families that make up its half-sib family. If five full-sib families make up each half-sib family mean, then five control plots should be used. Operationally this may be difficult because large uniform sites for progeny tests are hard to find. Numerous control plots can limit the value of the progeny test by reducing the number of families that can be evaluated. Generally, two control plots per replication should be considered a minimum, and four to six would provide excellent comparison in most tests.

Not all control plots in a test need be of the same genetic material. Often controls of different genetic composition will be included to make comparisons to meet different objectives. For example, in a test with four controls; two might be genetic checks, one a bulked sample from a superior geographic seed source, and another a bulked collection from a different seed orchard.

Not only must controls be planned into progeny tests, the seeds and seedlings must be treated the same as the test material. For progeny tests spread over several years it is desirable to use the same control seedlots in all the tests. However, concern has been expressed about deterioration of seeds in storage (McKeand 1983). Fortunately, seeds of spruces (Picea spp.), pines, Douglas-fir (Pseudotsuga menziesii) and many other commercially important conifers store well for years under proper conditions (USDA Forest Service 1974). Differential loss of viability among bulked families may be a concern, however. Seed viability in storage can best be assured by starting with high quality seeds, and by careful monitoring of seed and storage conditions. Many hardwood species and some conifers such as the true firs (Abies spp.) have seeds that cannot be dependably stored beyond one year. With these species the lack of a consistent control from year to year must be recognized.

Production of control seedlings must be by the same method as the test seedlings. Bare-root seedlings should never be used as a control for a container-grown progeny test. Likewise, "nursery run" stock should not be used as a control for bare-root progeny test seedlings. The check lots seedlings must be part of the same experimental design as the test seedlings in the nursery or greenhouse. They must also be handled and planted by the same methods. The effects of different nursery culture or seedling handling and planting techniques can persist for several years in the field and bias early test evaluations.

SUMMARY

Most progeny tests benefit from including controls to measure the performance of the parents or evaluate the effectiveness of the tree improvement program. Controls are not needed when the mean values of the traits measured in the progeny test can be used as reliable standards of comparison. Controls can serve several functions in progeny testing depending on the nature and the objectives of the test.

The genetic makeup of the parental material will determine the proper genetic composition of the controls. Depending on the test, the appropriate controls may be anything from source identified nursery stock to control-pollinated seedlings. It is important that the control represents a fair genetic alternative to compare against the tested material. A low genotype-environment interaction is also desirable for a control because many progeny tests are replicated on several sites. Control-pollinated genetic checks are useful common elements for drawing together partial tests separated by site or planting year.

Good progeny test controls are not afterthoughts. They must be planned into the test so they can be used in direct comparisons. The number of controls needed will depend on the kinds of comparisons desired and the operational constraints of the size of the test site and the number of parents to be evaluated. Lastly, control seedlings must be produced, handled, and planted using the same techniques as the other stock undergoing testing.

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CONVERTING A PROGENY TEST TO A SEED ORCHARD--AN EXAMPLE TO LEARN BY?

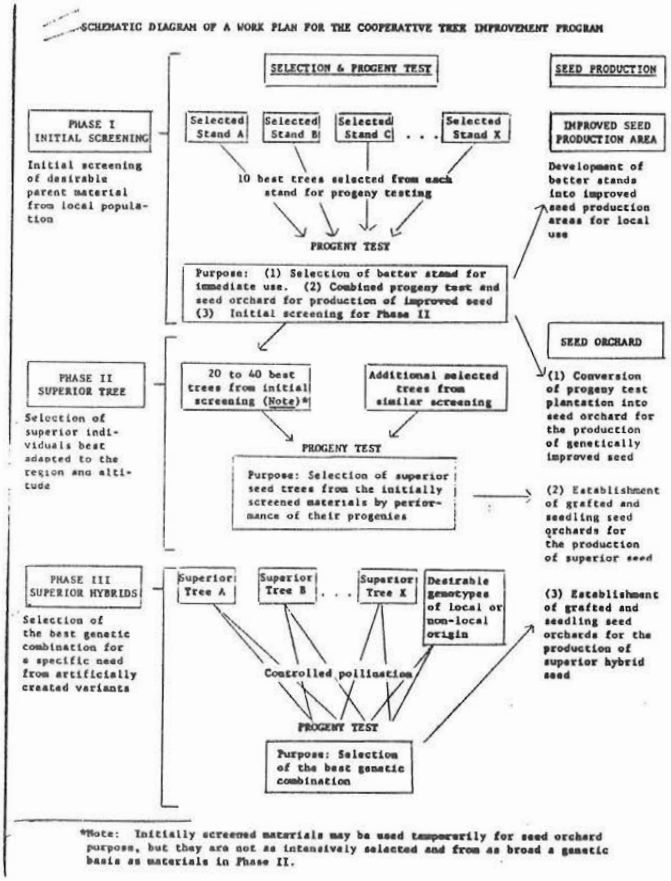
Ronald C. Hamilton*

Introduction

During the late 1950's and early 1960's, the Intermountain Region of the Forest Service, in cooperation with the University of Idaho, Bureau of Land Management, State of Idaho Department of Lands, Southern Idaho Forestry Association, and the Intermountain Forest and Range Experiment Station, developed a Cooperative Agreement providing for development of a ponderosa pine tree improvement program. What is present here is synopsis of a number of assessments that were made by various members of that cooperative in developing and assessing its program direction for the future. While most of the members of the cooperative are quick to admit a number of problems with the original program, most believe that much can be learned from the problems that were encountered.

The program undertaken was influenced greatly by Dr. Chi-Wu Wang, geneticist at the University of Idaho. The program (outline 1) was to use the progeny test-seed orchard conversion program discussed in detail by Wright and Bull.[5]/

Outline 1



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The program outlined was started in 1961. The testing program lagged behind the schedule outline by a number of years, although Phase II began nearly as scheduled.

As a result of on and off site findings and technical advancements, the program underwent several reassessments. This has caused all cooperators to look for a new direction in the ponderosa pine program.

The assessment the cooperative has gone through should help point out problems that should be dealt with when using a converting (progeny test-seed orchard (PT-SO)) program. This assessment does not attempt to show all the pros and cons, but is an attempt to highlight, for all interested, the problems to be dealt with in such a program when one is currently underway.

Background Information

Artificial reforestation failures of ponderosa pine, the most important species in Southern Idaho, prompted the formation of the Southern Idaho Ponderosa Pine Cooperative Program. The purpose of the program was to obtain basic genetic knowledge while overcoming the planting failures through development of drought resistance and increased the production rate of the species.

The objectives of the program were to (1) develop a progeny testing program, (2) implement a natural stand seed orchard, and (3) develop a second generation seed orchard.

The approach used 1/2 sib family selections from the best stands throughout the range of ponderosa pine in South Central Idaho. It involved parts of three National Forests and the surrounding state of Idaho, BLM, and some industrial lands. The lands were adjacent to the Payette, Boise, and northern Sawtooth National Forests, essentially the forested land between 46 degrees and 43 degrees latitude and 117 degrees and 115 degrees longitude. Access limited the extent of the collections.

The program called for 1/2 sib seed collections (open pollinated mother trees) by all cooperators from ten of the best trees within each of the selected best phenotype stands. The selection criteria was mild. Selections were made from sawtimber-sized stands of even-age that exhibited greater than average stand height and diameter growth; crown form was to be narrow; limbs short; bole form straight and free of defects, free from insects, and diseases; and expressing drought resistance. Little indexing was actually accomplished although it was suggested.

The drought resistance criteria caused considerable problems for those making selections. It was explained as being those that were growing on "dry severe sites..."--this resulted in some selections being made that did not fit the other desired criteria. This factor was believed, at the time, to be the key to success in the reforestation program. Better planting and seedling handling techniques have since eliminated most of the seedling survival problems.

In 1964, the seed was collected from the 271 mother trees included in the Phase I portion of the program. Four sites for progeny test-seed orchard establishment were selected by the cooperators. Criteria for these areas were as follows:

1. Two sites in each of the following groups:

   a. 3,000- to 4,500-foot elevation zone, and
   b. 4,500- to 6,000-foot elevation zone.

2. Fourteen acres or greater.

3. Ten percent or less slopes.

4. Dedication to seed orchards for 99 years.

5. No south or west aspects.

The criteria was not always followed--often because other resource uses were given priority when use conflicts occurred and because of lack of availability.

The sites choses were as follows:

1. Boulder Creek near New Meadows, Idaho, Payette National Forest; U.S. Forest Service administered; elevation 4,750 feet.

2. Jack's Creek; near McCall, Idaho, State of Idaho; Department of Lands administered; elevation 5,300 feet.

3. Holcomb; old guard station west of Idaho City, Idaho, Boise National Forest; U.S. Forest Service administered; elevation 3,600 feet.

4. Idaho City; Idaho City, Idaho, Boise District; Bureau of Land Management administered; elevation 4,000 feet.

The sites were prepared by Holtplow in 1966. The Idaho City site was prepared after a timber sale and landclearing was accomplished.

Planting was accomplished in 1966, using 2-0 bare root seedlings grown at Lucky Peak Nursery. The initial planting was made with randomly selected seedlings within progeny groups in the nursery bed. The planting was completed in 4-tree row plots at 5-foot intervals. Between row spacing in each of the ten blocks was 10-foot, allowing each tree approximately 50 square feet of space. Seedling shortages were left blank.

While survival and other growth rate data was collected on the progeny tests every 3 to 5 years, the data was selectively analyzed resulting in some questionable conclusions and decisions concerning the program. In 1979, Jerry Rehfeldt of the Intermountain Station analyzed the 11th and 16th year data.[2-3]/

The cooperative reviewed these results. It was suggested that cooperators reassess the old program. During this assessment, a number of considerations concerning the conversion of progeny tests to seed orchard in the manner planned by the cooperative were highlighted. It was during this assessment that the problems with the conversion to a seed orchard from the progeny tests were developed.

CONVERTING THE IDAHO CITY PROGENY TEST TO A SEED ORCHARD - AN EXAMPLE

The Idaho City progeny test area at 16 years of age had a survival rate of 48 percent. This rate is similar to the other three areas; insect, disease, and rodent predation have been a major factor on all sites discussed later.

Data - Idaho City PT-SO Area

273 Families planted as 2-0 seedlings (two local source controls, plus 271 selected families from 37 stands).

10 Blocks of randomized 4-tree family row plots at 5 feet x 10 feet intervals.

10,920 Trees planted with 5,191 trees alive after 16 years (48 percent).

Total acres - 12 1/2

The data resulting from the progeny tests because of the elevation variation allowed the establishment of seed zones based on Rehfeldt's analysis. Any adaptational requirements of species were not considered in the initial development of the program.

The seed zone was determined to be 450 M (1,500 feet) elevation, 1.4 degrees latitude (100 miles), and 2.4 degrees longitude (120 miles).[3] This information, was not available during establishment, but should have influenced the design of the orchard.

Several concerns surfaced as the cooperators reflected on the desirability of converting any part or all of the progeny tests to seed orchards as planned. A program put together by Rehfeldt and Bruce Young aided in projecting the conversion process and allowed a visual inspection of the results prior to any treatments. The example conversion used is for the low elevation ponderosa pine northern zone in the 3,500- to 4,999-foot elevation range. The ponderosa pine, while a specialist in an adaptional sense, has a zone size which is large in comparison to Douglas-fir or lodgepole pine. These species are restricted to about 600 feet elevational with similar latitude and longitude constraints.[4-5] Part of the problem with the conversion has come from the lack of determining the adaptional requirement before starting the program.

The initial selection of families resulted in 31 percent of the families coming from the low elevation northern zone. Had the zoning occurred before establishment, a greater number or better orientation of families could have occurred. Therefore, 1,838 individuals from within that zone were available to start the conversion. The lack of appropriate data to aid in design of the PT-SO program resulted in only 35 percent of the surviving individuals being available to the orchard for the conversion. The lack of zoning also compounded problems in the conversion process.

The conversion process, after adjusting all data for block environment effects, called for selection of the top 24 percent or 20 families from the adapted progeny. This resulted in the following rate of increase in height growth:

$G = Sh^2$ where: G = genetic gain in units of measure

$\overline{S} = 313 - 280 = 25$ cm $\overline{S}$ = selection differential

$h_f^2 = .33$, $\underline{G} = 10.9$ cm H_f^2 = family heritability (stand)

Height growth was the primary genetic variant in the selection criteria. Note in the exhibit the effect of these initial sets of constraints on the orchard population and its location within the blocks. The blocks were varied in arrangement to compensate for environmental variation, which alters part of the effect of randomness.

The next requirement was to thin the 4-tree plots to one tree per plot. A number of the 4-tree row plots contained at least two individual trees that were among the tallest of 1,838 individual trees initially selected for their ranking in height growth. Thinning these 4-tree plots to one tree per plot resulted in a 1 percent loss of gain in height growth due to losses among the 1,838 best initial selections. Due to the seed production spacing requirements for individual trees, this thinning was determined as necessary.

The last step in the process was to select four top height growth individuals of the top families. The results:

4 - 19 1/4 = 20 percent

The individual tree genetic gains were determined:

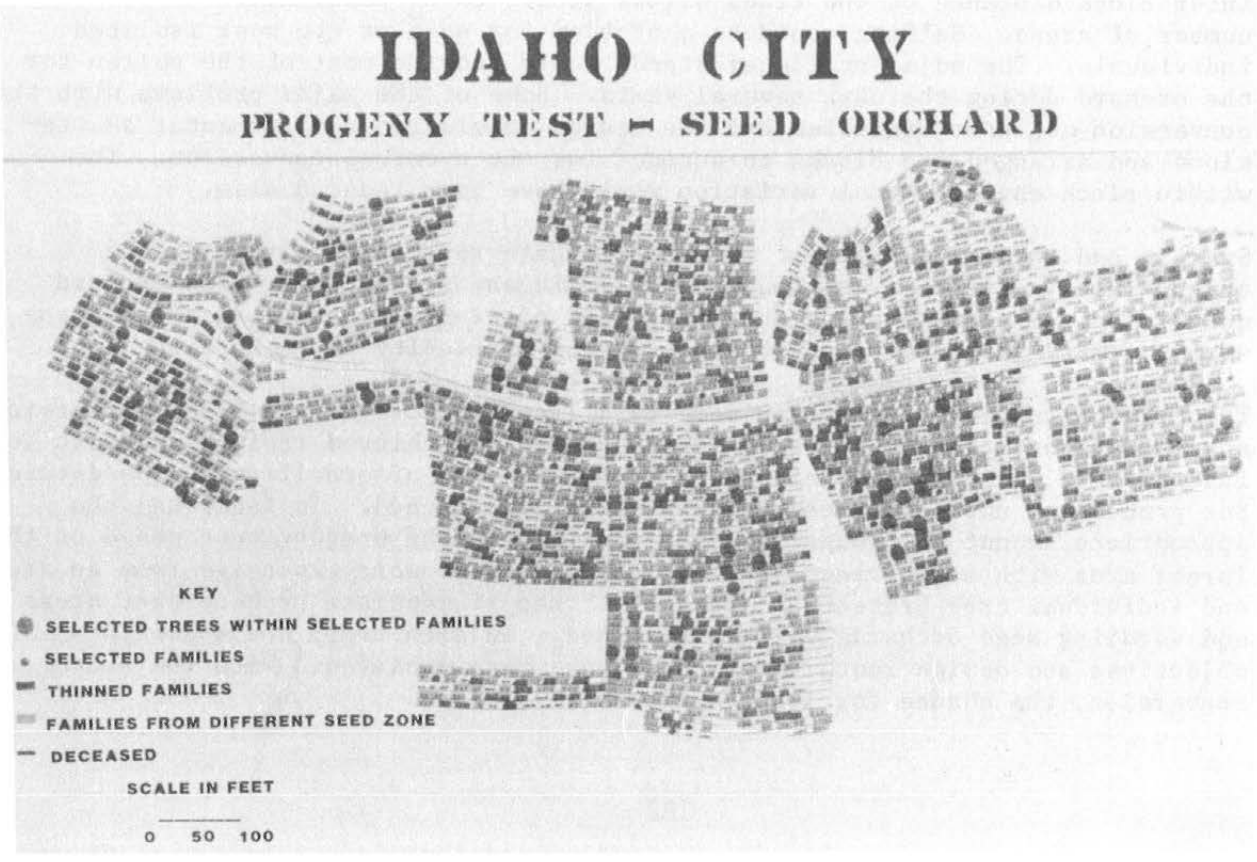
$\underline{G} = Sh_I^2$ where: (see previous explanation)
h_I^2 = heritability of individual family (stand) selections

$S = 396 - 313 = 86$ cm
$h_I^2 = .15$ $\underline{G} = 12.5$ cm

Total gain:

Family Selection = 10.9 cm
Individual Selection = 12.5 cm
23.4 cm

Percent $\underline{G}$ = 234/280 = 8 1/2 percent (1 1/2 percent off the target of 10 percent desired by the coop.)



To obtain this rate of gain, a seed orchard containing 74 trees is left. This rate of gain does not consider the problem with pollen contamination as the seed orchard area is currently surrounded by ponderosa pine. Due to a management decision by the controlling agency, isolation of the seed orchard has not occurred, and the pure stand of 80 to 100 years plus ponderosa pine surrounding the area would probably remain.

Problems of the Conversion Example

It is important to review the spacing and placement of the selected trees as you proceed through the conversion process. The choice of design in the initial proposal could have had considerable influence. Consider the initial between row spacing and the spacing between trees. Ponderosa pine is relatively late in sexual maturation (about 20-25 years). The current areas are nearly 20 years of age and have only recently produced a few (5-7) female flowers. In order to accommodate the growing space needed by ponderosa pine, at least 20 to 25 feet of between row spacing was necessary. This does not consider equipment used in an orchard an extremely important design consideration also.

The designed within row spacing did not allow sufficient spacing from the progeny test standpoint if limb form or length were important attributes to be measured over a 15 to 20 year span. The spacing did not allow this to occur because by the 10th to 12th year, many of the crowns were interacting sufficiently to retard elongation on at least two sides. The spacing was not sufficient for conversion to an orchard. If two selected family individuals were adjacent to each other, the crown area of both trees would be hindered in development--reducing substantially each of the individual's ability to contribute to seed production.

Pollination distance is a problem in the converted orchard if only the 74 individuals are retained. The pollen volume of these trees and the intra and inter block distance of the trees allows little to no pollination to occur in a number of areas. Selfing could be a problem for some of the most isolated individuals. The adjacent timber stands would provide most of the pollen for the orchard during the next several years. Some of the major problems with this conversion would be minimized had the design considered environmental adaptations and arranged the blocks to account for the eventual conversion. The within block environmental variation would have been reduced also.

Spacing and the maintenance of the genetic gain rate while retaining the appropriate individuals is a major problem in any progeny test-seed orchard conversion. By establishing the objectives of PT-SO program to deal with the within family variances, much of the spacing difficulty is taken care of.

The original program assumption made by all cooperators in the PT-SO conversion scheme was that tree improvement results could be achieved rapidly and with low investments. Cooperators felt that they could only afford limited expenditures for protection until the seed orchard phase was reached. In fact, had the appropriate amount of protection been provided to the progeny test phase on the larger area with more trees, it would ultimately be more expensive from an area and individual tree protection standpoint than if separate progeny test areas and seedling seed orchards were established. In each case, the specific objectives and design requirement could have been achieved. With the conversion, the chance for long-term testing is lost.

Insect, disease, and other predation problems were major factors in the Idaho City conversion. In 1981 and 1982, Forest Pest Management personnel from Region 4's Boise field office conducted a pest survey of the four test sites (Hoffman and Marshall report in press). The evaluation was to provide cooperators with some idea of influences on the area and the problems imposed on the data. The conditions of all the areas are shown in Table 1. Of particular interest is the amount of terminal insect damage. More than 1/3 of individual remaining trees have given less than accurate height growth rates influencing the selection of trees in the orchard. The principal pest, the Western Pine Shoot Borer (Eucosma sonomana kft.) appears to not exhibit any family or individual genetic preference seemingly attacking at random (Personal Communication, Ray Hoff, INT Station).

Table 1

PROGENY TEST EVALUATION: PHASE 1; TREE # 1-271

Hoffman and Marshall Survey, 1981-1982

CONDITION	HOLCOMB Boise NF		JACK'S CREEK State of Idaho		IDAHO CITY BLM		BOULDER CREEK Payette NF		TOTAL	
	#9,093 Plant. # w/cond	#3,518 Pres. % cd/pre	# Plant. # w/cond	#1,436 Pres. % cd/pre	# Plant. # w/cond	#5,063 Pres. % cd/pre	# Plant. # w/cond	#7,238 Pres. % cd/pre	# Plant. # w/cond	#14,257 Pres. % cd/pres
Gall Rust	9	.3	661	46.0	32	.6	992	23.4	1,694	11.9
Elytroderma	0	0	377	26.2	0	0	1	.02	378	2.7
Fomes annosus	0	0	0	0	20	.4	0	0	20	.1
Terminal Insects	1,303	37.0	352	24.5	1,831	36.0	23	.5	3,509	24.6
Pitch Moth	69	2.0	247	17.2	61	1.2	11	.3	388	2.7
Eurytomid	31	.9	0	0	16	.3	1	.02	48	.3
Top out	76	2.2	162	11.3	90	1.7	42	1.0	370	2.6
Forked Trunk	450	12.8	124	8.6	152	3.0	57	1.3	783	5.5
Stunted	179	5.1	130	9.0	104	2.1	40	.9	453	3.2
Mechanical Injury	63	1.5	273	19.0	90	1.7	2,922	68.9	3,338	23.4
Sapsucker	108	3.1	163	11.3	80	1.5	20	.5	371	2.6
Rodent Chewing	5	.1	12	.8	4	.1	9	.2	30	.2
Unknown mortality	26	.7	14	1.0	13	.3	18	.4	71	.5
No Damage	1,678	47.7	193	13.4	2,759	54.5	835	19.7	5,465	38.3

Another major problem has been the predation losses due to pocket gophers and the constant cost of controlling this rodent. The cost per acre of control is $8 to $14. The extent of the program area certainly makes the PT-SO conversion alternative a much more expensive program than a reduced area. Most of the losses in the initial plantings are attributable to the pocket gopher. Yearly control in some areas is still necessary.

An influence not normally considered a problem is the Fomes annosus losses due to the lack of stump treatments. This problem, because it is located in centers, has tended to eliminate two or three 4-tree row family groups surrounding the center. Loss of these test sources may have been significant although less than .4 of the present population currently are influenced--several families were lost in the first 3 to 10 years of development.[1]/ That loss is not indicated.

While testing for various insects and diseases in a progeny test is desirable, retention of certain affected genotypes may be desirable in a orchard. Again, the objective of both programs may conflict.

The choice of progeny test sites was accomplished with other genetic determinations in mind. The sites have provided quantitative information on population differences sufficient to establish seed zones for ponderosa pine.

This is not desirable in a progeny test-seed orchard conversion as the orchard arrangement is the ultimate objective in designing the project. Priority for the orchard is often contrary to the progeny test design criteria.

Another real danger is in the selection of the high elevation test sites are their suitability for seed production. The Idaho City site has a frequent rate of cone and seed production; however, the two high elevation sites appear to have frost problems that are sufficiently severe enough to almost eliminate sexual development most years. The old growth ponderosa pine surrounding the sites rarely produce seed although flowering occurs.

While it would appear from the partial analysis of the Idaho City area that progeny test-seed orchards have some major problems, the program does have potential if the progeny test objectives of statistical effeciency, quantitative genetics, and orchard requirements are accounted for in the program before its establishment. Other reports during this workshop will help provide the information necessary for the evaluation of the acceptability of such a program for your needs.

Summary

The program as developed has provided some of the genetic data once desired by the cooperators. The problems in reforestation were not genetically related and the effort toward development of drought resistance resulted primarily in some undesirable selections. If the cooperators will accept greatly reduced levels of gain, they may overcome the tree numbers and pollination problems that could result. However, the use of selected natural stands and their conversion to SPA's will result in about a 4 percent height growth gain. The material in the progeny test-seed orchard areas are available for developing a clonal orchard.

The PT-SO conversion must be approached with caution and may only have limited utility in many situations. It results in little cost-saving and may actually cost more than separate PT and SO developments. Many of the objectives of the progeny test are not compatible with seed orchard design requirements.

All the pros and cons are not discussed here, but I hope this example causes you to examine the progeny test to seed orchard conversion as critically as it should be.

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How Many Plantations to Establish?

John F. Kraus[1/]

Abstract. The number of test plantations to establish for a breeding program cannot be clearly defined. It may vary from two to many depending on the size of the breeding area, its physiographic and climatic variability, the heritability of the traits being tested and whether the test is for parent evaluation or production of new breeding material.

Keywords: Progeny tests, breeding area, genotypic x environment interaction

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There is no simple answer to the question of how many plantations to establish. Before one can even begin to approach an answer a decision must be made on whether the plantations are to serve as progeny tests, as sources of future breeding materials, or both. In any case the geographic size, and distribution of physiographic land area, covered by the breeding program will also be a prime factor in the decision of how many plantations to use.

What traits is the testing program primarily trying to evaluate? Some highly heritable traits can be easily assessed in single, short-term tests. An example is oleoresin yield in slash pine which can be evaluated in young trees and does not strongly interact with differing site conditions. At the other extreme are those growth traits which require years to fully express themselves, and respond differently in various environments. Plantings to evaluate such growth traits would have to be more numerous even if the breeding area was not large.

If the environmental variation is predictable to any long-term extent it will probably be necessary to develop seperate varieties for each environment. We see that happening in Georgia where the Georgia Crop Improvement Association (GCIA) recognizes three physiographic divisions, the mountains, the piedmont and the coastal plain for progeny testing forest trees. The recommendations for second-generation breeding and testing recently promulgated for the North Carolina State University-Industry Cooperative Tree Improvement Program also subdivides the south into broad physiographic areas. In the western states the situation is

more extreme, large elevational and climatic ranges dictate the subdivision of almost any species range into many units.

Conversely we can expect some environmental variables to be unpredictable. Hurricanes, severe droughts, insect epidemics might be some that fall in this category. These unpredictable variables may be of value in selection if they identify genetic material which is notably at hazard but their unpredictability will make them of limited use to our breeding programs. We cannot breed for the occassional hurricane or the drought that occurs every fifty years nor can we breed for an entirely uniform and predictable environment. It would seem then that our goal must be to produce varieties adaptable to a fairly wide range of both predictable and unpredictable enviromental variables (Allard and Bradshaw, 1964). One aid in achieving this goal will be to establish our test plantations in locations chosen to provide environmental differences. For example in the Georgia piedmont there is a substantial difference in the soils and topography of the eastern and western areas of the state, and even more in the coastal plain between the upper coastal plain and the coastal flatwoods. The genotypic x environment interaction found by planting in diverse locations will be a limiting factor in estimating variance components and will reduce the efficiency of selection unless the interactions can be easily expressed and show a simply inherited linear response. If the plantation locations can be chosen to sample the extremes of environmental variation regression can be used to predict performance on intermediate sites. In order to get relatively unbiased regression coefficients the between environments mean square should be significantly larger than the error mean

square and the test should contain a large number of seedlots. In order to make reasonably accurate decisions the average performance of the selected families must be based on at least two and preferrably more contrasting environments (Jinks and Connolly, 1973). In making its recommendations the N.C. State University-Industry Coop. used the coefficient of variation of family means/number of locations from first-generation progeny tests. The critical point in the curve came between three and four locations and the final decision was to suggest the establishment of four plantations, two locations in each of two years (Talbert, et.al., 1981).

As mentioned earlier the Georgia Crop Improvement Association recognizes three physiographic regions in the state for progeny testing and certification. They require test data from at least two locations in a region. The Alabama Crop Improvement Association divides its state into two regions, north and south, for progeny testing forest trees. They recommend that tests be conducted on two dissimilar sites in a region. The South Carolina Crop Improvement Association recognizes four physiographic regions: Mountain, Piedmont, Sandhill and Coastal Plain. In South Carolina only one test is required within a region but the addition of a second site is strongly recommended.

The recommendations of the N.C. State University-Industry Cooperative and of the state crop improvement association are primarily for progeny tests designed to assess breeding values of parent trees, usually those in seed orchards or selected for potential for such use. However, if the plantations are being established with seed from control-pollinated crosses, in a mating design intended for the estimation of variance

components and the generation of trees for future selection and breeding, it will be advisable to establish as many plantations as possible (Namkoong, et.al., 1980). If a number of plantations (5-15) on diverse sites are available they can serve as sources of differently adapted genotypes for breeding of narrowly adapted sub-populations, or as breeding material for the development of more widely adapted varieties.

To recapitulate, for reasonably accurate and efficient estimation of breeding values from progeny tests of selected trees at least two and preferably more plantations should be established, if possible on contrasting sites or in diverse environments. For estimation of variance components and efficient selection of adaptable breeding materials plantations should be established on as many and as variable locations as can reasonably be justified by the importance of the species and the size of the breeding area.

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MATING DESIGNS [3/]

by

J. P. van Buijtenen[1/] and G. Namkoong[2/]

Introduction

The usefulness of a mating design depends largely on the purpose to which the resulting trees are to be put. In many cases the mating design is closely tied into the overall breeding strategy of a tree improvement program. As described by McKinley (1982) the most common purposes for which progeny tests are to be established are a) to provide information for evaluating parents; b) to estimate genetic parameters; c) to produce a base population for advanced generation selection; and d) to estimate realized gain directly.

There is an infinite variety of mating designs. For our purposes we'll divide them into two main groups, single designs and complementary designs. Since in a practical breeding program one usually tries to achieve several objectives at once, the use of a single design often results in a compromise solution that may be reasonably good for all purposes but not necessarily the best for any one of them. The concept of complementary designs was introduced by the French at the IUFRO meeting held in Bordeaux in 1976 based on the philosophy that it could be an advantage to combine several simple designs, each of which was very efficient for one particular purpose.

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3/ Same paper in book "Progeny Testing of Forest Trees."

Mating Designs to be Considered

The following designs will be considered: 1) open-pollinated or wind pollinated; 2) polycross; 3) complete diallel; 4) modified half diallel; 5) partial diallel; 6) disconnected half diallel; 7) factorial designs; 8) disconnected factorial; and 9) nested designs. Following are some brief descriptions of each of the designs.

Open-pollinated or wind pollinated progenies consist of the seed resulting from pollination by the naturally occurring pollen cloud.

The polycross is in many ways similar, but instead of depending on a natural mixture, a set of pollens is mixed and used to make control pollinations.

The complete diallel consists of all possible crosses among the available parents.

The modified half diallel consists of all possible crosses omitting the selfs and the reciprocal crosses. The partial diallel can take various forms but usually consist of one or more sets of crosses following the diagonals across a diallel table. Sometimes such sets can be rearranged to form a factorial design. In a disconnected half diallel design the parents are divided into smaller groups and a half diallel is made within each group, no crosses are made between groups.

In a factorial design two separate groups of parents are crossed with each other in all possible combinations.

A disconnected factorial design follows the same principle as the disconnected diallel. The population is again subdivided into groups and the trees within each group are crossed according to a factorial design.

In a nested design one parent is crossed with a number of other parents. Usually the male is the rare parent which is crossed with several females. Each female, however, is crossed with only one male.

Much theoretical work has been done on the usefulness of these different designs for various purposes. The remainder of this paper will be devoted to the evaluation of these designs from a practical point of view, without going into too much of the theory behind it. It seems most convenient to look at each particular purpose and discuss which designs are most efficient for it.

Evaluating Parents

If one is only interested in evaluating the parents for general combining ability, it is not necessary to make individual crosses. The polycross test is quite satisfactory and highly efficient for this purpose. Other designs that will do a good job, although at an increased cost, include the diallel, modified half diallel, partial diallels and factorial designs. Nested designs give precise data on the multiply mated parent but much poorer data on the once mated parents which are far more numerous. Disconnected designs are less effective because the parents belonging to different groups cannot be compared as accurately (van Buijtenen, 1976). Open pollinated tests are good if they simulate a polycross but may be poor if each female parent has a unique and different pollen sample.

Pepper and Namkoong (1978) made a detailed economical evaluation of hierarchical and factorial designs for progeny testing. Using their assumptions, it is advantageous at low heritabilities to use as large a number of parents as possible, at the expense of accuracy. At high heritabilities there was an optimum of about 50 parents. The factorial design was generally slightly superior to the nested design.

Estimation of Genetic Parameters

Namkoong et al. (1974) recently made an exhaustive analysis of the efficiency of balanced mating designs for the estimation of additive and dominance variance, a brief summary of which follows. The case for unbalanced designs is not as well defined (Namkoong, 1981). They concluded that diallel and factorial designs are usually more efficient for estimating both dominance and additive genetic variance than a nested design. In most cases the diallel design appears to be somewhat superior to the factorial design. When using the factorial design it is usually most efficient to use equal numbers of males and females. This is to be expected since the design is completely symmetrical with regard to the sexes. Regardless of the mating schemes, increased efficiency of estimation can always be obtained by increasing the total size of the experiment. When using nested and diallel designs it is best to create as large a number of half-sib families as possible, and it is of little use to create more than six full-sib families per half sib. For reasonable estimation precision with the nested designs, it is necessary to use at least one hundred crosses with proper allocation among half and full-sib families. Fifty crosses are usually satisfactory for the factorial and diallel designs.

Establishing Populations from Which to Select Parents for the Next Generation

This section is distinguished from the next in its exclusive consideration of selecting parents for the next generation. In the next section, we address the issues of constructing a population for an on-going breeding system.

The usefulness of mating designs for the purpose of advanced generation selection depends strongly on whether one is depending on a single design or whether one is using the concept of a complementary mating design. In the case of the single design the choice of mating design is largely determined by the breeding strategy followed. The effectiveness of a given breeding method depends primarily on the heritability of the trait to be improved. Although combined family and within family selection is always most efficient, for heritabilities below .5 the predominant contribution is from family selection, while for heritabilities above .5, the major contribution is from within family selection (Falconer, 1960). Since most of the characteristics of importance in forest trees appear to have low heritabilities, mating designs need to be judged primarily for their usefulness with respect to family selection. Emphasis on family selection creates problems for future generation breeding which are discussed in the next section. See Nanson (1974) for detailed tables showing the relative efficiencies of individual tree selection, family selection, and within family selection compared to combined selection.

One also need to consider the selection differental that can be obtained. Designs creating large numbers of families have a distinct advantage here. Designs resulting in a reduced effective population size because of relatedness among families are less effective than might appear at first glance.

When one is using a complementary design the situation is quite different. Family evaluation is probably already done by a very effective method such as, for instance, a polycross test, and one only has to consider the effectiveness of the mating design for within family selection.

Creating an on-going breeding population may be partially separate from these designs.

Open-Pollinated Tests

We need to distinguish here between open-pollinated progeny tests obtained from the ortets or trees as they occur in the woods or from the ramets in the seed orchard. Material from open-pollinated progeny tests obtained from seed orchards may be related and crosses would then involve inbreeding and all the problems involved with inbreeding depression. Open-pollinated seed from ortets "in the woods" can be used. However, one loses the gain associated with selection of the male parent.

Polycross Mating

Burdon et al. (1971) give a detailed description of the polycross and its modification, a summary of which follows. Polycross matings normally use a mixture of pollen from a given group of parents which is used on all parents to be tested. This will give a good evaluation of the breeding values for the parents and the GCA covariance, but the progenies are less suitable as a source of selection for the same reasons as wind pollinated orchard seed. Most selections will be progenies of the same few pollen parents. Modifications of the polycross might get around this problem. In the nested polycross the selected parents are grouped into a series of nests of several clones each. This will help to increase the effective number of pollen parents and the selections of different nests will be totally unrelated.

Burdon distinguishes three types of polycross nests. The complete nest, the incomplete nest and the overlapping nest. In the complete nest all parents are used both as pollen and as seed parents. In the incomplete

nest part of the parents are used as pollen parents and crossed with the remainder of the trees, thus reducing the number of crosses required. In the overlapping polycross nest design the parents from one nest are pollinated by the pollen mixture from another, while the parents from that nest are in turn pollinated by a third parent. Self fertilization is eliminated at this point but opportunity for outcrossing at a later date is considerably reduced.

The tester polycross is similar to the incomplete polycross nest and may or may not be subdivided into nests. In this case the pollen mixture is made up of parents of proven GCA and is crossed with newly selected trees. The newly selected trees will thus be screened for GCA with respect to the established breeding population and will at the same time be mated to the best parents. If one is to take Allison et al. (1966) seriously, however, it might be advantageous to make up the pollen mix of the worst parents available. In this case one has to balance additional gain obtainable by this procedure against the loss of time resulting from the impossibility of using the progeny of the polycross as a source of selections.

Since polycross nests are forms of multiple population breeding, the technique is applicable to the breeding group strategy used by the WGFTIP program. One difficulty of the polycross is that in the complete or incomplete nest, the estimation of GCA effects is confounded with inbreeding depression. One could get around this problem by the use of a complementary design, using a generalized pollen mixture for the estimation of GCA and a mixture from the breeding group itself as a means of making new selections.

Diallel Mating Schemes

Although the complete diallel and the modified half diallel are usually not practical on economical grounds since often unmanageably large numbers of crosses are needed, some of the smaller diallel schemes seem to offer a good compromise, if one wishes to estimate both GCA and SCA effects for specific families, produce a population for advanced generation selection and estimate variance components. Recent work by van Buijtenen and Burdon (1982) indicate that small disconnected diallels may not be as efficient as generally assumed. First GCA is not estimated very well when the diallels are small. Secondly the genetic variation between diallels is $(\sigma_A^2)_{/P}$, where σ_A^2 is the additive genetic variance and p the number of parents in the diallel. If the diallels are planted in one test, one can recover this variation by giving an appropriate weight to each diallel for its average performance. If the diallels are planted in separate tests, as is often the case, much of this genetic variation may not be usable.

Factorial Designs

Al the factorial designs can do a very good job of estimating GCA and SCA and thus can be used very well for the basis of roguing existing orchards or assigning tested clones to new orchards. They do not do as good a job for providing a population for making new selections since all the selections will be related to a rather limited number of tester parents. A set of small disconnected factorials gets around this problem although they suffer from the same problems as small disconnected diallels. In addition no direct comparison is possible between the testers and the trees being tested.

Nested Designs

As a single mating design the nested designs are not very suitable for individual tree selection because of the weakness of the family selection aspects. However, if used in a complementary design where family selection is handled with a different design such as a polycross, a nested design can work very well. This would be particularly true if some of the parents are known already, in which case the best general combiners could be assigned to the rare parent.

Establishing Populations for Advanced Generation Breeding

The mating design used for developing the breeding population may include more crosses than just the matings used for seed orchard establishment, or may be a selected subset of those crosses. In this discussion, we assume that an adequate number of families is selected and forms the basis for the population's future generations. We also assume that we are in the stage of establishing improved closed populations.

Different single pair mating schemes have been reviewed by Namkoong (1976), Cockerham (1970), and Kimura et al. (1963). There appears to be an inverse relationship between the early avoidance of inbreeding and the eventual inbreeding reached after many generations of following the same mating scheme.

In comparing these schemes the assumption is made that only within family selection is practiced and that only enough individuals of each full-sib family are selected to maintain constant population size. In an initial population of N individuals, inbreeding can be avoided for k generations $N = 2^k$. Thereafter inbreeding increases rapidly. Systems studied

include maximum avoidance of inbreeding, circular matings and circular pair matings. In a maximum avoidance scheme only unrelated individuals are mated as long as possible. In a circular mating scheme each individuals is mated to both its neighbors. The number of full-sib families thus produced equals the population size and only one individual per family will be selected for the next generation. In a circular pair mating scheme, disconnected single pair matings are made among neighbors resulting in N/2 full-sib families. Two individuals per family are selected, one of which is mated to an individual of the preceding family, the other to an individual of the following family. The circular mating scheme will develop inbreeding sooner (where N = 8 after two generations), but will lead to lower inbreeding levels in the long run.

Clearly, inbreeding within populations will occur in any closed population breeding system. For forest trees, Bingham (1973) reviewed the possibility of using inbreeding as an improvement method and concluded that in Pinus monticola crossing success and seed yield were sufficient to carry out such a program. In a comparison of a number of possible breeding plans for slash pine, Squillace (1973) concluded that a greater gain was possible by selecting two or three individuals per full-sib family despite the resulting inbreeding.

In considering the problems of inbreeding, it is important to distinguish between the various populations of trees involved. Theoretically we may be dealing with as many as four separate populations: 1) the breeding population, 2) the progeny test populations, 3) the seed production population (the seed orchard, and 4) the forest stands producing the commercial product. Because of this it may be possible to sidestep the entire issue of

inbreeding. Since inbreeding invariably causes inbreeding depression it would be ideal to avoid inbreeding altogether in the plantation for commercial production. Inbreeding can, however, be tolerated in the other groups as long as it doesn't interfere with seed production and the seed orchards are arranged in such a way that seed for commercial production consist of outcrosses.

A system has been devised in which mating groups are created in which trees are mated among each other. One needs a minimum of nine such breeding groups to get an effective mixture for seed orchards, but it is desirable to work with a dozen or more groups. In the procedure implemented by the WGFTIP program, trees are organized in groups of 24 or 25. Since each cooperator is required to select 100 trees, this is four groups per cooperator. By combining groups within a seed collection region, a sufficient number of groups are easily obtained for a continuing breeding program.

Within the breeding groups inbreeding can be carefully managed by the use of a co-ancestry matrix. Such a matrix lists the degree of relatedness between all trees in the program, thus predicting the degree of inbreeding resulted from all possible crosses. Carefully choosing the crosses to be made, one can deliberately increase or decrease the degree of inbreeding. The method lends itself very well to computer manipulation and programs are available to do so.

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THE FOREST TREE BREEDING PROGRAMS
OF THE NORTHERN REGION 1/

BY

GEORGE E. HOWE
REGIONAL GENETICIST

DECEMBER, 1933

1/ PREPARE FOR THE 1933 NATIONAL GENETICS WORKSHOP; CHARLESTON, S.C.

SUMMARY

Species	Test Plantation Established In	Convert to SO On-Site?	Type of Test	
			Progeny	Family Comparison
White Pine Phase 1	1953 - 1974	No	X	X
White Pine Phase 2	1978 - 1988	No	X	X
Douglas-fir	1982 - 1987	Yes		X
Western Larch	1981 - 1983	Yes		X
Lodgepole Pine	1980	Yes		X
Grand Fir	1978	No		X
Ponderosa Pine Phase 1	1974	No		X

OBJECTIVES COMMON TO ALL PROGRAMS

1. IDENTIFY GENOTYPES GENETICALLY SUPERIOR IN GROWTH AND FORM FOR SITES TO WHICH THEY ARE ADAPTED.
2. PROVIDE GENETICALLY SUPERIOR PLANTS FOR SEED ORCHARDS AND BREEDING.
3. ESTIMATE HERITABILITIES AND GENETIC GAINS.
4. IF OPPORTUNITY ARISES, IDENTIFY GENOTYPES GENETICALLY SUPERIOR IN RESISTANCE TO SPECIFIC PESTS.

MATING DESIGNS

PRINCIPALLY OPEN POLLINATED

TYPES OF MATERIAL

PRINCIPALLY OPEN POLLINATED
ONE-PARENT FAMILIES

CHECK LOTS

VARIABLE

TESTS PER BREEDING UNIT

RANGE: ONE TO FIVE

BREEDING UNITS DELINEATED MOST BY ON STRENGTH
OF SEPARATE ADAPTATION STUDIES.

FAMILIES TESTED OUTSIDE BREEDING UNIT?

SOME SPECIES YES, OTHERS NO

EXPERIMENTAL DESIGNS

VARIABLE, BUT MOST FREQUENTLY RANDOMIZED COMPLETE BLOCK, WITH ONE ROW PLOT OF EACH FAMILY IN EACH BLOCK.

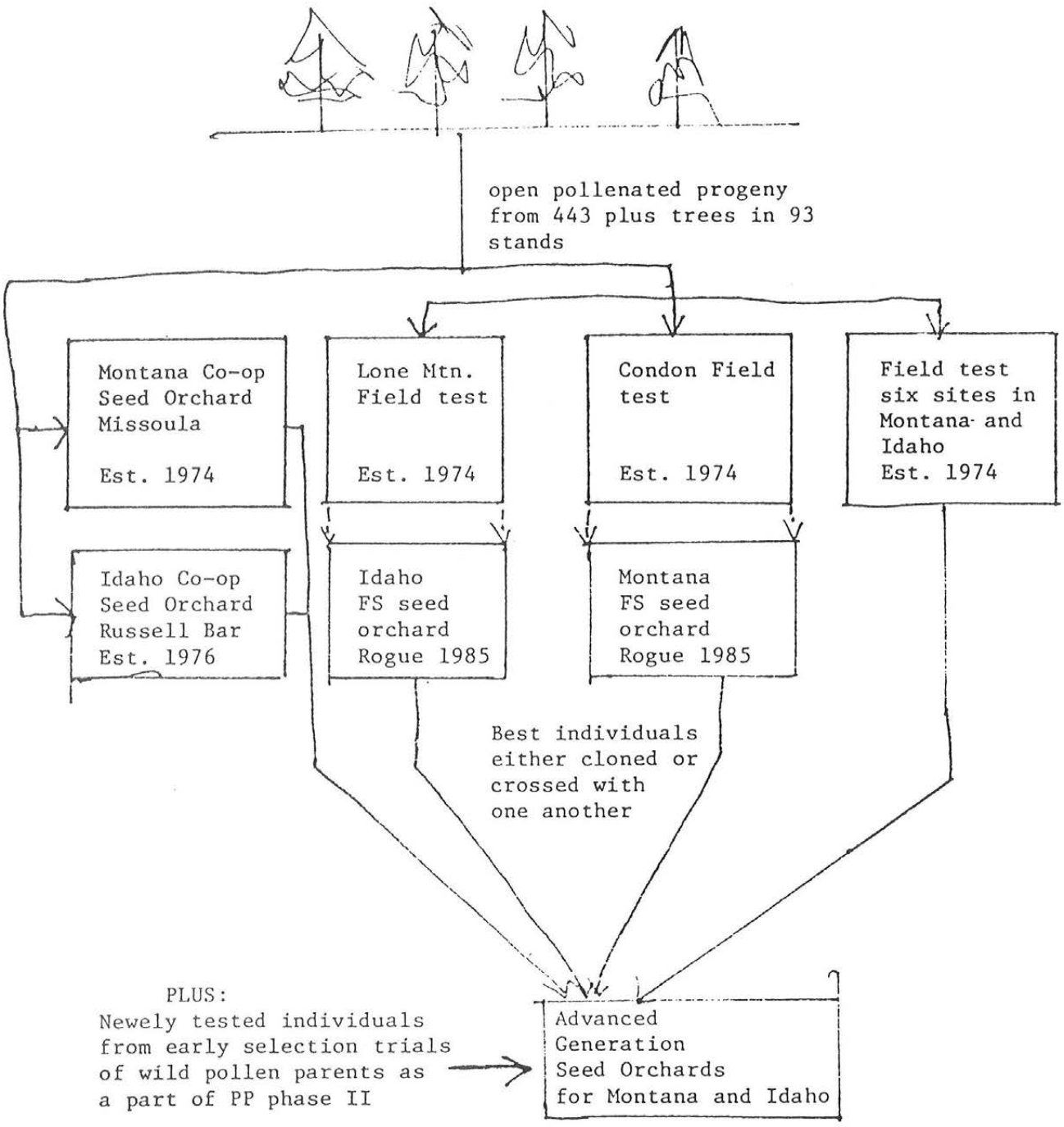
AGE AT ROGUINGS

3 TO 12 YEARS

TRENDS

DO NOT RELY ON ONE KIND OF TEST, BUT ESTABLISH BOTH EARLY SELECTION TRIAL AND LONG-TERM TESTS OF THE SAME MATERIALS. INTENSIVELY MANAGE AND RELY MORE ON THE FORMER.

The Ponderosa Pine Seed Orchard Plan



THE PONDEROSA PINE PROGRAM

NORTHERN REGION

MATING DESIGN

OPEN POLLINATED

TYPE OF MATERIAL

"HALF-SIB" (OP, 1-PARENT FAMILIES)

CHECK LOTS

ONE BULK FROM EACH STAND IN WHICH PARENTS WERE SELECTED.

TESTS PER BREEDING UNIT

BU	# Tests
E. Washington	1
Idaho - North	2
Idaho - South	1
Montana - West	1
Montana - East	1
Montana - South	2

Breeding units established on strenth of these family comparison test results

FAMILIES TESTED OUTSIDE BU?

Yes

EXPERIMENTAL DESIGN

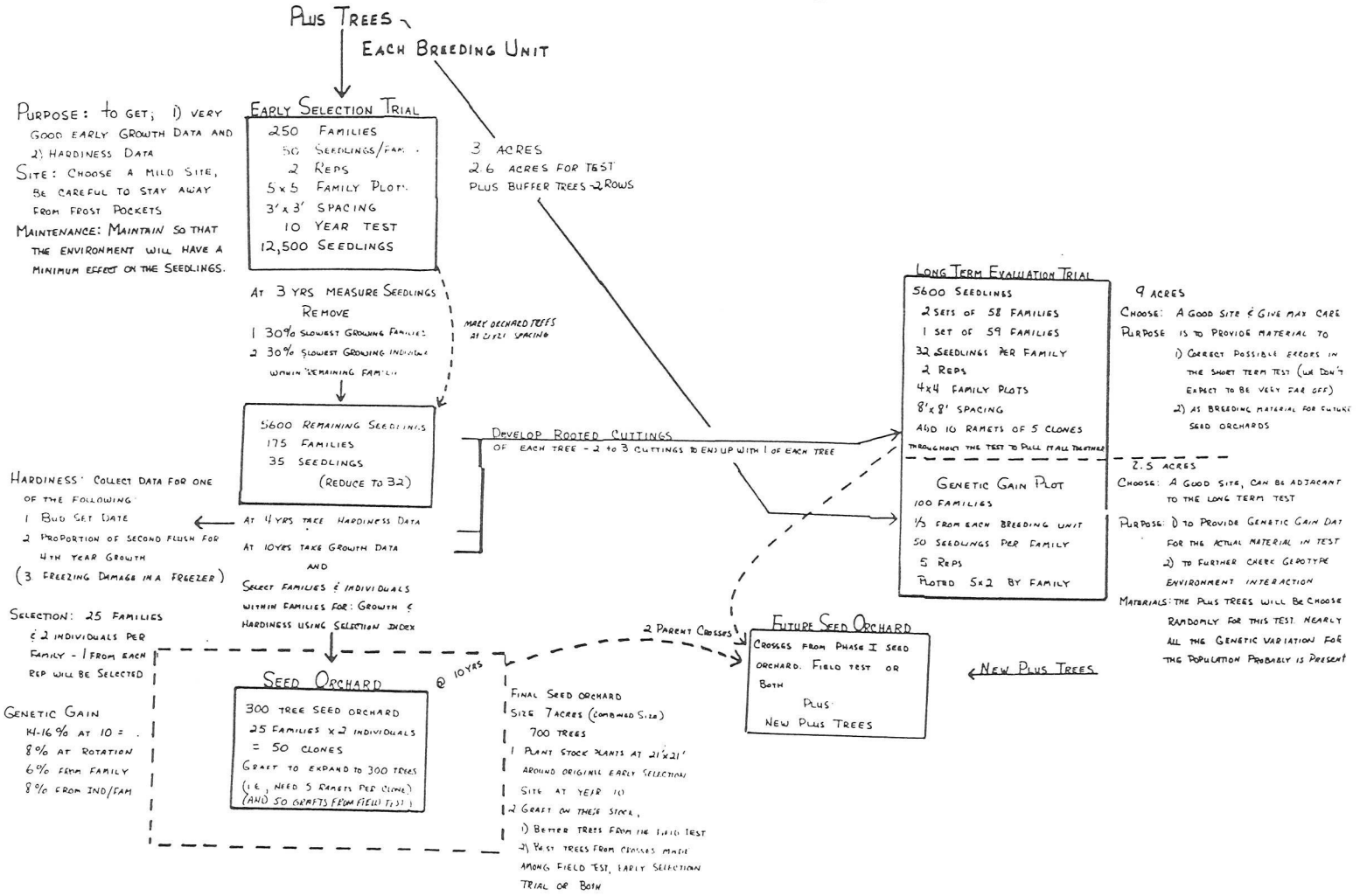
Randomized complete block. Five blocks per site. One four tree row plot per family per block.

Age at first Roguing

12 Years (from seed)

(Missoula Seed Orchard rogued in 1983)

Douglas-Fir Tree Improvement Plan For Second Generation Seed Orchards



THE DOUGLAS-FIR PROGRAM

NORTHERN REGION

SUPPLEMENTAL OBJECTIVE

1. IDENTIFY MONTANA GENOTYPES GENETICALLY SUPERIOR IN RESISTANCE TO WESTERN SPRUCE BUDWORM.

MATING DESIGN

OPEN POLLINATED

TYPE OF MATERIAL

"HALF-SIB" (OP 1-PARENT FAMILES)

CHECK LOTS

LOCAL OPERATIONAL

TESTS PER BREEDING UNIT

3 LONG-TERM X 3 ELEVATION BANDS = 9
+1 EARLY SELECTION TRIAL
10
X7 BU
70 TESTS

BU'S ESTABLISHED ON STRENGTH OF SEPARATE ADAPTATION STUDIES. NUMBER PER BU BASED ON GUIDELINES FROM COASTAL PROGRESSIVE PROGRAM.

FAMILIES TESTED OUTSIDE BU?

NO

EXPERIMENTAL DESIGN

LONG-TERM FIELD TESTS: MODIFIED, RANDOMIZED INCOMPLETE BLOCK. FAMILIES RANDOMLY ASSIGNED TO SETS. ONE REPLICATION OF EACH SET PER BLOCK. FOUR BLOCKS PER SITE. NINE TREES PER FAMILY PER SET IN SINGLE-TREE PLOTS.

EARLY SELECTION TRIALS: RANDOMIZED COMPLETE BLOCK. TWO BLOCKS. ONE 25-TREE SQUARE PLOT PER FAMILY PER BLOCK.

AGE AT ROGUINGS

(EARLY SELECTION TRIALS ONLY)

FIRST: AGE 3 YEARS

"SEMI-FINAL": AGE 10 YEARS

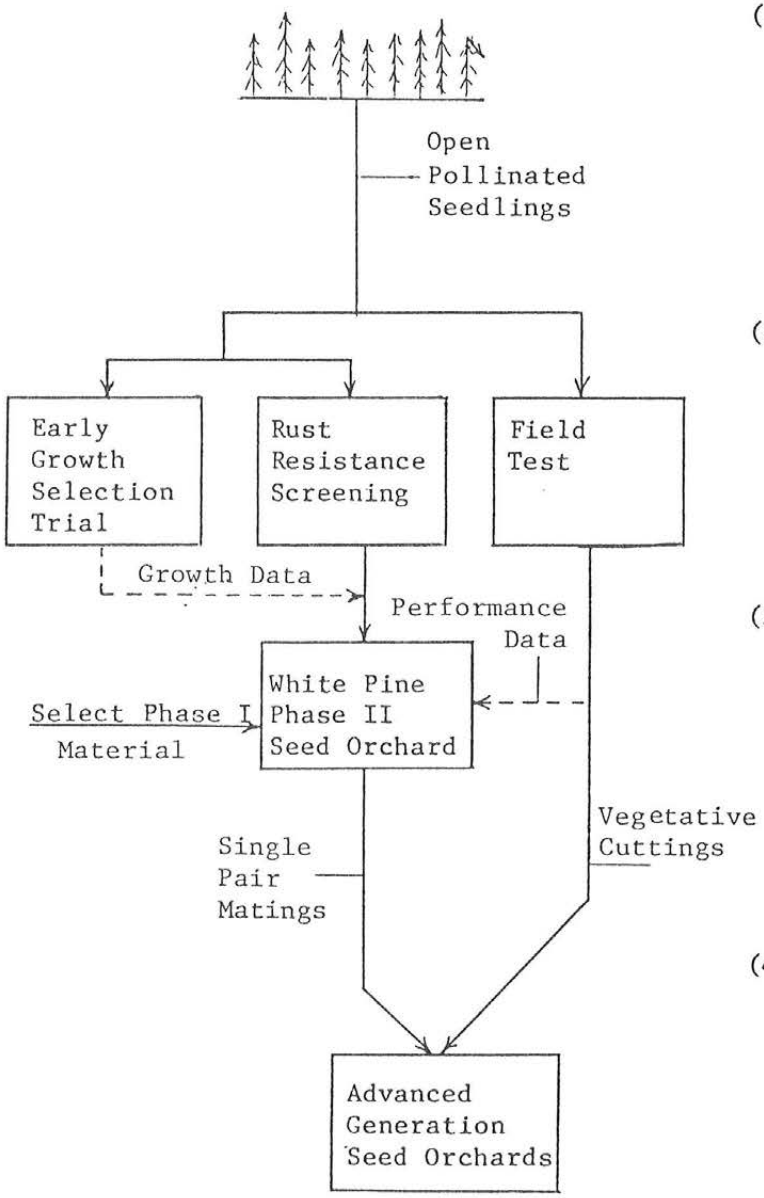
UNIQUE FEATURES

1. EARLY SELECTION TRIAL IS TO BE CONVERTED TO A SEED ORCHARD.
2. EARLY SELECTION TRIAL IS <u>INTENSIVELY</u> CARED FOR TO INCREASE RELIABILITY OF EARLY SELECTIONS.
3. GENOTYPES IN EARLY SELECTION TRIAL CLONED IN LONG-TERM TRIAL, TO PERMIT SELECTION OF BEST INDIVIDUALS IN BEST FAMILIES, DESPITE THE TRIALS GROWING ON DIFFERENT SITES.

THE WHITE PINE TREE IMPROVEMENT PROGRAM, PHASE II

The objective of Phase II of the white pine tree improvement program is to develop strains of white pine that are not only resistant to blister rust but also have improved growth. Research on breeding for rust resistance in western white pine (now called Phase I) began in 1950 with the testing of 400 rust free candidate trees. That program resulted in the establishment of five individual seed orchards two of which have been producing genetically improved seed since 1970. The other three phase I seed orchards are just now becoming productive. Phase II differs from Phase I in that a larger genetic base is being tested and selection is being made for growth as well as for rust resistance.

The Phase II program is as follows:



(1) Over 3,000 rust free "candidate" trees were selected in heavily rust damaged white pine stands in northern Idaho and western Montana. Only dominant trees of good growth and form were selected.

(2) Progeny from each of the wild parent trees are included in a nursery test for rust resistance, an early growth selection trial and a field test on a natural site.

(3) Individual seedlings from families that rank high in growth and rust resistance are transplanted from the rust screening beds at the Coeur d 'Alene Nursery into a seed orchard at Lone Mountain.

(4) Advanced generation seed orchards will come from select material in the field tests and in the Phase I and Phase II seed orchards.

Five cycles of testing will be required to test all of the Phase II candidate trees. Select individuals from the first cycle of testing were planted in the Lone Mountain seed orchard in March of 1982. Material from the last cycle of testing will be transplanted in the Spring of 1992. Seed should be available from the first plantings by 1992.

A more detailed account of the White Pine Tree Improvement Program is given in the accompanying articles.

THE WESTERN WHITE PINE PHASE 2 PROGRAM

NORTHERN REGION

SUPPLEMENTAL OBJECTIVE

1. IDENTIFY LINES POSSESSING AT LEAST THREE MECHANISMS OF RESISTANCE TO BLISTER RUST.

MATING DESIGN

OPEN POLLINATED AND HIGH GGA X HIGH GCA TESTER

TYPE OF MATERIAL

HALF-SIB, FULL SIB AND "HALF SIB" (OP, 1 PARENT FAMILIES)

CHECK LOTS

STANDARD CROSSES (CP)

TESTS PER BREEDING UNIT
(THERE IS ONLY ONE BU FOR WMP)

TYPE OF TEST	#
BR SCREENING	1
EARLY SELECTION	1
LONG-TERM FIELD TESTS	10

BU DELINEATION ON STRENGTH OF EARLIER ADAPTATION STUDIES. NUMBER OF TESTS BASED ON ARRAY OF BR HAZARD AND COOPERATOR INTEREST.

FAMILIES TESTED OUTSIDE BU?

NOT APPLICABLE

EXPERIMENTAL DESIGNS

BR SCREENING: RANDOMIZED COMPLETE BLOCK. THREE BLOCKS. ONE 18 TO 54 TREE PLOT PER FAMILY PER BLOCK.

EARLY SELECTION: COMPLETELY RANDOMIZED. TEN SINGLE TREE PLOTS PER FAMILY.

LONG-TERM FIELD TESTS: RANDOMIZED COMPLETE BLOCK. THREE BLOCKS PER SITE NINE SINGLE TREE PLOTS PER FAMILY PER BLOCK.

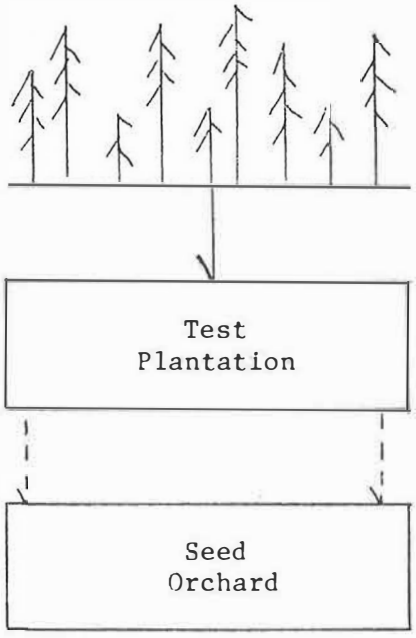
AGE AT FIRST ROGUING

3 YEARS (FROM SEED)

THE GRAND FIR TREE IMPROVEMENT PROGRAM

The objectives of the grand fir tree improvement program are to increase production through improved growth and disease resistance and to define seed transfer rules. In the spring of 1978, six grand fir test plantations were established using open pollinated progeny from 356 wild parent trees in 48 stands throughout the grand fir type in north Idaho and western Montana. Parent trees were selected visually for growth, form, and lack of disease. The test plantations will be converted into seed orchards after growth measurements are made in 1989. Grand fir is slow to produce cones but flower induction techniques may eventually become available that will allow production to be achieved at an earlier age.

The grand fir program is as follows:



1. Cones were collected from 356 better than average grand fir trees in 48 stands.

2. Progeny from these trees were used to establish six test plantations in 1978.

3. The test plantations will be rogued in 1989 using the latest growth data and converted into seed orchards.

THE GRAND FIR PROGRAM

NORTHERN REGION

SUPPLEMENTAL OBJECTIVES

DELINEATE SEED TRANSFER BOUNDARIES

MATING DESIGN

OPEN POLLINATED

TYPE OF MATERIAL

"HALF SIB" (OP, 1 PARENT)

CHECK LOTS

FAMILIES OF LOCAL SELECTIONS

TESTS PER BREEDING UNIT

THREE (IN EACH OF 2 BU'S). BREEDING UNITS ESTABLISHED ON STRENGTH OF EARLY TEST PERFORMANCE.

FAMILIES TESTED OUTSIDE BU?

YES

EXPERIMENTAL DESIGN

RANDOMIZED COMPLETE BLOCK. FIVE BLOCKS PER SITE. EIGHT SINGLE TREE PLOTS PER FAMILY PER BLOCK.

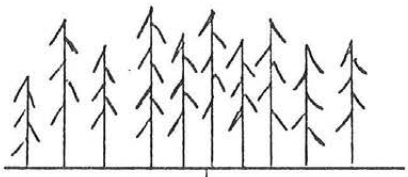
AGE AT FIRST ROGUING

13 YEARS (FROM SEED)

THE LODGEPOLE PINE TREE IMPROVEMENT PROGRAM

The objective of the Lodgepole Pine Tree Improvement Program is to increase production by developing trees of faster growth and increased disease resistance. In 1980, 20 test plantations were established in Idaho and Montana. The plantations will provide both progeny and provenance information on 625 plus-trees selected from 94 stands throughout the Region.

The program is as follows:



(1) open pollinated cones were collected from 5 to 10 average or better disease-free trees in 94 stands.

open pollinated seedlings

Progeny/Provenance Field Test

(2) twenty progeny/provenance field tests were established in 1980.

(3) Lodgepole pine is an early flowering species and as soon as flowers are produced, controlled crosses will be made between outstanding individuals in the test plantations. Seed from these crosses will be used to establish...

control pollinated seedlings

"Third" generation Seed Orchards

and...

Evaluation trials on natural sites

Seed orchards and evaluation plantations will be established for each of the breeding units delineated from the provenance data. The seed orchards will be established in 1994 and should start producing seed by the year 2000.

Advanced generation lodgepole pine seed orchards will be established in the future by crossing the best material in both the third generation seed orchard and the evaluation trials and with progeny from additional parents to be selected as part of a "Phase II" lodgepole pine program.

THE LODGEPOLE PINE PROGRAM

NORTHERN REGION

SUPPLEMENTAL OBJECTIVES

1. Identify genotypes genetically superior in resistance to western gall rust.
2. Delineate seed transfer boundaries.

MATING DESIGN

Open pollinated

TYPE OF MATERIAL

"Half sib" (OP, 1 parent families)

CHECK LOTS

Bulks from the same and neighboring stands

TESTS PER BREEDING UNIT

BU	# Tests
Idaho	7
Mt. West	6
Mt. East	7

BU's established on strength of separate adaptation stuides.

FAMILIES TESTED OUTSIDE BU?

YES

EXPERIMENTAL DESIGN

RANDOMIZED COMPLETE BLOCK. FIVE BLOCKS PER SITE, WITH 8 SINGLE TREE PLOTS PER FAMILY IN EACH BLOCK.

AGE AT FIRST ROGUING

7 TO 10 YEARS

The Western Larch Seed Orchard Plan for the Northern Region



open pollinated progeny from one to ten average of better trees per stand

Idaho Early Selection Trials -Family Plots- Lone Mtn. (or Dry Ck.) Est. 1984

Idaho Long Term Field Tests -Single Tree Plots- Six Plantations Est. 1983

Montana Long Term Field Tests -Single Tree Plots- Ten Plantations Est. 1981

scionwood

best individuals in best families

Grangeville Seed Orchard -Clonal- 1987-89

Convert to Second Generation Seed Orchards -Seedling & Clonal- 1987-89

performance data

Convert Condon Test Plantation to a Second Generation Seed Orchard -Seedling & Clonal- 1988-89

best individuals

best individuals

PLUS Newly tested individuals from additional early selection trials of wild pollen parents

Advanced Generation Seed Orchards

Advanced Generation Seed Orchards

THE WESTERN LARCH PROGRAM
NORTHERN REGION

MATING DESIGN

OPEN POLLINATED

TYPE OF MATERIAL

"HALF SIB" (OP, 1 PARENT FAMILIES)

CHECK LOTS

FAMILIES FROM LOCAL SELECTIONS

TESTS PER BREEDING UNIT

BU	# TESTS EARLY SELECT	LONG TERM
IDAHO NORTH	1	3
IDAHO SOUTH	1	3
MONTANA	1	10

BREEDING UNITS ESTABLISHED ON STRENGTH OF SEPARATE ADAPTATION STUDIES.

FAMILIES TESTED OUTSIDE BU?

No

EXPERIMENTAL DESIGN

W. MT. Long-Term

Randomized complete block. Five blocks per site. Nine single-tree plots per block.

N. Idaho (long term)

Modified, randomized incomplete block. Families randomly assigned to sets. One replication of each set per block. Four blocks per site. Nine trees per family per set in single tree plots.

EARLY SELECTION TRIALS

Randomized complete block. Three blocks. One 3 x 24 tree rectangular plot of each family per block.

AGE AT ROGUINGS

First: Age 3

Semi Final: Age 10

PROGENY TESTING--OBJECTIVES AND DESIGN

Jay H. Kitzmiller [1/]

Introduction

Progeny testing is presented here in an overall program context. Emphasis is given to the interrelationships among breed zone, tree selection, progeny testing, and orchard activities. For easy reference summary statements are separately included for: goals and objectives, major attributes, major activities, field design, and costs of progeny testing (Tables 1 through 5).

Basic Strategy

Selection of trees for the first generation clonal seed orchard is a two-stage process:

(1) intensive phenotypic selection of mature trees in natural stands, and

(2) genotypic selection of the better parents based on progeny performance.

To avoid delay, wind-pollinated natural stand seed collections are the basis for progeny tests.

The orchard is at first established on phenotypic selection and later rogued on genotypic selection. The framework for these activities is the breed zone.

This Region favors intensive mature tree selection for those parents that will be sorted in short (15-to 20-year) progeny tests. A random or low intensity mature tree selection provides no "insurance" that juvenile progeny selection will generate rotation age gains. Whereas, a foundation of mature, phenotypic superiority reduces risks and increases the probability that subsequent progeny selection will result in sustained superiority through harvest.

Initial Breed Zone Delineation

An initial step in a tree improvement program is subdivision of the total forest area into relatively homogeneous zones called breed zones. A breed zone is a forest land unit for which improved trees are developed and planted.

[1/] Regional Geneticist, USDA Forest Service, Pacific Southwest Region

Each breed zone represents a separate selective breeding project. The total number of breed zones define the scope and magnitude of the tree improvement program. Each species has its own separate breed zones. In order to plan and schedule developmental work for improvement, species and their breed zones must be identified and prioritized.

Initial delineation of breed zones must be considered tentative and subject to refinement as work progresses. The tentative breed zones are prioritized based on their reforestation acreage needs, species value, and land productivity. Highest priority is given to zones within the prime commercial range of the most valuable species.

Boundaries are delineated to encompass relatively homogeneous forest environments and tree populations. Native trees within the same zone should be genetically more similar and growing in more similar environments than trees from different zones. Furthermore, native trees within any given zone should be generally adapted to all future plantation sites throughout that zone. The underlying assumption is that trees will be best adapted to those environments that closely resemble their place of origin.

Priority breed zones were tentatively delineated in the 1976 Master Plan. Since provenance trials are generally lacking in California, the genetic structure of populations was largely unknown. However, California Seed Zones, which were carefully constructed from known environmental, biological, economical, and administrative factors, provided a basic reference for stratifying variability. A typical breed zone encompasses two to three very similar seed zones (ca. 100 mi. of Lat.). Although nursery trials and isozyme analyses were not previously available, they will be used to refine original zones and define new ones as the scope of the program expands.

Initial zones have been useful for making tree selections and grouping these for progeny tests. The breadth of zones has also provided the opportunity to design progeny tests so that provenance variation could be examined. The latter will be valuable along with isozyme results for evaluating current seed zones and for initial arrangement of clones for breeding in the orchard.

Initial Phenotypic Selection

Intensive selection of outstanding phenotypes for mature tree characteristics is done in natural stands. Stands are chosen for relatively high: health, vigor, and uniformity of density, age class, and site environment. The comparison tree method is used within stands to select the tree with the highest annual wood production coupled with excellent stem and crown form. Wood density is determined from 12mm cores of the best one or more trees in a stand.

Approximately 200 trees are selected per zone. These are well-distributed with only one tree per stand and 200 meters or more between selected trees to reduce relatedness. A small portion are single tree selections (without comparisons) that are made after the best stands have been exhausted and experience has been obtained by the comparison tree method. These broaden the genetic base and distribution of parents.

Phenotypic selections are the main foundation of genetic material since they have actually demonstrated their capacity to attain dominant size and superior form at rotation age. The average superiority in annual volume production is 50% above comparison trees for ponderosa pine and Douglas-fir in this Region. Assuming there exists some additive genetic basis for this mature tree variation, intensive selection should capture some portion of it. Certainly, some trees gained an environmentally-based advantage, perhaps early in life, that resulted in later superiority. Even so, their genetic composition at least permits such superiority though it may not always be the primary cause.

Progeny Testing for Genetic Selection

The uncertainty of gains from initial phenotypic selection coupled with the value of genetic superiority for juvenile traits in production plantations provide ample justification for short-term progeny tests.

Direction for a concerted effort of progeny testing was established in the 1976 Master Plan. The first progeny sets were sown in 1977 and outplanted in 1978. In 1979, a new nursery and

field design was adopted and all subsequent tests have conformed to it (see separate report in these proceedings for details). The field design is summarized here in Table 4.

Support for using a field design with close initial spacing (6 ft) and provision for two systematic thinnings is from Namkoong and Conkle ("Time trends in genetic control of height growth in ponderosa pine", For. Sci. 22(1), 1976). Results indicated that three growth phases: (1) exponential, ages 3 through 8 years, (2) steady, ages 9 through 20 years, and (3) declining, ages 21 through 29 years (last measurement) affected the levels of genetic and environmental variances. Elevation zonal affects were expressed early and peaked at age 20, whereas, families within zones did not stabilize until after age 20 when competition became intense at the 8 ft spacing. Authors suggest that close spacing on good sites with delayed thinning may shorten the test period required for accurage selection of stable families.

These results indicate that major zonal effects are expressed early enough to make adjustments in seed orchard design and establishment. But final roguing of clones must succeed stabilization of family growth curves, which we anticipate between ages 12 and 15 years at our close spacing.

Number and Distribution of Progeny Plantation Sites

The PSW Region uses four and five sites per zone for fir and pine, respectively. Zones for fir are smaller than for pine. This represents the maximum numbers that can be administered and the minimum numbers that are required. Sites are selected to attain representative edaphic, geographic, and elevational distribution. Sites are at least average or higher in productivity for the zone. In some zones, cooperation with private industry has resulted in many USFS families being tested on several additional sites.

Grouping of Families into Sets

There are several reasons why the entire 200 to 220 selections per zone need to be subdivided into smaller units (sets) for testing:

(1) all trees do not produce seed in the same year,

(2) too much time is lost in waiting to get seed from all trees prior to making an outplant test, and

(3) planting site variability is usually too great to allow direct comparison among all families.

Our goal is to obtain sufficient seed for testing about 180 selections. Thus, four full sets of 45 families can be formed along with four standard control lots. Our design can handle partial sets but not as efficiently. This set size is large enough for good comparison among families and for sampling the zone for major provenance differences. It is small enough for field plot uniformity. And, it is ideal for our container and handling system.

It is important to note and worthy of extended discussion that the progeny test set design must be compatible with the seed orchard design for roguing. A detailed viewpoint is given in the Appendix.

Family Representation

Wind-pollinated families are quite variable. Survival is often lower than expected. Pests and other agents often affect performance in a random manner. Test sites are very expensive to establish and manage. For these reasons, families require strong representation on each site (Table 4). This provides the opportunity to thin periodically and carry the test longer. Moreover, it is insurance against unreliable family data and in particular against the occurrence of an artificial Family x Site interaction, which can result from an inadequate design and high non-genetic biases.

Control Lots

These include: 1 local site lot, 1 general lot, and 2 control crosses. The local lots are different for each test site and they give a measure of adaptability of test families relative to locals. Local lots normally have a five-tree base collected from the stand adjacent to the test site. The general lot has a broad base and origin near the center of the zone. Genetic gain can be estimated relative to locals and/or general lots. Control crosses are narrow base for monitoring environmental differences within and among sites.

General and control cross lots are common to all sets and sites within the zone. Locals are common to all sets on one site. Each control lot is represented the same as test families in a set. With four sets on each site the controls are strongly represented. Furthermore, when shortages occur in the nursery for test families, control lots are used as replacements.

A small proportion of families are retested in different sets (and years) and even across breed zones when insufficient seed is available to make up the "target" set. The same control crosses are commonly used in two adjacent zones. However, there have been no other efforts to test families in more than one zone.

Orchard Design

The first two orchards, both ponderosa pine, were designed without much progeny performance data to support the arrangement of clones. Subsequently, fifth-year data have supported the design.

Initial breed zones included selections from a wide elevation band. Therefore, each 15-acre block was subdivided into low, middle, and high elevation sub-units. Sub-units represent 1000 ft elevation intervals. These are adjacently located and arranged to minimize inter-pollination. These arrangements will allow separation of seed by elevation if necessary.

For Douglas-fir, initial breed zones are smaller in area and elevation range than pine. If any subdivisions are made in orchard blocks, they will be based on 5-year progeny data plus isozyme analyses.

Within orchard blocks or sub-units, clones are randomly arranged by a computer program to minimize inbreeding and maximize out=crossing. Initial espacement is 5 m. on a hexagonal pattern.

Progeny Performance and Orchard Roguing

The initial close (6 ft) spacing of progeny will force early intergenotypic competition and hopefully provide better prediction of mature performance. The two thinnings, at ca. ages 8 and 14, will prevent "stagnation" and maintain vigor at least through 25 years.

Clonal orchards will need thinning and will be approaching large scale seed production at the 15-year progeny evaluation. The major roguing will occur then. For orchards that have elevational sub-units, clones left after roguing will be based on: 1) stable high performance across all test sites, 2) high performance on specific sites with elevations corresponding to the sub-unit, and 3) heavy flowering. For example, some clones in the high elevation sub-unit may show high performance across all sites, while others

may show high performance only on the high elevation test sites. Clones in both categories would be left provided they are good flower producers.

Table 1. GOALS AND OBJECTIVES OF THE PSW REGION GENETIC TESTS 1/

GOALS

1. Provide the kind and quality of information on genetic material that will produce high seed yields with moderate genetic gain and broad genetic diversity from first generation production orchards.

2. Estimate genetic parameters using statistical techniques.

3. Provide a supplementary or emergency source of seed in addition to the production orchard, clone bank, and original wild parents.

4. Generate silvicultural information on performance of intensively managed plantations.

5. Exchange information and materials with other cooperators.

OBJECTIVES

1. Maintain genetic integrity of seed lots.

2. Use experimental designs to segregate genetic and environmental effects (nursery and field designs).

3. Grow high quality planting stock in the nursery.

4. Minimize differential nursery effects on subsequent performance.

5. Maximize environmental uniformity within nursery and field blocks (replications).

6. Protect from injury and mortality due to pests.

7. Minimize competition from undesirable vegetation.

8. Simulate operationally feasible intensive environmental management.

9. Provide efficient logistics and recordkeeping systems.

1/ Genetic tests here refer specifically to wind-pollinated progeny trials.

Table 2. MAJOR ATTRIBUTES OF THE PSW REGION GENETIC TEST SYSTEM

1. Intensive selection, measurements, and records on wild parents.

2. Strong protection of genetic integrity of progeny.

3. X-ray seedlots to enhance seed to seedling efficiency in nursery test.

4. Assignment of families to sets such that each set has the proportional distribution relative to that of all selections in the breed zone for geographic and elevational dispersion. Standard controls are also assigned.

5. RCB nursery experimental design with seed and seedling performance records.

6. Strong experimental design in field--random non-contiguous plots with interlocking replication (Libby and Cockerham 1980, Silvae Genetica 29, 5-6, 183-189). Systematic thinning of reps within blocks leaves balanced design unbiased.

7. Container nursery system operationally linked with the field design for efficient handling of stock and records. Families are placed in container trays to match outplanting spots. Computerized maps predetermine outplanting locations and facilitate planting in proper positions in field.

8. Control seedlots are planted in each set of test families. Controls consist of 2-parent crosses (for environmental monitors), local seedlot, and general nursery lot (for gain estimation). Controls are standard to all plantings in the breed zone (excluding the local lot which is standard to each set in one plantation area).

9. The number of families and controls per set can vary from 7 to 49 in increments of seven, allowing necessary flexibility.

10. Site preparation is intensive. Stumps are removed when necessary to fully utilize limited space and/or generate spacing uniformity.

11. Unwanted competition is minimized while within block uniformity is maximized.

12. Closer than normal spacing (6 x 6 ft.) is used to conserve space and allow accurate early evaluation (Juvenile x Mature correlation may be enhanced by close spacing).

13. Performance data are taken frequently and computerized using portable data recorders (PDR) in field with linkage to computer storage and analyses.

Table 3. MAJOR ACTIVITIES FOR PSW REGION GENETIC TESTS

1. Delineate tentative breed zone (Master Plan).
2. Select approximately 200 superior phenotypes.
3. Collect and process seed from each parent separately.
4. Select and prepare test sites (incl. EA).
5. Assign families to sets with control lots and extra families.
6. X-ray, weigh, and stratify seed by family.
7. Sow seed in Leach supercell containers.
8. Arrange in RCB nursery design.
9. Grow and tag seedlings and consolidate filled cells in trays.
10. Record important traits for family differences.
11. Inventory plantable stock.
12. Generate computer maps that assign family members to specific locations within trays to correspond with exact field layout.
13. Sort and arrange family members to proper tray positions.
14. Record height of seedlings in trays. Subsequent field measurements will "tie back" to nursery heights of specific individuals.
15. Place trays in labelled boxes for cold storage.
16. Layout field sites with flagging pins for each tree location.
17. Plant seedlings in field as arranged in trays (which corresponds to computer map). Check layout with map.
18. Maintain test planting (release, pest control).
19. Record survival (Yr. 1, 2), height and condition class (Yr. 3, 5, 7, 10, 15) and dbh and form class (Yr. 7, 10, 15) using MSI PDR's.
20. Thin systematically at Yr. 8 and 14.
21. Rogue seed orchard to final spacing using Yr. 15 data.

10/22/82

Table 4. FIELD DESIGN OF WIND-POLLINATED PROGENY TESTS IN PSW REGION

I. Environmental Design

A. 4 or 5 plantation locations per species-zone

B. Spacing: 6x6 ft hexagonal pattern

C. RCB with 8 blocks per plantation - set (4 sets per plantation)

D. 3 interlocking replications per block

E. Each Block:

1. 14 rows, 21 trees per row = 294 trees

2. every fourth tree within a row belongs to Rep A, likewise for Reps B and C.

3. blocks to be systematically thinned by removing a complete Rep (e.g. Rep C).

F. Border trees: 2 rows around test trees on periphery of plantation.

II. Genetic Design

A. Wind-pollinated (W-P) families from wild collections

B. 4 sets of families per plantation (180 test families per species-zone)

C. Each set:

1. 45 W-P families sampling entire species-zone

2. 2 standard full-sib families (environmental monitors)

3. 1 standard general source lot (genetic and environmental monitor)

4. 1 local lot from plantation locale (genetic monitor)

D. Individuals per family (before thinning to yr 7)

1. per zone= 192 to 240

2. per plantation = 48

3. per block = 6

4. per rep = 2

Table 5. Cost of a planted progeny test seedling. [1/]

LOCATION		ACTIVITY	$COST PER FAMILY	$COST PER SEEDLING	PERCENT
Field	1.	Select Superior Trees	190.	0.792	23
	2.	Collect Seed	90.	0.375	11
Nursery	3.	Extract/Clean Seed	16.	0.067	2
	4.	X-Ray/Count Seed	20.	0.083	2
	5.	Weigh/Stratify Seed	4.	0.017	<1
	6.	Sowing Design Plans	3.	0.012	<1
	7.	Materials (soil, containers, fertilizer, tags)	40.	0.167	5
	8.	Fill Containers	8.	0.033	<1
	9.	Sow Seed	11.	0.046	1
	10.	Tag Seedlings	13.	0.055	2
	11.	Consolidate Filled Tubes	8.	0.033	<1
	12.	Germination/Inventory	4.	0.017	<1
	13.	Culture	13.	0.055	2
	14.	Utilities	8.	0.033	<1
	15.	Computer Maps	4.	0.017	<1
	16.	Sort and Measure	48.	0.200	6
	17.	Transport to Cold Stores	6.	0.025	<1
	18.	Cold Storage (4 months)	4.	0.017	<1
Planting Site	19.	Site Preparation/Fencing	(varies by site and use of K-V Funds)		
	20.	Transport to Planting Sites	30.	0.125	4
	21.	Staking Tree Spots	132.	0.550	16
	22.	Planting Trees	180.	0.750	22
		TOTAL	832.	3.47	100%

[1/] Based on: 1983 dollars and sowing 392 seed to outplant 240 seedlings per family.

The assignment of families to sets is controversial and needs some discussion. Two options have been used:

1) Sub-Zone Sets - assign families such that each set represents a localized grouping of families originating from a certain contiguous portion of the breeding zone, e.g.

Set 1 = families from North, low elevation portion of zone
Set 2 = " " " high " " " "
Set 3 = " " South, low " " " "
Set 4 = " " " high " " " "

2) Whole-Zone Sets - assign families such that each set contains a representative sample of families from the entire breeding zone; the proportion of families from any subdivision of the zone should correspond to the proportion of selections made in that subdivision, e.g. if 10% of the selections were from Seed Zone 525.45 then 10% of the set total of families should occur in each set.

Assumptions have to be made in order to analyse these options. The most direct and accurate comparison among families will be for families occurring in the same set. For any set of 45 families the best 25-50% will be selected. As a guide consider that the best 25-50% of the families in each set will be selected for using their parent clones for seed orchard production. Others will be rogued (removed)

from the orchard (or alternatively never grafted).

Assumption 1 - Poor comparison among sets

A. Provenance differences are strong e.g. North latitude low elevation families perform best on all sites (provenance x environment absent), or the most local families perform best on each site (P x E strong).

a) sub-zone set - selection will result in the best families from each set and will include from the poorest sets (provenances) to the best sets. Disadv[s]:

1) requires having all seed from the sub-zone prior to any testing;

2) requires some a priori knowledge of provenance variation in order to form sets;

3) actual provenance differences will be undetected since provenances are confounded with sets and sets are different in time of establishment and/or soil-site influences; and

4) since provenances cannot be compared on each site, no estimation of provenance x site interaction is possible, therefore, no breeding zone changes can be made. The main advantage is that the seed orchard will produce a broad genetic base due to inclusion of even the poorest provenances, however, this is largely offset by the reduced genetic gain.

b) whole zone set - selection will result in the best families from only the best provenances. The major advantages are: 1) provenance differences will be

detected; 2) P x E interactions can be detected making it possible to change breeding zone boundaries if necessary; and 3) genetic improvement will be greater since selection will capture the provenance level as well as family level of variation. The main disadvantage is tendency to rely completely on test results and reduce genetic base (eliminating poor provenances); however, since all information will be in, a better decision can be made relative to any compromise between diversity vs gain.

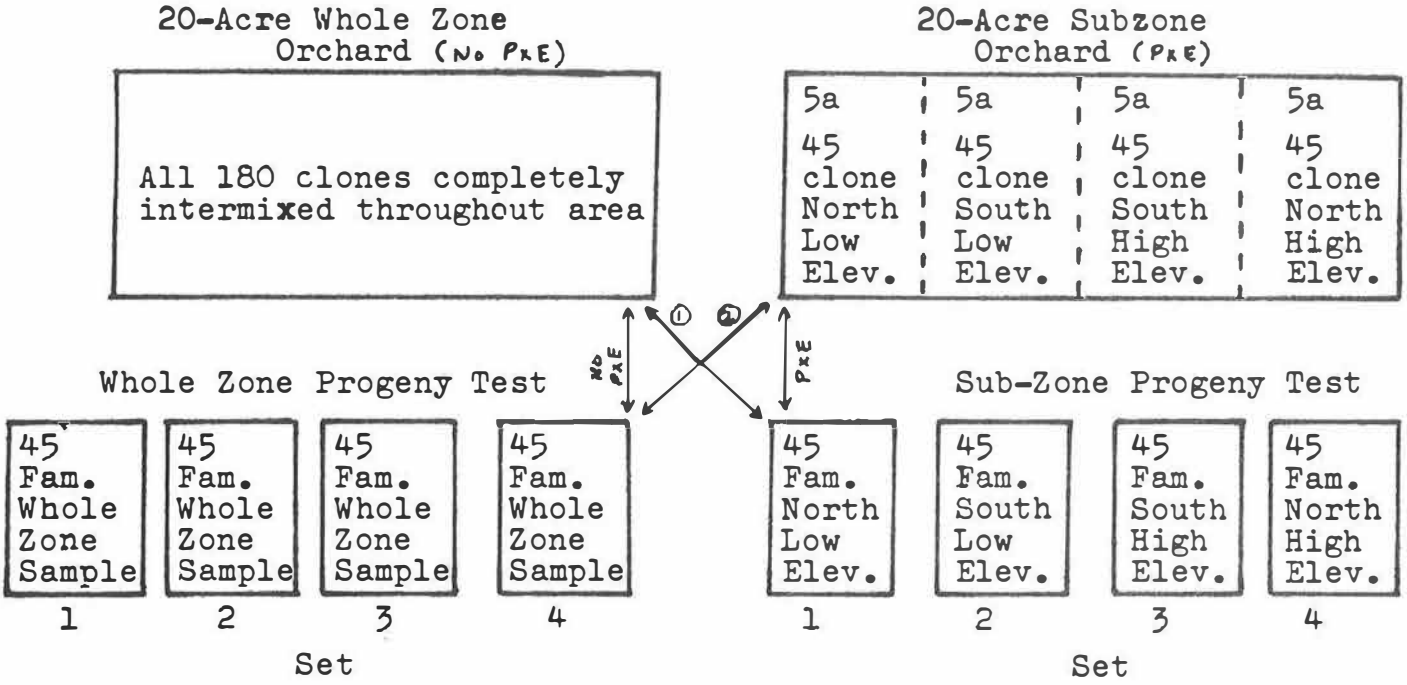
B. Provenance differences are weak or absent

The result of selection will be the same for both types of sets. If sub-zone sets are used an uncomfortable state of ignorance will prevail concerning the provenance effect.

Assumption 2 - Good comparison among sets (i.e. all seed available within short period, all test seedlings planted same year on uniform sites)

In this case any sub grouping into sets would be unnecessary and have no advantage one way or the other.

Before leaving this topic one further consideration is warranted. If some commitment is made about the arrangement of clones in a seed orchard before progeny test results are available, then the designs of the orchard progeny test sets should be compatible for roguing. To illustrate, consider these possibilities below:



Progeny Test Design

Orchard Design	Whole Zone	Sub-Zone
1. Whole Zone	a. P x E absent: Roguing leaves best clones from best provenances. Minimum rearrangement of clones for uniform final spacing. Narrower diversity, higher gain. b. P x E strong: Complete rearrangement needed.	Roguing leaves best clones from each sub-zone completely intermixed in orchard. Minimum rearrangement of clones for uniform final spacing. If P x E is strong but undetected, then orchard will produce broad mix with reduced performance. ①
2. Sub-Zone ②	a. P x E absent: Must either: 1) compromise gain by leaving best clones from all sub-zones, or 2) eliminate all clones from poorer sub-zone and move best sub-zone clones to replace vacant areas by transplanting or establish new orchard b. P x E strong: Rearrangement needed depends on accuracy of initial orchard sub-zoning.	May compromise gain by leaving all sub-zones represented. Best accuracy of within sub-zone selection if sets correspond to actual provenance variation pattern which will not be known. Most conservative approach, but satisfactory only if P x E is strong and corresponds closely to initial sub-zone arrangement.

To summarize this evaluation, it is apparent that families in different sets will probably have low accuracy of comparison even with the inclusion of environmental monitors (standard narrow-base control lots), and if they were comparable, there would be no advantage to forming sets of any type. In the former case, sub-zone sets will give poor estimates of provenance variation and provenance x site (P x E) interactions. Without this knowledge improvement possibilities are limited, because selection cannot capture provenance differences nor will there be opportunity to change breeding zone boundaries.

Accepting this, then whole zone sets are most desirable. But what should be the orchard design? If P x E is absent, then whole zone orchards are best. If P x E is moderate and can be closely approximated early, then sub-zone orchards are best. If P x E is very strong, then isolation from pollen movement between sub-zones is needed and this requires formation of new, smaller breeding zones, as subdivisions of the large original zone.

PROGENY TESTING - REGION 6 OBJECTIVES AND DESIGN

by

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for

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INTRODUCTION AND OBJECTIVES

The Region 6 Tree Improvement Plan indicates that 1326 evaluation plantations are planned for the Region and that approximately 500 (including cooperator efforts) have already been established.

The basic objectives for the Progeny Tests are to rank the parents for their genetic worth over the whole breeding zone and to determine those additional parents which are suited, better than average, for some particular slope, aspect, elevation, soil type or habitat type. An alternative objective found in the Region is to determine the amount of geographic Genetic Variation and therefore determine the breeding zone.

MAJOR ELEMENTS OF R6 EVALUATION PLANTATIONS

The major elements of Region 6 evaluation plantations are as follows (modified from U.S.D.A. Forest Service, R-6, Tree Improvement Training Paper No. 19, Revised 3/31/81):

1) Test breeding values of selected parents, 2) Plantations will be measured and analyzed over a medium-term (15 years) to long-term (½ - ⅔ rotation age) time period, 3) Plantations will provide a sample of various breeding zone environments, 4) Plantations will be as homogeneous as practically possible within the smallest unit, a Rep Set, and sets will be tested with contiguous placement, in order that the environmental variance be kept to a minimum, 5) Plantations will incur vegetation control measures to insure optimum survival during the establishment period and minimize variation due to competition, 6) Animal control measures will be utilized at the plantation sites to insure optimum survival, establishment and growth potential during the juvenile period of growth, 7) Selected progeny on the plantations may be utilized in future generation testing or breeding and 8) An evaluation plantation design will be utilized which will be statistically and economically efficient in meeting the goals of the experiment. Some of these goals are at odds and the priority given to each finally determines the design.

MATING DESIGNS

At present we do not have any advanced generation breeding going on in the Region except at the experimental levels. We are almost exclusively testing open pollinated progeny from single tree selections. There are a number of exceptions with various mating designs. Partial diallels are being used at the Dorena Tree Improvement Center on western white pine. These diallels are used to track white pine blister rust and to see how the resistance is holding up or how the races are changing. They use a standard (resistance known) and a diallel for each run to determine the culling level. There are a couple of programs on westside Douglas-fir using a polycross system to estimate General

Combining Ability and produce seedlings for testing. In Douglas-fir and ponderosa pine there has been some biparental crossing in the forest. This crossing is used to produce interim second generation orchards and is not a breeding population. Other exceptions do exist in the Region but will not be discussed here.

CHECK LOTS

There are a number of different opinions about including check lots in the evaluation plantations. One suggestion from the PNW Experiment Station is to randomly select 6 parent trees near each test site and use the progeny as the check within the plantation. This has some practical disadvantages requiring a decent seed crop sometime between site selection and sowing of the progeny. The method used most often in the Region is to use the set mean as the check and not raise the cost substantially by bringing any more trees into the test. With a standard commercial check we have no real idea whether we have selected a poor or good lot. When we put a checklot into all plantations, we don't know the Genotype X Environment interaction. Therefore it is often recommended to go with the set mean and/or to use a local group of parents as the check.

SAMPLING THE BREEDING ZONE

For an intensive program we are selecting a minimum of 200 trees per species per breeding zone and testing the progeny of these phenotypically superior trees on approximately 6 to 12 sites across the breeding zone. In the mountainous topography of the northwest this number is required to adequately

sample the breeding zone. Critical criteria for evaluation plantation locations are: to sample the environmental range of the breeding zone, to sample the range of site quality with emphasis on the most common areas, to sample all aspects, elevations, slopes, ranges, habitat and soil types in the proportions they occur.

TESTING OUTSIDE LOCAL BREEDING ZONES

Testing families outside of local breeding zones is a strictly economic decision because at this phase of the program we are testing anywhere from 200 to 400 parent trees per breeding zone and ranking the parents. It is likely that in future generations, when we are testing fewer parent trees, we will probably test across breeding zones. One suggestion that may be implemented in the progeny tests yet to be established is to put the boarder trees around plantations from approximately 10 parents from adjacent breeding zones. This involves no added cost but will need a seperate regression analysis.

STATISTICAL DESIGNS

A number of different evaluation plantation designs are used throughout the Region depending on the objectives of the test. The majority of forest genetic evaluations in Region 6 will utilize one of three basic evaluation plantation designs. They are SETS within REPS (Blocks in Replication), REPS within SETS (Replication in Blocks) and RANDOM INTERLOCKING.

SETS within REPS is a balanced incomplete block design (Figure 1). A plot within a set consists of 4 or 5 seedlings from the same family placed at

random (Figure 2). There will generally be from three to five replications per plantation. So this equals 12-25 seedlings/family/plantation. Most have 16 seedlings/family/plantation. The sets are randomized within each plantation. Spacing of the individual planting spots is usually 10' x 10'. This method is used to map the pattern of genetic variation.

REPS within SETS is a balanced incomplete block design. This is different from the SETS within REPS because the sets have the replications placed in a contiguous manner (all replications of a set are placed as a group) (Figure 3). The sets are placed at random in a plantation and the plots are randomized within each set. This method strengthens the test for ranking the families.

Figure 1. Schematic diagram of field layout for a SETS within REPS Design.

SET 1 REP 1 Plots 1-40	SET 4 REP 1 Plots 121-160	SET 3 REP 1 Plots 81-120	SET 1 REP 4 Plots 1-40	SET 3 REP 4 Plots 81-120	SET 2 REP 4 Plots 41-80
SET 5 REP 1 Plots 161-200	SET 6 REP 1 Plots 201-240	SET 2 REP 1 Plots 41-80	SET 6 REP 4 Plots 201-240	SET 5 REP 4 Plots 161-200	SET 4 REP 4 Plots 121-160
SET 4 REP 3 Plots 121-160	SET 5 REP 3 Plots161-200	SET 1 REP 3 Plots 1-40	SET 4 REP 2 Plots 121-160	SET 1 REP 2 Plots 1-40	SET 6 REP 2 Plots 201-240
SET 2 REP 3 Plots 41-80	SET 3 REP 3 Plots 81-120	SET 6 REP 3 Plots 201-240	SET 5 REP 2 Plots 161-200	SET 2 REP 2 Plots 41-80	SET 3 REP 2 Plots 81-120

6 Sets

4 Reps/Set, where set is replicated throughout the plantation.

Sets are randomized within each group of replications.

Plots are randomized within each replication and set.

Figure 2. Example of one replication of a set including 40 plots.

SET 1; REP 1; PLOTS 1-40

8	4	11	28	(1)	36	7	30	2	27	11	15	40	2	(1)	33	29	13	4	35
12	26	9	16	32	30	25	12	3	10	22	18	3	20	19	7	24	16	6	13
18	5	15	20	22	8	17	36	24	14	21	25	32	(1)	27	34	23	38	18	14
16	26	22	8	28	31	3	33	37	10	23	29	5	36	9	17	2	35	21	38
6	38	2	28	(1)	39	7	34	24	16	11	4	32	12	34	15	30	14	25	39
34	36	15	40	20	13	40	37	27	19	21	10	29	17	32	8	31	26	5	18
9	24	14	39	33	31	19	22	40	17	39	23	38	3	37	28	21	35	12	6
10	4	13	20	30	7	6	27	23	11	29	33	37	5	35	26	31	25	19	9

(○) designates one plot.

Seedlings are placed at random within the replication.

Total Selections		Progeny/parent		Total Progeny		No. Sites		Progeny/Site
240	x	160	=	38,400	÷	10	=	3,840

Progeny/parent		Progeny/plot		Total plots
160	÷	4	=	40

Total Parents		Parents/set		Total sets
240	÷	40	=	6

Progeny/rep		Reps/site		Progeny/parent site		Parents/set		Sets		Progeny/site
4	x	4	=	16	x	40	x	6	=	3,840

Parents/set		Propeny/rep		Seedlings/rep	
40	x	4	=	160	(Smallest unit tested together)

Figure 3. Schematic diagram of field layout for a REPS within SETS design.

SET 3; REP 2; PLOTS 81-120	SET 3; REP 3; PLOTS 81-120	SET 5; REP 3; PLOTS 161-200	SET 5; REP 4; PLOTS 161-200
SET 3; REP 4 PLOTS 81-180	SET 3; REP 1; PLOTS 81-200	SET 5; REP 1; PLOTS 161-200	SET 5; REP 2; PLOTS 161-200
SET 2; REP 1; PLOTS 41-80	SET 2; REP 2; PLOTS 41-80	SET 4; REP 4; PLOTS 121-160	SET 4; REP 2; PLOTS 121-160
SET 2; REP 3; PLOTS 41-80	SET 2; REP 4; PLOTS 41-80	SET 4; REP 3; PLOTS 121-160	SET 4; REP 1; PLOTS 121-160
SET 1; REP 2; PLOT 1-40	SET 1; REP 4; PLOT 1-40		
SET 1; REP 1; PLOT 1-40	SET 1; REP 3; PLOT 1-40		

5 Sets randomly placed in the plantation of 40 plots each.

4 replications per set with reps in a contiguous manner.

4 seedlings/plot randomized within reps.

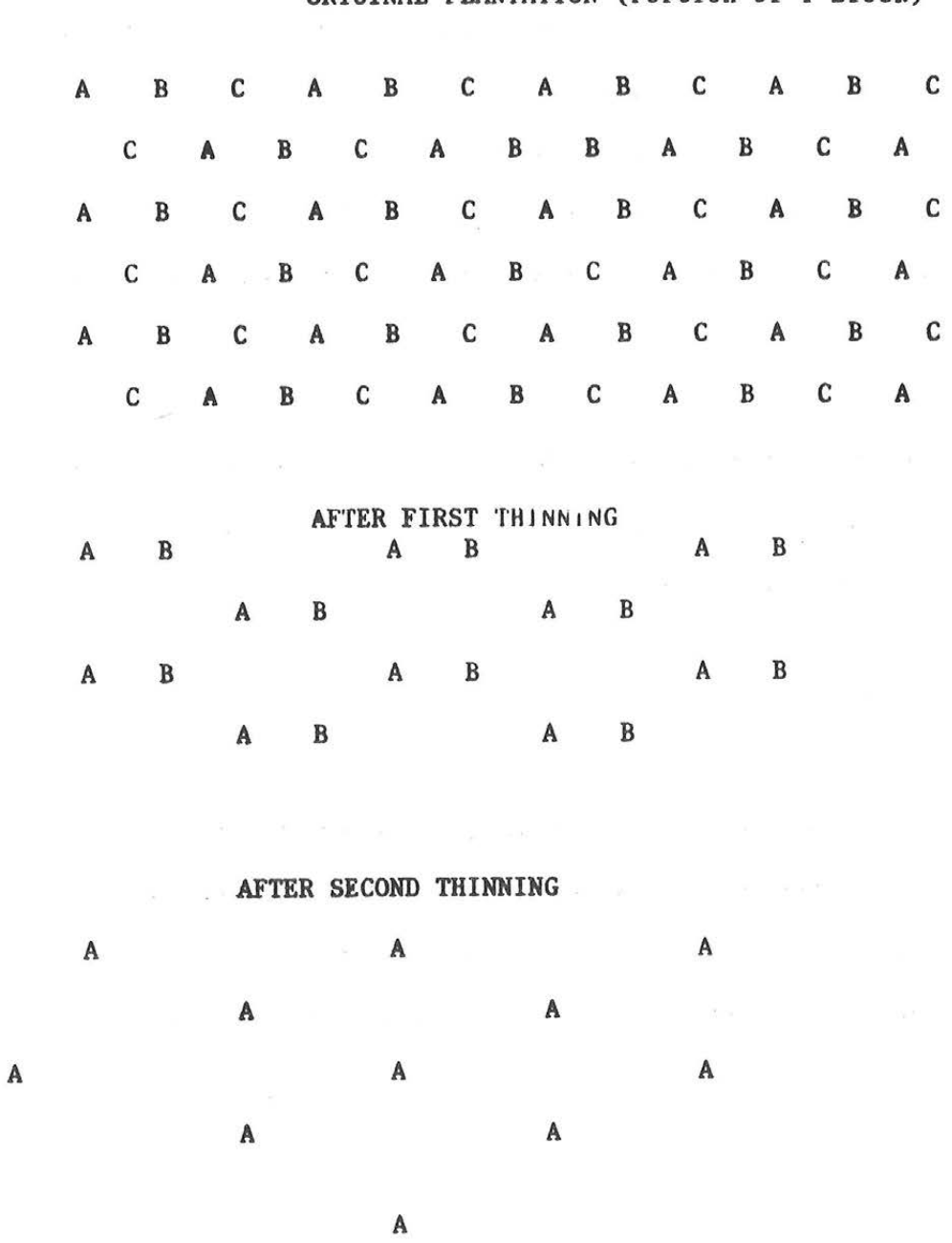
The RANDOMIZED INTERLOCKING is an incomplete block design originally developed by Dr. W. J. Libby. The main feature of this design is that it allows subsequent thinnings to occur while maintaining the statistical integrity of the experiment. Sets consist of a number of non-continuous multi-tree plots which range between 10 to 40 in order to keep the sets within a homogeneous area. This design has 3 replications placed in an interlocking design (Figure 4). This design requires a lot of space and therefore increases the environmental variation.

Randomized Complete Block designs are not used in this Region. The reason is that the Incomplete Block Designs allow fewer entries per block thereby reducing the environmental variation.

MEASUREMENT YEARS

Region 6 plans on taking 5, 10 and 15 year measurements on the evaluation plantations. The breeding population will most likely be decided after the 10 year measurements. This timing is highly dependent on the average size of the tree attained in the period. At higher elevations, a longer time will be needed.

Figure 4. Schematic diagram of field layout for a RANDOM INTERLOCKING design.



USDA, Forest Service
Region 8

PROGENY TESTS
REGION 8, OBJECTIVES AND DESIGN 1/

James L. McConnell 2/

The Region 8 Tree Improvement Program contains seven pine species - loblolly, longleaf, slash, Virginia, shortleaf, sand, and white pine. The National Forests have been broken down into geographic sources which, in most cases, include the natural range of the species in the program. Each geographic source contains 50 superior tree selections. These divisions were based upon the best provenance data available at the time the program was started. Since then, Research has come up with new provenance data that will be incorporated into our second generation program.

Priorities for the pine program are:

1. Establishment and maintenance of first generation pine seed orchards and stimulation of early and abundant seed crops.

2. Creation of populations of controlled pollinated pine progeny from which selections may be made for use in the establishment of second generation orchards.

3. Establishment of second generation orchards using the outstanding individuals from populations created by the controlled pollinations and outstanding progeny tested individuals from other state, industrial, and university tree improvement programs.

First generation orchards are composed of clones of the superior tree selections from each species-geographic source. The first objective or priority has been reached. Seed production for operational planting, in most cases, is adequate and often abundant.

For purposes of controlled pollinations, the different species-geographic sources were placed in breeding populations. For example, shortleaf pine breeding Population 4 is composed of three geographic sources: (1) the Cherokee NF in Eastern Tennessee; (2) the Nantahala and Pisgah National Forests in Western North Carolina; and (3) the Chattahoochee National Forest in North Georgia. This is classified as the Southern Appalachian Ridges and Valleys and Blue Ridge Physical Division.

1/ Paper presented at Servicewide Genetics Workshop and Region 8 Seed Orchard Managers' Workshop, Charleston, S. C., December 5-9, 1983

2/ Regional Geneticist, Region 8, Timber Staff Unit, Silviculture Group, Atlanta, Georgia

The breeding populations are broader in area and size than the geographic sources. They represent updated research information and reflect our intuition as to the correct species for a geographic location.

Each breeding population has been carefully planned. The R-8 plan contains the number and locations for the progeny test plantations, the composition of check lots and the mating design for the control crosses.

The mating design is a six-tree, disconnected, partial diallel. We refer to each six-tree diallel as a crossing group. Over time, changes have been made within and between crossing groups to handle problems associated with poor or no flowering, timing of flowering, and poor pollination results (e.g., empty seed).

We try to take each crossing group to the field as a unit. Generally, this works, but we have not delayed planting, waiting for one or two crosses in a group to be made. Since our second generation program depends upon selecting the best from progeny tests, we are concentrating on getting progeny tests into the ground.

Our progeny tests are ten-tree row plots. So far, the majority have been planted within the areas being regenerated on the different National Forests. To date, the Region has 297.4 acres of progeny tests of all species, with approximately an additional 150 acres planned in FY 84.

The size and number of families vary, but we feel that 30 families of 5 replications are ideal for the Piedmont and Mountain areas. Even in Florida, with vast flat areas, we have had problems finding uniform sites without ponds or other undesirable site changes.

Most clearcuts in R-8 average 50 acres in size. We have tried, with good success, to work within these areas.

Over the past six years, we have lost about six progeny tests to drought, a couple to rabbit damage, and one to fire.

The progeny tests program on the Forests and Districts has been received with enthusiastic support.

FOREST GENETICS WORKSHOP

December 5-9, 1983

Charleston, South Carolina

EVALUATION PLANTATION ESTABLISHMENT AND MANAGEMENT

Regional objectives and designs - Eastern Region

John Murphy, Regional Geneticist

The Eastern Region consists of three zones, the Lake States, Central States and Eastern States. The tree improvement program is primarily directed toward conifers, conifers and hardwoods, and hardwoods in the respective zones. The tree improvement program was initiated in the early sixties and has the following objectives:

A. To produce genetically improved seed for seedling production and/or direct seeding that will yield fast growing, high quality, and pest resistant forest trees, and to incorporate this material into the reforestation program.

B. To develop and demonstrate cultural methods for producing timber and other products by applying sound genetic principles.

These objectives are directed toward obtaining the goal which is "to insure that all reforestation is done with the highest level seed source available that is economically efficient, but not less than a level 1 program (FSM 2475)."

The proper design and establishment of evaluation plantations is a vital process of providing "good" data to reach our goals and objectives.

Basic Evaluation Plantation Objectives.

The objectives of our evaluation plantings (EP) are dependent on the species and the intensity of program for that species. In general our objectives are:

1. Evaluation of superior tree selections for either inclusion in a seed orchard or to rogue a seed orchard.

2. Provide uniformly grown seedlings for future generation selection.

3. To provide data for further refinement of existing seed zones and/or breeding zones.

Mating Designs being used.

Those species for which an intensive program is planned, including a breeding program, some form of a connected half diallel is used. In some cases such as white spruce selfing is included. In some species small groups of disconnected completed diallels are used.

EXAMPLES OF MATING DESIGNS

WHITE SPRUCE MATING DESIGN

	1	2	3	4	5	6	7	8	.	.	.
1	X	X	X	X	X						
2		X	X	X		X					
3			X	X			X				
4				X				X			
5					X	X	X	X			
6						X	X	X			
7							X	X			
8								X			
.											
.											
.											

WHITE PINE MATING DESIGN

	1	2	3	4		5	6	7	8		9	10	11	12
1	X	X	X	X	5	X	X	X	X	9	X	X	X	X
2	X	X	X	X	6	X	X	X	X	10	X	X	X	X
3	X	X	X	X	7	X	X	X	X	11	X	X	X	X
4	X	X	X	X	8	X	X	X	X	12	X	X	X	X

Type of material used. Most of our EP at this point in time have been with 1/2 sib (open-pol) seed from the ortet and in some cases included 1/2 sib seed from clonal orchards. As our breeding programs progress we have used and will use full sib seed.

Check lots used. We have tried to include one or more check lots from a seed zone where the EP is established. We prefer to use seed from a source such as a seed production area, as a part of the evaluation planting. We have in some cases included run of the mill or normal nursery stock which has not been grown under the same procedure as the EP material.

The Number of Tests within Breeding Zone. The number of EP established is usually one or two per seed zone or breeding zone. A greater number would be desirable since unforeseen problems can quickly reduce the number of established, useful plantings. There needs to be a balance established between a minimum number needed and the number that may be lost with the logistics and cost of establishment that can be handled.

Are families established outside of the breeding zone? In most cases some families from outside the breeding zone will be included in the EP. These provide information for zone boundary refinement and can also serve as a control between zones. The number of seedlings available, the information known about zones, and the overall logistics will dictate the number of families included in an EP from outside the planting zone.

Statistical designs used. The purpose or objective of the planting influences the overall design. Most plantings consist of 4 tree row plots, with 5 to 10 replications. In some species two nurseries have been used to produce stock resulting in split plot design. Most EP consist of a randomized complete block design.

At what age can decisions for roguing orchards, making family or within family decisions be made? Decisions depend on the species and objectives involved in the EP. In some cases, such as yellow birch, the elimination of some families (lower 10-20%) to be included in seed orchards or as a seed source can be made at age five. Family and within family selections within an established seed zone can probably be made in 5 to 10 years. The decision to move seed from distant sources would probably require a time frame of 1/2 to full rotation.

Conclusion.
The overall objective of our EP is to provide the data that can lead to the best seed available to use for reforestation as soon as possible while providing for genetic integrity for the future.

Our present system of establishing EP is costly and subject to losses from insects, disease, wind, animals, man and weather. We need to devise and implement cheaper, quicker and economical methods for obtaining the needed EP data. This may mean increased number at the sacrifice of minute accuracy. This should be analyzed carefully.

JOHN D. MURPHY
Regional Geneticist, R-9

FOREST GENETICS WORKSHOP
Charleston, South Carolina
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Advantages and disadvantages of bare-root and container seedlings and vegetatively propagated plant material for progeny tests.

William K. Randall, Area Geneticist
Pacific Northwest Region

Purpose of Testing

Plant material is evaluated in progeny tests to determine which have the greatest value. This is accomplished by growing many seedlings or cuttings under the same environmental conditions. Uniform environmental conditions are selected at a single location and, when multiple locations are used, they represent uniform sets of different environments. Those test sites must represent the range of environmental conditions under which the selected material will be used for commercial reforestation. Sometimes special environments are chosen to evaluate specific plant characteristics or unique growth responses, such as when a growth chamber is employed to evaluate long distance species movement, or drought testing. Our systems approximate seed germination and growth under field conditions, but are far from perfect.

Test Seedling Production

The starting point is collecting seed of high quality that represents the sample area. When collecting seed in marginal seed years, some seedlots may include seeds from only a small non-representative sample of parent trees (Campbell & Sorensen, 1983), and major portions of the sample area may not be represented.

Seedling production systems should produce genotypes that represent the genetic structure of the seed collected. Man's nursery or greenhouse can produce a population different than that produced by nature (Campbell & Sorensen, 1983). It is entirely possible that seedlings in the test plantations do not contain the range of variation available in the seed population.

Growing conditions influence nursery survival and even extend to survival at the planting site. For example, a wet and shaded nursery environment can pre-condition seedlings to close their stomata too quickly and thus suffer high temperature damage on sunny warm days (Unterscheulz et al, 1974). They also found, for their situation, that nursery conditions were much closer to "natural" seedling environment than were growth chambers.

Various mechanical and chemical processes are employed to adjust and regulate the seedling's shoot and root growth. Some of those processes exert major selection on certain families, while having little or no effect on other families (Campbell & Sorensen, 1983). Some nursery practices tend to produce seedlings that cannot survive after outplanting. For example, seedlings may be slightly out of phase in respect to dormancy.

Seedling emergence date influences not only a seedling's size and shape, but also it's growth rhythm. Growth rhythm can be easily modified and will persist for at least two years and perhaps even longer (Heide, 1974). Lifting date and storage conditions have important first year field survival consequences. All too often, tree improvement seedlings in production nurseries are lifted prior to or after all regular seedlings. Moving from the optimum lifting date has direct influence on survival, but even more important is that certain familiars or provenances may be eliminated. Even when evaluating the nursery factors of light, soil, moisture, temperature, and nutrient supply, Pollard and Logan (1979), found that there were no provenance times treatment interactions, but when moving material to the field, many interactions were observed (Wright, 1973).

Preparing seedlings for field planting requires that they complete their three stages of growth: germination, juvenile growth, and exponential growth. The growth period is followed by a resting stage of three to five weeks, where buds are set but seedlings are not yet cold hardy. The final phase of six to ten weeks produces fully hardened seedlings. The chilling requirement is met for bud break when warm weather arrives at the planting site. The best nursery practices maximize both the number of plantable seedlings and survival of seedlings after outplanting.

Why Use Container

Why produce test seedlings with a tightly confined root mass when natural seedlings have a fan-shaped root system? A logical reason is that container seedlings, with their compact root system and good balance between root and shoot, are very plantable. That shaped root system facilitates planting. Survival often is better and they make faster early growth than bare-root seedlings (Stein and Owston, 1977). It is never fair to compare the two classes of seedlings based only on root system and ease of planting; long-term growth results must also be considered.

Another non-biological reason is ease of handling during the entire seedling operation. Handling trays of seedlings is easier than individual bare-root seedlings. Container seedlings can be pre-arranged in trays so that during planting time is not spent locating a specific seedling from among a large number. This allows the complicated lattice designs to be used instead of completely random or randomized complete block designs. Persons growing container seedlings often do not replicate the different genetic groups. To minimize the location effect of water, sun, heat, and light, container trays are rotated throughout the greenhouse during the growing season. Also, we can't overlook the fact that containers are the new type of seedling and use of a new method so often seems the way to do a project.

The major biological reason for using container-grown seedlings is uniformity (van Buijtenen and Lowe, 1982). Even though not absolutely uniform, there is less variation than in outdoor grown bare-root seedlings. Outdoor nursery conditions of germination, soil texture, moisture differences, and weed competition all add to lack of uniformity.

The number of plantable seedlings per number of seeds (tree percent) often is higher for container-grown seedlings than for outdoor bare-root nursery seedlings. With high quality seed, only one seed per container is needed. Some species can be collected in the fall, grown overwinter in a greenhouse, and outplanted in the spring. This gains a year over outdoor bare-root stock.

For many species, a major disadvantage to the use of container seedlings is that reforestation often is with bare-root stock and containers are a step removed from how the seedlings are used in practice. However, as pointed out by van Buijtenen and Lowe (1982), progeny tests survive for uniformity and they generally are not treated the same as general reforestation plantings. In some areas containers are heavily used and experimental procedures today often become standard practice by the time progeny test information becomes available.

Survival and growth of bare-root and container seedlings are about the same in the Pacific Northwest (Stein and Owston, 1977), but the generally smaller container stock used in the South results in slower initial growth (van Buijtenen and Lowe, 1982). First year survival of live oak progeny in six test plantations outside of it's natural range was dramatically increased by the use of container seedlings (van Buijtenen and Lowe, 1982). In the West, Sitka spruce, western hemlock, and western redcedar are difficult to produce in bare-root nurseries, so are increasingly grown in containers. When sites are well prepared and vegetation controlled, small seedlings have done as well as large ones (Alm et al, 1982). However, time of planting must be observed with all seedlings. The supposed extension of the planting season and speed of planting often are not fully biologically and practically possible.

Generally container seedlings are younger and smaller than bare-root seedlings; their stems are neither as thick nor as woody. However, survival was as good or better than bare-root, except for container-grown ponderosa and lodgepole pine where survival was poorer, which could be due to animal damage because stems were less woody (Stein and Owston, 1977). Experience of a major container producer is that survival rates of small container stock are superior to bare-root because of their root characteristics and physiological makeup. They are also able to combat planting shock considerably better during the establishment phase than are the larger and older bare-root seedlings (Hahn and Smith, 1983).

The most attractive feature for container stock is the closer physical and environmental control possible with a greenhouse than with outdoor nursery beds. Environmental conditions that regulate seedling growth are easily standardized and repeated resulting in more uniform seedling size and shape. This uniformity carries to the field, since container-grown seedlings are complete. Part of the root system is not left in the nursery bed during the lifting process.

Additional advantages of container-grown seedlings are as follows:

1. Maximize seedling return from genetically improved seed.
2. Ease of maintaining seed source identification for small lots.
3. Make up for production fall down in outdoor beds.
4. Produce seedlings on short notice.
5. Provide large stock for specialty purposes.
6. Some species do better in containers.
7. Reforest rocky, debris covered, and brushy sites.
8. Extend planting seasons.
9. Replace bare-root seedlings whenever cost per living surviving seedling is less or growth better.

Potential disadvantages of container stock when compared to bare-root stock are:

1. Higher production and transportation costs.
2. Small amount of potting mix is subject to rapid moisture and nutrient losses.
3. After outplanting, moisture stress may occur because of inadequate contact of roots with soil, or inadequate depth of roots after planting.
4. The generally smaller seedlings often are more subject to burial, overtopping by competing vegetation, and damage from animals or insects.
5. Higher potential for root binding or spiralling. Poor anchoring in the soil may cause problems after many years.
6. More subject to frost heaving, especially if planting dibble glazes soil.

Bare-root

Bare-root seedlings are lifted from outdoor nursery beds and shaken to remove the growing media from around their roots. Then, at the time of planting, the root system is again introduced to its growth environment. With some extremely unfavorable planting conditions, a paper towel and potting mix are wrapped around the root system prior to planting. In addition, some bare-root seedlings are produced in raised greenhouse beds.

Size and physiology of bare-root seedlings are controlled by the following five cultural techniques: irrigation, fertilization, seedbed density, transplanting, and undercutting and wrenching. Vigorous seedlings with high survival and good growth potential result with correct employment of nursery practices and poor field performance when they are mismanaged. Even date of sowing will influence seedling growth and development (Sorensen, 1978), and provenances may interact with treatments that change timing of growth. Seedling germination was found to vary with elevation and latitude of the seed (Campbell and Ritland, 1982), which may result in certain sources being lost to spring frosts. At the other extreme, outdoor nursery soil temperatures may become too high, even for a short period, for optimum seed germination. Genotype seedbed temperature interactions can occur (Wilson et. al., 1982), which limit genetic variation, since some families may be eliminated or within-family variation reduced.

Since different sources require varying amounts of cold exposure to stimulate capacity for root growth which in turn determines top growth, different provenances may not grow at their initial potential (Jenkinson, 1980). Overton and Ching (1978) found that nursery effect on field growth was present but not large, even though one nursery produced seedlings that were quicker to reach 30 inches in height. Even nursery spacing can influence field survival, which was better for seedlings grown at wide spacing (van der Driessche, 1982).

Survival, growth, and development are little different between container and bare-root seedlings (Stein and Owston, 1977). A direct comparison of seedlings from 100 half-sib cherrybark oak families planted as 1-0 bare-root and in two types of containers had the same height after three years in the field (Randall, 1973). First year survival was the same, but after three years bare-root seedlings and large container seedlings had better survival than seedlings produced in the smaller containers. A black walnut evaluation of bare-root 1-0 seedlings planted in large pots, a nursery, and two field locations gave no family environment interactions for one-year growth nor for one year's biomass (Bey, 1972). Hahn and Smith (1983) using a single commercial source of Douglas-fir seed found that stock type (bare-root of various ages and container seedlings) gave some growth difference depending upon aspect. However, very little survival difference was noted.

Bare-root nurseries are not as likely to change or modify the growth rhythm as are container nurseries, but the possibility of major loss is generally greater in an outdoor bare-root nursery than with a container facility. In addition to major loss, there are the small losses that change the genetic structure of a population or eliminate some of the within-family variability.

Vegetative Propagation

Vegetative propagation in United States forestry is generally limited to unrooted cuttings of cottonwoods for pulp and sawtimber, willows for streambank stabilization, and a few redwoods for timber in northern California. Rooted Douglas-fir orchard understock is planted in the Pacific Northwest, and Monterey pine understock is used in New Zealand. The Scandinavian countries plant some rooted spruce each year, and for centuries the Japanese have planted Cryptomeria. World-wide, the poplar species and their interspecific hybrids constitute the bulk of planting with vegetatively-propagated material.

Vegetative propagation is attractive because, once specific properties are identified, they can be multiplied without alternation and all future ramets possess the same qualities as the parent. For that reason, full broad-sense gain is available instead of the lesser gain obtained with narrow-sense heritability from sexually propagated material. This allows the tree breeder to capitalize fully on superior plants which owe their outstanding value to a specific combination of genes.

These unique characters with their impressive gains are not without problems. A decline in survival and growth rate often occurs when material is continually repropagated and advancing age of ortet limits ramet performance (Dunberg, 1977). Some relief from the problems of aging that result in vigor loss can be reversed but those resulting from maturation usually cannot be reversed by vegetative propagation (Brix and van der Driessche, 1977). Maturation necessitates that superior growth be recognized early so that chosen individuals can be vegetatively propagated since propagules from older trees do not root easily.

Douglas-fir cuttings and seedlings grew at the same rate (Copes, 1976), and for slash pine, a similar result was noted (Schultz, 1972). However, seedlings of some Japanese pine grew faster than cuttings (Toda and Isikawa, 1971). Seedlings were susceptible to insects and diseases while cuttings were resistant (Toda, 1974). Cuttings generally have an adequate root system, but, since root emergence is at right angles to the stem, the root system of cuttings may be a little shallower than that found for seedlings. However, long-term success with cuttings indicates that their root system is adequate and they are not overly sensitive to windthrow. Cuttings may be more sensitive to planting conditions than are seedlings (Kaszkurewicz, 1975).

Disadvantages of rooted cuttings are: (1) higher cost, (2) poor or inconsistent rooting potential for many species with all but very young parents, (3) inherent poor growth form for many years, (4) a possible decrease in growth potential with increase in parent age, and (5) a limited genetic variability which, apart from giving certain advantages, may result in increased biological risks to site adaptation, insects, and diseases.

Cuttings, when used for genetics tests have the major disadvantage that rooting ability is markedly influenced by age of the ortet, and somewhat influenced by position of the tree from where the cutting was taken. Generally success is limited to collection from parents that are no more than five to ten years of age. C effects (physiological or morphological characteristics unique to the ortet because of its specific environment may cause heritability estimates to be overestimated.

The major advantage of using vegetatively propagated material is that once superiority is identified it is easily incorporated into a reforestation program, there is no need to wait for seed production. A cutting garden (orchard) is easy to establish and may be much less expensive than producing stock from tissue culture (Foster et. al., 1981). For genentics studies, clonal material has the advantage of easy measurement of site differences and interaction of genotype with environment. Parent and progeny can be used in the same test which provides an additional measure of heritability.

Interactions

Changes resulting in the nursery that modify the growth habit, or produce a genetic change in the seedlot, or result in genotype times treatment interactions have major influence on genetic evaluation and predictions (Heide 1974, Campbell and Sorensen 1983, and Jahromi et. al., 1976). Progeny tests often evaluate quite diverse material and when some of the high elevation species are included they may not grow very large. To increase their size supplemental lighting is used. We must remember, however, that ecotypes have optimum photoperiods and long days in the greenhouse may not produce the best growth when later planted in the field (Heide, 1974). The effect of temperature and photoperiod may give erroneous conclusions since frost may kill certain provenances due to changes in time of flushing triggered by the extended photoperiod of the nursery.

The nursery environment can also change the genetic composition of a seedlot from that which would have been produced by nature at the planting site (Campbell and Sorensen, 1983). To minimize genetic changes use nursery practices that maximize tree percent and survival of seedlings after outplanting. Nursery spacing can influence field survival (van der Driessche, 1982) and seedling growth in the nursery bed is influenced by intergenotypic competition (Adams et. al., 1973). Amount and type of fertilizer also can produce interaction of genotype with fertilizer (Jahromi et. al., 1976).

Two final factors are length of stratification and date of sowing. Sowing under unusually low or high temperature probably will result in genetic changes as was observed in sorghum where certain genotypes germinate and emerge under high temperature (Wilson et. al., 1982). Probably the fluctuating temperature in outdoor nurseries extends the germination period longer than when germination is in a greenhouse. Since date of seedling emergence influences seedling growth rhythm the early germinating ones are larger and there will be greater variation in outdoor beds than in a container greenhouse. From that standpoint early measurements may not be as precise or as well correlated to later performance as occurs when seedlings are produced in a controlled environment.

Since progeny tests sample the range of environmental conditions found in the intended use zone, there probably will be genotype times site interactions. These interactions and stock type probably will not be as important at optimum planting sites as at the extremes (Alm et. al., 1982; and Hahn and Smith, 1983).

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PROGENY TESTING--NURSERY TECHNIQUES

David F. Van Haverbeke[1]

ABSTRACT

Quality seedlings for progeny testing can be produced bare-root or in containers. There is an increasing trend toward the latter for increased uniformity and acceleration of breeding programs, but at a greater cost. Sowing densities should be lighter than for operational seedings. Replication is recommended for progeny evaluations in the nursery. Nursery evaluations screen progenies prior to field establishment. There is little evidence of interaction between genotype and environment resulting from intensive cultural treatments. Careful attention to lifting, sorting, and packing insures maintenance of quality seedlings.

Key Words: Progeny testing, nursery, sowing, replication, culture, assessment, lifting, sorting, packing.

INTRODUCTION

Progeny testing is a necessary component of a successful tree improvement program. Progeny tests evaluate the breeding value of the selected trees, and create populations from which parents for the succeeding generation can be selected (Kellison and Lea 1983).

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Successful establishment of a progeny test requires quality seedlings, and quality seedlings require good seed. Seed quality is affected first by its genetic makeup and numerous environmental factors during seed development; and second by man-influenced factors such as time of cone and fruit collection, and technique of seed extraction, cleaning, sizing, storage, testing, and stratification. Comprehensive discussions of these latter aspects are contained in Seeds of Woody Plants in the United States (U.S. Dep. Agric. 1974). This presentation is limited to the nursery components of progeny testing: sowing; replication; culture; assessment; and lifting, sorting, and packing as related to bare-root-grown and container-grown seedlings.

Prior to the mid-1970's, most progeny tests were established with bare-root seedlings. With the development of containerized techniques for raising forest tree seedlings in the early 1970's, more progeny tests have been established with container-grown material. Plantable container-grown seedlings can be produced one or more years sooner than nursery-grown bare-root seedlings, thus shortening the time between generations for obtaining progeny test information. Although often more costly, the savings in time and seeds and the improved uniformity of seedlings have increased the popularity of container-grown planting stock.

REPLICATION

Bare-root-grown Seedlings

Replication permits estimation of the magnitude and significance of environmental variations (light, water, soil, protection) within and among nursery beds, and prevents loss of entire progeny families. Some researchers, however, question the importance and necessity of replicating progeny families in the nursery if pre-planting data are not to be taken. They suggest that differences among families in seedling size and quality, attributable to nursery effects, are diluted by selecting the best seedlings from each family during

sorting and packing. Furthermore, they believe that the small differences remaining as a result of nursery environmental differences are masked within three to four years of establishment in the field test (Kellison and Lea 1983). Also, some feel that the small efficiency gain in estimating genetic gain parameters resulting from replication is more than offset, especially in large tests, by the problems of recording and handling large numbers of entries.

Others contend that, even with the greatest care, some variability in growth conditions can be expected. They stress that some nursery-induced differences have been maintained for as long as 15 years, with a consequent decrease in experimental precision (Wright 1976).

In general, however, it is a good practice to replicate within the nursery to reduce the possibility of any one progeny family being lost or receiving preferential treatment prior to field planting. If the collection of nursery data is not planned, 3 or 4 replications of each progeny family should be adequate.

If data are to be collected during the nursery phase, a greater number of replications, at least for a portion of each progeny, is recommended. For example, in an 80-source ponderosa pine provenance study, 300 seeds from each of the sources were hand-sown across nursery beds in a 10-replicate randomized complete block design (Read 1980). Seedlings were subsequently thinned to 10 per replication, resulting in 8,000 seedlings in the experiment. These seedlings were used for a nursery evaluation of the sources.

Container-grown Seedlings

Variations in the greenhouse or shadehouse environment (sun, shade, humidity, air currents, edge effects) can influence the growth of containerized seedlings. Thus, replication is also recommended for container-grown materials, especially if pre-planting data are to be collected.

Replication of container-grown material is easier to handle logistically than bare-root material, because the seeds of a given family progeny are normally sown in movable units of cells that can be consolidated at time of transplanting or field planting. Frequent rotation or re-randomization of unreplicated containerized material is possible, and recommended, as a means of reducing environmentally induced effects.

The appropriate number of replications for an experiment depends on the degree of precision required. A statistician should recommend an experimental design. Six replications are currently advocated in nursery experiments; and it is desirable to maintain the integrity of these replications in the field. With an increasing trend toward earlier progeny evaluation, the effects of environmentally induced variation on seedling performance will become increasingly important. This strengthens the argument for replication during the seedling stage for both container- and bare-root-grown seedlings.

SOWING

Viability of the seed to be used in progeny tests is routinely measured, especially if the quantity of seed available is limited. When adequate quantities of seed are available, a common practice is to determine the percentage of sound seed, then sow twice or more the amount of seed required to produce a specified number of seedlings.

Bare-root-grown Seedlings

Seeds for progeny testing in nursery beds are often hand-sown or broadcast, but they may also be sown with templates or mechanized drills. Seed sizing, sometimes practiced in nurseries, permits precison sowing with mechanical seeders. Seed sizing tends to improve uniformity of seedling size and quality, and decreases experimental error (Kellison and Lea 1983). Sizing is of lesser importance when seeds are broadcast or hand-sown.

In addition to seed size uniformity, the quantity of seed available is also a determinant in the choice of sowing method; small lots of expensive seed are usually hand-sown. Campbell and Sorensen (1984) point out that all of the seeds of an original seedlot provide the optimum gene pool for adaptation to the future planting site, and that nursery procedures--especially seed grading, and to a lesser extent nursery location, stratification, sowing date, watering regime, lifting date, storage time, culling, and other scheduling--may have important influences on adaptation. They stress that nursery (and greenhouse) procedures that maximize tree percent (the percentage of seeds that germinate and develop into usable seedlings) and seedling survival will minimize losses of genes sampled in the original population.

Because uniformity and quality of seedlings are important in progeny testing, seeds should be sown at a uniform spacing, wide enough for the seedlings to grow without severe competition, until the time of field planting. This usually means a wider spacing than would be used in a commercial nursery for the same species. For example, densities of approximately 24 seedlings/ft^2 (270 seedlings/m^2) for conifers and 10 to 15 seedlings/ft^2 (108 to 162 seedlings/m^2) for hardwoods are targeted for production beds throughout the country.[2] Southern conifer and

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[2] Personal conversation with John Hinz, Nurseryman, Bessey Nursery, USFS, Halsey, Nebraska.

hardwood seeds sown for progeny testing, by comparison, are broadcast, drilled, or templated at densities of 6 to 12 seedlings/ft^2 (65 to 130 seedlings/m^2) (Kellison and Lea 1983). Less dense sowings also provide opportunity for seedlings from small seed to develop to comparable size and quality as seedlings from larger seed. Two procedures for sowing seeds, to produce bare-root seedlings, are detailed below.

A seed source test of eastern redcedar and Rocky Mountain juniper involved hand-sowing seed in six parallel rows 8 in. (20 cm) apart running the length of 400 ft. (122 m) nursery beds (Van Haverbeke, Sprackling, and Hovland 1982). Seeds were spaced 3/4 in. (2 cm) apart. Plastic markers were placed in the center of the bed, one at each end of each 6-row seed source lot, and set deep enough to allow mechanized equipment to pass over without dislodging them. Seed source numbers were inscribed on the markers with weatherproof pencil to insure maintenance of seed lot identification during the 2-year nursery period. A 12 in. (30 cm) divider space was left between seed lots to prevent the mixing of seed lots during root-pruning and lifting. Seeds were covered lightly with 1/4 in. (0.6 cm) of nursery soil and sprinkler irrigated. A map was drawn showing the location of each seed source and the length of seedbed it occupied. The sown beds were covered with plastic sheeting, and secured with lath frames for winter protection. The plastic sheeting was removed at the time of seed germination the next spring. The seedlings then received routine cultural treatments (temporary lath frame protection, irrigation, fertilization, cultivation, spraying, weeding, root-pruning, and others) during the 2-year nursery period.

Wright (1976) detailed a 9-step procedure for establishing outdoor nursery experiments. To establish a 100-seedlot, 20-tree-per-plot, 5-block experiment, he suggests the following procedure:

(1) Place the 100 seed containers in a row with 5 envelopes near each, inscribe the seedlot number on each envelope and place 20 (more if seed is variable in quality) sound seeds in each envelope.
(2) Place 1 envelope per seedlot in each of 5 piles (to become blocks 1-5) and randomize envelopes in each pile.
(3) With another color ink re-number the envelopes in each pile from 1 to 100.
(4) Prepare a nursery map placing blocks 1-5 in seedbeds 1-5, respectively, and including both sequence and seedlot number for each envelope.
(5) Prepare nursery stakes, including sequence and seedlot number on each.
(6) Carefully prepare nursery seedbeds and mark equidistant (exact distance to be obtained by a steel tape) crosswise rows.
(7) Place nursery stakes at ends of rows and make a final check against the nursery map.
(8) Distribute envelopes and plant seeds equidistant in rows, checking each envelope against nursery stake.
(9) Cover the seed.

Container-grown Seedlings

Cells are filled with a medium consisting of one or more of the following materials: sand, compost, peat, sphagnum moss, vermiculite, topsoil, or some synthetic material (Tinus and McDonald 1979). A frequently used mixture consists of equal parts sand, vermiculite or perlite, and peat moss. It is important that the medium retain moisture, provide nutrients, contain no harmful agents, and hold its form when seedlings are removed from the container. Mycorrhizal fungi are sometimes added to stimulate seedling development and/or inoculate the planting sites when the soils have low or no populations of mycorrhizal fungi (Riffle and Maronek 1982).

The filled cells are tamped, leaving a 1/4 to 1/2 in. (0.6 to 1.3 cm) depression in the medium at the top of the cell. One or more seeds are placed on top of the medium and can be covered with perlite.

Two techniques are frequently used to sow seeds in containerized operations. First, seeds of a progeny family may be hand-sown (broadcast or in rows) in flats, and the seedlings transplanted (pricked) into individual container cells. This technique insures that all cells are initially filled. Second, one to several seeds of the same progeny family may be sown by hand or with mechanized template devices into container cells and thinned to the one best seedling per cell after germination.

While containers vary widely in design and composition, they are of two general types: the biodegradable container that is planted with the seedling, and the non-plantable container from which the seedling is removed. It is either discarded after a single crop, or reused. Containers, regardless of type or design, have four primary functions: (1) provide a medium for support and nutrition of roots; (2) protect roots from mechanical damage and desiccation; (3) shape roots into a form advantageous to the tree; and (4) maximize field survival and early growth (Tinus and McDonald 1979).

Containers must be carefully labeled to prevent loss of identification when materials are moved in the greenhouse or consolidated for field planting.

CULTURE

There is a trend, both in outdoor nursery and container operations, to apply more intensive cultural treatments to the raising of progeny seedlings. Gain per unit of time is important in a breeding program, and there seems to be little indication that genotype x environment interactions exist, or are intensified as a result of cultural practices. There is no reason, however, to apply expensive cultural practices more frequently than needed to produce quality seedlings in a reasonable time.

Bare-root-grown Seedlings

Generally, techniques for raising nursery-grown bare-root progeny seedlings are similar in most regions of the nation, with adaptations to accomodate local climatic and soil conditions and species requirements (Stoeckeler and Jones 1957, Stoekeler and Slabaugh 1965, Williams and Hanks 1976).

In the South, the nursery bed soil is routinely fumigated with Dowfume MC-2[3] (98% methyl bromide and 2% chloropicrin at 400 lb/A); and a 10-10-10 fertilizer, at the rate of 500 lb/A, is incorporated into the soil prior to seeding (Kellison and Lea 1983). Additional nutrients are added during the nursery period as needed.

In the Midwest (Nebraska), a cover crop of sorghum, or other crop, is summer seeded, followed by oats (winter crop) sown in August and plowed under the following spring. Soil in the nursery beds is fumigated under plastic with Dowfume MC-2 (400 lb/A), a 0-46-0 fertilizer is applied, and the beds are leveled and sown with seed.[2] Care of progeny seedlings in the nursery, including watering, fertilizing, weed control, pesticide applications, root-pruning, and others should be at least comparable to that given to operational seedlings. Top-dressings of a 21-0-0, and 6-2-0 fertilizer (Milorganite) are applied periodically in some nurseries.

In some regions, transplanting within the nursery is required to produce plantable seedlings. Root-pruning is frequently practiced, because it promotes the development of a more compact root system and aids in lifting the seedlings.

Container-grown Seedlings

Raising seedlings in containers saves one year in the South and two years in some northern regions in establishing progeny tests.

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[3] The use of trade and company names is for the benefit of the reader and does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Temperature, humidity, water, nutrients, light, and CO_2 are regulated in many controlled greenhouse environments to produce quality seedlings in a minimum of time. Growing schedules and cultural practices have been developed to produce quality seedlings of many species in containers (Great Plains Agricultural Council 1974, Goodwin 1975, Tinus and McDonald 1979, Reese 1982).

Problems in raising container-grown seedlings arise mainly from limiting the growth of roots to a finite soil volume and achieving a desirable root-shoot ratio. It is usually necessary to apply fungicides regularly because high temperatures and relative humidities create ideal conditions for infection of seedlings by Fusarium, Pythium, Rhizoctonia, and other fungi (Kellison and Lea 1983).

Regular fertilization is necessary to provide needed nutrients not contained in many media, or to replenish nutrients that have leached out of others. Seedlings must be fertilized carefully to prevent salt burn from excessive applications in media that are poorly buffered. Bi-monthly applications of a weak Hoagland's Solution, Hyponex, or other fertilizer are suggested. Fertilizers can be applied in solution through watering systems or with agitated pump tank devices.

ASSESSMENT

Many economically important traits of forest trees are expensive to measure or require several to many years to evaluate. Thus, there is keen interest in the early evaluation of progenies to speed the rate of genetic gain (Goddard, Land, and Kossuth 1983). The measurement of juvenile traits which are related to characteristics of mature trees and measurement of different but correlated traits may be evaluated early in the progeny tests. Early progeny evaluation

is an active area of research, but relatively few indirect measurements have been widely accepted as reliable indicators of future performance. In the South, Walkinshaw, Dell, and Hubbard (1980) developed a system of classifying fusiform rust galls by origin and other characteristics on less than one-year-old inoculated slash (and loblolly) pine seedlings, traits which are highly correlated with later field performance. Waxler and van Buijtenen (1981) showed that shoot weight and shoot-root ratios of open-pollinated progenies of loblolly are significantly correlated with bole volumes of trees in field tests of the same progeny families.

Early testing procedures can be used for a preliminary screening of material in the nursery or greenhouse, thus reducing the number of trees (progenies) outplanted in the field, and for individual tree selection in an accelerated breeding program (Goddard, Land, and Kossuth 1983).

LIFTING, SORTING, AND PACKAGING

Bare-root-grown Seedlings

It is best to plant freshly lifted, dormant seedlings to achieve the most accurate expressions of survival and development among the progeny families. If seedlings are to be lifted in the fall and kept in cold storage over the winter for spring planting, it is essential that all of the families be dormant for the following reasons: (1) seedling survival is adversely affected by cold storage if lifted before dormancy is set; and (2) progeny families can be expected to vary in the time they set dormancy (Kellison and Lea 1983).

During lifting, sorting, and packing operations it is essential to maintain the identity of every seedling, even if several hundred families are involved. It is also essential to work quickly and carefully to insure that the seedlings do not suffer from prolonged exposure.

Wright (1976) outlined a systematic method for lifting, sorting, and packing seedlings from a replicated nursery expeiment to establish 4 plantations, each to include 100 seedlots, 5 trees per plot, and 4 blocks:

(1) Make a final check of the nursery stakes against the nursery map.
(2) Label (with seedlot number) 1 of every 5 trees in the seedbeds.
(3) Loosen all trees so that they may be pulled easily.
(4) Proceeding down one seedbed pulling 5 trees per seedlot (including a labeled one), tie the 5 seedlings in a bundle and keep the bundle moist.
(5) When all 100 five-tree bundles are ready, randomize them and pack them in a 500-tree bundle destined for block 1 in plantation 1.
(6) Repeat the process in seedbed 2 to obtain the stock for block 2 in plantation 1.
(7) Repeat the process in seedbeds 3 and 4.
(8) On the same or another day prepare the stock to plant blocks 1-4 in plantations 2-4.

Van Haverbeke, Sprackling, and Hovland (1982) machine-lifted Juniperus seedlings of more than 200 seed sources sown in a completely randomized design from outdoor nursery beds at 2 years of age for a 5-replication, 4-tree linear plot, 14-plantation seed source test. To prevent seed sources from becoming mixed, even though separated by a 12-in. (30 cm) isolation strip, one person walked closely behind the lifting machine to reposition the plastic seed source markers, since they sometimes popped out of the soil when the lifting blade passed beneath.

The seedlings of a given source were pulled, shaken lightly to remove excess soil from the roots, and placed into a large, plastic-lined kraft sack along with the plastic marker tag. The seed source number was written on the outside of the securely closed bag and the bag was immediately placed in a large walk-in refrigerator at $40^{\circ}F$ ($4^{\circ}C$). There the bags were reopened, the seedlings wetted with a fine water spray, the roots covered with damp sphagnum moss, and the bags reclosed and placed in numerical order on shelves in the refrigerator room.

With a 3- to 4-person crew, the lifting, sorting, and packing operation functioned in assembly-line fashion. This system reduces the time of outdoor exposure to seedlings after lifting, and provides constant humidity to the seedlings during sorting, and packing.

Container-grown Seedlings

Schedules similar to those for handling outdoor nursery stock, with adaptations, can be used for container-grown stock. The following systematic method, used by the author, proved entirely satisfactory in a recent experiment involving 200 control-pollinated Scotch pine progeny families planted at 3 locations in 5 replicates of single-tree plots:

(1) Each seedling was labelled while in its container cell.
(2) A field map was drafted for each planting, showing the intended position of each seedling.
(3) Seedlings were lifted individually from their replicated multi-cell frames.
(4) These newly loaded frames, containing seedlings arranged in field planting order, were transported to the field by truck and loaded onto the planting machine.
(5) The tagged seedlings were lifted from the frame cells and planted in sequence as the tractor proceeded along each row.
(6) After the planting, the positions of the seedlings were checked against the map and the tags were removed.

A variation of the above method that has also proved satisfactory involves lifting the labelled seedlings individually from their container-cells, wrapping the roots in a wet paper towel, and placing the seedlings in large boxes in planting sequence for transport to and planting in the field.

Transport of container-grown seedlings, because of the weight and bulkiness of the medium, is less convenient and more expensive than for compactly packed bare-root seedlings. Trucks or trailers with racks are frequently used to transport container-grown seedlings.

The seed sources were listed numerically, along with an indication of which seed sources each cooperator was to receive. Large wooden boxes, each labelled with the name of a cooperator, were placed alphabetically along a wall in the refrigerated room.

The bag (or bags) containing seedlings of one source was opened and the seedlings spread onto a sorting table. The seedlings were sorted into bunches of 20 seedlings for each cooperator receiving that source. The 20 seedlings were sub-divided into 5 groups (replications) of 4 seedlings each (4-tree plots). Each group of 4 seedlings was secured with a twistem, and one seedling in each 4-tree bundle was labelled by wrapping a strip of masking tape around the stem with the seed source number written on it with indelible ink. The 5 bundles of 4 seedlings each were tied into one bundle and placed in the appropriate cooperator's wooden box; a layer of damp sphagnum moss was placed over the roots. When the sorting of one seed source was completed, the entry on the distribution list was circled for each cooperator, another source opened, and the procedure repeated. To insure a continued supply of moisture to the seedlings, the bundles of seedlings in the wooden boxes were lightly sprayed with water at the end of the working day and covered with damp burlap bags.

After all seed sources had been labelled and sorted into the appropriate wooden boxes, they were packed in waterproof, lined cardboard mailing boxes. Seedlings were lightly moistened again by spraying water on their tops, and wet peat was placed on the roots before the boxes were stapled shut and banded. The seed sources contained in each box were listed on the outside of the box; the boxes were stored at $40^{\circ}F$ ($4^{\circ}C$) until they were shipped air freight to the cooperators.

The remaining seedlings were transplanted into the nurserybeds, to be distributed the next spring as 2+1 stock for replacement of seedlings that did not survive in the initial plantings.

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COMMENTS FROM A NURSERY MANAGER

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BACKGROUND

Tree Improvement programs across the nation are in various stages of development. The Southeastern area has been active for many years, seed orchards are established and producing seed for new plantations. In fact, it is my understanding that very little "wild seed" is now being collected. In some instances, improved seed is being used in third generation plantings. This can be contrasted with the west where fewer orchards have been established. The Dennie Ahl Douglas-fir, pseudotsuga taxifolia (poir) Britt, seed orchard in Washington State is the most publicized and plantations are being established using seed from this orchard. Western white pine, pinus monicola (Dougl) and sugar pine, pinus lamertiana, (Dougl) orchards are producing some seed but, there is nothing that compares with the South. In addition, numerous evaluation plantations have been established with orchard development following closely behind.

Many species are beginning to become part of the tree improvement program. In Southern Oregon, both east and west of the Cascade Mountains, new starts are beginning with lodgepole pine, pinus contorta, (Dougl); ponderosa pine, pinus ponderosa (Laws); white fir, abies concolor (Gord. and Glend.) Hooper; shasta red fir, abies magnifica var. shastensis (Lemm). I foresee additional starts with other species.

CONCERNS AND OPPORTUNITIES

Even though there is a lot of work being accomplished in tree improvement, there continue to be concerns about the program. Some of these concerns surfaced during an August, Rogue River National Forest tree improvement familiarization and evaluation trip and others have surfaced through experiences I and others have had with the program. Today, I want to share some of them with you.

CONCERN I

Is tree improvement cost effective? This question has been tossed around a great deal. Most agree that in the long term, it will be cost effective. However, some feel that the up front costs for tree selection, cone collection, seed extraction, seedling production with individual tree tagging orchard development in the form of clearing, grubbing, fencing, staking, planting, measuring, etc. are excessive. Until something is developed that illustrates what the projected long term gains are in relation to the costs incurred, there will continue to be concerns coupled with guarded optimism.

OPPORTUNITY I

Develop a computer model that vividly illustrates the magnitude, cost effectiveness, growth projections, FTE (Full Time Equivalents) and equipment needs in the out years. This model must be simple enough to allow personnel who are only minimally familiar with the program to understand it.

CONCERN II

This concern is related to costs and is the high, some say unlimited tree improvement, funding levels that are occurring during the time of severe austerity in other programs. It is extremely difficult to explain and justify the funding imbalances to employees in the resource areas of recreation, wildlife, range, etc.

OPPORTUNITY II

Two opportunities are present here, one is the previously mentioned Opportunity I and the other is assignment of specific targets for the tree improvement activity.

CONCERN III

Coupled with the apparent funding/spending inequities is the question of FTE's. "Hard targets" receive attention, whether it is timber cut and sold, acres planted, or stands thinned, the unit manager does his/her utmost to meet them. After all, these targets are related and tied to performance standards and accomplishment, documented in the performance evaluation. In direct contrast is the apparent lack of "hard targets" for tree improvement. When an FTE crunch is felt, the areas that are measured and evaluated in the performance interview will receive the most emphasis.

OPPORTUNITY III

Will be satisfied by Opportunity II, Part 2.

CONCERN IV

Lack of line involvement in the tree improvement project. I visualize this as being a problem from the W.O. down to where the work is accomplished on the ground. Without line involvement in the program, it is difficult to obtain committment. Without committment, there is resistence and with resistence, accomplishment suffers and is usually less than desired.

OPPORTUNITY IV

Develop a plan that will force line involvement, such as encouraging line to be a part of planning and the decision processes.

CONCERN V

Future projections of fiber/timber production are based on the assumption that future intensive management will proceed without interruption. This includes the presumption that growth will be increased, rotations will be reduced by improved management techniques, which include tree improvement. I am skeptical that all parts of the puzzle will fall into place. I base this on the current delays in timber harvest caused by timber sale extensions, the economy, curtailment of the use of herbicides caused by protests, reluctance to use fertilizers and lack of funds for timber stand improvement. I am hopeful that our future timber/fiber production predictions are conservative enough to keep us from inadvertently misleading future generations.

OPPORTUNITY V

The opportunity I see here will be answered partially by Opportunity I. Another opportunity is the Land Management Planning effort that we are now involved with. The opportunity is to make adjustments in future projections and base these projections on historical data that has been gathered. I however, see some pitfalls as many on these teams are struggling with yield tables that are a part of calculating pre-commercial and commerical entries and harvest schedules of future crops. These folks are finding it difficult to develop accurate meaningful tables that are supportable with factual data.

CONCERN VI

There seemingly is a stumbling block that prevents good information flow between the tree improvement specialist and the nursery specialist. I am not sure whether this information flow is hampered by lack of trust or lack of recognition for the professionalism that both possess. I don't have enough confidence to say that the problem is real or imagined.

Tree improvement specialists have a tendency to expect nursery services, failing to realize that even though we like to be a part of the tree improvement, our major program is production stock. Finally, we both fail to visualize that ultimately, seed orchards will be producing most seed for production stock.

OPPORTUNITY VI

There is a definite need to discuss and set down plans well in advance of any activity. This will ensure written documentation of what is expected of each party and should alleviate conflicts and misunderstandings.

I see another opportunity and that is the number of nursery specialists being invited to and asked to participate in this national meeting. There are other opportunities that are occurring in my home region, Region Six, where nursery personnel began attending and participating in regional tree improvement sessions in 1982 and will continue to be involved in future sessions.

CONCERN VII

A better planning effort is needed for tree improvement activities. I see seedlings being produced in advance of evaluation and orchard sites being established, necessitating holding over bareroot stock from 2-0 to 3-0 and transplanting container seedlings.

OPPORTUNITY VII

Better planning would certainly help. The plan must be closely coordinated to ensure that seedlings are produced when they are needed. With FTE constraints/reductions and emphasis being placed on contracting work, contingency plans must be built in to allow for defaults, problems with weather, slowdowns in timber removal and impacts from other programs such as the Jobs Bill.

Contract Growing Progeny Test Seedlings

by

Peter A. Theisen, Regional Geneticist

Region 6

November 1, 1983

In the Region 6 (R-6) tree improvement program, private and government nurseries are used to produce bareroot and container grown seedlings for progeny tests. All of the progeny test seedlings for breeding zones in which we cooperate with others (83 breeding zones) are grown under contract either at private or Forest Service, R-6, nurseries. When the seedlings are grown at private nurseries the Forest Service enters into a contract with the private nursery to grow the stock. When the seedlings are grown at a Forest Service nursery the cooperators enter into a contract with the Forest Service to grow the stock.

Nursery services at both private and Forest Service nurseries include the growing of the trees, placing an individual identification tag on each seedling, packaging the seedlings in the test design to be used in the progeny test, and the identification of each container of seedlings to the set and replication in which the seedlings in the container will be planted.

With one exception all of our contract growing at non Forest Service nurseries has involved nurseries in which one or more of our cooperation in a breeding zone has a financial interest. Therefore, the managers of these nurseries have had a vested interest in the production of quality stock properly identified, packed, stored, and shipped. We have had excellent results from these nurseries. The one exception involved a private bareroot nursery with a good reputation for the production of general forestation stock. However, it produced marginal stock for progeny testing due to nursery cultural practices. This particular nursery also had marginal tree storage management which could have resulted in very low survival in the field if the Forest Service had not taken prompt action on a weekend to correct the situation. I am not eager to repeat this episode.

All of our memorandums of understandings for cooperative tree improvement programs include the following clause except the identity of the cooperators may change.

"Seed to be sown for evaluation plantations and seedling seed orchards will be furnished by the parties to a mutually acceptable nursery having the capability to produce seedlings under satisfactorily controlled conditions. BN, DNR, and the SERVICE will negotiate the cultural nursery services as a mutual effort to assure uniform production. Each party will be responsible for its costs of growing seedlings, and will assume

risks of loss through causes beyond its control for production losses. A separate procurement document will be executed between the SERVICE and the nursery producing seedlings from the SERVICE seed for evaluation plantations or seed orchards prior to transfer of SERVICE seed to said nursery."

To implement this clause in the memorandum of understanding, the Region has developed a sole source justification statement for the production of seedlings for progeny testing (Appendix 1). Appendix 2 is a copy of a contract for the growing of container seedlings for progeny testing.

When the Forest Service, R-6, grows progeny test stock for other cooperators a separate memorandum of understanding is executed. Refer to Appendix 3 for a sample memorandum of understanding for this purpose.

In our cooperative programs over 1.6 MM high quality seedlings have been produced in non Forest Service nurseries for 220 progeny test sites. The one marginal nursery produced about 30,000 seedlings for one breeding zone.

Progeny test seedlings for breeding zones in which we do not have cooperators are grown at R-6 nurseries. Our experience in growing test seedlings in R-6 production nurseries has been varied but overall guite good. When a nursery first becomes involved in the growing of progeny test seedlings a great deal of attention must be devoted to proper communication between the genetics people and the nursery manager to insure that both understand each other, the type of product to be produced, and the responsibilities of each person.

Frequent trips to contract and in-service nurseries growing progeny test seedlings by the involved genetics people are recommended. The purpose of these trips should be to further the understanding between the parties involved and to identify and correct any developing problems that may compromise the use of the seedlings for progeny testing.

APPENDIX 1

June 20, 1980

Justification Statement for Sole Source Seedling Production for Evaluation Plantations.

The Region has entered into a number of tree improvement cooperatives with other Governmental agencies and private companies. Each cooperator performs and pays for their porportional share of the cooperative work on their own lands based on the amount of acres of commercial forest land they have in the cooperative. The type of work involved in these cooperatives is tree selection, establishment of evaluation plantations of progeny from the selected trees, and in some seed orchard development.

This cooperative approach not only reduces total cost of tree improvement to each cooperator, but enables each cooperator to have a broad sampling of the gene pool in the cooperative area (breeding zone). This broad sampling of the gene pool in a breeding zone is needed to locate the good performing trees and to provide ample genetic variation for tree breeding programs. A cooperator has no assurances that the good performing trees will be located on his land or on other lands. If they are on other lands he will be able to obtain forest reproductive material from these trees.

In order to determine which are the good performing trees it is necessary to evaluate the selected trees by planting their progeny in evaluation plantations. Each cooperator plants progeny from all the selected trees in a breeeding zone in each evaluation plantation assigned to him as part of the cooperative effort. These plantations are laid out following a design that will give the genetic information needed (to an acceptable degree of statistical accuracy) to identify the good performers and the trees that will be useful in a breeding program. The location and parentage of each seedling in the plantations is carefully maintained.

The seedlings to be used in evaluation plantations must be produced under as uniform as possible conditions in the same nursery in order to avoid unquantifiable nursery influences that will affect the performance of the seedlings in the evaluation plantations. Nursery influences which cannot be accounted for in the statistical analysis of data collected from the evaluation plantations reduces statistical accuracy and could severely impair the usefulness of the plantations.

The nursery that produces the seedlings for evaluation plantations must be capable of maintaining the identity of each seedling and at time of packing tag each seedling and arrange the seedlings in a predetermined design to facilitate planting in the evaluation plantations. Few nurseries are willing or able to perform these very specialized services.

In addition to the nursery factors mentioned above, it is necessary to consider the ability of a nursery to produce acceptable seedlings for survival and growth in the plantaitons after planting.

To cover the nursery items, the cooperators agree to produce seedlings for evaluation plantations in a competent nursery mutually agreed upon by the cooperators. The nursery costs are shared by the cooperators and each cooperator's share is proportionate to the amount of his seed sown for the production of seedlings for the evaluation plantations.

Peter A Theisen

PETER A. THEISEN
Regional Geneticist
Timber Management

SOLICITATION, OFFER AND AWARD | 3. CERTIFIED FOR NATIONAL DEFENSE UNDER DPS REG. 1 AND/OR DMS REG. 1 RATING | 4 PAGE 1 OF 13

1 CONTRACT (Proc. Inst. Ident.) NO	2. SOLICITATION NO	5 DATE ISSUED	6 REQUISITION/PURCHASE REQUEST NO
53-05K3-1-04528a	R6-3-81-21s ☐ ADVERTISED (IFB) ☒ NEGOTIATED (RFP)		

7 ISSUED BY CODE
U. S. DEPARTMENT OF AGRICULTURE
GIFFORD PINCHOT NATIONAL FOREST
500 West 12th Street
Vancouver, WA 98660

8 ADDRESS OFFER TO (If other than block 7)
GIFFORD PINCHOT NATIONAL FOREST
Attn: Contracting Officer
500 West 12th Street
Vancouver, WA 98660

F.S. R-6
RECEIVED
JAN 19 1981
TIMBER MANAGEMENT

In advertised procurement "offer" and "offeror" shall be construed to mean "bid" and "bidder"

SOLICITATION

9. Sealed offers in original and 0 copies for furnishing the supplies or services in the Schedule will be received at the place specified in block 8, or IF HAND CARRIED, shall be delivered to Contracting, Room 145, 1st Floor Fed. Bldg. until _____ on _____, local time at place of bid opening. If this is an advertised solicitation, offers will be publically opened at that time. CAUTION-LATE OFFERS. See Par. 7 and 8 of Solicitation Instructions and Conditions.
All offers are subject to the following:

1. The Solicitation Instructions and Conditions, SF 33-A, (1/78) edition which is attached or incorporated herein by reference.
2. The General Provisions, 6300-38 (1/80) edition, which is attached or incorporated herein by reference.
3. The Schedule included herein and/or attached hereto.
4. Such other provisions, representations, certifications, and specifications as are attached or incorporated herein by reference. *(Attachments are listed in schedule.)*

FOR INFORMATION CALL (Name & telephone no.) (No collect calls) ▶ Contracting Officer (206) 696-7537

SCHEDULE

10 ITEM NO.	11 SUPPLIES/SERVICES	12 QUANTITY	13 UNIT	14 UNIT PRICE	15 AMOUNT
	GROWING CONTAINERIZED TREE SEEDLINGS See pages 7 through 8 Continuation Sheet, SF-36, for list of attachments and schedule of bid items. Bidder agrees to perform in accordance with all of the terms and conditions of this invitation incorporated as listed on page 7, SF-36, Continuation Sheet. Failure to return Pages 1 through 8 may result in a nonresponsive bid.				

OFFER *(pages 2 and 3 must also be fully completed by offeror)*

In compliance with the above, the undersigned agrees, if this offer is accepted within * calendar days *(60 calendar days unless a different period is inserted by the offeror)* from the date for receipt of offers specified above, to furnish any or all items upon which prices are offered at the price set opposite each item, delivered at the designated point(s), within the time specified in the schedule. *Less than 30 days - offer will be nonresponsive

17. OFFEROR CODE	FACILITY CODE	18 NAME AND TITLE OF PERSON AUTHORIZED TO SIGN OFFER (Type or print)	
NAME AND ADDRESS (Street, city, county, State and ZIP code): Industrial Forestry Association, 225 SW Broadway, Room 400, Portland, OR 97205			
AREA CODE AND TELEPHONE NO ▶		19 SIGNATURE	20 OFFER DATE
☐ Check if remittance address is different from above — enter such address in Schedule			

AWARD *(To be completed by Government)*

21 ACCEPTED AS TO ITEMS NUMBERED	22 AMOUNT	23 ACCOUNTING AND APPROPRIATION DATA	
1 and 2	$9,060.00	2041	
24 SUBMIT INVOICES (4 copies unless otherwise specified) TO ADDRESS SHOWN IN BLOCK 8		25 NEGOTIATED PURSUANT TO	☐ 10 U.S.C. 2304(a)( ) ☒ 41 U.S.C. 252(c)(10)
26 ADMINISTERED BY (If other than block 7) CODE		27 PAYMENT WILL BE MADE BY CODE	U. S. DEPARTMENT OF AGRICULTURE GIFFORD PINCHOT NATIONAL FOREST 500 West 12th Street Vancouver, WA 98660
28 NAME OF CONTRACTING OFFICER (Type or print)		29. UNITED STATES OF AMERICA	30 AWARD DATE
Aaron R. Brown		BY (Signature of contracting officer)	

Award will be made on this form, or on Standard Form 26, or by other official written notice

Standard Form 33 Page 1 (REV. 3-77)
Prescribed by GSA, FPR (41 CFR) 1-16.101

STANDARD FORM 36, JULY 1966 GENERAL SERVICES ADMINISTRATION FED. PROC. REG. (41 CFR) 1-16.101	CONTINUATION SHEET	REF. NO. OF DOC. BEING CONT'D. R6-3-81-21s	PAGE 7 OF 13

NAME OF OFFEROR OR CONTRACTOR

ITEM NO.	SUPPLIES/SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT

PART I - LIST OF ATTACHMENTS

The following attachments hereto form a part of this solicitation for offers and any resultant contract.

Solicitation, Offer and Award, SF-33 (3/77), Pages 1 through 3

Supplemental Representative and Certifications and Acknowledgements to SF-33, Page 4

Solicitation Instructions and Conditions, SF-33A (1/78), Pages 5 and 6

Continuation Sheets, SF-36, Part I - List of Attachments, Page 7

Part II - Schedule of Items, Page 8

Specifications - Division 100 - General Specifications, Pages 10 and 11
Division 200 - Technical Specifications, Pages 12 through 13
Division 300 - Inspection and Acceptance, Page 14
Division 400 - Measurement and Payment, Page 14

Forest Service General and Labor Standards Provisions, Form 6300-38 (1/80)

Supplemental Provisions for to 6300-38

Instructions to Contractors, Form AD-425a (7/74)

STANDARD FORM 36, JULY 1966 GENERAL SERVICES ADMINISTRATION FED. PROC. REG. (41 CFR) 1-16.101	CONTINUATION SHEET	REF. NO. OF DOC. BEING CONT'D. R6-3-81-21s	PAGE 8 OF 13

NAME OF OFFEROR OR CONTRACTOR

ITEM NO.	SUPPLIES/SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	PART II - SCHEDULE OF ITEMS Furnish all labor, supervision, equipment, seedling containers, and other incidental materials and peform all work necessary to grow seedlings, using Government-furnished seed, in compliance with the terms, specifications, conditions, and provisions herein.				
	Name / Seed Lot No.	M		$/M	
1	Year-One, Mid-Columbia Cooperative / 205-03032-SB, 205-03033-SB	30		$282	$8,460.00
2	Year-Two / 205-03032-SB, 205-03033-SB	6		$100	$600.00
	TOTAL CONTRACT AMOUNT				$9,060.00
	Location of Contractor's nursery where seedlings will be grown: Industrial Forestry Association Tree Improvement Laboratory (Name) 135 Nisqually cut-off road SE (Street Address) Olympia, WA 98503 (City, State, Zip Code) 206/491-6920 (Telephone No.)				

DIVISION 100 - GENERAL SPECIFICATIONS

110 - Scope of Contract

111 Furnish all labor, supervision, equipment, seedling containers, and other incidental materials and perform all work necesary to grow seedlings, using Government-furnished seed, in compliance with the terms, specifications, conditions, and provisions herein.

120 - Production and Pick-up Schedule and/or Delivery Schedule

121 30M Douglas-fir seedlings produced are planned to be used in the spring of 1982, February through May planting season. 6M seedlings will be grown a second year in a bare root nursery bed.

122 The Contractor shall provide the Government with an estimated inventory of live Douglas-fir seedlings as of October 1, 1981 and an estimated inventory of shippable seedlings as of January 15, 1982.

123 Forest Service will provide the contractor with a tentative shipping schedule for Douglas-fir seedlings prior to January 15, 1982.

124 The Forest Service will pick up the seedlings at the IFA Nursery and will deliver the seedlings to the evaluation plantations.

130 - Government-furnished Property

The Government shall deliver to the Contractor the following listed materials, supplies, property or services (hereinafter referred to as "Government-furnished property") at the places and times specified above. The Contractor shall be liable for all loss or damage of such delivered Government-furnished property until completion and final acceptance of work required under this contract. If the Government fails to make timely delivery of such Government-furnished property suitable for its intended use, and upon written request from the Contractor, the Contracting Officer shall make an equitable adjustment of contract time, delivery or performance dates or contract price, or both, pursuant to the "Changes" clause of the General Provisions of this contract.

131 The Forest Service will supply tree seed at Forest Service expense to the Contractor's place of business. The tree seed will be packaged and identified by parent tree number. Seed will be furnished by January 15, 1981.

DIVISION 100 - GENERAL SPECIFICATIONS (Continued)

130 - Government-furnished Property (Continued)

132 The Forest Service will provide to the contractor an inventory list of seed lots which are delivered to the contractor by January 15, 1981.

DIVISION 200 - TECHNICAL SPECIFICATIONS

210 - Growing Media

211 Any standard combination of peat and vermiculite may be used provided it will hold together when the seedling is pulled from the container and remain intact during shipping and the normal handling of planting operations.

220 - Seed Lot Identification

221 All seed lots will be handled and labeled so that parent tree identity will be maintained.

230 - Seedling Containers

231 Douglas-fir seedlings shall be grown in supercell containers for one year.

240 - Sowing

241 Seed lots will be stratified by contractor in "sausage" plastic containers which are soaked in water and then placed in cold storage. Seed lots shall maintain parent tree identify throughout this stratification process.

242 After statification, 2-3 Douglas-fir seeds shall be sown by hand into the supercell containers. The supercell trays shall be labeled by parent tree number.

250 - Care of Trees

251 Douglas-fir seedlings shall be hand-thinned to one tree per supercell.

252 The seedlings shall be labeled with a parent tree identification number when the side branchs are large enough to hold the label.

DIVISION 200 - TECHNICAL SPECIFICATIONS (Continued)

250 - Care of Trees (Continued)

253 The Contractor shall provide heat, water, fertilizer, insecticides, fungicides and photo period as needed to assure that healthy seedlings meeting minimum acceptable conditions are produced by February 1, 1982.

254 The induction of dormancy (hardening-off process) shall be started in a timely manner which will result in seedling dormancy at time of delivery.

260 - Minimum Acceptable Conditions

A. A terminal bud must be evident.

B. All acceptable seedlings must be alive, healthy and free of any disease, chlorosis, or mechanical damage. When diseases are present in the nursery and the seedlings are to be put into cold storage, the seedlings will be given a fungicidal treatment ten days before delivery to the Government, if determined necessary by pathologist.

C. When delivered, only one seedling per cavity will be permitted.

D. Root elongation from bottom of containers will be restricted by growing seedlings in a manner which will provide air-pruning of roots. Roots extending outside of container shall be cut prior to packaging.

E. The root plug will fill at least 90 percent of container length.

F. The plug formed by the roots and growing media must remain intact when pulled out of the cavity and must be firm enough to remain intact during shipping and handling associated with the tree planting operation.

G. The plug formed by the root and growing media will be moist and the foliage shall not have any free water.

H. Seedlings shall not be so spindly that they are unable to support themselves in an upright position.

DIVISION 200 - TECHNICAL SPECIFICATIONS (Continued)

270 - Preparation for Shipping

271 The seedlings shall be packed in cardboard boxes which are labeled by cooperator, breeding unit, evaluation plantation site, set and replication.

272 Within each box, 30 parent trees will be presented four times. Each group of 30 parent trees will be placed in plastic bags to keep the four groups separated within the box. Each parent tree shall be represented once in each of the four plastic bags.

273 Seedlings will be handled in a careful manner during packing to avoid tearing the parent tree number off the seedlings.

280 - Records

281 The contractor shall provide to the Forest Service a list of parent tree numbers by breeding unit of trees which have been packed for shipment.

282 The Contractor shall currently maintain and provide the Forest Service upon request with a record by date listing the cultural work undertaken for this contract. Records shall include dates of stratifications, sowing, fertilization, fungicide treatment, watering, additional photo period, induction of dormancy and any other work performed.

290 - Nursery Test for Growth

291 6M of the Gifford Pinchot's Douglas-fir seedlings will be grown together with seedlings from the other cooperators in a randomized and replicated experimental design. They will be grown in this design for one year in the supercell containers inside a greenhouse. In the spring of 1982, they will be hand-transplanted to a bare root nursery bed, maintaining the experimental design. They will remain in the nursery bed until they are lifted in late fall of 1982.

DIVISION 300 - INSPECTION AND ACCEPTANCE

310 Inspection and Tests

311 Periodic inspections based on a minimum of 1/2 of 1% sample of the total stock will be made and documented by the Government to insure compliance with contract terms and specifications. Deficiencies noted at such inspection shall be promptly corrected. Final inspection and acceptance will be made at time of delivery.

312 The COR or his Inspector may accompany the Contractor during his tabulation of the inventories.

320 Acceptance

The Goverment will accept 100% of the contract quantity of seedlings produced that meet all contract requirements.

DIVISION 400 - MEASUREMENT AND PAYMENT

410 The Government will pay the full contract price for all seedlings delivered up to 100% of the contract quantity which meet all contract specifications.

420 Any reusable seedling containers and cardboard boxes will remain the property of the Contractor and will be returned prepaid by the Forest Service to the delivery point.

430 Invoices for payment(s) will be prepared by the Govenment, based on the number of seedlings accepted by the Government. Each invoice will be signed by the Contractor and COR prior to processing for payment.

APPENDIX 3

Memorandum of Understanding

Between

U. S. Department of Interior, Bureau of Land Management

Diamond International Corporation

Gilchrist Timber Company

and

U. S. Department of Agriculture, Forest Service, Region 6

to

Grow Tree Improvement seedlings at the Forest Service Bend Nursery

For

The Central Oregon Tree Improvement Cooperative

This Agreement is entered into by and between Diamond International Corporation, hereinafter referred to as DIAMOND, acting by and through Vice President, Oregon Lumber Division; United States Department of the Interior, Bureau of Land Management, hereinafter referred to as the BUREAU, acting by and through the State Director of Oregon under authority of the Public Land Policy and Management Act of 1976, P.L. 94-579, Stat. 2766-43 U.S.C. 1737; Gilchrist Timber Company, hereinafter referred to as GILCHRIST, acting by and through the President, Gilchrist Timber Company; and the United States Department of Agriculture, Forest Service, hereinafter referred to as the SERVICE, acting by and through the Regional Forester, Pacific Northwest Region, under authority of the Granger-Thye Act 64 Stat. 82, as amended, 16 U.S.C. 490 and Section 601, Act of June 30, 1932, 31 U.S.C. 686.

WHEREAS, Section B3 of the Memorandum of Understanding between U.S. Department of Interior, BLM; Diamond International Corporation, Gilchrist Timber Company, Warm Springs Confederated Tribes, and U.S. Department of Agriculture effective December 5, 1980, provides for the production of seedlings for the evaluation plantations in Central Oregon Tree Improvement Cooperative at a mutually acceptable nursery.

WHEREAS, it is necessary to grow these seedlings in a nursery as close to the cooperative area as practical to avoid to the extent possible nursery environment interactions that could result in the loss of genetically desirable seedlings or the compromising of these seedlings so that they do not perform well in the field.

WHEREAS, DIAMOND, BUREAU, GILCHRIST, and the SERVICE wish to produce bare root 2-0 seedlings for breeding zones 108-01035 and 108-01025 for use in evaluation plantations on their lands in the Cooperative area.

WHEREAS, the SERVICE's Bend Nursery is located in the Cooperative area and is the most suitable nursery for growing these seedlings based on photoperiodic and temperature regime environments at the nursery and the planting sites.

WHEREAS, the growing of these seedlings at the Bend Nursery will be mutually beneficial to DIAMOND, BUREAU, GILCHRIST, and the SERVICE.

A. Now, therefore, in consideration of the above premises, the SERVICE hereto agrees to grow the seedlings at the Bend Nursery using a replicated sowing design and spacing mutually agreed upon by the parties to the Agreement and cultural nursery practices that will assure uniform production and to identify, lift, and package the seedlings for outplanting in evaluation plantations in accordance with evaluation plantation design.

B. It is mutually agreed and understood by and between the said parties that:

1. DIAMOND, and GILCHRIST shall make deposits in advance for the estimated annual cost of performing work on their behalf. Additional deposits will be made in advance when needed as requested by the SERVICE prior to performance of work.

2. The BUREAU shall make semiannual progress payments to the SERVICE for the actual cost of doing work on their behalf.

3. The SERVICE will estimate the annual cost of work to be performed on a fiscal year basis, October 1 through September 30, and shall maintain records documenting the type and cost of work performed. These records shall be made available to the other parties to this Agreement upon request. Annual costs will be proportioned between the parties to this Agreement based on the number of seedlings scheduled to be produced for them and an adjustment will be made after the end of the fiscal year based on the actual costs incurred.

4. The SERVICE will advise DIAMOND, BUREAU, and GILCHRIST of the expected costs for each fiscal year prior to incurring costs for that year.

5. Funds received in advance from DIAMOND and GILCHRIST shall be deposited by the SERVICE in a cooperative work account which will be charged for performance of work on their behalf. Funds received as progress payments from the BUREAU shall be deposited to the account charged for performance of work on behalf of the BUREAU.

6. Nothing herein shall be construed as obligating the SERVICE or BUREAU to expend or as involving the United States in any contract or other obligation for payment of money in excess of appropriations authorized by law and administratively allocated for this work.

7. No member of, or Delegate to Congress, or Resident Commissioner shall be admitted at any share or part of this agreement, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this agreement if made with a corporation for its general benefit.

8. No party to this agreement shall be liable to the other for any loss, damage, personal injury, or death occurring in consequence of the performance of this agreement, except for negligent acts of either party, thier agents, or their employees.

9. Any party to this agreement may terminate their portion of the agreement by providing 90 days written notice. The entire agreement will terminate when the seedlings are received by each cooperator and final adjustments in cost of producing the seedlings are made.

10. In WITNESS WHEREOF, the parties hereto have executed this agreement as of the last date written below.

Date	Vice President Oregon Lumber Division Diamond International Corporation
Date	State Director Bureau of Land Management
Date	President Gilchrist Timber Company
Date	Forest Supervisor Deschutes National Forest

NURSERY TECHNIQUES FOR THE PRODUCTION OF TREE IMPROVEMENT STOCK IN REGION ONE

JOSEPH F. MYERS
COEUR D'ALENE NURSERY
USDA, FOREST SERVICE
COEUR D'ALENE, ID

In the past five and one-half years the Coeur d'Alene Nursery has produced approximately 400 M western white pine, 150 M lodgepole pine, and 220 M western larch for use in various field test designs for the Inland Empire Tree Improvement Cooperative. This year the nursery will grow an additional 90 M western white pine and 60 M Douglas-fir for use in Tree Improvement programs. Under the direction of a Tree Improvement technician, stationed at the nursery, nursery personnel extract and clean the Forest Service portion of the Tree Improvement seed.

In recent years nursery personnel have also been involved in transplanting container stock to bareroot beds along with subsequent transplanting to the Lone Mountain Seed Orchard site. We are in the second year of a pilot test program to look at the feasibility of rooting Douglas-fir cuttings on a semi-operational scale for use in the Region-1 Tree Improvement program.

CONES

The process all starts with the selection and subsequent collection of open-pollinated cones from candidate trees. The nursery's involvement starts with the receipt of the cones. Tree Improvement cones arrive at the nursery in a wide variety of containers and ways. I have seen cones arrive packed in everything from plastic GSA sandwich bags to paper bags to burlap bags to plastic mesh bags. The method of transporting cones varies from UPS to 18-wheel flatbeds to the Tree Improvement technician's truck. Herein lies a big variable which has a significant impact on seed use and subsequent seedling yields. The lack of consistent and careful handling prior to interim storage and extraction at the nursery has resulted in the complete loss of families or the production of insufficient numbers of individuals to be included in many of the tests.

If the cones are labeled properly, they will have a Region-1 Tree Improvement Cone Collection tag tied with string around the top of a mesh or burlap bag. A duplicate tag is enclosed with the cones. These tags will remain with the lot through the entire extraction and cleaning process. The pertinent information on the tag will be transcribed to the outside of the seed envelope prior to storage and recorded on data sheets for subsequent entry in the computer.

SEED STORAGE

Tree Improvement seed is currently stored in a manila envelope placed in a file-like cabinet in a seed storage freezer room maintained at 0° F. This leads to another area of concern. Since the seed is not maintained in an airtight (more important, watertight) container, the seed is subjected to changes in moisture content.

SEED RECORDS

All Tree Improvement seed records are maintained in the computer at Washington State University. Data entry and processing is handled through the Executive Director of the Inland Empire Tree Improvement Cooperative.

NURSERY GROWING

Once the genetists agree on the design for a particular experiment -- this can take some time -- the nursery is solicited for input on length of time to stratify the seed, number of seeds to sow per tube, amount of oversow necessary to produce the desired number of seedlings, and how the nursery would like to grow the seedlings. Based on this information, a computer list is generated of the seedlots to be included in the test.

a. Stratification

Seed is withdrawn from the storage cabinets and the necessary quantity of seed is weighed out. Two labels are prepared at this time. One label is on a soft aluminum tag; the other is written on a plastic tag with a grease pencil. The plastic tag is enclosed inside the 4" x 4" mesh bag and the soft aluminum tag is attached to the outside. The seed is soaked for 48 hours in running tap water before being placed in the stratification room. Stratification time varies from three weeks to 100 days, depending on species.

b. Facility

Seedlings are grown under accelerated conditions in a greenhouse equipped with complete environmental controls. The greenhouses are a quonset design covered with two layers of six mil polyethelene plastic. The greenhouses are equipped with pad and fan cooling, gas fired unit heaters, photoperiod cyclic lighting, and carbon dioxide generators. Tree Improvement has priority on two 30' x 96' greenhouses in our 15 greenhouse complex. This gives them the ability to grow in the neighborhood of 700 M seedlings per year (assuming pine cells with two crops per year). We are usually able to custom fit the environment to the species and in some cases the elevation. We have determined that the environment is sufficiently uniform in the greenhouse that seedlots are simply sown in numerical order.

c. Sowing

After stratification is completed the seed is taken to the greenhouses for sowing. Most of the Tree Improvement stock produced at Coeur d'Alene has been grown in Ray Leach pine or super cells. The Ray Leach container system consists of a hard plastic rack containing 200 (pine cell) or 98 (super cell) individual soft plastic tubes. The advantage of this system is the seedlings may be handled and labeled on an individual basis without concern of physiological or morphological damage to the seedlings. This has proven particularly advantageous with Region-1's program, which has included numerous studies requiring production of test stock for single tree plantations. At the time of sowing the seedlot numbers are checked against a computer printout. The tag attached to the outside of the bag is attached to the seedling tray. The tag from inside the bag is placed in the first tube of the seedlot. From a nursery standpoint, it is always more convenient to work in multiples of 200 trees in pine cells or 98 trees in super cells. When this does not fit the needs of the experiment, more elaborate labeling systems must be conceived. Most of the Tree Improvement sowings are done by hand. This means two, three, four or more seeds are placed on top of the growing media in the tube. Since seed is withdrawn from storage on a weight basis, it is usually unnecessary to remove excess seed placed in any one tube. The seed is then covered with perlite and placed on a greenhouse bench.

d. Thinning

After germination is complete (two to four weeks after sowing), the trays are thinned to one seedling per tube by pulling excess seedlings from the tube with forceps. The thinning crew is instructed to leave the healthiest seedling located toward the center of the tube. No attempt is made to transplant excess seedlings to blank tubes.

e. Randomization

Many of our tests in Region-1 have involved single tree plots. Based on the results of a seedling inventory, custom numbered plastic tags are ordered for insertion into the individual tubes. Computer generated lists assign varying numbers of individuals to the replications in the various plantations. The families are distributed to the replications by each member of the crew pushing a standard grocery shopping cart containing one family at a time. Each person receives a computer slip with each family, showing how many and where tree seedlings are to be placed. The replications of the plantations are set up in aisles and the individually numbered seedlings are placed in the appropriate replication.

f. Inoculation

This activity is associated with the western white pine - blister rust resistant screening project. A shadehouse at the nursery is converted to an inoculation chamber. The walls and roof of the shadehouse are covered with sheets of plastic and canvas tarps.

Infected Ribes leaves are evenly spread on chicken wire screens suspended 18" above the seedlings in the chamber. The leaves are covered with a 1-mil layer of plastic. By using mist nozzles and the irrigation system, temperatures are maintained at 55 to 70° F. and 100% RH. As a consequence of problems encountered in obtaining sufficient quantity and quality of infected Ribes leaves, a Ribes garden was planted at the nursery's Lone Mountain Seed Orchard site. The garden was established in the spring of 1983 with approximately 450 plants. In September, 1983, 5,000 Ribes leaves were collected from the garden. Spore cast of 3,000 spores per square centimeter was achieved within 14 hours of the start of inoculation. This was a far cry from the six days required to reach the minimum acceptable spore cast of 600 spores per square centimater on the previous year's test. The chamber is left in place one day following removal of inoculum to provide optimum conditions for infection.

COST

Cost of custom growing Tree Improvement stock is computed on a project basis. For comparison purposes, Tree Improvement stock has cost from $250 to $350 per thousand trees produced. Normal production reforestation stock costs $145 per thousand for pine cells and $254 per thousand for super cells. Tree Improvement activities incorporated in the nursery's budget have amounted to 8 to 10% of the total direct costs. This translates into approximately $200,000 for the current Fiscal Year.

TRANSPLANTING

Progeny from the inoculation screening test are dibble planted in the fall into prepared nursery beds. Three replications are planted in numerical order by family number. The first three cycles were planted in family row plots. Currently, we are dibble planting at a 4" spacing in a block design. The change was made to facilitate rust inspections. Both layouts allow for the use of standard nursery equipment and practices.

FIELD TEST AND EARLY GROWTH TEST

Irrigation lines are laid at 35' intervals with 18" risers every 20' to provide overlapping, even coverage. This is the nursery's standard section configuration. The seedlings are planted in rows, and tiers on 1 1/2' x 1 1/2' intervals. Trees are dibble planted and mapped twice to insure proper identification of seedlings. Seedlings with illegible numbers are recorded as filler stock. Permanent markers are established every seventh row and tier (approximately 2%) to insure easy identification. Border stock is planted around the perimeter and on either side of the irrigation pipeline. The design of this test has caused several problems. There is no way to use any of the nursery's motorized equipment in this area. As a consequence, all operations, including weeding and fertilization, must be performed by hand.

ASSESSING

With western white pine, needle spots are counted in June and September of the year following transplanting. Canker and spot counts are made in successive Septembers until final selections for seed orchard materials are made.

SHIPPING

Once the seedlings have completed the necessary growing period, they are moved to a shadehouse-hold facility until the test site is ready for planting. The racks of tubed seedlings are packed in boxes. The outside of the box is labeled with the plantation name and the replication number. Border and demonstration stock is also appropriately labeled.

CONTRACT GROWING

The Region has had very little experience on contract growing Tree Improvement stock. Currently, one other member of the Cooperative (Potlatch Corporation) is growing some western white pine for field tests, and Douglas-fir for progeny tests. Their price has been on a par with the Forest Service Nursery costs. The Cooperative is also having some of the Douglas-fir in the early selection trials (nursery tests) grown at a private nursery.

The Coeur d'Alene Nursery is a very active participant in the Tree Improvement program for Region-1 and the Inland Empire Tree Improvement Cooperative.

Nursery Techniques
Chico Tree Improvement Center
Chico, California
Pacific Southwest Region, R-5

Gaylord K. Parks
Zone Geneticist
Central Zone
November 28, 1983

GENERAL

Progeny test stock for the PSW Region's tree improvement program is program is produced at the Chico Tree Improvement Center (CTIC). CTIC is also the center for the region's seed orchards and vegetative propagation.

The CTIC is located on the eastern edge of the Sacramento Valley midway between Sacramento and Redding. Average annual rainfall is 27" primarily from November to March. Summer daytime temperatures generally exceed 95^0 F and frequently exceed 100^0 F., Humidities are often from 15 - 20%. Minimum temperatures can drop to 24^0 F but normally are above 32^0 F.

Growing facilities consist of two small greenhouses and a shade house. Currently the capacity is 200M containerized seedlings and 40-50M 3 gal pots.

GROWING FACILITIES

The old greenhouse is an aluminum and glass even span gable greenhouse with a fully automated heating and cooling system. The heating is provided by three gas fired heaters and cooling by a fan and pad system very similar to a swamp cooler. These are controlled by a Wadsworth step controller which provides for seven different stepts in the heating and cooling of the greenhouse.

The new greenhouse is a fiberglass convered Quonset Greenhouse with roll up sides for cooling and natural air ventilation. A mist system is installed for additional cooling and to increase the humidity along with a gas fired heater to maintain a temperature range between 60^0 F and 90^0 F. This greenhouse has the capability to extend the daylength with cyclic lighting for the growing of true firs. We are able to force some of our grafting rootstock during the winter months when it is normally empty.

The shade house is completely inclosed in shade cloth to provide shading and a physical barrier to birds and some insects. One half is under 30% shading for the growing of the more sun loving plants, i.e., ponderosa pine, and the other half is under 47% shade for the true firs and other shade loving plants. The shadehouse also has a mist system and cyclic lighting.

Four foot by eight foot steel tables with expended metal are used to raise the progeny test seedlings 9" above the floor to enhance air pruning of the bottom roots and to help prevent the spread of diseases.

An Anderson ratio feeder allows us to inject our fertilizer into the irrigation water. It has an injection ratio of 1:950 for each of four injectors and the capacity for two more. This allows us to vary the fertilizer regime very quickly for the different growing facilities, and we can range from twenty gallons per minute up to one hundred GPM with the accuracy required.

Misting through out the growing facilities is an air-injected mist system, Herrmidifier Mist System. This air injected mist system allows us to increase the humidity without excessive free moisture on the plants. Losses due to root rot caused by too wet a soil is reduced with this system.

TYPE OF MATERIAL

The CTIC produces container seedlings for progeny testing and some reforestation. The Leach Super Cell, 10 cu. in. with 98 cells in a 12 in. x 24 in. tray is used for the progeny. Treetainers, 10 cu. in. with 144 cells in a 12 in. x 24 in. tray, are used for reforestation. The growing medium is a mixture of fine peat and fine vermiculite (Forestry Mix) with a PH of 4.5, phosphorus fertilizer is added.

NURSERY DESIGN

Four replications are sown for each family. Each replication is a full tray of 98 cells, the fourth replication is used for borders around the three randomized complete blocks. After germination is complete, the three primary replications are evaluated and empty tubes are replaced with filled tubes from the border trays. At this time tree tags are placed in each cell denoting the family identity and the trays placed in the shade house in an RCB design.

IDENTITY CONTROL

An accuracy level of 100% is attempted by always having two people checking to ensure family integrity from the time of tree selection, seed collection, sowing and outplanting. Any questionable identities are discarded.

The superior tree number is the identity used throughout the process from collection of cones through sowing, planting and progeny evaluation. General, local and control cross seedlings are given coded identities to reduce space, the code relates to the seed lot for ease in identification.

Seed is received by CTIC identified by tree number, breeding zone and seed zone and plastic tags are written for stratification and placed with the seed in cloth seed bags for naked stratification. At the time of sowing, all tags and seed are checked with the inventory sheet and signed out to a 2 - 4 person sowing crew. Two people on the sowing crew double check all tags before sowing. Only one lot is ever handled by a crew at a time with complete cleanup between lots. Pre-written plastic tags are placed in the four corners of a tray at the time of sowing. After a family is consolidated, plastic tags printed with the tree number or code is inserted in each cell where it remains until planted.

SPECIAL CULTURAL PRACTICES

Seedling production is divided into eight stages from sowing to winter maintenance. The general difference being fertilizer regimes of varying amounts of N. P & K to match the stages of growth. See Table 1.

Photo period control is not used for ponderosa pine or Douglas-fir due to length of the growing season, March 1 to December 15, but is used for

sugar pine, red fir and white fir. Seedling density, 49 per ft^2, requires forcing bud set when the seedlings are 4 - 6 weeks from reaching the targeted height growth in late August. If allowed to continue growth the seedlings will be tall and spindling due to the density and limited rooting zone.

This year, we removed the shade cloth when the seedlings had reached 50 - 60% of their targeted height. The seedlings then grew under full sun for the rest of the growing season. Two objectives were obtained: 1) eliminating the water stressing to induce bud set and some of the problems that to along with it; i.e. root die back and re-wetting of the peat. And 2) increased branching, bud formation and needle retention along the entire length of the stem.

ASSESSMENTS MADE IN NURSERY

Nursery assessments are by family for speed of germination, extent of secondary needles and degree of bud set. Speed of germination is reflective of seed quality and can enable the greenhouse manager to determine which seed lots to resow if necessary. Other assessments are made if easily determined, i.e. number of albinos, early height growth, etc..

Extent of secondary needles and bud set are generally closely related, but not always. Early secondary needle formation is pp has been found to be strongly related to seed zone.

After sorting, epicotyl length and diameter below the cotyledons are measured for family evaluations.

HARDENING - OFF

The trays are returned to the shade hourse by plantation and block after sorting for final hardening off. In the holding area, irrigation and fertilization continues at Stage VIII. Just prior to storage, the containers are irrigated, fertilized and fungicide applied to reduce molds.

COLD STORAGE

The trays with seedlings are boxed in special wax boxes, shipped to cold storage units and stored at 32^{o} - 33^{o} F until planting. Each box is labeled with plantation, block and rep.

When storing: 1) assemble all boxes for a plantation and, 2) place the last plantation to be planted in first and the first plantation to be planted in last. Monitor moisture content of the growing medium to prevent drying out, no problems have been encountered with five months storage.

TABLE I

C T I C

Container production

Seedlings B. Boom 11/81

Stage I Sowing to Seed Coat shed
(90% of seed coats have fallen off)

Duration:	15 to 20 days (April)
Fertilizer:	None
Temperature:	Night 70^0 F, Day 80^0 F.

Preventive fungicide schedule only
Sow March 10 through April 30 depending on species.

Stage II Seedling establishment - root growth

Duration:	14 days (May)
Fertilizer:	N,P,K of 50ppm: 44ppm: 82ppm: FE 5ppm
Temperature:	Night 70^0 F Day 80^0 F

Preventive fungicide schedule

Stage III Accelerated height growth
to 50% of targeted height growth (7-10)

Duration:	5 - 8 weeks (June - July)
Fertilizer:	N,P,K - 200:88:164ppm
Temperature:	Night 70^0 F Day 80^0 F

Stage IV Height - Caliper Growth

Duration:	4 weeks (to August 15)
Fertilizer:	N,P,K - 100:88:164ppm
Temperature:	Night 70^0 F Day 85^0F

Stage V Bud set induction

Duration:	2 - 3 weeks (around September 5th)
Fertilizer:	None
Temperature:	Night 60^0 F Day 80^0 F

Preventive fungicide schedule for Botrytis
Water flush for three hours.
Then water stress to -15ps; pre dawn reading
(or photo period shorting to 10 hr day)

Stage VI Final Bud set induction

Duration:	2 - 4 weeks
Fertilizer:	N,P,K of 10:22:40ppm
Temperature:	Night 55^0 - 60^0 F Day 75^0 - 80^0 F.

Normal watering schedule
Preventive fungicide schedule

Stage VII Caliper Growth

Duration:	4 weeks
Fertilizer:	N,P,K 50:88:164 Re at 5ppm
Temperature:	Night 65^0 F Day 80^0 F

Preventive fungicide schedule

Stage VIII Winter maintenance

Duration:	Until March 1
Fertilizer:	N,P,K of 50:44:82ppm
Temperature:	Night Min. 30^0 F Day 60^0 F

Before seedlings are to be placed into cold storage they are given a shot of fungicide for rootrots and Botrytis and a shot of fertilizer at 100 ppm N, 88 ppm P, and 164 ppm K just prior to cold storage. With the Iron Fertilizer, you can use the 5 ppm constant feed or use 18 ppm once a week.

We feed fertilizer into every irrigation when fertilizing.

SORTING GENETIC STOCK INTO TRAYS IN THE NURSERY

Sorting is done in the headhouse after the growth period is complete and prior to cold storage (Mid - October to mid - December). The sorting process involves selection and placement of test stock in their proper locations in trays for subsequent cold storage and then out planting.

Placement of stock into trays is guided by the "Tray coordinate Index". This work sheet shows coordinate locations of each family by rep and block. Families are listed in numerical order beside their tray coordinates. (Fig. 1.)

The physical setup is illustrated in Fig. 2. The four nursery blocks and trays of each family are placed together just outside the headhouse and families are arranged in numerical order. Families are brought into the headhouse and processed in assembly line fashion one at a time. One area of the headhouse is set up for pulling the better trees of the family group (selection phase) and placing them in 1 - gal. pots for distribution to the second area of the headhouse where trays are loaded. (Placement phase).

In the "selection phase", 1 - Gal. pots labelled by block and rep (i.e. 1A) are set on a cart in an arrangement that corresponds with that of the "placement phase" set up. Each pot receives two trees for each plantation. The best trees (based on stem caliper and bad development) are put in pots for the first blocks of Reps A and B. The lesser quality trees end up in the last blocks of Rep C. This stratification was chosen to create more uniformity within blocks and because Rep C will be removed in thinning.

The physical setup in the "placement phase" consists of three long rows of trays on tables. Rows represent Reps A, B, and C trays. Each tray is labelled by its unique block rep, and plantation with an identity tag at coordinate 1-1. Thus Block 1, Rep A would have four trays in a linear group representing four different plantations. The pot placed at that station would then contain eight trees. Two trees would be placed in each tray using the Tray Input Coordinates Work-sheet. The same two coordinate locations would be used in each plantation tray for a given family for that block rep. Once a family has been processed for all blocks, reps, and plantation trays, another family is processed. When all families of a set have been placed, every cell in every tray is filled and the "check phase" begins.

The "check phase" involves physically checking the location of each tree against the "BY Rep" map to make sure no mistakes were made in loading families into trays. Since all plantations are the same within a given rep-block, this phase is expedited. One person reads aloud family numbers from the "By rep" map while others check the tags in the trays. Any mistakes are corrected at this time.

Next is the "measurement phase". Usually, twenty-four individuals of each family are measured for epicotyl length for the four plantations for Block 1 of all three reps. Data is recorded on the "By Rep" map sheets. These data form the basis for: a) evaluation nursery performance of families, and b) tracking specific individuals from nursery through field performance.

The sorting process is most efficiently done with thirteen people although twelve is adequate. One set can be completed in one day with fourteen people. Our best arrangement was: 1) selection phase - 4 people, 2 per family (work 2 families but maintain numerical sequence 2) distributing loaded pots, collecting empty pots and arranging pots on carts 2 people; 3) placement phase - 6 people, 2 for Rep A, 2 for Rep B, and 2 for Rep C. The "check" and "measurement" phases require about 2 hours to complete when working with two crews of five people each (one map reader plus one person per plantation).

Occasionally, it is necessary to use control lots to replace test families when test families have insufficient members for all trays. When this occurs, revisions must be made on the computer before outplanting so that an accurate map is available for outplanting.

Figure 1.
TRAY INPUT COORDINATES

1980 NURSERY PROGENY

SPECIES PP
BZ 3
SET 4

PLANTATION 11
BLOCK 3

FAMILY	REP A		REP B		REP C	
	Col-Row	Col-Row	Col-Row	Col-Row	Col-Row	Col-Row
3001	5-5	5-6	10-1	14-7	13-5	3-7
3003	9-6	5-7	14-1	6-4	14-1	2-5
3004	7-1	14-5	11-4	1-6	3-2	13-2
3005	5-2	6-5	6-3	12-3	7-1	8-6
3007	8-4	1-7	14-3	9-5	13-6	7-7
3008	10-4	9-5	2-4	4-4	8-2	6-4
3031	2-4	5-4	11-5	12-6	8-3	9-4
3035	2-1	14-2	1-1	12-7	10-4	7-5
3043	11-1	3-2	2-2	4-5	11-1	10-7
3046	2-3	4-6	6-1	12-4	13-1	5-4
3049	14-1	3-6	11-1	4-6	9-6	11-7
3062	9-4	12-7	5-1	5-7	2-2	2-6
3064	13-5	7-7	12-2	1-3	4-5	3-6
3085	4-5	11-6	3-3	2-5	14-3	12-7
3091	1-1	4-3	8-1	8-5	6-5	14-6
3095	2-7	6-7	5-4	8-6	8-1	14-2
3098	6-3	10-6	4-2	3-4	3-3	5-5
3174	11-2	12-5	2-1	9-6	4-1	1-4
3186	8-1	12-4	11-3	10-4	6-2	1-5
3189	12-2	11-7	6-7	1-7	12-1	14-4
3230	12-3	7-4	4-1	6-6	10-1	6-6
3232	9-2	6-6	9-4	12-5	9-1	14-5
3304	6-4	1-5	7-3	1-5	7-3	11-5
3308	11-3	11-4	12-1	5-3	10-6	12-6
3312	13-1	7-2	10-2	10-7	12-3	2-4
3314	5-1	9-3	8-4	10-6	5-7	9-7
3316	8-5	13-7	13-3	6-5	13-3	4-4
3319	12-1	1-6	11-2	7-5	2-1	2-3
3321	9-1	12-6	9-2	2-6	8-5	1-6
3323	2-2	14-7	5-2	14-5	3-1	3-5
3342	3-4	10-5	10-3	11-6	1-2	10-3
3347	5-3	10-3	1-2	3-2	5-1	5-6
3350	10-1	4-2	13-2	4-7	7-2	11-3
3356	7-5	11-5	3-1	6-2	9-5	4-6
3357	4-1	6-1	10-5	14-6	12-2	6-3
3363	1-4	4-4	9-1	8-3	1-3	8-7
3393	13-2	8-7	13-5	9-3	7-4	6-7
3397	4-7	9-7	3-7	13-7	13-7	14-7
3398	14-4	2-6	14-4	9-7	13-4	3-4
3403	8-2	13-6	7-2	7-7	10-2	8-4
3305	2-5	7-6	2-7	11-7	10-5	1-7
3307	3-3	14-6	7-1	1-4	4-2	12-5
3309	10-2	1-3	4-3	8-7	6-1	2-7
3415	1-2	8-3	8-2	13-4	1-1	11-2
3419	3-1	5-5	2-3	5-6	4-3	12-4
CC 705	8-6	3-7	5-5	13-6	5-3	9-3
CC 809	13-3	13-4	13-1	3-5	9-2	4-7
G 531	6-2	10-7	14-2	7-6	5-2	11-4
L	7-3	14-3	7-4	3-6		

Fig. 2. Physical layout for sorting genetic test stock.

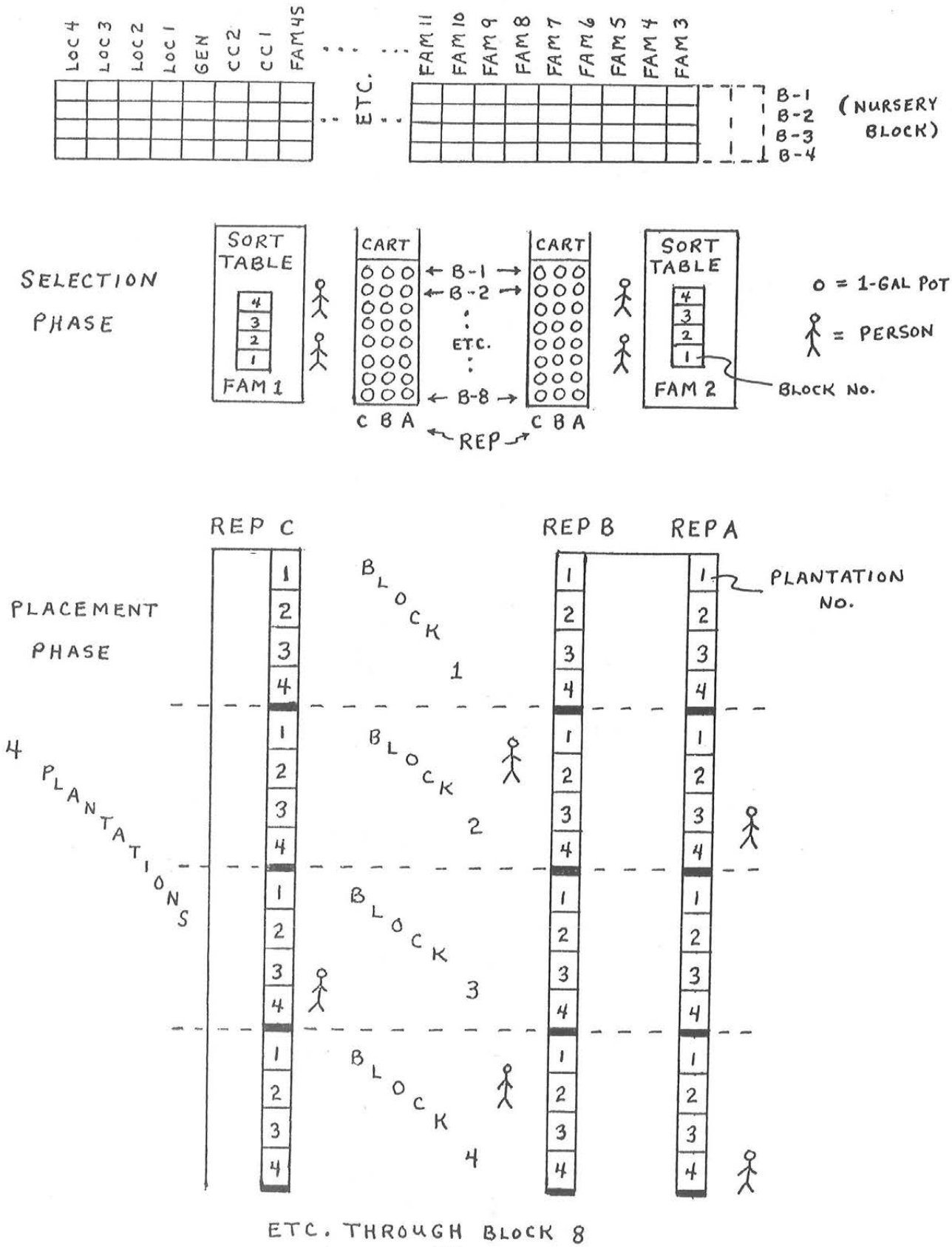
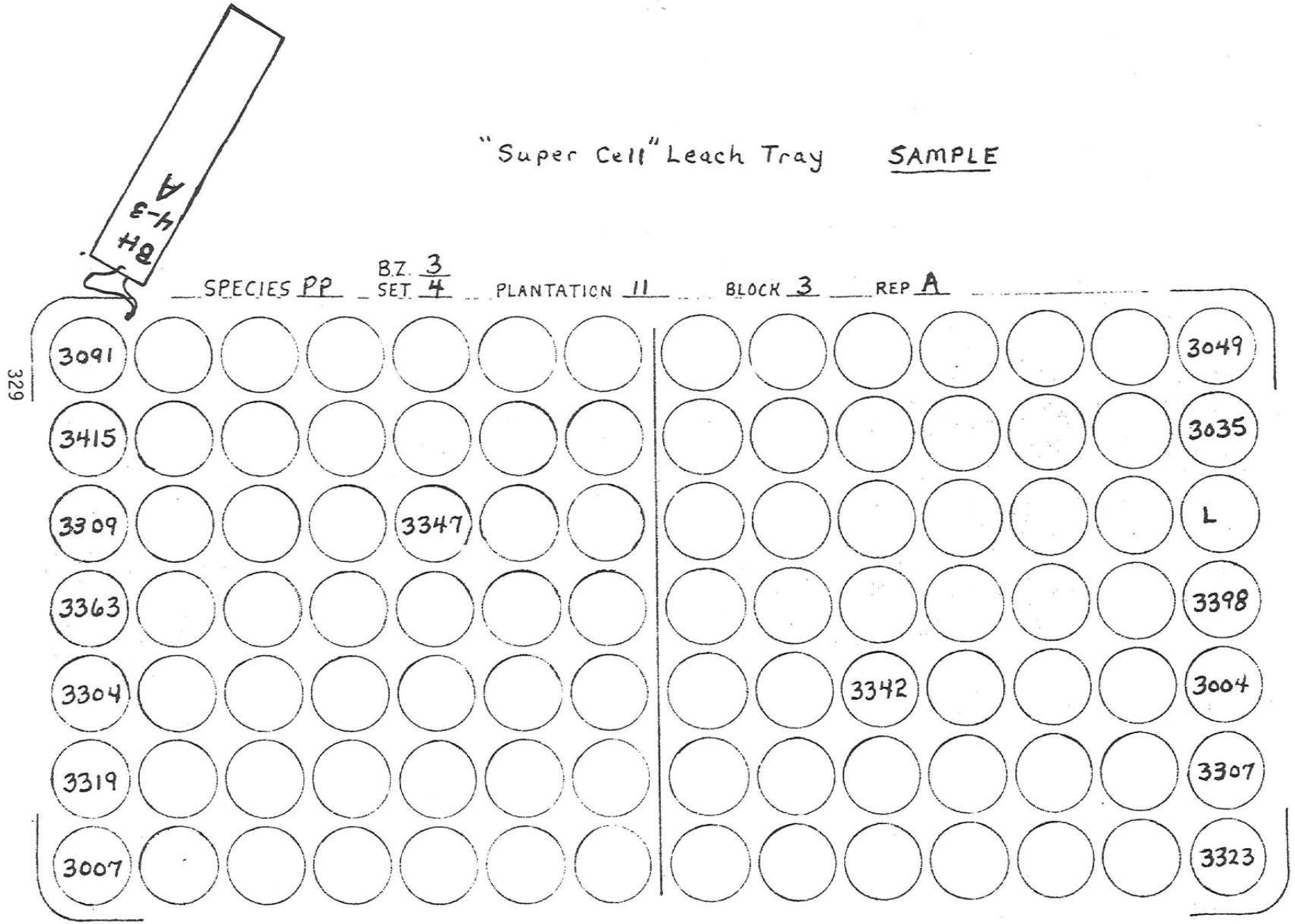


FIGURE 3.


"Super Cell" Leach Tray SAMPLE
BH 4-3 A
SPECIES PP
B.Z. 3
SET 4
PLANTATION 11
BLOCK 3
REP A
329
3091
3415
3309
3347
3363
3304
3319
3007
3049
3035
L
3398
3342
3004
3307
3323

PROGENY TESTING - NURSERY PRACTICES
USFS, REGION 6

Jim Hamlin

Introduction

Region 6 National Forests are presently involved in or plan for progeny testing in 225 breeding zones (Theisen 1983). Eleven of the 19 National Forests are involved in one or more cooperative tree improvement programs with other cooperators. The principal species involved are Douglas-fir, western white pine, ponderosa pine, sugar pine, noble fir, lodgepole pine, western larch, and western hemlock. The U.S. Forest Service and cooperators are currently growing approximately 550,000 progeny per year for placement into evaluation plantations.

Nursery Practices

Stocktype

A variety of stocktypes are grown dependent on the species and outplanting site conditions. The westside Forests (western Oregon and Washington--Figure 1) have been predominately engaged in the growing of Douglas-fir, noble fir, and western hemlock for progeny testing. The majority of the stock has been grown at three container nurseries. The majority of any transplant stock has been grown at three different bare root nurseries. The seedling materials used on the westside are as follows:

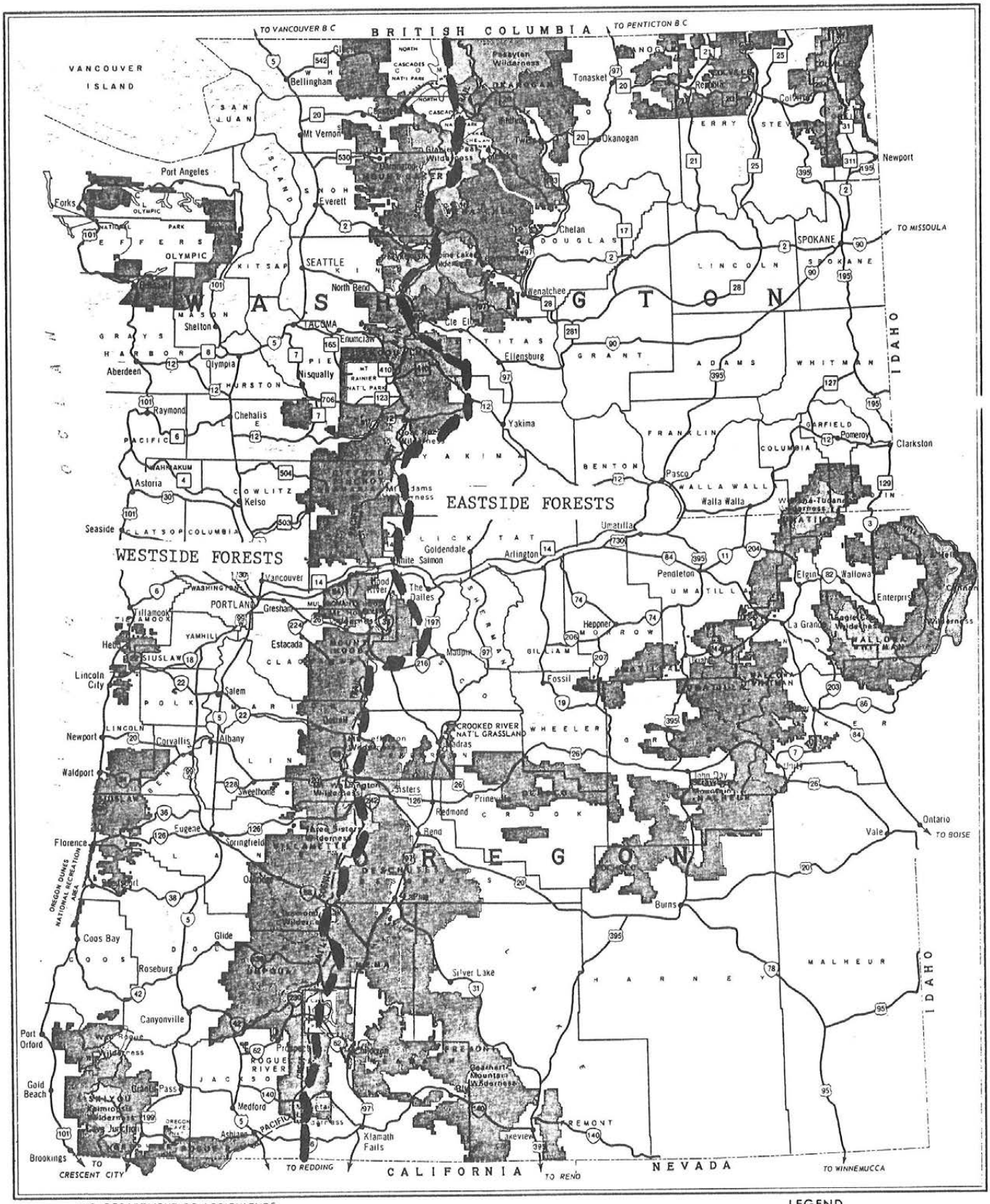
A. (1) Douglas-fir; Western Hemlock - Majority of progeny test material is container stock and is grown for 1 year in 10 cubic inch superleach tubes.

(2) This seedling material also has been transplanted into bare root nurseries and has gone into the field as plug +1 stock.

(3) A third type of material being grown is a plug +1 seedling which is grown in a styro-2 (2 cubic inch cell) block and then is transplanted into a bare root nursery bed the second year.

B. (1) Noble fir - The Industrial Forestry Association Nursery (Olympia, Washington) grows a plug +1 noble fir seedling. It is grown for 1 year in a styro-2 (2 cubic inch cell) block, and is transplanted into a D-pot (28 cubic inch container) for the second year.

The eastside Forests (eastern Oregon and Washington--Figure 1) to date have predominately been growing ponderosa pine and lodgepole pine for progeny testing. The majority of this stock has been grown for central Oregon progeny tests. This material goes into the field as 2-0 bare root stock.



U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Scale in Miles

LEGEND

- U S HIGHWAY
- INTERSTATE HIGHWAY
- OREGON STATE HIGHWAY
- WASHINGTON STATE HIGHWAY
- NATIONAL FOREST
- COUNTY LINE
- NATIONAL FOREST WILDERNESS
- PACIFIC CREST NAT'L SCENIC TRAIL

Figure 1. -- NATIONAL FORESTS
of
PACIFIC NORTHWEST REGION

Contract Growing

The majority of our progeny tests are planned as a cooperative venture. Therefore, the type of material to be grown and the specific nursery or nurseries are agreed upon.

The cooperators have had excellent success with the various contract growers. In general, the various nurseries have produced excellent quality seedlings. The main problems that the USFS has encountered in contracting to non-USFS nurseries is in the accounting procedures (e.g., payment schedule).

A more comprehensive review of contract growing is given by Theisen (in this proceedings).

Nursery Design

In the container nurseries, the seedlings are grown in family blocks. The family blocks are not replicated in the nursery. The family blocks, however, are moved around in the nursery in a systematic manner throughout the growing season. This periodic rearrangement has the effect of reducing nursery environmental variance (Snedecor 1957). The family blocks are grown together with families of the same breeding zone if more than one breeding zone is represented in the container nursery.

If container stock is to be transplanted, the material is generally transplanted into family blocks with no replication. The main reason for this is due to the logistics of handling replications in a bare root nursery. The number of individuals of a proposed replication may often be less than 30, and this low number presents problems in the entire operation (i.e., planting, layout, lifting, sorting, etc.). Therefore, transplants are handled in family blocks and each family is randomized in the nursery within the respective breeding zone.

The bare root (2-0) stock presently being grown for the central Oregon Forests' progeny tests utilize a randomized complete block design. The number of replications used are equal to the number of replications in the field design.

Nursery Sowing

The nursery sowing is accomplished by hand. This applies to both the container and bare root grown stock. See Appendix A for description of hand sowing in a container nursery.

In the transplant operations, the plug seedlings are planted by hand.

Cultural Practices

The container nurseries use standard practices with each breeding unit receiving the same treatments. The Bureau of Land Management container nurseries (Colton, Oregon, and Merlin, Oregon) monitor all nutrients. Nutrients are compared with bi-weekly foliar analysis and growth curves of seedlings. Adjustments are then made in the growing schedule based on the monitoring.

See Appendix B for an example of the cultural practices at the Nisqually Container Nursery (Industrial Forestry Association, Olympia, Washington) for one growing season.

The cultural regime at the bare root nurseries are the same as used for regular reforestation stock. The cultural regime can be specifically tailored to fit specific needs if these differ from the standard practices (e.g., fertilization, watering, root pruning, etc.).

Nursery Assessments

The container nurseries monitor the growth, development, and germination of individual families. This provides the cooperators an inventory with which to plan. One year height and diameter readings (or other suitable measures) have not been taken at the container nurseries.

Progeny test material being grown as plug +1 generally have no assessments (i.e., height, diameter, etc.) made. Some cooperatives have taken height measurements on the plug +1 stock, but this is not a standard procedure.

Assessments (total height, diameter) are being made on the 2-0 bare root stock in the central Oregon zone. Ten trees per family per rep are scored in the center of each family plot.

Lifting, Sorting, and Packing

The lifting, sorting, and packaging process provides an individually packaged replication for the field. Prior to lifting, all trees are tagged. Container grown seedlings remain in cells until planting. The actual sorting and packaging process is accomplished by various methods (see Appendix A and B for examples).

Sorting is based on the replication unit. This unit is the individual set (a number of specific families assigned to a respective set). Therefore, sorting and packaging places a known number of individuals from each family into a specific set (and replication). An example sort would be as follows:

> One replication of set #1 = 4 seedlings each of family #1 through #30 (120 seedlings total).

The replications are packaged for a specific breeding zone, cooperator, and plantation. The final package label specifies the following:

- -Breeding Zone
- -Cooperator
- -Plantation Name
- -Set #
- -Rep #

The lifting, sorting, and packaging process for bare root seedlings follows the same process as in the container nurseries. Lifting and sorting bare root seedlings create additional problems in logistics, timing, and quality control.

The process is more time consuming and inclement weather (e.g., too cold, too hot, too wet) creates problems in handling bare root material.

In addition to the progeny test trees, the extra seedlings (reserves, extra families, or filler trees) are packaged for each cooperator in a pre-determined manner.

Identity Control

Identity control begins with the initial seed collection. The seed lot is given a Forest Service number and co-op number (if applicable). All of the tree improvement lots in Region 6 are stored at the Dorena Tree Improvement Center (Cottage Grove, Oregon). The seed lot numbers are checked before and during the sowing. Any duplicate numbers are clarified or the seed lots are not used. The seed lots are stratified in individual casings. One individual sows an individual seed lot (family) in the nursery sowing (container nursery). Proper tagging of seedlings is arranged at the nursery.

The lifting, sorting, and packaging handles individual seedlings; and numbered seedlings are properly allocated during this process. The field planting is recorded on a permanent map and double-checked. Permanent tags or markers are placed in the field next to the test seedlings.

The people at the nurseries and in the field take a great deal of time to insure a high level of quality control throughout the progeny test phase of tree improvement.

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Theisen, Peter A. 1983. Overview of tree improvement in Region 6. USDA Forest Service, Region 6, Tree Improvement Paper No. 10, 20 pp.

APPENDIX A

Detailed Procedures Used for Progeny Test Seedlings at the Horning Tree Seed Orchard Nursery (Bureau of Land Management, Colton, Oregon)

By

Terry Garren (Horticulturist)

A. Sowing Preparation

B. Preparation of T.I. Seed for Stratification

C. Filling 10^3 Inch (T.I.) Containers (1983)

D. Hand Sowing Tree Improvement

E. Tagging Open-Pollinated Progeny T.I. Seedlings - 1980

F. Packing Tree Improvement Seedlings

G. Shipping and Handling of Tree Improvement Stock

A SOWING PREPARATION:

Sowing preparation usually begins in December with contact from the State Office concerning growing space. As final packing instructions are coming in, so is information concerning the space requirements for the next crop. The State Tree Improvement Specialist, Liang Hsin, is responsible for coordination and providing the Greenhouseman with the information needed.

If Tree Improvement sowing is to occur about April 1st, then seeds must be packaged for stratification by February 28th. This means information concerning the families involved in the sowing should reach you by January 15th, and no later than January 31st. It is up to the State Office to be sure you have this information by these dates.

The time needed to package and prepare Tree Improvement seed for sowing is approximately 5 to 8 working days for two or three people. If caseings are prepared before-hand, one person can package about 8.5 families per hour. One greenhouse will hold approximately 1,136 families sown, two trays per family.

Exact instructions for identification and packaging of Tree Improvement families has been outlined under the headline concerning this topic. In general, all coniferous tree species should have a minimum of thirty days cold stratification time prior to sowing.

B. PREPARATION OF T.I. SEED FOR STRATIFICATION:

Organize seed for sowing by family identification. This can be done by using a sausage casing which is pre-cut to a width of 4 5/8" X 4 3/4" case size. This size of casing will hold 400-500 seeds which is usually the maximum needed to sow a family.

First fold sausage casings into fourths from the long end. Then using scissors cut nicks into both edges of the folds. This will allow proper water drainage after 24 hrs. soaking time.

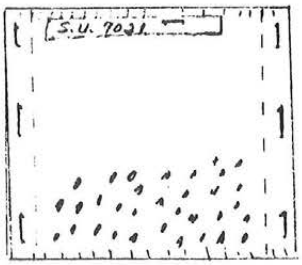
After nicks are put in long edges, unfold casings and place on paper cutter. Black marks are provided for correct alignment to cut casings into 4 5/8" lengths. Next, one cut side can be folded over and stapled. The fold should be about 1/4" and three staples should be used, one on top edge, one in middle, and one at the bottom edge.

Casings are now ready to be filled with seed and folded and stapled

closed.

Before adding seed to prepared casing envelope, a plastic I.D. tag should be placed into the envelope and stapled at the top of the envelope with one staple. The proper I.D. should be written on the plastic tag with a black sharpie and should give the breeding unit, Cooperative number, or B.L.M. number, and the number of seeds if less than the amount requested. This I.D. number should be written on both sides of the tag so that it is visible from either direction.

Example:



Sowing is usually done by breeding units, so all families for one breeding unit can be organized in drainage trays by Family lot I.D. After lots are organized and checked for correct order, an extra tray can be put over the filled drainage tray, and rubber bands can be used to keep them together. This will keep the seed lots from floating out and getting mixed up or out of sequence. Trays should remain in water for at least 24 hours and no longer than 48 hours.

After soaking, trays are removed and allowed to drain. Drainage should last at least 4 hours and checking will be required to see when seeds are free of held water in envelope, but still quite moist. When drainage is complete a plastic bag can be put over the filled tray and tagged according to the breeding unit inside. Then the tray can be placed into cold storage at 34^{0} to 38^{0} degrees for at least 30 days, depending upon tree species involved.

C. FILLING 10^3 INCH (T.I.) CONTAINERS (1983)

The soil used will be a 3:2 mixture---60% peat and 40% vermiculite. The peat mix should ideally be a 1:1 mix of Delta Peat and Manitoba Peat. This gives a blend of a fine dark textured peat with a slightly lighter more coarse textured peat. However, this is very hard to achieve because most companies only handle a bulk peat. In most cases, their bulk peat will be sufficient. The vermiculite should be #2 grade Vermiculite. No other grade of vermiculite should be accepted.

As of 1984, all soil mixes will be steam sterilized to avoid a peculiar disease or chemical problem that has, as yet, not been fully identified. It may be optimal to use an ammendment of lime to adjust the pH. If lime is added, it will be pre-mixed by the company who is selling the mix. The ammendment should not exceed 3# of Dolomite and 1# of Gypsum per yard of soil, or 4# of Dolomite only.

It takes 140 yds. of soil to complete the filling of 10^3 inch containers when both houses are filled. The filling procedure begins with the dipping of the tray into a shallow pan of water. The trays are then placed on the filling line and everything is automatically operated until the trays come off the other end and are ready to be seeded. The filling machine is operated to get the right compaction depending on the soil mix, and the containers are dibbled automatically to leave a depression of about 3/4". This leaves room for the seed and #2 vermiculite cover media.

D. HAND SOWING TREE IMPROVEMENT

(10/5/80)

First of all, to prepare for hand sowing, the tables in the greenhouse should be arranged so that a free table can be used for a working area. The empty tables to be filled with sown containers are arranged in four rows---A, B, C, and D with enough room to work around the first table of each row.

When arranging tables for the start of sowing, consideration should be given to the area of the greenhouse chosen. The south end of the greenhouse is the slowest area for germination, so sowing should be started in this area to take advantage of the extra time from the start to the end of sowing. With four tables in place at the south end of the greenhouse and room for the working table and slide-cover apparatus, sowing is ready to start.

Six people are required for hand sowing, using one person per row, one person operating the slide-cover apparatus, and one person issuing seed and checking off each family on the seed inventory list.

After the seed has been stratified, in the prescribed way for Tree Improvement sowing, the person who will issue the seed can organize the sowing and make out the necessary identification tags for each family. These tags can be made just before issuing seed if there is no time to make them prior to this. In preparation of issuing seed, a flat surface is needed to lay-out seed for drying and organize by rows. This can be made by laying down plywood on an empty table so that seed can be set out by rows to dry. Paper towels are needed for blotting and drying the seed. Also, the numbered plastic tray tags are needed as well as scissors to cut casings open when removing the seed.

The sowing order is established so that one person has row A, one has B, etc....The seed must be put out to dry in like order so that the person sowing row A comes to the side of the table where row A is established to pick-up seed.

The seed will be set out in sowing order by the supervisor, along with identifying plastic traymarkers and the seed lot I.D. tag. As the person sowing comes to get their next family, they take the paper towel with the dry seed on it and dump all the seed into the plastic sowing cup. Then they take the plastic identification tray markers

and quickly verify the I.D. number with the stratification I.D. tag before placing one in the end of each tray to be sown with this seed.

The sowing is done by using a wood stick or plastic tray marker to slide each seed out of the plastic sowing cup. At least two seeds are sown per container. Sowing is usually done between the tags so that in the case of sowing two full trays, you would have a tag in the middle container on the end of each tray. This is the case with open pollinated seedlings used in progeny testing. In this case, the tags will be pushed down in the soil while the vermiculite seed covering is added and pulled back up when placed back on the table. These trays will be organized on the tables by families with the I.D. tray marker facing west on the west tray and east on the east tray.

For the sowing of controlled cross seedlings, the method is similar with the seed being sown in each container between two tray tags. However, the tray tags will be positioned in the first container and the last container sown, leaving two completely empty rows between different families. This helps alleviate problems later on during tagging. Also, only one seed is sown per container for controlled cross sowing.

As each family is sown, the sowing record sheet is marked with a check to indicate completed sowing by family. This sheet, also, records which families are on which tables. After tables are completely sown they are marked by the table number to indicate their place in the greenhouse. This mark is always on the west side of each table and is written on time tape with a black sharpie so it can be taken off before starting next seasons sowing.

* Note one person can sow an average of 3.5 tables per day or about 5,488 containers

E. TAGGING OPEN-POLLINATED PROGENY

T.I. SEEDLINGS

1980

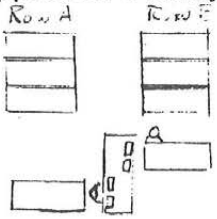
When tagging progeny seedlings, the system that works best for maintaining accurate records, and the ability to check individual work is one designed for one person per family.

It is absolutely necessary that a rigid system be utilized and maintained while working with Tree Improvement seedlings. Therefore, the following system has been set up, and will be utilized until modifications can be proven.

The system will center upon the use of 6 cut-down tables which measure approximately 2' X 8'. These tables were designed so that one person can work off of one side of each table, and it can be easily pushed down the aisle-way between the rows of seedlings.

To start with, the outer rows of seedlings must be pushed up closer together, leaving adequate room in the major aisle-way with which to work.

Once this is done, the working table will fit between the rows in the major aisle-way. Room must be left so that two people can work off the same table, only on opposite sides, tagging families from tables on opposite rows.

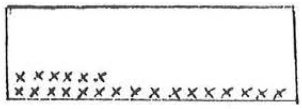


After the working tables are in place, tagging can begin. This will always start with the family in the Northwest corner of each table. For progeny seedlings, there are usually two trays per family, so before any trays are removed from a table, the tray tags should be checked and verified as being from the same family. Both tags of one family are then taken to be tagged. The families taken to be tagged are always taken off the tables in sowing order and only one family at a time.

With the family selected for tagging in place, it is necessary that each person tagging have at least two empty trays. One tray is used to transfer the seedlings which have been tagged, and the other is placed under the work table. Those seedlings which have

died or are questionable as far as tagging is concerned are placed in this tray. If there are any questions about the suitability of any seedlings for tagging, they should be tagged and placed in the tray under the work table. Later, the supervisor can check them to decide if they should be included with the family. When this tray becomes full and the seedlings in it have been checked by the supervisor, it can be dumped into the tote bin for later cleaning.

When tagging seedlings, the tag should be placed on the sturdiest side branch nearest the top of the seedling. To insure randomization, the seedlings of the original family tray are tagged from left to right and right to left going down the long side (length) of the tray. These seedlings when tagged are placed in the empty tray provided, starting at the farthest end and going back and forth across the narrow length of the tray (see example).



original tray



empty work tray

After tagging and filling the empty tray with tagged seedlings, the tray tag can be reset to the same position as before. Tray tags will always be located near the center of the tray. The tray nearest the outside edge of the table will have the tag facing out. The matching tray for that family will have the tag located either in the last seedling tagged, if there is only a partial row, or in the middle of the tray, if the row is complete. After the second tray is tagged, both trays may be put back in their original space on the table. The full tray always goes on the outside edge of the table, while the second tray, which is normally not completely filled after tagging, goes inside with the empty spaces towards the middle. This facilitates the taking of the final inventory.

This tagging process is repeated over and over, until all families of one table have been tagged. It should be stressed again that all families are tagged in sowing order and go back in place just as they were prior to tagging.

F. PACKING TREE IMPROVEMENT SEEDLINGS

After tagging is complete and seedlings are completely hardened off, packing may begin. Packing is by request, and after the final inventory is sent out, the State Tree Improvement Specialist has the responsibility to see that the greenhouseman has the complete packing instructions by Jan. 15th. These packing instructions will include the organization of each breeding unit into sets of families.

As part of the pre-planning that takes place prior to packing, the original sowing request form is used. The information given under planting design is used in ordering boxes and planning the easiest method for packing the seedlings. The sowing request form is very important and assists in planning from the time of sowing on through tagging and packing seedlings. Because of changes from year to year in the number of cooperators, plantations, set size, etc., the following procedures will be general.

Seedlings should be packed in an upright position to promote air flow and reduce the hazard of disease problems during cold-storage. There are two standard box sizes used, one is 30" X 14" X 21" for 160 seedlings, the other is 30" X 12" X 21" for 120 seedlings. Families of a set are placed on tables in a horseshoe design. Each family must have a distance of at least one step (about 3 feet) between them. This is needed to reduce packing errors. The families are placed on the tables starting with the lowest family number on the left side of the half-circle and continuing in order with the highest number on the right.

Usually, a minimum of three people and a maximum of six people are needed for packing. All seedlings for a bundle are placed in plastic bags, size 13" X 12" X 24". These are tied to help keep the seedlings from falling out. Normally, there are 30 seedlings in a bundle, and 4 bundles make up one replication of a set for a plantation. The plastic bag should be folded down near the top of the plastic containers before tieing the knot. This will allow more air flow around the seedling itself. The packing design is ordered by cooperator, plantation name or number, set number and replication number. The seedlings which are to go to the progeny test site for outplanting

are usually labeled in this manner, ex.:

Cooperator	U.S.F.S.
Plantation	Cook Creek
Set	2
Replication	3

After the test site trees have been packed, there are often many seedlings left to be divided by the cooperators. These are usually divided as reserves, holdovers, surplus, and extras. The reserve seedlings are the trees which usually are designed as replacements for any fall down within the plantation. These seedlings are normally shipped along with the test trees to the plantation site. The normal number of reserve seedlings consists of 3 trees per family. The next division, that of holdovers, occurs when plantation sites are not ready, and the test seedlings must be held another year in a nursery. The surplus seedlings are those seedlings which were above the optimum number needed to complete all the test site planting. These seedlings are either used as fillers in the test site or are included in the nursery planting when seedlings must be held-over. The extra families are those families not included in the set design, and they are usually shipped to the test site as fillers.

Accomplishing the division of all these seedlings into the various categories is done best by first packing the seedlings to be outplanted at the test sites. Next, the second largest category can be separated out by cooperators and packed. Then this procedure is repeated until all categories are separated by cooperators and packed.

The people, who place the seedlings in the plastic bag, start at the left side taking one tree per family and proceed around the half-circle until they have taken one tree from each family. This bag makes up a completed bundle of a set of families. Usually, four of these bundles makes up one replication of a set. The person picking up the seedlings and placing them in the bag is responsible to see that all seedlings are tagged as they are placed into the bag. When the last seedling for a bundle has been taken, this person also ties a knot in the plastic bag before handing to the person packing. One person usually packs and is responsible to see that the correct number of bundles goes in each box and that the labels are correct for each box. Another

person is also needed to make the boxes, label them correctly, and keep them in place for the person packing.

When packing, the box is set up at a 40° angle to aid in placement of bundles. The box is then stapled shut and stocked according to division by cooperators for ease in loading and shipping.

G. SHIPPING AND HANDLING OF TREE IMPROVEMENT

Shipping and handling of Tree Improvement stock involves keeping boxes sorted by cooperator or district, and all records associated with shipment and return of containers and boxes.

Six large pallets are used to stack boxes on while moving them into the walk-in cooler. These pallets are 5' X 5' and can hold 24 large boxes (30" X 14" X 21"), and 30 small boxes (30" X 12" X 21") of Tree Improvement seedlings. The walk-in cooler will hold approximately 450 of these large boxes.

The records for shipping are filled out after packing is completed, and one copy is kept for our records and one copy is shipped with the seedlings. The copy that is sent, is made out to go to the District Tree Improvement Specialist. Also, a copy of procedures for handling our re-usable boxes and containers should be sent as a reminder.

The re-usable boxes should be folded flat when returned unless they are used to hold containers. Upon return, the boxes are sorted and placed on pallets by size and the containers are stored in tote bins until they can be put back in trays.

APPENDIX B

Detailed Procedures Used for Progeny Test Seedlings at the Nisqually Container Nursery (Industrial Forestry Association, Olympia, Washington)

By

Joe Wheat, Mike Bordelon, and Rich Reeder

A. Cultural Practices on Progeny Crop - 1981 and 1982, Mid-Columbia

B. Sorting and Packing Instructions - Outline

C. General Sorting and Packing Instructions for Progeny-Test Seedlings

INDUSTRIAL FORESTRY ASSOCIATION

SERVING FOREST OWNERS, LOGGERS, WOOD USERS
THROUGHOUT THE DOUGLAS FIR REGION

NISQUALLY CONTAINER NURSERY
135 NISQUALLY CUT-OFF RD. S.E.
OLYMPIA, WASHINGTON 98503

Telephone:
(206) 456-5669

November 4, 1982

A. Cultural Practices on Progeny Crop-1981 and 1982
Mid-Columbia

Seeds were stratified for 32 days with soak chill method. Seeds were then direct sown into super leach cells with 10 cu. in. soil capacity and covered with perlite to hold seeds in place.

Growing media ingredients were the following: (per cu.yd. soil mix.)

50% Canadian peatmoss
35% Vermiculate #3
15% Perlite
1½ lbs. Triple Superphosphate (0-45-0)
2½ lbs. Dolomite limestone (Kaiser AG-65 or equal)
½ lb. Potassium Nitrate
3 oz. Maganese Sulfate
2 lbs. Gypsum.

Directly after sowing and placement in fibreglass covered greenhouses a soil drench of Benlate and Terrachlor fungicide was applied to the crop for control of damping off fungi. Only light watering, without nutrients, are applied to the crop until germination is complete.

After germination, a medium nitrogen, high phosphorus and medium pottassium fertilizer formula, with other minor elements are applied to promote root development. Using data taken from soil and foliar analysis the fertilizer regime is altered to give optimum plant performance throughout the growing season.

The use of incandescent lights on the 1981 crop were necessary to prevent premature bud set and extend the growing season. The 1982 crop didn't receive any lighting.

Usually starting mid August plants are leached with plain water and allowed to dry to a slight wilt stage before a low nitrogen, high phosphorus, feed formula is applied for hardening off purposes.

As fall temperatures decline fungicides, such as Botran, Daconil and Captan are applied as foliar sprays to discourage foliage mold. In late fall before plants completely stop growing a soil drench for root rot diseases such as Banrot is applied to the crop to assure that they are free from any damaging fungi.

Prior to crop being packaged for shipment they are irrigated to complete saturation and a foliar fungicide applied. The foliage is allowed to dry before going into cold storage.

Rich Reeder
Nursery Superintendent
Nisqually Container Nursery

B. SORTING AND PACKING INSTRUCTIONS
Outline

1. Seedling sorted by set. - (30-40 families)
   One set is removed from bench and both trays of each family are placed on a table in numerical order.

2. One box = 1 rep./set. We normally use a 4 person crew. One person walks around the table and picks up one tree of each family and places it in a plastic bag (turkey sack) - 4 plastic sacks of 30 trees each equals 1 rep./set. Each crew person does several things.

   a. verifies that the tree has a tag and the tag no. corresponds to other numbers in that tray.
   b. Counts as she goes around to make sure she picks up 30 trees. If not they inventory and figure out the mistake.

3. For families that are short on trees - a list is made prior to sorting based on inventory so that trees can be divided equally among plantations. i.e. first priority is to short 1 tree of a family in each rep. we never go below 2 trees/family/rep.

4. Each crewperson has a ID number which she places in the plastic bag. Thus cooperators could foreseeably identify if one person was constantly making mistakes.

5. So that cooperators know when a tagged tree is left out we do 2 things. (a) Write the number on an empty cell which is placed in the turkey bag (b) write the number of the missing trees on the box flap.

6. All sites are packed out for the particular set on the sorting table. Likewise - reserve trees and surplus are also divided among cooperators proportionately.

7. Boxes are labeled with
   Cooperator
   Set No.
   Rep No.
   Site Name

8. All boxes are strapped with plastic banding material.

9. Turkey sacks are stapled around the root-collar of the 30 seedlings (¼ of a rep) not pulled over the foliage.

10. After a set is completed - trees go to cold storage unless being picked up within 1-2 days.

11. Watering and fungicide treatment are advisable prior to sorting especially if long term cold storage is anticipated. Foliage must not be wet however when trees are actually placed in the boxes.

12. A physical divider is placed between families on the sorting table. Also - tagged trees are moved to the front and non-tagged (surplus) are at the rear - This helps prevent getting a non-tagged seedling in a rep.

13. TAGGING - is usually done 2-3 months prior to packing. We use paper tags with permanent black numbers. In 1983 our tagging procedure is to start with a 3" tag with 2 numbers on each 3" tag. After wrapping around the side limb, the number is visible from either side.

C. GENERAL SORTING AND PACKING INSTRUCTIONS FOR PROGENY-TEST SEEDLINGS
November 26, 1979

Sorting and packing of progeny should begin shortly after the first of the year and should be geared for conclusion by the end of January, which is about the earliest that any test sites should be planted. This schedule also avoids cold storage prolonged more than necessary.

Sorting and packing should be the same time for sites within the breeding unit, since greenhouses must be emptied for the next sowing.

Information specific to each test site will be provided to those in charge of the sorting and packing. This will be handled through IFA.

Maximum efficiency is with a crew of 4 plus a supervisor. For an average test, they can be expected to sort and pack about $2\frac{1}{2}$ sets per day.

Sorting

Lists of families within sets will be furnished by IFA--each set on a separate work sheet for use by the supervisor. Most coop programs have sets of 30 families, though some units in the Medford and Roseburg programs have sets of 40.

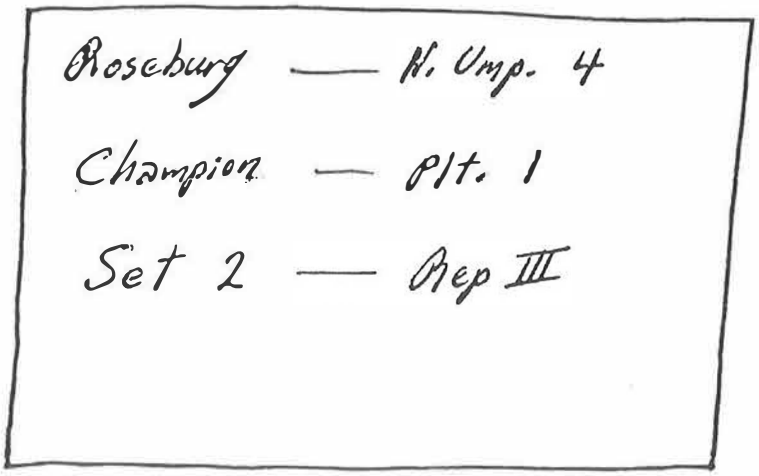
One set at a time will be brought from the growing area into a work area where the trays can be arranged as an incomplete circle. Each of the 4 sorters will pass around the trays taking one seedling from each family and placing in a plastic bag and holder (see "Materials" for description). The 4 plastic bags together are Rep 1 within the set. The number of reps will vary from 3 to 5 depending upon the breeding unit. Plastic bags (as described) will be tight for sets of 40, but for sets of 30 the slack is taken up with a soft flat stick (about $\frac{1}{2}$" x 8") and stapled with a pliers-type stapler. Sorters will line their holders with new plastic bags and repeat the procedure for Rep II, etc.

The two most common errors in the sorting procedure are: 1) wrong number of seedlings in a bag from skipping or repeating a family, and 2) including non-tagged seedlings. The latter is prevented by making sure that only tagged seedlings are available to the sorters. The supervisor should run a continuous check for the first error by establishing a pattern in which the sorters remove seedlings from the trays. For example, the first sorter always takes closest seedling in column 1, second sorter from column 2, etc. Then at the end of each round (a rep) the supervisor can tell at a glance if all trays are still even, and an error can be caught before the seedlings are boxed.

Short families. Sometimes a family must be used that does not have enough seedlings. The shortage is usually small--from one to a dozen seedlings. (If it is great and there is a question of why it has been included, please do not hesitate to give me or Mike Bordelon a call.) Shortages should be distributed as equally as possible amongst the reps and plantations. For example: 10 plantations with 3 reps = 30 reps overall. Minimum seedlings needed are 30 reps x 4 seedlings per family per rep == 120. Actual number of seedlings is 95, so 25 reps will be shorted one seedling and 5 can be full. For convenience make all reps at first plantation full, and Reps I and II at the second plantation. Holdover plantations also would be considered in any such seedling distribution. Obviously, there would be no reserve seedlings.

Packing

The crew supervisor is also the packer, who receives the groups of 4 bags from the sorters. Each group of 4 bags is boxed separately. Boxes can be marked ahead of time while flat. Information on each box should indicate Program, Breeding Unit (if more than one), Cooperator, Plantation name or number, Set, and Rep. An example follows:



Seedlings must be packed and must remain upright in the boxes. This is simple to do in boxes of the right size (see "Materials"). Plastic bags containing the groups of 30 or 40 will remain turned down so that little more than the Leach Cell is covered. Cooperators have been asked to notify their growers as to when they plan to pick up their seedlings. For those taking them within 10 days to 2 weeks, they can be held open-top in a cool shelter kept above freezing. For longer periods it is better to put them in cold storage. Some cooperators will provide their own cold storage.

Remaining Seedlings

Up to this point, only the test seedlings that are going to be outplanting during the current planting season have been taken care of. The remaining seedlings fall into 3 categories: 1) Holdover plantations (plus their reserves), 2) Reserves for the sites to be planted this season, and 3) surplus. While the families of a set are yet in the work area, the seedlings remaining after the sorting must be divided amongst these uses.

Holdovers will not exist for some breeding units since all plantations will be established this season. The demand for holdovers is the next to be satisfied following the initial sorting. We hope that provision can be made for all holdovers within a breeding unit to be transplanted at the same nursery. If such is the case, all holdovers (plus their reserves) can be kept together by family. It will be up to the grower to determine whether these are to be packed at this time--or consolidated in one tray and held in this manner until transplant time.

Reserve seedlings for replacement of first-year mortality are held at the rate of one per rep. Thus, in a program with 3 reps per plantation, there would be 3 reserves per family per plantation. The work sheets provided for each cooperator will indicate where reserves are to be held for any plantation. For USFS and BLM some will stay in the family group and be transplanted at the same nursery. All others will be boxed for their plantation with seedlings of a family held together by a rubber band (groups of 3 to 5, depending upon number of reps). Boxes need to be identified by Program, Breeding Unit, Cooperator, Plantation, and range of families within box.

Surpluses are those seedlings left after the other demands have been met. These can be bulked and should be divided amongst cooperators on the basis of their share in the sowing. Cooperators have been asked to let it be known if they do not have a use for their share of the surplus.

With surpluses allotted, all of the seedlings in the set have been assigned; and the work area is cleared for the next set.

Extra Families

For some breeding units there will be extra families that could not be included in present sets. Where there is a sufficient number of extras, these may be put in a partial set for planting at sites that have the extra room. Where there is no extra room, a few extra families can be included in the inside border rows. The responsibility of assigning extras to these uses is as follows:

Materials

Plastic bags. "Poultry bag" -- 10" x 8" x 24", or 9" x 9" x 24"
Gauge: no less than 0.0015.

Holder. Plastic bucket cut down to about 8". Bottom needs to be at least $10\frac{1}{2}$" diameter. Plastic bag is inserted and turned down over bucket edge.

Small packing box (for 4 bags of 30): 21" x 14" x 16" high. This is common size on hand. If ordering, ask for 18" high.

Large packing box (for 4 bags of 40): 30" x 14" x 18" high.

Rubber bands. 3" minimum x $\frac{1}{2}$" x 1/32".

ROUND TABLE DISCUSSION - REVIEW OF NURSERY TECHNIQUES

REGION 8

BY

JIM GATES

Region 8 grows its progeny test seedlings at three locations. They are USFS Ashe Nursery in Mississippi, Beech Creek Seed Orchard in North Carolina, and a state nursery in South Carolina. We are producing approximately 78,000 seedlings plus border trees for 52 progeny tests to be planted this winter. Procedures differ slightly between nurseries.

1. Type of material. All progeny test materials are bareroot seedlings.

2. Experience with contract growing. The region has very limited experience with contract growing. In each case, Forest Service crews would sow the seed, maintain identity, take inventory, lift, and package the seedlings. The nursery was responsible for preparing beds, growing the seedlings, and undercutting beds prior to lifting. A state nursery in South Carolina is the only location now being used. The only problem encountered to date is the 70 mile drive from the seed orchard.

The other two contracts were not satisfactory. One was a state nursery where they were very cooperative, but did a lousy job of growing seedlings. The other was a local ornamental nursery that did only a fair job. There were enough problems so that we would not want to use this nursery again. They submitted the low quote and got the job. The only way we would contract grow is to negotiate rather than by the low bid process.

3. Number of replications used in nursery. Each of the nurseries is different. Procedures include one replication in one nursery location, two nursery locations with order of families the same in each, and three true replications (random placement of families in three nursery locations).

4. Method of nursery sowing. All sowing is done by hand. Most is by using a planting board or template. The crew in South Carolina broadcast the seed and are satisfied with the results. Only one or two people do all sowing. They practice the day before and make frequent counts of seed per square foot during the sowing. They feel the big advantage is that it takes only 1/4 to 1/3 the time they were spending with a planting board. No visible differences have been noted between seedlings sown by broadcasting and those with a board.

5. Special cultural practices being used. Since very heavy rainfall in south Mississippi is not uncommon, shade cloth is spread over the beds until germination starts. Other than a lot of attention, no other special practices are used.

6. Assessments made in nursery. No family assessments of germination rate, growth, etc. are made. Either 2 or 3 seedling inventories are conducted. Routine surveys to determine pathological problems, growth rate, and cultural needs are directed toward the entire crop rather than the individual family.

7. How are trees lifted? After beds are undercut, all seedlings are lifted by hand. Each family is placed in a separate bag or tub. All seedlings of one family is placed in the same bag.

8. How are trees sorted and packaged? R8 uses 10-tree row plots. The assembly line is used. Seedlings of a single family are placed on a table where obvious culls are removed and lateral roots pruned as needed. One person then selects 10 plantable seedlings. This final grading is done by the same person for a particular test. The next person recounts, ties, and attaches temporary tags to the 10-tree bundle. Seedlings required for each replication are placed in a bag for shipping. A test having 5 reps would receive 5 bags of seedlings.

9. Identity control through process - seed through packaging. The ID tag placed on the tree when a cross is made stays with the seed until it is sown. Each package of seed has identification inside and outside the container. Anytime seed are removed from a package only 1 family is handled in the same work area at a time. The work area is cleaned between seedlots. Seedlots are separated in nursery beds by wood or metal slats and are marked with tags. A map or record showing location of each seedlot is made soon after sowing. It includes the number of drills per seedlot.

The nursery tag is checked against information on the tub or bag when seedlings are lifted. After being sorted and packaged, the shipping bag is labeled with species, breeding population, number of families, replication number, Ranger District, and date of lifting. The bags are often color coded by test location.

10. Seedling shipment to test site. Seedlings have been shipped by several methods. From the FS nursery, most are included on regular seedling shipments. The following precautions are taken: (1) bags marked

by color and/or flagging to distinguish them from normal nursery stock; (2) listed as separate item on shipping ticket; (3) loaded so they are first to be removed at designated stop; (4) inform driver; and (5) inform district before scheduled stop to leave them alone and district with the test to expect them.

The second commonly used method is by FS truck. The maximum distance is about 500 miles. Refrigerated trucks are not used when we do the delivering. Limited use has also been made of local charter air service.

REVIEW OF NURSERY TECHNIQUES
REGION 9

Richard J. Meier
Zone Geneticist

Nursery techniques for progeny test material in Region 9 are a close approximation of those used for growing production stock. Some of the variations from practices are noted below as well as packaging and labeling techniques. It should also be noted that the techniques are not standard within the Region. This is caused in part by species differences and in part by differences of opinion among the three zone geneticists.

Both bare root and containers have been used by all zones. Shading problems have hampered the use of containers for hardwood progeny tests. It has also been demonstrated in the Northeast that hardwood containerized stock has no growth advantage over bare root. The main advantage for containers is the year gained over growing bare root stock. Some container types also offer the advantage of being able to lay out plots and replicates in the greenhouse that can be carried directly intact to the field. A set of jack pine evaluation plantings will be established this spring using 5 replicates of containers and 5 replicates of bare root. This winter the Lake States Zone will plant a black spruce evaluation plantation in containers in a greenhouse, grow them for 10-12 weeks, and then transplant them into a nursery for two growing seasons to be lifted as bare root stock. This appears advantageous for very small-seeded species. Also, greenhouse replication will be carried to the nursery and then on to the field. No contract growing of either type of stock for evaluation plantations has been attempted in Region 9.

All progeny tests are replicated in the nursery 2-4 times. Reasons for replication vary. One zone uses replication for safety purposes. Another zone replicates in the nursery, but bulks all replicates before making up plot bundles so the integrity of the replicates is lost. The third zone replicates in the nursery and maintains the integrity of the replicates into the field planting. Two of the zones have split progeny tests in half and used 2 nurseries for replication. These were also replicated in the nurseries.

All tests are hand planted. Larger seeded species are planted with the use of dowled templates for spacing. Small seeded species are mixed with sawdust or vermiculite and broadcast sown by hand.

Cultural practices for progeny tests in the nursery are similar to standard practices. The exceptions are: 1. No vertical root pruning is done because of non-standard spacing. 2. Tests in the central zone are given extra fertilizer because of delayed sowing. Tests are spring sown and production stock is fall sown. 3. Broadcast seeded tests are thinned to achieve standard densities.

Germination and height measurements are taken in the nursery by one zone. Height was previously taken in all zones, but two zones have stopped. The reason for elimination of height measurements is purely a lack of time.

Sorting varies across the region. As previously stated, one zone bulks all replicates from the nursery and divides the entire family into plots which are assigned to plantations and field replicates at random. The second zone maintains the integrity of the replicate and splits it into subsets for outplanting. Four nursery replicates usually are divided into 10-12 field replicates. A more complex system of sorting has been used in Region 9 and is still used by one zone. It involves measuring all seedlings before lifting. The seedlings of each family are then divided into the number of height classes that equals the number of trees per plot. One seedling from each height class is then put into each plot. Computer and hand held calculator programs are available to divide the families into classes. Information required is number of trees per plot, total number of trees per family, number of height groups required, and minimum height that can be used. The system is time consuming, but it reduces between-plot variance within families at the expense of within-plot variance.

Identity of each seedlot is maintained by numbers on the seed envelope. Seedlots planted with templates are tagged with soft-backed aluminum tags on a wire at the first row of the seedlot. Template rows run across the bed as well as along it. Broadcast tests require better separation between seedlots. Usually, each seedlot is separated by a strip of wood or bamboo stick. In both template spaced and broadcast seeded tests, dividers are placed between families during lifting to prevent mixing of seedlots. Bundles (plots) are identified by soft-backed aluminum tags or marking tape double stamped with a number with special waterproof ink.

Round Table - Progeny Test Establishment & Management
Moderator - Richard Jeffers/Donald Dorn

Tasks: Carried out by forestry technicians who are partly financed by the improvement and who have tree improvement duties as major part, but not complete part of job description. One technician per forest or one technician to serve two adjoining forests. Carry out routine tasks such as measurements, maintenance without direct supervision of Zone Geneticist.

Training: Zone Geneticist personally instructs technicians or accompanies them when new or different jobs are started. Zone Geneticists have annual meeting with Regional Geneticist and Research personnel to evaluate past year's accomplishments and plan next year's program.

Site selection: Earlier planting locations were selected on basis of availability, representing elevation, aspect, and topographic situations on which species is managed; surrounding timber was used as a basis of site index. More than one site was selected and zone geneticist picked the "best" of the selected sites. Later sites were examined by a soil scientist accompanied by Zone Geneticist. On some forests, sites are selected on basis of ecological land types.

Site Preparation: Various levels of intensity have been used as shown by three examples.

1. Cottonwood - Discing and clean cultivation.
2. Black Cherry - Chemical treatment with round-up the summer previous to planting.
3. Yellow Birch - None, except to plant the first spring after clear-cutting.

Test Layout: All tree locations are marked with wire surveyors flags before planting. Contrasting colors are used to delineate blocks. Occasionally scalps made by mechanical scalper are used for spacing. Prefer to measure spacing in each direction. Hand compass and tapes or ropes marked at the designated interval are used.

Planting: Except in few instances where row plots are used for demonstration, planting is done by hand. Planting done by district crew which includes YCC, YACC, etc. Zone Geneticist supervises during planting. Trees are all sorted in the nursery operation and are packaged by block with each plot in the block individually tied and tagged. Randomization is achieved by chance selection of bundle in package by planter. No package (block) is opened until previous block is completed.

Maintenance: Varies by forest and age of plantation. Goal on forests where deer fences are erected is to check fence monthly for deer penetration up to age 3. Thereafter it will be every 3 months. At age 10, and thereafter, they

should be checked every 6 months. Goal on forests where deer are not a problem is a check every six months for insects, disease, competition, storm damage, etc. Forestry technicians on ranger districts where plantations are located are assigned to do the checking.

Zone Geneticist makes annual inspection and makes maintenance recommendation on some forests. On other forests Zone Geneticist sees plantations only every 2 or 3 years and depends upon tree improvement technician for maintenance recommendations.

A mixture of simozine and round-up is applied in June and March on the walnut plantings for the first three years.

Animal Control: Mice and deer are the principal animal problems. Mouse control is achieved primarily by elimination of grass within a 3 to 4 foot diameter circle enclosing the tree. Where plantings are in fields, mowing is done twice a year with the last mowing in September so that there will not be any tall grass left through the winter. Repellents containing thiram applied to the tree stems have been effective, but very labor intensive.

Deer control on the Allegheny is difficult and expensive. Deer browsing occurs on other forests also, but generally has been considered tolerable, although deer numbers appear to be increasing on the Monongahela and Green Mountain.

After experimentation with repellents and individual tree fences, it was concluded that the only effective way to control deer is by area fences. Eight-foot woven wire fences can be effective if they are well maintained and the botton wire is kept within 3 to 4 inches of the ground. This is difficult and expensive in a forest situation where rough terrain and wind-thrown trees are common.

Several variations of vertical electric fences have been constructed to reduce costs and increase effectiveness over that of eight-foot woven wire fences. These fences use high tensile steel wire and low impedence energizers powered by a 12-volt storage battery which is kept charged by a solar cell. These develop about 4000 volts and a pulse length of 0.002 seconds. The pulse interval can be varied between 30 and 50 times per minute. The high voltage enables maintenance of a highly charged fence in spite of a weed load. The short pulse length prevents injury to humans and wildlife and avoids starting fires.

Initial construction and maintenance is less than half the cost of a woven wire eight-foot fence, and more effective, although most of the fences are not 100% deer proof. Cost is about .40 to .60 per perimeter foot depending upon size of the exclosure. We are now installing a 7-wire slope fence and hope to achieve 100% control as even one deer in a newly planted hardwood plantation is "too many."

Release: Usually hand release. Have used some aerial application of round-up on jack pine plantation. Plantings on clear-cuts without site prep usually need two releases from competing hardwoods.

Thinning: In black walnut plantations, the best 2 trees in each 5-tree plot have been left without regard to spacing. The only other thinning done in the Eastern region was in cottonwood where certain blocks where thinned, again leaving the best 2 trees in the plot without regard to spacing.

Fertilization: None on the conifer plantings. Black walnut has been fertilized with 12-12-12. The nitrogen component is in the form of urea. This black walnut plantation has also been seeded with hairy vetch both to reduce weed competition and release nitrogen. Autumn olive has also been interplanted with black walnut to add nitrogen to the site.

For black cherry and white ash on Allegheny N.F., 21 grams triple superphosphate and 55 grams ammonium nitrate spread over a 3-foot diameter circle enclosing tree. This is a rate of 200 lbs. N and 100 lbs. P per Ac. Purpose is to quickly get trees above reach of deer and competition.

This corresponds to standard management practice on Allegheny where the same fertilizer rates are applied by helicopter on clearcuts.

Fertilizer is applied after seedling has broken dormancy and the soils have dried below field capacity to minimize leaching loss. The first application is applied during the spring of establishment. A second application of ammonium nitrate will be applied in year 3 to maintain good growth.

Insect & Disease Control: Very little done to date. Endemic levels are considered good screening of resistant families and individuals. Gypsy moth may become a serious problem when it reaches our area.

Identity Control: Each tree or at least one tree in each plot has a temporary (one to two years) label attached at the time of packaging in the nursery. The labelled tree is planted at the beginning of each row plot. A plantation map is made during or immediately after the planting operation.

Permanent tags are attached to a metal or fiberglass stake by each planted tree as soon as possible, but not more than one year after planting. Any natural seedlings of the same species within two feet of the planted tree are pulled out at the the time of planting and each time the plantation is measured.

Submitted by:

Donald Dorn
Zone Geneticist

Eastern Zone, Region 9

SITE SELECTION, SITE PREPARATION AND TEST LAYOUT

JAMES E. GATES 1/

INTRODUCTION

The fact that a lot of time and effort have gone into progeny testing is evident by the 754 acres of evaluation plantations established by the Forest Service in FY 82. Total acres established to date is 3,288. Of course each step of the process is important, but site selection, site preparation, test layout and establishment are critical in obtaining reliable genetic information. Mistakes made here are not likely to be corrected later and could result in the test yielding erroneous data.

Procedures during this phase of progeny testing will vary depending on test objectives, design, species and local conditions. For this discussion, it is assumed the test design as to plot size and shape, number of replications or blocks, randomization, number of locations and spacing has been made. No effort will be made to deal with a particular test or specific design. If information developed by a progeny test is to be accurate and useful, correct procedures must be followed.

SITE SELECTION

Depending on test objectives, the following prerequisites should be considered when selecting sites for planting progeny tests.

Site Uniformity. Uniformity of site is an important factor when establishing a progeny planting regardless of test objectives. Often, as contact with a district is made and they are told a 3 acre site is needed for a progeny test, it is perceived as no problem. After all, there are several large areas to be regenerated so the district can surely stick such a small planting anywhere.

Even though the necessity of uniform conditions within a block or replication is stressed, it is a fact of life that the typical forest site is quite variable and all environmental variation can not be eliminated. These differences can be reduced through a well designed test and selecting planting areas as uniform as possible for such features as slope, aspect, soil types, drainage, etc.

1/ R-8 Western Zone Geneticist, Kisatchie National Forest, USDA Forest Service, Pineville, Louisiana.

One way to reduce "invisible variability" which becomes visible only after the trees begin to grow is to evaluate the area before site preparation is done. Even though it is often difficult to climb over slash or through the "jungle" that develops followig harvesting operations, this may be the only time to locate spots or areas to be avoided. Site preparation may eliminate certain indicator plants, disguise logging roads or landings, and in general make it more difficult to see other site variables.

Site Quality. Sites selected should be typical or representative of the forest lands to be regenerated with that improved stock. Since trees growing on better sites tend to result in greater differentiation than progenies of the same families grown on poorer sites, efforts should be directed toward the better sites.

Naturally, if the prevailing acreage have low site indices, progeny testing on the poorer sites will be required. It may be necessary to test on both high and low quality sites if sufficient acres of both types are to be planted with the same genetic stock. Where the objective is development of specialty stock, i.e., drought resistance, cold hardiness, etc., sites subject to such conditions must be used.

Site History and Use. In order to avoid heartache later, it is wise to be aware of the following external factors that may affect the plantation:

1) Incidence of fires - On some districts, in the south especially, such as the "Burning Vernon" on the Kisatchie, there are certain areas that get burned almost annually. The type of people responsible for many of these fires would delight in stepping across a fire break to torch anything that might be considered special. Even though the number of man caused fires has decreased in recent years, it can still be a factor in site selection. The occurrence of railroad fires in an areas may also be frequent enough to eliminate a site.

2) Range and wildlife use - It may seem strange that this item is included. What do cows, deer, rabbits, etc. have to do with progeny testing? If the site is within a range allotment, the additional expense of fencing should be included in the progeny test plans. The R-8 program does not contain provisions for selecting the trait of cattle resistance. Tests established in areas experiencing heavy deer browsing, rabbit or rodent damage are excellent candidates for failure or at best compromised results unless additional protection measures are taken. Tests in Arkansas have been wiped out by rabbits and/or rodents reducing first year survival to less than 10 percent.

3) Proximity to town or heavy public use - Since it may not be possible to prevent a test from being converted to a garbage dump, race track/ obstacle course for all terrain vehicles, or shooting range, it is best to consider these possibilities before establishment. Depending upon community attitude and support, proximity to a town can influence plantation survival or usefulness.

Site Accessibility. Site access is another factor to consider when selecting a test location. Most tests require frequent visits for measurements or observations. In the event of wildfires, prompt control or attack is essential.

Establishment of tests in remote or hard to reach sites should be considered only when more suitable or accessible sites are not available.

Forest Landownership Adjustment Plan. Future ownership of the tract of land containing the plantation should be considered for Forest Service progeny tests. Since most field plantings will be long term, it is important to consult the current Forest Landownership Adjustment Plan to determine status of the tract being considered. Forest Service lands available for disposal through exchange should be avoided unless the plan can be amended to delete the area.

Testing Disease or Insect Resistance. When a test is designed to evaluate family resistance to a disease or insect, uniformity of soil or site conditions may not be the overriding factor. The primary concern is to achieve uniform exposure to the disease or insect. However, uniform exposure is not enough. The level of infection of disease or insect infestation must be high enough to adequately evaluate the planting. This means selecting a site with good potential for infection or infestation is necessary. As with many aspects of life, too much of a good thing can be bad. The North Carolina State University - Industry Cooperative Tree Improvement Program suggests avoiding test sites where fusiform rust infection greater than 70% is likely because such high levels make it difficult to discern family differences.

SITE PREPARATION

Progeny test site preparation is not unlike most subjects discussed. There are at least two sides of the story. In fact, there may still be a few around that speak out in favor of "operational" site preparation rather than doing a more intensive job. This view is being heard less and less in the south. As a minimum, the need to utilize the best or most intensive form of site preparation being done on the district or forest must be recognized.

Anything done to the site before planting is considered site preparation. Whatever is done the site should receive uniform treatment. Measures that will help insure high survival plus early seedling development and growth should be the objective of any site preparation work. Even though the site may be uniform as far as soil type, slope, etc., the competing hardwood sprouts quickly introduces bias since such competition is patchy. This non-uniform environment introduces variation to the test. This is one reason why more intensive site preparation is recommended.

It is also well to keep in mind when piling or windrowing that a portion of the test must not be planted over a burned windrow. The opportunity to select a better site is improved when close detail or supervision can be given during the time when the treatment is being done. In the case of windrowing, the piles can be placed a specified distance apart and in straight lines. When treatment is bedding or ripping, the extra care required in maintaining a uniform distance between the rows will result in more standard spacing of seedlings.

There are several treatments to follow up an operational site preparation job which will enhance test results. These include use of herbicides, removing debris from site to allow early maintenance by mowing, disking, felling rather than injecting any trees left on an area and removing all natural seedlings of the same species to be planted.

TEST LAYOUT AND ESTABLISHMENT

Although it can be argued each step of progeny testing from pollination or cone collection to evaluation is the most important, test layout and establishment have to be ranked among the most critical. No matter how much effort was devoted to site selection, most sites will have environmental differences that must be considered. Care should be taken to reduce this variation within each replication or block.

Laying out the test. The replication or block should be set up so that each family samples the major variation within that replication. When using row plots on sloping terrain the replication should stretch along the contour with family rows or plots planted up and down the slope (see figure 1).

Reduce within replication variation on areas that have been subsoiled or bedded by planting the family rows perpendicular to beds or subsoiling. When it is necessary to install drainage ditches, the family rows should run perpendicular to the ditches. Filler trees can also be used to eliminate variation caused by changes in the site such as an old road, small

drainage area, gully, etc. The filler trees are not measured but serve to reduce border effects.

Test design will determine plot size and shape. Whether the design calls for row, single tree, or square plots it is desireable to flag or stake planting spots in advance. Of course, the manner of flagging and number of spots to mark will depend upon individual situation and Forest direction.

Planting. Planting procedures must include measures to maintain identity of many small bundles of labeled seedlings. Proper handling, care and planting procedures are a must since survival and growth are essential. It is most important to provide uniform handling to all seedlings throughout the planting process. Allowing some seedlings to dry could affect test results just as much as planting across a burned windrow.

Machine or hand planting may be used to establish progeny tests. Machine planting requires close supervision and a good crew to achieve uniform within row spacing. Making use of guidelines marked at designated spacing provides straight rows and uniform spacing when hand planting. Efforts should be made to have the same crew plant the complete replication. Do not begin planting a replication if there is not enough time that day to finish.

All have seen the edge effect around a stand of trees. Planting a two row border of the same species around the test will eliminate this source of variation. Where replications are adjacent, border rows are not needed.

Labeling and Mapping. As soon as planting is completed, labeling and mapping of the test should be done. The objective is to label and map the test accurately and in enough detail to enable someone not familiar with it to locate the test and identify every tree. Markers or tags should be permanent and either large enough to be found easily or located in the same designated positions throughout the test. Standards for each Forest or Region should be established.

Establishment records should include the following: test number or identification; method of site preparation and planting; species; spacing; date; description and/or map of the location of families; replications; and test site. Be sure to add the distance and direction to test from a permanent reference point. All test records should be kept at a minimum of two locations.

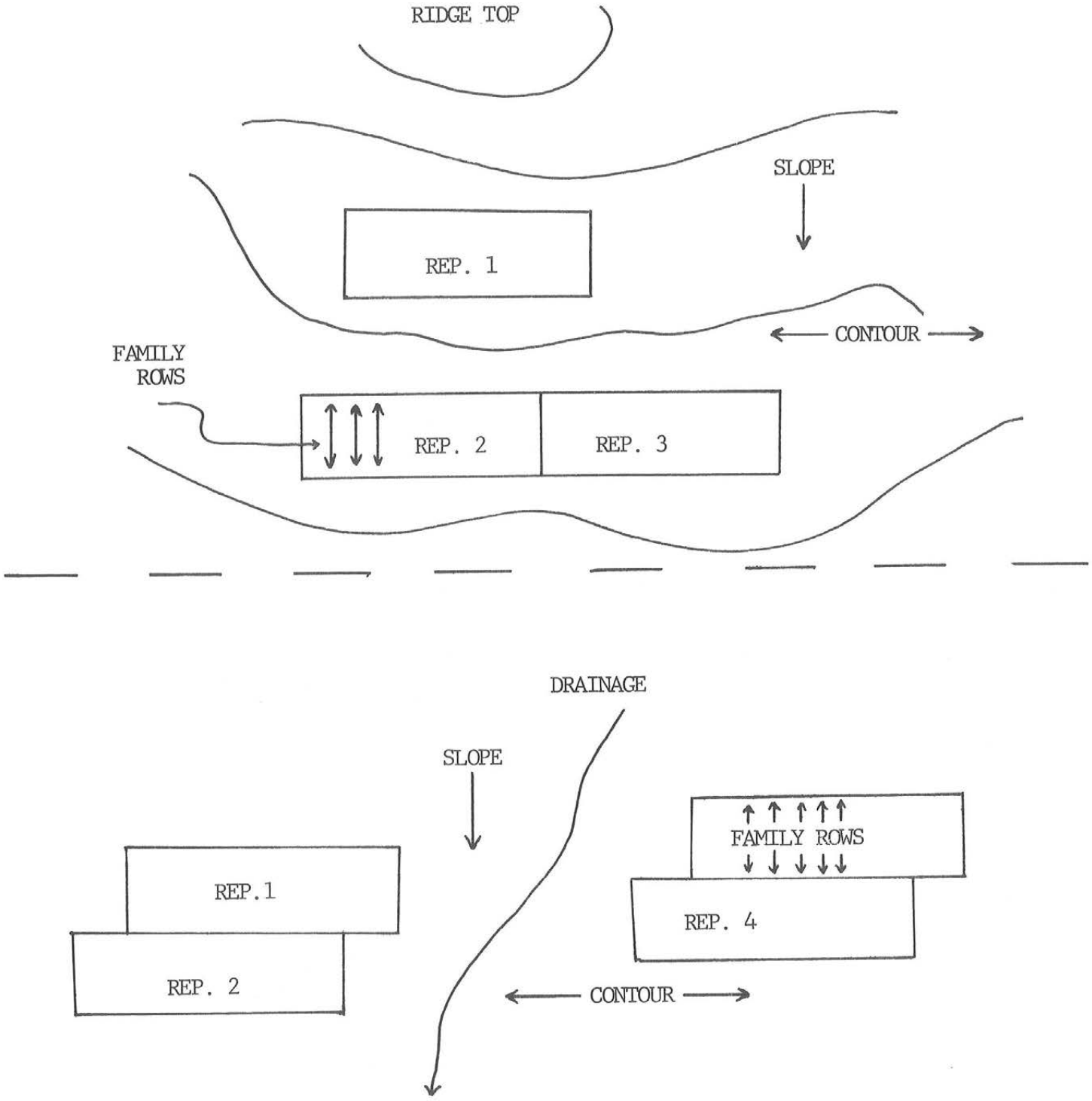


FIGURE 1. Row plot progeny test layout on sloping terrain to minimize within replication variation.

Animal Damage Prevention and Control in Evaluation Plantations

Carol Apruzzese
Mt. Baker-Snoqualmie National Forest - Region 6

Introduction

This paper was written to be used in conjunction with the R 5-6 Animal Damage Control (ADC) Handbook FSH2609.22. My objective is to provide decision-making procedures for animal damage prevention, detection and control on evaluation plantations (EPs). In general, I will not attempt to review all the information found in the handbook or in other available sources. I will, however, indicate when these references can be very useful.

Although the Handbook was written for the Pacific Coast states, it does cover all the major animal species that damage trees in the United States. So it can be very useful no matter where your sites are located. It is also the only book available of its kind. Supplement it with a key to local wildlife if possible.

Controlling or, better still, preventing animal damage to EPs is a crucial part of test site maintenance. Each individual seedling is as important to the test as every other. The goal is not some minimum stocking level but the survival, in good form, of as many seedlings as possible.

The impact and extent of forest-animal damage at least in the Pacific Northwest has only recently been recognized and there is a serious lack of quantified data (Evans, et al. 1981). The results of the Cooperative Animal Damage Study (CADS) (Black, et al. 1979) provide the only region-wide quantitative information on forest-animal damage.

The survey evaluated 194 plots of 110 seedlings each in Oregon and Washington. The plantations were established from 1962-64 with Douglas-fir or ponderosa and Jeffrey pine, and were studied for 5 to 10 years. One out of every 10 seedlings was protected from wildlife by a wire mesh cylinder to act as a control. At year 5, animal-related mortality was 43% in the pine plots and 33% in the Douglas-fir plots. Thirty percent of surviving Douglas-fir, and 15% of surviving pines suffered some animal damage.

Most other information is in the form of general articles or treats only a single species or a restricted geographic area. The available material does tell us is that forest-animal damage is wide-spread, highly variable and can have a great impact on seedling survival, growth and form.

Animal damage can be a real threat to successful plantation establishment and it can be a difficult problem to tackle. Successful identification of the animal species responsible requires training. Responses to any site will vary with time, the number of species present, fluctuations in animal populations, age of the trees and interactions among the animal species and between the animals and their habitats. The response of an animal species to a particular habitat may also be different from one experience to the next (either yours or that of the animal population).

Figure 1 shows the percent of damage in two Douglas-fir plots in the CADS study and illustrates the succession of damage agents that occurred over a ten year period. Both plots are high-sites in southwestern Washington. Plot A is at low elevation, plot B at mid-elevation.

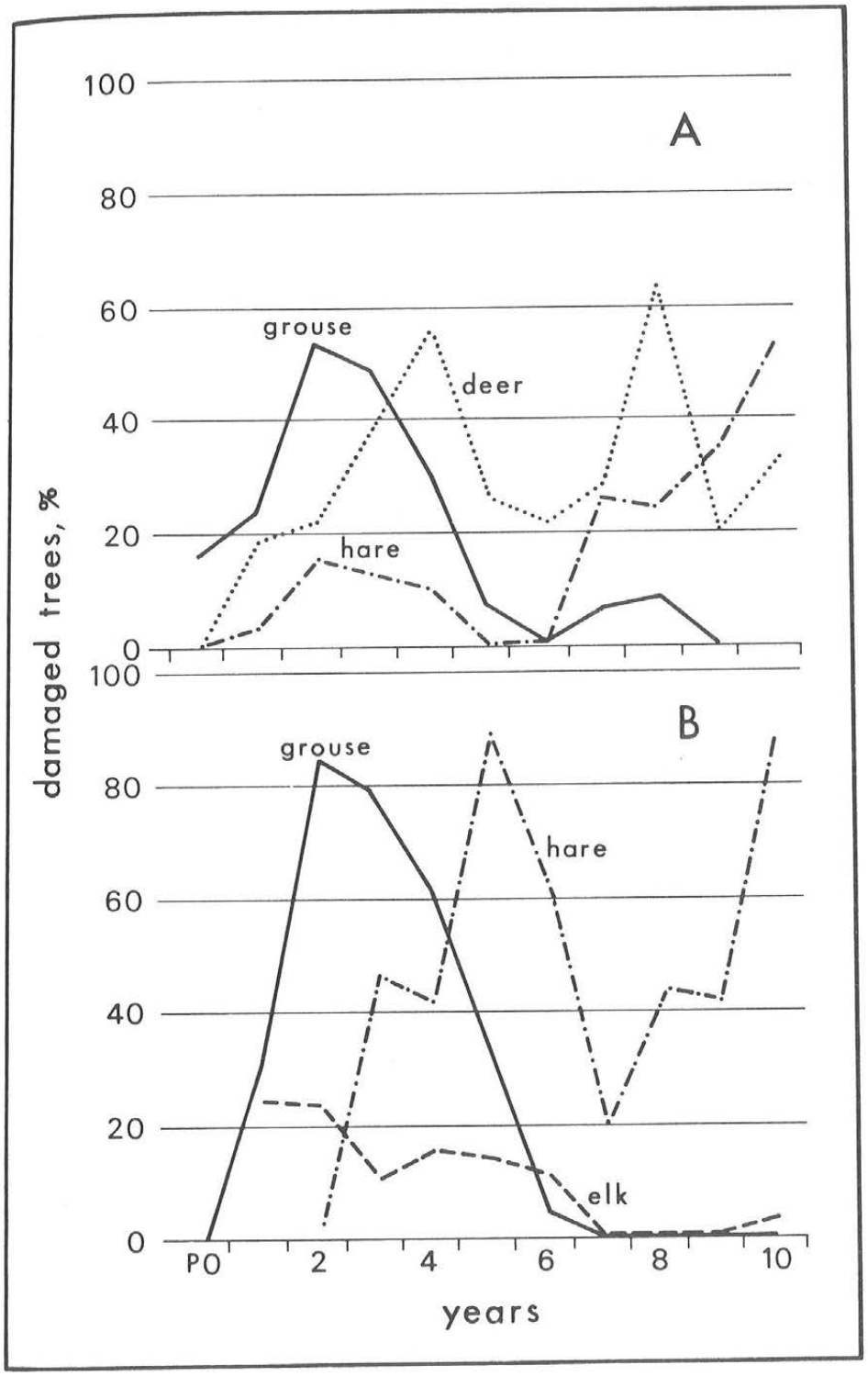


Figure 1. Percent of Douglas-fir trees damaged by specific agents on Plot 314 (A) and Plot 414 (B) of the CADS study in southwestern Washington, years 1-10 after planting (Black, et al. 1979).

Deer were the principal browsing agents in plot A and elk caused most of the browsing damage in plot B. Grouse damage followed a similar pattern in both plots but differed in degree. Hare damage peaked in the 2nd year in plot A, declined after that, and then showed a continual increase after the 6th year. In plot B, hare damage peaked at year 5 at close to 90%, declined between years 5 and 7 and was then heading toward a similar or even higher peak at age 10 when measurements were discontinued.

This is just one example of the differences in levels of animal damage possible from site to site. Clearly, animal damage control procedures must be site specific. Any given method must be tailored to your individual situation. You must rely on your growing experience and that of knowledgeable people you can use as resources to correctly interpret animal behavior. Because specific control methods are offered in other publications and since each solution must be site specific, only general tactics and those peculiar to EPs will be given here.

The Region 5-6 ADC Handbook is the single best reference tool available to you. Its aim is to provide basic information and direction for animal damage control programs in Washington, Oregon and California. There are several things to remember when applying the handbook to EP management. One is that it is a general reference and does not address EPs specifically. Another is that it was last updated in 1978 and new information may be available on your particular problem. A third and most important consideration is that it must be used only as a tool and not regarded as the final word.

To stress the value of the handbook, here is an outline of the subjects it covers:

1. Animal responses to habitat changes.

2. A key to the types of injury to conifers caused by wildlife in the Pacific Northwest. This section is used in conjunction with the detailed descriptions of species and their control found in a later chapter.

3. Animal surveys used to determine animal use and animal population size.

4. Damage control methods. Chemical toxicants, repellents, hunting, trapping, habitat manipulation and mechanical protection are all discussed in detail.

5. Pesticide labels are given in the appendix along with a glossary and details on selected control measures.

With this source, you can go a long way to identifying and then finding, solutions to most animal damage problems. Additional copies of the handbook are available from the Office of Adminstrative Management - Regional Office, R-6.

Evaluation Plantation Site Selection

Investing the time to find EP sites that indicate the least potential for animal damage is the best strategy to avoid problems after establishment. Develop a strategy for site selection that includes an evaluation of present and potential animal use. Plan well enough in advance so you can afford to be somewhat choosy. If possible, use a site which is under a logging schedule that fits your planting schedule. The less time the site sits between logging and planting, the less likely you are to have problems with competing vegetation which invites movement of small mammals into the newly-cut area by providing cover. Carefully consider which portion of a clearcut will become the test site. Large openings characteristically receive the most use by ungulates (deer and elk) along the edge near the cover of older stands. This will change as cover develops during the early successional stages of the opening. A site can also be selected and logged specifically for an EP under the small sale program. Under either scheme, you should consider the logging and site prep operations which will help keep animal damage problems to a minimum.

The amount of effort you devote to site selection will depend on the type of animal damage possible in your area, how great the damage can be, and the predictability of the behavior of the animal species occurring there. For example, if livestock, deer or elk will present a constant threat, then fencing may automatically be part of the site preparation. If mountain beaver or pocket gophers may be present, then a thorough survey of the area is warranted.

It may be valuable to have the prospective sites reviewed by a wildlife biologist/range conservationist. If you want the sites to be reviewed by a soil scientist, or other specialist, arrange to visit the sites with the wildlife biologist/range conservationist the same day. Pick several alternative sites so you will have a choice and your 'team' can compare them on the ground.

An important thing to keep in mind is the difference between the extent of ADC needed on EPs as compared to reforestation sites. Since the data available from each tree in a test site is important, the percent of damaged trees that can be tolerated is very low compared to a reforested plantation. However, demanding 100% unaffected seedlings is unreasonable. Misunderstandings can arise when the percentage of damage you consider intolerable is thought by a wildlife biologist or range conservationist to be next to nothing. This comes from their experience with reforestation sites. So you must be prepared to express the degree of control needed when you employ their expertise.

In general, 5% mortality from all sources can be tolerated on any one EP (Roy Silen, pers. comm.). You should consider leader damage to be equivalent to mortality in most cases because the growth rate and form of the seedling is usually severely altered. Lateral branch damage is not as critical and more of it can be tolerated before either the seedling or the test is seriously affected. When evaluating damage then, it is important to make a distinction between terminal and lateral damage.

The CADS study found that 30% of all unprotected Douglas-fir trees, and 15% of all unprotected ponderosa pine trees suffered animal damage each year during years 1 - 5. Although the study did not differentiate between lateral and terminal branch damage, it clearly shows that a sustained effort must be made to keep critical animal damage down to a tolerable level on evaluation plantations.

Summary of the important differences between reforestation plantations and evaluation plantations in relation to potential animal damage.

Reforestation Plantations	Evaluation Plantations
All logged sites must be reforested; any animal competition present must be contented with.	Sites can be carefully chosen from a number of possible sites.
Seedlings can withstand considerable browsing pressure (deer, elk and hare) and still survive and grow. Reforestation can be successful even when animal damage is relatively high.	Seedlings are to be tested with as little browsing damage as possible. One reason for this is the assumption that all seedlings are tested under the same conditions. Animal damage is usually not uniform, and therefore disrupts the experiment being carried out in the EP.
These sites can withstand higher mortality levels. I am thinking here of clipping, trampling, barking or complete removal of the tree.	Replacement trees are limited and can only be planted 1 or 2 seasons after the original planting. When replacement cannot be made, the data from that individual tree is lost.
These sites can withstand damage to seedling form from heavy browsing pressure or mechanical protection.	Trees must be grown with as little change in form as possible so comparisons can be made between individuals.
More seedlings than will eventually be needed for recommended stocking levels can be planted to guard against high levels of mortality. A species with low palatability can be used.	Each EP must be planted under a particular design and only with the species of interest, which may be highly palatable.

When evaluating a prospective site, consider checking nearby plantations for signs of animal activity. Find out what the stocking success has been in the area and the species composition of the competing vegetation. This will give you an idea of the habitats and food sources that will be available to potentially injurious animals. Look for migration routes and animal trails. Consider the palatability of the tree species you will be planting. For example, deer and elk have little interest in true firs except for initial curiosity, and Crouch and Frank (1979) found that pocket gophers exhibited no apparent preferences among the tree species they sampled: grand and subalpine fir, western larch, ponderosa and lodgepole pine, Englemann spruce and Douglas-fir.

Is the area part of a winter range for deer or elk? Plantations near big game winter ranges can provide a source of food when other sources are insufficient. What time of year is it and what level of animal use do you expect in this season compared to the rest of the year? If a particular species was using the area, would you expect to see fresh sign or would the primary use have been six months ago, making the damage less noticeable?

What impact will the development of a plantation at the chosen site have on local animal populations? A large clearcut in the early stages of regrowth can create an area of prime habitat for ungulates. Plantations adjacent to old clearcuts, and therefore often close to high populations of deer and elk can suffer considerable damage in western Oregon and Washington (ADC Handbook).

Are there any permanent bodies of water or streams on or near your site which will invite animal use? Mountain beavers, for example, prefer habitat with streams and moist soils. Also keep in mind the changes in habitat and animal use with changes in aspect and elevation.

Site Prep

Use site preparation to create an environment least likely to foster animal damage; avoid creating habitat. Unburned slash will provide cover for rabbits, hares and rodents (ADC Handbook) while providing an opportunity for preferred big-game forage to thrive. This may, however, reduce browsing pressure on the seedlings. So there is a conflict here: unburned slash can be a help or a hindrance with regard to ungulate damage. However, you probably will have decided to fence the EP if deer, elk, cattle or sheep present a threat. In this case, your efforts should be concentrated on reducing favorable habitat for small mammals. Broadcast burning will, in general, reduce small mammal populations. If burning is not desireable for other reasons, consider logging practices which will reduce the amount of slash as much as possible.

Browsing by deer was the most prevalent form of conifer damage in the CADS study affecting 22% of all unprotected Douglas-fir seedlings and 10% of unprotected ponderosa pine seedlings. EPs with highly palatable tree species such as these must be protected effectively.

Vexar plastic seedling protectors have been found to be effective in protecting seedlings from browsing (Anthony 1982). However, Vexar must be faithfully maintained. Soil movement and strong winds can cause the tubes to lean excessively. Snow can bend the tubes, resulting in deformed seedlings. Small Vexar tubes that are not checked on a regular basis will very often restrict the growth of both lateral and terminal shoots thus causing spiral or bent branches as the tree seeks room to grow. Seedlings with severely bent terminals do not recover. Anthony (1982) found deformed terminal shoots to be an inevitable result of using Vexar. Although Vexar can be a valuable animal damage control method for reforestation sites, it has too many drawbacks to be used in EPs.

The Forest Tree Improvement Activity Review Team (USDA Forest Service 1982a) recommended that "The use of small diameter Vexar cages should be discontinued in evaluation plantations." The Action Plan for Region 6 (the reply to the Activity Review Team's findings and recommendations) (USDA Forest Service 1982b) stated that "Most of our evaluation plantations are fenced for protection from browsing animals. We have used large diameter Vexar tubes on a few plantations but we have found fencing to be more satisfactory and less expensive for protection from browsing animals."

The suggested control measure then, for EPs with highly palatable species in areas with sizable populations of conifer-damaging animals, is fencing.

Fence construction and planting should be done as soon as possible after tree removal. A delay may result in re-entry of target species and you may actually fence in animals such as rabbits or hares. On some sites, it may be wise to fence the site immediately even though planting will be delayed for a season or if the site is excellent for an EP, but is simply being logged one year too early for your needs. The treatment of many west-side EP sites with herbicide during the fall before spring planting may be necessary to control the vegetation that has grown unchecked inside the fence.

Fencing reforestation sites for protection from damage by deer, elk or livestock has only been done when excessive damage has been demonstrated. Little work has been done in the Pacific Northwest on effective fence designs. Since fence construction is so expensive, the emphasis of animal damage protection has been concentrated on less costly methods such as Vexar and Bud Caps. Deer fences are the most common type of fence used and several examples are described in the ADC Handbook. These fences will not protect the seedling from rodent or hare damage. Improvements made in order to exclude these smaller mammals have been used but their success has not been quantified. Chicken wire at the base of the fence extending one foot up from the ground and buried one foot below ground level has brought inconclusive results, and in addition, any appreciable snowpack will permit hares to enter the site by going over the chicken wire during the winter. The success of electric deer fences has been variable. More work must be done to determine the most effective, economical fence design for deterring large mammals and the feasibility of fencing out hares and rodents.

Consider all the species you wish to exclude from the site; get recommendations from experienced people before you make the final decision on a fence design. Fences are generally expensive and it is best to be conservative, make the fence effective to avoid having to make changes in it later on which will be much more costly.

Trapping and baiting can be done before planting if burrows of gophers or mountain beaver are present. However, it is preferable to avoid any site with mountain beaver. If prime habitat is present, they are very hard to eliminate.

Animal Damage Identification

Accurate identification takes training and you should rely on the expertise of wildlife biologists or range conservationists at the District or Forest level to assist in this training. Local biologists at colleges and universities may also be able to supply expertise or participate in putting on a workshop.

The ADC handbook provides a detailed key for damage to seedlings, saplings and trees. After reaching a tentative ID with the key, check the referenced section on the species to get detailed information on feeding habits, damage problems, control, etc.

Damage may be first noted during maintenance or survey of the EP. All affected seedlings should be noted in the EP records. Before using a key (usually back at your desk) you should follow a checklist such as the one provided below, to make sure you have all the pertinent information.

Quick Checklist for Documenting Animal Damage

Seedling Condition

Shoots - browsed (torn off with ragged edge), clipped (broken off cleanly)?

Buds - neatly removed, intact?

Needles clipped - partially or completely removed?

Bark removed? - note condition.

Roots - gnawed, clipped?

Tooth or claw marks - distinct or indistinct, width of the tooth mark, direction of marks horizontal, diagonal or vertical

Completely pulled out of the ground - damage to any specific part of the seedling?

Damage-recent, if not, how long ago?

Animal Sign

Game trails.

Tracks.

Runways in grassy ground cover.

Clippings of herbaceous vegetation in small piles along runways.

Burrows.

Droppings.

Damage wide-spread, local or apparently along a trail?

Other Items To Note

Age of seedlings, saplings.

Time of the year - is damage likely to get worse or decrease?

If during the first growing season - how soon after planting?

People are animals too and can cause damage.

After you have made a tentative ID, verify it with a wildlife biologist. If you have all your facts in hand, you may be able to get some quick information over the telephone if no one is available to examine the site. Consider the acceptable level of damage and whether present conditions exceed it or will exceed it if left unchecked. It has already been suggested that 5% mortality (or leader damage) should be the maximum tolerable level of damage on the plantation overall. However, a 5% overall mortality level that includes 20% mortality within any one particular family, is not acceptable. There is evidence that certain families or genotypes can show either genetic resistance or susceptibility to animal damage (Dimock 1974; Dimock, et. al. 1976). Therefore, regardless of the overall mortality level, no more than 5% mortality per family should be tolerated.

Implementation of Control Methods

In deciding on the methods of animal damage control to undertake, there are several factors to consider.

1. The types of control available and the length of their effectiveness. The ADC Handbook outlines many methods both by type and under the species descriptions. It may be necessary to combine two or more techniques to achieve the desired level of control. A survey was conducted by Timber Management in the Regional Office on the types of animal damage control methods used on the national forests in the Pacific Northwest (USDA Forest Service 1981). The memorandum includes all the responses from the forests and summarizes the major control methods and costs. This survey may be helpful in gathering information on the effectiveness of certain procedures in your area.

2. Cost. Compare costs and include any regular maintenance that is necessary. A less expensive solution is no good if it is less effective and requires a lot of attention.

3. Personnel needed to implement control. Are they available?

4. Documentation required. Is an EA necessary and has one been written which covers the procedure and situation?

5. Time of year. Apply control when it will be most effective. Damage by many animal species can increse in winter when other food sources are scarce. Also, damage can escalate after small mammals breed in the spring and summer.

6. Weather and terrain. Controls may need to be implemented before the site becomes inaccessable in winter.

7. Remember that all the seedlings must be treated the same way to preserve the assumptions of the test.

Evaluation Plantation Maintenance

Animal damage control is a major part of EP maintenance and forseeable activities can be built into the budget and work plans. Fences must be checked and sometimes repaired or modified; trapping, baiting, the application of repellants, vegetation control, etc. are costly and must be considered when planning expenses for each year.

All trees with leader damage should be included when doing replacements for mortality. As mentioned earlier, animal-damaged leaders usually cause severe alteration in growth rate and form.

The control of herbaceous vegetation has two positive effects. One is to diminish competition for space, moisture and other resources. Often this competition affects some seedlings more than others violating one of the assumptions of the test: that all trees are grown under the same environmental conditions. The other benefit is a reduction in favorable habitat for small mammals. Small rodents, especially voles, need herbaceous vegetation for cover and food. While fencing does protect seedlings from browsing it also allows unrestrained growth of unwanted vegetation. Consequently, fenced sites will have more unwanted vegetation than would be found on non-fenced sites. Some EPs will need to be treated with herbicides until the trees are large enough to resist small mammal damage.

Environmental Assessments are required for certain control methods. Consider developing an EA covering all the sites and all the control methods that may be used. Or, if vegetation control is covered in a Forest EA for projects other than tree improvement, you may save time and money by including the EPs in that assessment. Plan ahead, evaluate all the procedures you may need to adequately maintain the sites and prepare the proper documentation. This will allow you to implement immediately if the need arises.

Summary

Forest-animal behavior and damage is variable. Experience in a particular locale is necessary to be able to identify or predict the impact of animal populations on conifer plantations with any degree of accuracy.

The Region 5-6 Animal Damage Control (ADC) Handbook is a valuable tool which provides basic information and direction for animal damage control programs.

Seek out the wildlife biologist or range conservationist to assist in site selection, animal damage control, suggestions for fencing designs and training in AD identification.

Investing time in EP site selection is the best way to avoid animal damage problems after establishment.

Use site prep to create an environment least likely to foster animal damage.

Animal damage control is an integral part of EP maintenance. Prepare required documentation in advance so control procedures can be implemented when needed without delay.

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Vegetation Control in Evaluation Plantations

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Controlling vegetation on evaluation plantations (EPs) is often an integral part of site maintenance. In some cases, vegetation control may be necessary simply to insure tree survival. It can remove available habitat for potentially injurious small mammals and reduce competition for resources.

Variation in the availability of resources will violate a major assumption of the test: that each seedling is grown under the same conditions as much as possible.

Thoughtful site selection and site prep can reduce the need for herbicide use later. Choose sites where there is little or no competing woody vegetation. This is the most difficult type to control because woody species often sprout. Planting the site as soon as possible after logging will reduce the time weeds will have to establish themselves. A watercourse on or near the site may preclude the use of herbicides later and also will require monitoring; these sites should be avoided. Do not clear the site as you would a seed orchard or nursery bed; this will only create an ideal seedbed for herbaceous species.

Planting large seedlings may give them a headstart over the weedy species that invade the site. The advantages of using larger stock must be weighed against the added costs of slower planting.

You can also apply herbicides one or two seasons before planting. This is one way to hold over a site that, for whatever reason, planting has been delayed.

Control Methods

Vegetation management can be accomplished by hand or by herbicide application. Here is a list of the various methods and their uses.

Manual

There are certain advantages to hand control methods. Documentation (environmental assessments and monitoring) is not required and timing the work with particular events in the plant's life cycle may not be necessary. However, there is a major disadvantage - effects are usually good for only one year and control must be repeated. If you have a site where herbicides cannot be used, it may be your only choice.

Hand pulling weeds	Small pockets of competing vegetation, especially vines; labor available.

Cutting competing vegetation around each the trees over the entire site.	Can be cost effective when the vegetation is dense, woody and herbaceous and one herbicide can not control them all. The only alternative may be aerial application after covering the trees; labor available.

Herbicide Application

Herbicides can be extremely effective if applied at the right time of the year and the trees are protected. Documentation must be done, so planning is essential. There is a risk of burning the trees if the chemical is not applied properly. There is also the risk that the application will be ineffective if the weather changes and it rains heavily soon after application.

Aerial Application Trees covered with paper bags.	Vegetation over entire site. Use when it is impossible to apply herbicide using backpack sprayers and the vegetation is dense.

Ground Application - Backpack Sprayers

Herbicide applied over entire site. Trees covered.	Water source nearby which precludes aerial application.
Herbicide applied around seedlings only. Trees covered.	Vegetative competition is moderate.
Competing hardwoods only. Trees usually not covered.	Hardwood seedlings or sprouting is the only vegetation problem.

Implementing Control Methods

There are several things to keep in mind when choosing and implementing vegetation control.

1. Length of effectivess. If the trees are large enough and need only one more season to get above the brush, manual control may be enough and may be less expensive.

2. Cost. Be sure to look at how often the method will have to be repeated.

3. Documentation required. Planning is essential since it takes several months to prepare an EA for herbicide use.

4. Optimum times of the year. This will vary with the weed species, herbicide, and the geographic locality.

5. All seedlings must be treated the same. Herbicide must be applied over the whole site if applied at all.

THINNING IN PROGENY TESTS:
Some Concerns Related to Competition and Yield Improvement

Sharon T. Friedman 1/

Tree improvement programs are designed to provide seedlings or vegetative propagules for the plantations of the future. These stands, like the plantations of today, will have to grow under a variety of conditions. Trees have an initial period of growth after planting, with little or no intraspecies competition, but potentially severe competition from other plant species. They then enter a period of competition with neighboring trees; this competition may be for water, light, nutrients, or some combination of these factors. Depending on the factor involved, competition may be discernible to the forester (e.g., crown closure), or difficult to separate from other causes of reduced growth. In an attempt to maintain high rates of growth, concentrate growth on larger stems, and remove future competition-induced mortality, the forester will thin. Due to thinning, intra-species competition is likely to be reduced for some time; nevertheless, some such competition is likely to be a continuing fact of life for managed forest stands.

For tree improvement to improve stand volume yields, families or clones should be selected which are:

1. Good isolates. Families should have good height growth and survival during the initial establishment period. This is particularly important for areas in which travel to planting units is long or difficult. Management costs of herbicide and animal damage control programs could be reduced if trees could get above the brush or animals a few years sooner. This would have some economic value even if the plantation never yielded an extra board or chip. If precommercial thinning is planned, the period during which being a good isolate is important would be extended. Genetic improvement in early growth cannot substitute for good nursery and seedling handling practices, but should be used in conjunction with the best available practices.

2. Good competitors. These are families which are competitive (grow well themselves) in the mixtures in which they are planted. For certain

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industrial ownerships in the Southern U.S., these may be 200 acre family blocks (Clem Lambeth, pers. comm.). For the Forest Service in the West, it is likely to be a mixture of families from a breeding zone.

3. Good neighbors. A family which uses water, nutrients, and light efficiently is a "good neighbor" to other trees. If a family is a good competitor, as in 2 above, but reduces the yield of neighboring trees, enough of these families in the stand could cause an overall reduction in stand yields compared to those expected for a stand of superior trees.

4. Good releaser. This is a family which grows rapidly when released to reoccupy the site in a short time.

5. High harvest index. This term (Donald 1962) refers to a plant which has a high proportion of its dry market production in a harvestable form. In the case of forest trees, this generally means a family which concentrates a high proportion of its biomass on the stem.

6. Adapted. This is a family which is adapted to the abiotic (climate, soil) and biotic (diseases, insects) environment on a planting site.

Certain attributes of an ideal forest tree, then, can be generalized, despite the fact that there are special uses which may require additional properties (e.g., high wood specific gravity). But the attributes above occur under differing conditions of stand development. Some of these may be negatively correlated. The literature on these subjects is often confusing. Nevertheless, a brief review of this literature will establish a helpful framework for considering the problem of thinning in progeny tests.

There are three basic components of the literature which bears on these problems: the crop ideotype, competition, and density literature. First, the 'crop' ideotype as defined by Donald and Hamblin (1976) for field crops is a small plant with few erect leaves, which, when grown in monoculture, will increase the total yield per acre. The 'isolation' ideotype, for cereals, is a leafy plant able to explore its environment as extensively as possible. The 'competition' ideotype is leafy and free-tillering, but also tall and spreading enough to shade its neighbors.

These concepts were applied to forest trees by Cannell (1978). The isolation ideotype in trees has a high branching frequency, low apical dominance, and slow branch ageing so that the crown becomes tall, dense, and broad (Cannell 1978). These trees should be highly competitive with other vegetation and other trees. These trees would be similar to the good isolates above, except that the good isolate is measured by its juvenile height growth only, regardless of the physiology or appearance of the tree. Selection before canopy closure in progeny tests, Cannell (1982) suggests, favors this type of tree.

A competitive ideotype, which grows rapidly in mixture at its neighbors' expense (Cannell 1982) is equivalent to a good competitor, combined with a poor neighbor (above). These are the trees selected in long-term progeny tests with mixed genotypes, according to Cannell (1982). The problem is basically how to identify a poor neighbor; as a good competitor and good neighbor would be similar to a crop ideotype. A crop ideotype was defined as (Donald 1968) "a plant model which is expected to yield a greater quantity or quality of grain, oil, or other useful product when developed as a cultivar." Cannell (1978) states, "In practice, 'crop' ideotypes are difficult to identify in mixed-genotype communities, but as pure stands they will produce the greatest yields per hectare." In 1982, Cannell sought to identify crop ideotypes in Sitka spruce by growing trees for four years as isolates, and in family blocks. He found that the family ranks using open-grown trees were similar to the 4-6 year field tests, but neither of these was related to growth under competition. If these families are planted operationally in family blocks, these are indeed 'crop ideotypes'. They are also good neighbors within the family and good competitors within the family. But, if plantations are planted with a group of families which grow well in family blocks, will this group continue to have the highest stand yields?

The competition literature seeks to answer these types of questions. Some studies have examined the relationship between growth in pure stands (one family) and that in mixed family stands. Two of four loblolly pine families (Adams, Roberds and Zobel 1973) exhibited faster growth when grown in pure stands than when grown in mixed, before competition set in. At age four, again before competition set in, sixteen loblolly pine families were significantly taller, and had greater volume, when grown in pure family blocks than when grown in mixtures (Williams, Bridgewater and Lambeth 1983).

It appears, then, that there may be some growth advantages to planting in family blocks. However, in crop plants, mixtures of varieties often outperform the mean of component varieties and sometimes exceed the yield of the best performing variety (studies cited in Adams, 1980). Mixtures are generally also more stable over environments (studies cited in Adams, 1980) and may be more resistant to pests, although the latter is the subject of some controversy. Forest Service plantations, despite certain advantages of family blocks, then, are likely to remain mixtures of families.

Relatively little work on the performance of specific mixtures has been done in forest trees. Adams and Demeritt studied competition in six hybrid poplar clones (Adams, 1980). As is often found in crop plants, the clones which performed the best in pure stands were generally poor competitors in mixture and vice versa. In general, the clones could be classified as good, poor, or neutral competitors or neighbors based on their average competitive ability or influence. One clone was the best pure-stand performer and a good competitor, but was a poor neighbor. As Adams (1980) states, "This is the kind of genotype that could cause real problems in a mass selection program. Because of their adverse effects on neighbors, selecting a high proportion of these genotypes might result in a reduced or even negative response in the population mean." Thus, the competition literature indicates that stand yields in mixtures cannot be improved by selecting the best families in pure stands and vice versa. Therefore, Cannell's Sitka spruce may be a crop ideotype for family blocks but not for family mixtures as the crop ideotype appears to be specific to a planting mix. Other studies are attempting to quantify the effects of genetically different competitive regimes in long-term field tests (Nance, Land and Daniels 1983). Such attempts to assess the importance of these competitive effects in field tests should be given high priority in research. Ignoring competition effects, if they are important, could lead to sacrificing gains in yield from tree improvement.

The concept 'crop ideotype' has also been used by Karki (1983) to refer to genetically narrow-crowned trees, trees which can be cultivated in dense plantations, and which have a high harvest index. These trees are identified by observing their form and growth. In moist areas, where light may be the limiting factor, does a small crown mean that a tree is a crop ideotype? Cannell (1982) found no differences in crown from between good and poor performers of Sitka spruce in closed stands, and stated that the idea that crop

ideotype trees have certain form characteristics is based "more on theory than on evidence". So, while the crop ideotype of Karki (1983) is related to high harvest index (5, above) its relationship to actual competitive ability or influence is unknown.

To summarize, a crop ideotype is defined as any plant which is expected to yield a greater quantity or quality of product when grown as a cultivar. The use of this term is often confusing because different families can be identified as crop ideotypes depending on whether quality or quantity is desired, and also depending on the mixture in which they are grown. If a family is referred to as a generally good neighbor or competitor, or has a high harvest index, on the other hand, specific measurable traits are involved. Whether tests done at known ages reflect future performance as neighbors or competitors is or should be the subject of further research.

Finally, the literature on density by genotype interaction is also useful in considering thinning in progeny tests. Since performance in isolation is generally not related to competitive performance, regardless of the identity of the competitors, we would expect a genotype by density interaction if at some densities, trees were competing, and if at other densities, they were not. So the real question is whether, under competition, different densities cause different family rankings. There are two reasons why this is of interest. First, we need to know how important spacing is for field progeny tests, and test at different spacings or be careful about spacings after thinning, if necessary. Secondly, if growth under competition at an early age is used to select the "good competitor" families, we need to know what spacing of this test will produce results comparable with an older field test.

Different growth variables have been used in different studies of genotype by environment interaction. Wearstler (1979) found no family differences in height at all in loblolly pine under three densities, so therefore there was no genotype x density interaction. No genotype x density interaction for volume or height was found for Eucalyptus (Rockwood 1983). Campbell and Wilson (1973) found no appreciable genotype x spacing interactions in diameter or height among 30 full-sib Douglas-fir families grown for three years in a nursery. Malavasi (1984) found significant genotype by density interaction in shoot weight for one year old western hemlock and silver fir, and changes in family ranks with density also in Douglas-fir, although the interaction term was not significant. Significant genotype by spacing interactions were found for all three species

for shoot/root ratio. Stonecypher and McCullough (1981) found significant genotype x spacing interaction in volume of 30 full-sib families in 8 year old Douglas-fir in a Nelder design. Due to the low densities in the study, as low as 735 trees/hectare (298 trees/acre), some may have not entered into substantial competition by the 8-year measurements. Competition induced mortality or growth loss would be an indication that competition had begun; another would be crown closure in areas where light is limiting. When these studies are reported, it would be helpful if authors clearly stated whether crown closure had occurred or whether competition-induced growth loss or mortality had occurred at any or all of the spacings. Competition induced growth loss could be detected in comparison with the same material grown in isolation. If entries being evaluated are genetically diverse and the experimental design encourages competition among entries, Campbell (1973) suggests that genotype-spacing interaction may be more important than when observed in nursery tests. Interpretation would be facilitated if competition and density were both controlled in the same studies.

To summarize, then, ranks may change depending on whether trees are competing or not, depending on what type of competition it is (within family or mixed families), and, perhaps, depending on the density at which trees are growing.

This information is helpful for making decisions concerning thinning. For one thing, pre-commercial thinning, although planned in some operational plantings before crown closure, would allow several more years before inter-tree competition develops. Knowledge of which trees grow best in isolation is already available from the first years of the test. Therefore, it would be beneficial to allow competition as soon as possible, so that the good competitors and good neighbors can be identified. In most cases in progeny tests, then, in contrast to operational plantings, it would be best to wait to thin until competition has begun.

The type of plot in which trees have been planted can constrain the type of thinning which can be done. In block and row plots, either systematic or silvicultural thinning can be done. Silvicultural thinning involves the removal of suppressed, misshaped and damaged trees, and beyond that attempts to obtain an even distribution of the remaining trees. Systematic thinning involves the removal of trees on a systematic basis. Ideally, systematic thinning would allow each tree to have equal amounts of competition. But this depends on how

much mortality there is in the plantation. Since the trees to be kept in a systematic design are predetermined, these should be thinned before severe suppression of growth takes place; on the other hand, silvicultural thinning can be more flexible with regard to timing, since the suppressed trees will be removed anyway.

Row plots have several disadvantages. In terms of competition, they are neither entirely competing within family, nor among families. The row plot is statistically less efficient than the noncontiguous plot design (Lambeth, Gladstone and Stonecypher 1983). Differences among dominants, codominants and suppressed trees can be exaggerated in row plots (McKeand 1983). If competition is allowed to progress too far in this situation, opportunities for systematic thinning may be foregone. The specific objectives of the test are important. To estimate variance components, and to estimate disease resistance (McKeand 1983) as well as minimize error due to different spacing, a systematic design may be preferred. To simply not bias later estimates of performance, on the other hand, forms of silvicultural thinning can be used (Talbert, Bridgewater and Lambeth 1981). In the N.C. State Cooperative, which uses row plots, approximately equal numbers of trees are left to represent each family in a plot. Family plots are thinned to a density of about one-half the planting density, or three trees per plot. Within these constraints thinnings are silvicultural, with trees unlikely to reach harvest size removed. No more than two trees are left adjacent in family plots, and, if possible, the same rule applies to trees in adjacent plots. Only a subset of tests are thinned; final measurements in most are at one-half rotation age. Only a few tests for each cooperator are thinned and measured periodically until rotation age.

A trade-off in thinning, especially systematic thinning, or silvicultural thinning where spacing is a major concern, is the need to remove some of the best trees in the best families. These trees would potentially be selections for the next generation. For this reason, unless good isolates only are to be selected, the stand should be under some level of competition before selections are made. It would be useful to know the earliest time after the onset of competition when good competitors and good neighbors could be accurately assessed. Due to site heterogeneity and competition effects, the "best" trees within families could be selected using improved selection methods similiar to those discussed by Cannell, Njuguna, Ford and Smith (1977). These then could be grafted; the disadvantage would be that later information on the trees' perfor-

mance would be unavailable. The importance of this disadvantage would be expected to vary with length of rotation, difference between time of first thinning and end of the rotation, and the importance of adaptive traits relative to growth traits for a given species and breeding zone. One way to partially avoid this problem would be to have some plantations thinned systematically so that variance components, juvenile-mature correlations, competitive effects and other such variables could be estimated as accurately as possible. Other plantations could be measured until the first thinning, and selection thinnings be done after that such that all the trees in the best families would be left so that adaptation could be assessed, and outstanding trees in other families in growth, form, and pest resistance could be left, with even spacing a secondary factor. To reiterate, for the 'best' families to be accurately assessed before the first thinning, some amount of competition would be necessary, as having good neighbors and good competitors in an improved population would be important to yield improvement. On the other hand, it would be difficult to assess the best trees within families as good neighbor and good competitors under conditions where spacing was a secondary factor, and might be erratic. Nevertheless, relatively good information on adaptation and harvest index could be obtained regardless of spacing. Therefore, when thinking about selection within family in progeny tests, and thinning versus selection, it is important to consider which traits are most important for a given breeding zone and how they are affected by spacing.

These concerns with second generation selection apply to systematic thinning in family block, row, and noncontiguous plots. As stated above, family block plots are preferred only when family blocks are planted operationally, and row plots have several disadvantages. In the Pacific Northwest, California, and the Inland Empire, the noncontiguous plot is most commonly used. These are commonly found in three designs: completely randomized within rep-sets (CR), square interlocking block (SIB) (Osterhaus and Stevens, pers. comm.), which is a form of random interlocking block (LIB)(Libby and Cockerham, 1980). The CR design does not allow systematic thinning while retaining equal family representation. Both the SIB and the LIB designs do allow systematic thinning. The LIB design differs from the SIB design in that: 1) the staking is hexagonal, rather than square, 2) there are usually two thinnings in LIB, each removing one-third of the original number of trees, while in the SIB design, one-half of the trees are removed at one time. With either SIB or LIB designs, final spacing should allow growth until rotation or close to it. The advantage of the SIB design is

that it is very similar to CR, so that workers used to CR can usually easily change to SIB. LIB, on the other hand, requires hexagonal positions which are difficult for workers used to square rows and columns. In either LIB or SIB design, the choice of which groups to remove is based on trying to maintain equal representation of families and minimize mortality. In the case of mortality, trees from other thinning groups can be left in an attempt to equalize spacing. If the decision is made to use systematic thinning, then the use of the LIB or SIB design makes thinning relatively simple. In contrast, thinning in the RB design while attempting to maintain equal family representation is likely to be very challenging. Tim White (International Paper Company, pers. comm.) has modeled thinning, using a computer algorithm to consider mortality, and to allow retention of a certain number of each family per site, with two or three trees adjacent to each tree. The lowest twenty-five percent of families had to be completely removed, or left only to adjust for spacing, to allow a solution. By removing twenty-five percent of families, genetic information such as estimates of juvenile-mature correlations, and variance components will be sacrificed.

This information is based on modeling, however, and no such algorithm is operational. Due to borders between sets and reps, the computer program would have to be set up to operate on an entire plantation basis. A great deal of work will go into establishment of such a program, but it will ultimately be necessary for thinning the many progeny tests of this design. The extra work during layout and planting which distinguishes the SIB and LIB from the CR design may well pay off with reduced costs in thinning and with the additional long-term information which could be obtained.

The above considerations hold for plantations which are already in the ground. But what considerations are important for future progeny tests? To return to the different life-stages of the tree, it would appear that juvenile height growth could be assessed in a much more cost-effective manner in a single, separate test rather than in six to sixteen progeny test sites spread throughout the breeding zone. Early nursery height growth rankings can change considerably, however, depending on the environment of the test site, so that proper choice of the test site would be important (Friedman, unpublished). It is also possible that growing young trees in competition may cause them to express future traits as competitors and neighbors (Franklin, 1979, 1983). This should become the subject of more intensive study, as the economics of any sort

of early selection or screening would seem to be extremely favorable, particularly for species with long rotations. While testing for adaptation will still require long-term tests, the number of families in these tests could be pruned considerably at a great cost saving by using appropriate early screening procedures. Everyone in tree improvement has probably had experience with using (one is tempted to say "wasting") expensive field test space on families with totally unacceptable levels of early height growth. Based on present information, which is not complete, there is no reason that populations cannot be developed with rapid juvenile height growth and the other desirable commercial traits outlined above. If juvenile-mature correlations are relatively predictable (Lambeth 1980), then some increase in later height growth could be obtained simply by screening for juvenile height growth. If, however, only families previously tested for juvenile height growth are used, the implications are first, that removing twenty-five percent of the families early in the test would be unacceptable, and therefore, SIB, LIB, or other systematic design would be necessary. Secondly, field testing would be long-term, and designed to measure adaptation itself, rather than early growth and adaptation. In this case, problems which affect early measurements would not be as precisely controlled. To continue along the same lines, perhaps extra trees could be planted to substitute for mortality which is random with regard to family, and, otherwise, the plantation would be managed as an operational plantation, except that thinning, in at least some, would be systematic. Estimates of yield improvement from such tests would be underestimates of yield improvement from genetically superior operational stands, as no precommercial thinning would have taken place, and greater yields would be expected from silvicultural thinning (compared to systematic in tests) in operational stands.

It is clear from the above discussion that the topic of thinning in progeny tests is inextricably interwoven with the design and objectives of the tests. The choice of the best thinning option also depends on the traits on which most emphasis will be placed, and plans for operational forest management. Finally, the choice also depends a great deal on questions for which there are, at present, only incomplete answers: we need information on the interrelationships of the desirable commercial traits, and under what conditions we can effectively measure such traits, both among and within families.

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INSECT AND DISEASE CONTROL IN PROGENY TESTS

by Sharon T. Friedman 1/

Insect and disease problems will occur in the operational plantations in which improved tree seed will ultimately be used. Adaptation to the biotic environment may be as important to survival and growth as adaptation to the abiotic environment. Hence, ability to survive and grow under operational conditions may depend on resistance to insects and diseases. There is a trade-off, however, in that detecting differences in resistance may compromise our ability to detect differences in growth. Insects and diseases may cause decrease in survival or growth loss, which causes a reduced capability to detect family differences in growth. Moreover, the situation of too few survivors to detect family differences will continue for the rest of the life of the test. Finally, populations of insects or diseases in progeny tests may be localized, and not in proportion to their prevalence in the breeding zone. In such cases, control measures are often considered. Perhaps the simplest decision is that in which control measures are generally used in operational plantations, such that testing should also include this type of control. There is a genetic component to resistance or tolerance to a great many insects and diseases.

Insect and disease management should be considered at four stages during progeny testing: planning, site assessment, planting and plantation management, and crisis management.

I. PLANNING

Proper planning at the beginning of the project can often lead to fewer crises during progeny testing. First, assessment of the common pest problems of the breeding zone, and, especially, those likely to attack plantations, is helpful. For each pest, the following questions can be considered:

1. On what proportion of acres to be planted in the breeding zone is this pest a problem?

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2. What is the average population level of this pest in a breeding zone? Does it vary over years? On different sites?

3. How do we (or do we) manage this pest in operational plantations?

4. On what ages or sizes of trees can we expect it to be a problem?

5. What does the pest do to trees (kills, causes growth loss, kills shoots)?

6. How does the pest spread (temporally and spatially)?

7. Are we interested in resistance to the pest?

8. Do control measures exist?

9. What are organizational constraints on pesticide use?

Certain arboreal equivalents of childhood diseases can have a disproportionate effect on early growth measurements, and can be easily controlled (e.g., tip moth). Others attack trees thoroughout the life cycle and are less easy to control. The longer protection is required, generally, the more difficult it is to accomplish. Some diseases, such as stem rusts, may be ubiquitous and no control measures may be available. But prior screening of families in the nursery for resistance may save space in field tests. In the N.C. State Cooperative it is recommended to place test sites where there is a high potential for fusiform rust infection, but where infection is less than 70 percent.

Pests which kill trees should generally be controlled; especially if the number of trees of each family in the test is near the minimum to distinguish family differences. Root rots, because of their patchy distribution, should generally be avoided.

II. SITE ASSESSMENT

Site assessment is an opportunity to put the information learned in planning to use, and to reject sites which may have unwanted problems. The initial site visit should be used to inventory existing pest problems, and conditions such as soil compaction. Such conditions can stress trees, and make them more susceptible to pest problems. For these reasons, entomologist, pathologist, and soil scientist review of test sites is beneficial. Geneticists should also develop expertise in field identification of local problems.

The proposed progeny test site and the surrounding area should be checked for the pest problems identified above. Neighboring plantations should also be checked, if available, for evidence of problems unique to plantations or younger age classes. Again, root rots should be items of particular concern. Sandy soils may harbor root-eating tree-killing insect larvae. Soils may have been compacted excessively from previous logging activity. Sites should be chosen so that pesticides can be applied if necessary; this generally means (in the Northwest) not close to streams or private land. Any recommendations from specialists should be kept on file and communicated to the appropriate people. They may affect the planning of the harvest (e.g., cutting a buffer strip for dwarfmistletoe protection, designated skid trails or logging over snow to protect soils, sprinkling stumps with borax for Fomes annosus), affect site preparation, or planting (e.g., dipping seedlings in systemic pesticides to protect them from root insects).

III. PLANTING AND PLANTATION MANAGEMENT

By keeping tested trees healthy and vigorous, resistance to most insects and diseases should be increased. On the other hand, some insects, unfortunately, prefer to attack healthy trees. Seedlings should be checked carefully for insects and disease before they leave the nursery so that diseases or insects do not invade test sites from the nursery. Site preparation and vegetation management should be accomplished so that trees are not exposed to excessive stress from vegetative competition. A careful planting job is extremely important as the poorly

planted tree is susceptible to certain pests (e.g. Armillaria root rot). Thinning of tests should be accomplished before competition stress is severe enough to allow an insect or disease population to increase to a level which endangers healthy trees.

IV. CRISIS MANAGEMENT

Despite one's best efforts during planning, harvesting, site preparation, and planting, insect and disease surprises are likely to occur. Such is the nature of long-term testing. Two factors are important in crisis management; regular monitoring of test sites, and early proper identification of the damaging agent.

By catching the problem early, and properly identifying the problem, the pest questions (1-9 above) can be considered. Sometimes pests are relatively unknown prior to their occurrence in progeny tests, and hence, little information on these pests is available. When the spread or patchiness of the pest distribution is unknown, and information is needed, a random survey of the plantation can yield this information as well as the percentage of trees attacked.

In summary, then, insect and disease management should be considered during planning, site assessment, planting, and plantation management, so that a minimum of future crises will occur. When crises do occur, it is important to act promptly, if necessary, so that the objectives of the test can be met.

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Patterns of Genetic and Environmental Variance in a Short-term Progeny Test of Loblolly Pine

by E. C. Franklin[1/]

Abstract.--Thirty-five loblolly pine families from eastern North Carolina, South Carolina and Georgia orchards of 4 companies were grown for 5 years in a short-term progeny test in Charleston, SC. The four spacings were 33, 50, 67, and 100 cm square. Each spacing consisted of 4 randomized complete blocks of sixteen-tree square plots. The objectives were (1) to determine if young trees grown at close spacing would mimic the genetic and environmental variance patterns of stands at conventional spacings at much older ages, and (2) to compare families on the basis of their competitive performance with varying numbers of sibling versus nonsibling competitors. Patterns of additive genetic variance which evolved in the closely spaced tests followed very closely those patterns found in older tests grown at conventional spacing. No differences were found in height, diameter and volume growth between groups of 8 trees containing 3, 5 or 8 sibling competitors.

Additional keywords: Short-term progeny testing, selection, heritability, Pinus taeda L., tree improvement, competition.

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Acknowledgements. This paper is a preliminary review of a large study which is continuing through the concerted efforts of many people. I thankfully recognize the contributions and continuing cooperation of the staff of the USDA Forest Service Research Laboratory at Charleston, SC for their diligent efforts in acquiring the data; the N.C. State Tree Improvement Cooperative for use of progeny test data; Continental Forest Industries, Savannah, GA, Union Camp Corporation, Savannah, GA, Westvaco Corporation, Summerville, SC, and Weyerhaeuser Company, New Bern, NC for supplying the seed. I recognize the large individual contributions of the two supervisory technicians who have in turn shepparded this project from its inception: William S. Dvorak and Edgar L. Davenport both formally based at Charleston, SC with the Southeastern Forest Experiment Station. Lastly, thanks to my staff for the extra effort they continue to devote to this project.

INTRODUCTION

Rate of genetic improvement of any long-lived organism can be increased by early testing and selection if certain genetic relationships exist between juvenile and mature growth phases. Most research on maturation in woody perennials concerns fruit and seed production because of the economic importance of these traits to crop yields. With commercial forest species, products are more varied and problems are compounded by less environmental control, and by the size, complexity and longevity of individual trees and stands.

Strategies for dealing with juvenile-mature phase change vary according to genetic and environmental characteristics of the traits involved. For many traits such as wood density and fiber length, careful sampling has shown that single samples at almost any age will yield good estimates of relative whole-tree values for individuals and families, because variation patterns with age are systematic and very regular. In contrast, parameters measuring growth rate are influenced by age and environment to a much greater extent. Recent research has pointed to a need for much better understanding of the effects of age and associated stand environment on juvenile-mature relationships.

Analyses of long-term progeny tests of four North American conifers led to the development of a hypothetical model to describe genetic phase changes in the growth of stands (Franklin, 1979). The model divides stand development into three genetic phases based on the behavior of the additive genetic variance and the heritability of the trait (Fig. 1). The juvenile genotypic phase is characterized by extremely low levels of additive genetic variance with a peak in heritability (juvenile genetic culmination) in the early to middle part of the phase. The mature genotypic phase is characterized by rapidly increasing additive genetic variance and heritability with a peak in heritability (mature genetic culmination) occuring early in the phase . The codominance-suppression phase is characterized by a rapid decline in additive genetic variance and an especially rapid decline in heritability as mortality removes suppressed trees and the stand approaches uniformity in stocking, and heights of dominants and codominants.

Recent results show that levels of additive genetic variances for height, diameter and volume growth vary widely but systematically in the course of stand development (Namkoong et al. 1972, Namkoong and Conkle 1976, Franklin 1979). The implication of these results for selecting in natural stands and plantations at conventional spacing is that selection should be done around half-rotation age. In the hypothetical model, this is called the mature genotypic phase (Franklin 1979). A much

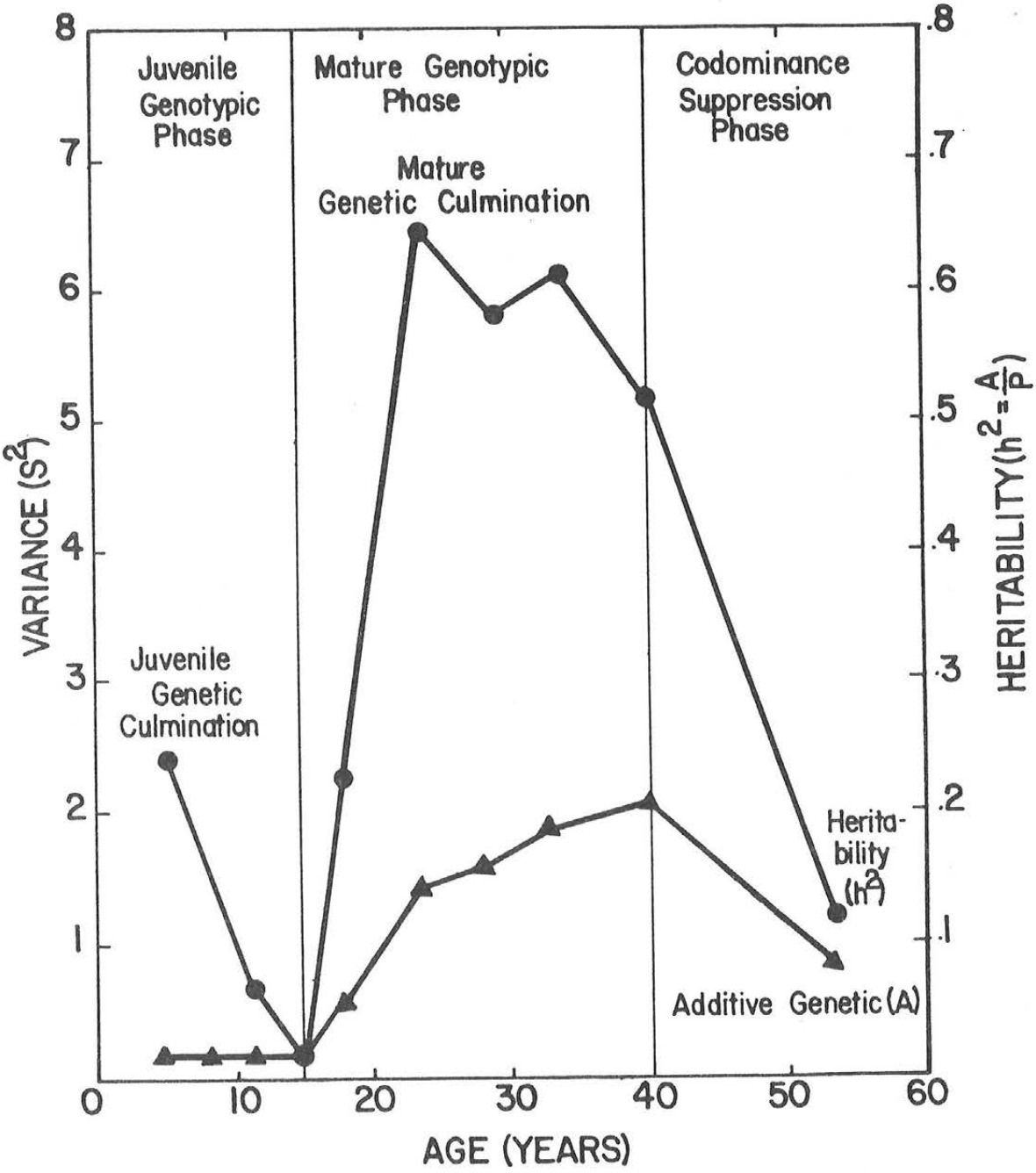


Figure 1.--Genetic phases of stand development interpreted for height in a Douglas-fir family trial. Data on Wind River population from Namkoong et al. (1972) (after Franklin 1979; Fig. 4).

greater rate of genetic gain per unit time could be obtained if selections could be done at younger ages. Because trees are so plastic in their growth response to environmental influences, particularly spacial relationships, I developed the hypothesis that stands of trees growing close together might simulate stand development at very young ages typical of more widely spaced stands at much older ages. From a practical point of view, once a poorly competing family falls behind, it never catches up. So why wait ten to twenty years at conventional spacing to develop enough competition to make that happen?

METHODS

The experimental design consisted of four separate trials grown at 33, 50, 67, and 100 cm square spacings in a small agricultural field at the USDA Forest Service Laboratory in Charleston, SC. Each trial contained 4 replications of 35 16-tree square family plots. The families were orchard open-pollinated from four companies in North Carolina, South Carolina and Georgia (Table 1). Clones were chosen on the basis of having been crossed with large numbers of other clones and of having 12- to 16-year measurements in progeny tests at conventional spacings.

Table 1.--Companies which made seed available from selected clones in their commercial production orchards

Company	No. Families	Provenance
Continental Forest Industries	8	GA Piedmont
Union Camp Corporation	8	GA/SC Coastal Plain
Weyerhaeuser Company	14	NC Coastal Plain
Westvaco Corporation	5	SC Coastal Plain
	35	

Families totaling about 12,000 trees were grown as container stock in a greenhouse and outplanted in early June, 1978 at 12 weeks of age. The site was prepared by raking and disking; only grasses remained on the site. Survival was generally good but some replacement planting was done during the first 6 months of the study. Competition from grasses was controlled until crown closure by mowing in the 100-cm spacing and with herbicides in the closer spacings. Soil tests indicated no fertilization was needed. Infestations of spider mites and tipmoths were controlled with periodic spraying of insecticides.

Measurements of total height were made during the second through the ninth growing months over a five-year period. December, January and February were classified as non-growing months and excluded from the measurement schedule. Measurements in the 10th through the 19th growing months included height and diameter. Diameters were measured first at one inch above the ground (10th month) then at mid-height (15th through 23rd growing months) and from then on at 4 1/2 feet above ground. Heights and diameters were measured in alternate growing months in the 21st through the 37th growing months. An index of volume equal to diameter squared times height was used.

Cumulative mortality, total phenotypic variance, additive genetic variance, environmental variance, and heritability were estimated for each measurement. Variances were interpreted based on the simpliest additive model:

$$P = A + E, \quad \text{and} \quad h^2 = \frac{A}{P},$$

where:

P is phenotypic variance,

A is additive genetic variance,

E is environmental variance, and

h^2 is individual tree, narrow-sense heritability.

RESULTS

Mortality

Cumulative mortality did not begin to reflect large differences in growing space until the fourth and fifth years of the study. In 1981, the amount of mortality sharply increased in the 33-cm spacing, and in 1982 in the 50-cm spacing (Table 2).

Genetic Variances

The rapid increase in additive genetic variance, marking the juvenile/mature phase change (as interpreted based on Fig. 1), occurred in the 9th growing month for height and the 21st growing month for diameter and volume in all spacings (Table 3). Similarly, highest heritability in the mature genotypic phase (mature genetic culmination) occurred at 15 months for height and 23 months for diameter and volume in all spacings except 21

Table 2.--Culmulative mortality percentages by spacing and growing season

YEAR	SPACING (CM) 33	50	67	100
	Percent			
78	2	2	1	2
79	4	3	2	5
80	9	4	2	6
81	43	8	4	6
82	67	22	12	10

Table 3.--Number of growing months to reach the juvenile/mature phase change as interpreted based on the model by Franklin (1979)

TRAIT	SPACING (CM) 33	50	67	100
	Months			
Height	9	9	9	9
Diameter	21	21	21	21
Volume[a]	21	21	21	21

a/ Volume index based on diameter squared times height.

months for volume at 33-cm spacing (Table 4). The mature genetic culmination heritability was highest for height, with the two intermediate spacings yielding the highest values. Heritabilities for diameter and volume were lowest at the 33-cm spacing and trended higher at the wider spacings (Table 5). All heritabilities steadily decreased after reaching the mature genetic culmination, except heritability for height at the 100-cm

Table 4.--Number of growing months to reach mature genotypic (maximum heritability) as interpreted based on the model by Franklin (1979)

TRAIT	SPACING (CM)			
	33	50	67	100
	Months			
Height	15	15	15	30[a/]
Diameter	23	23	23	23
Volume[b/]	21	23	23	23

a/ In the 100-cm spacing, a sharp, distinct peak occurred at 15 months, but a rounded, less distinct peak which was .05 units higher, ocurred at 30 months.
b/ Volume index based on diameter squared times height.

Table 5.--Heritability at mature genotypic culmination as interpreted based on the model by Franklin (1979)

TRAIT	SPACING			
	33	50	67	100
	Heritability			
Height	.73	.87	.90	.70
Diameter	.37	.45	.64	.60
Volume[a/]	.36	.50	.60	.63

a/ Volume index based on diameter squared times height.

spacing.[2] For height this was a period of 22 growing months over 3 seasons, and for diameter and volume, a period of 14 growing months over 2 seasons (Figs. 2, 3, 4).

The 16-tree square plots provided a test for trends in competitive influence of sibling versus nonsibling neighbors.

2/ In the 100-cm spacing, a sharp, distinct peak occurred at 15 months, but a rounded, less distinct peak which was .05 units higher, occurred at 30 months.

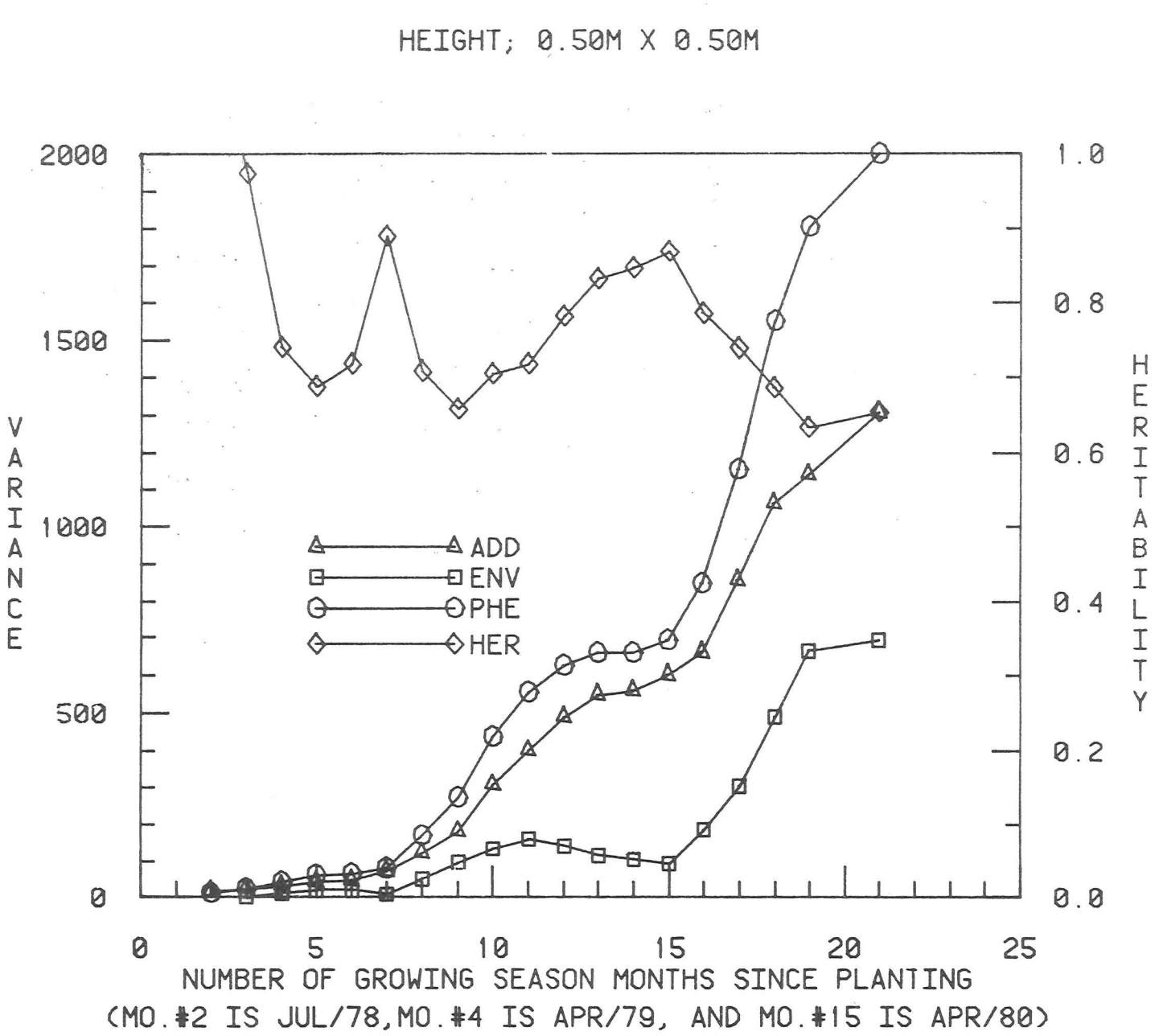


Figure 2.--Trends in the additive (ADD), environmental (ENV), and phenotypic (PHE) variances, and in the heritability ratio (HER = ADD/PHE) of height of 35 loblolly pine families growing at a 1/2-meter square spacing through 37 growing months.

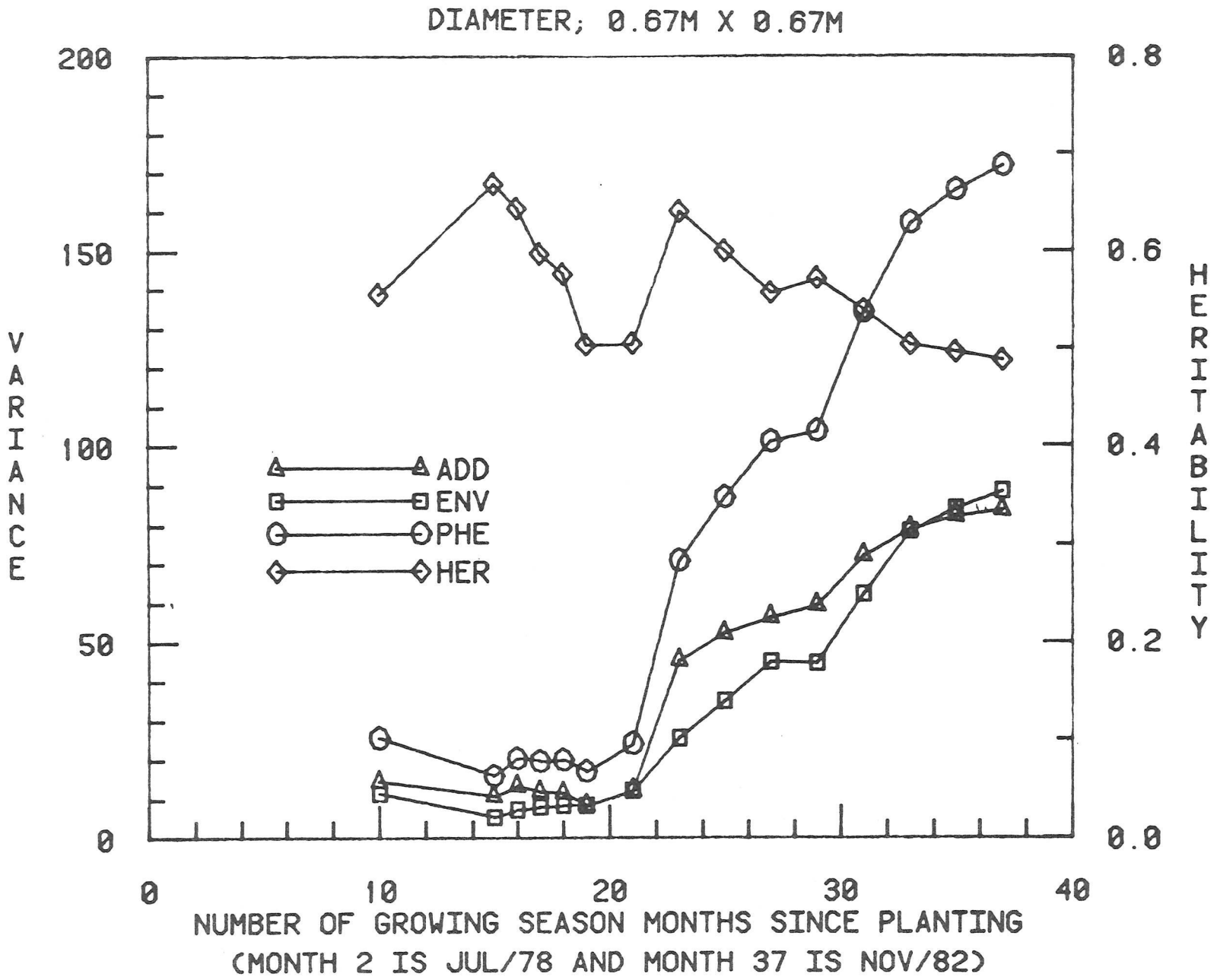


Figure 3.--Trends in the additive (ADD), environmental (ENV), and phenotypic (PHE) variances, and in the heritability ratio (HER = ADD/PHE) of diameter of 35 loblolly pine families growing at a 2/3-meter square spacing through 37 growing months.

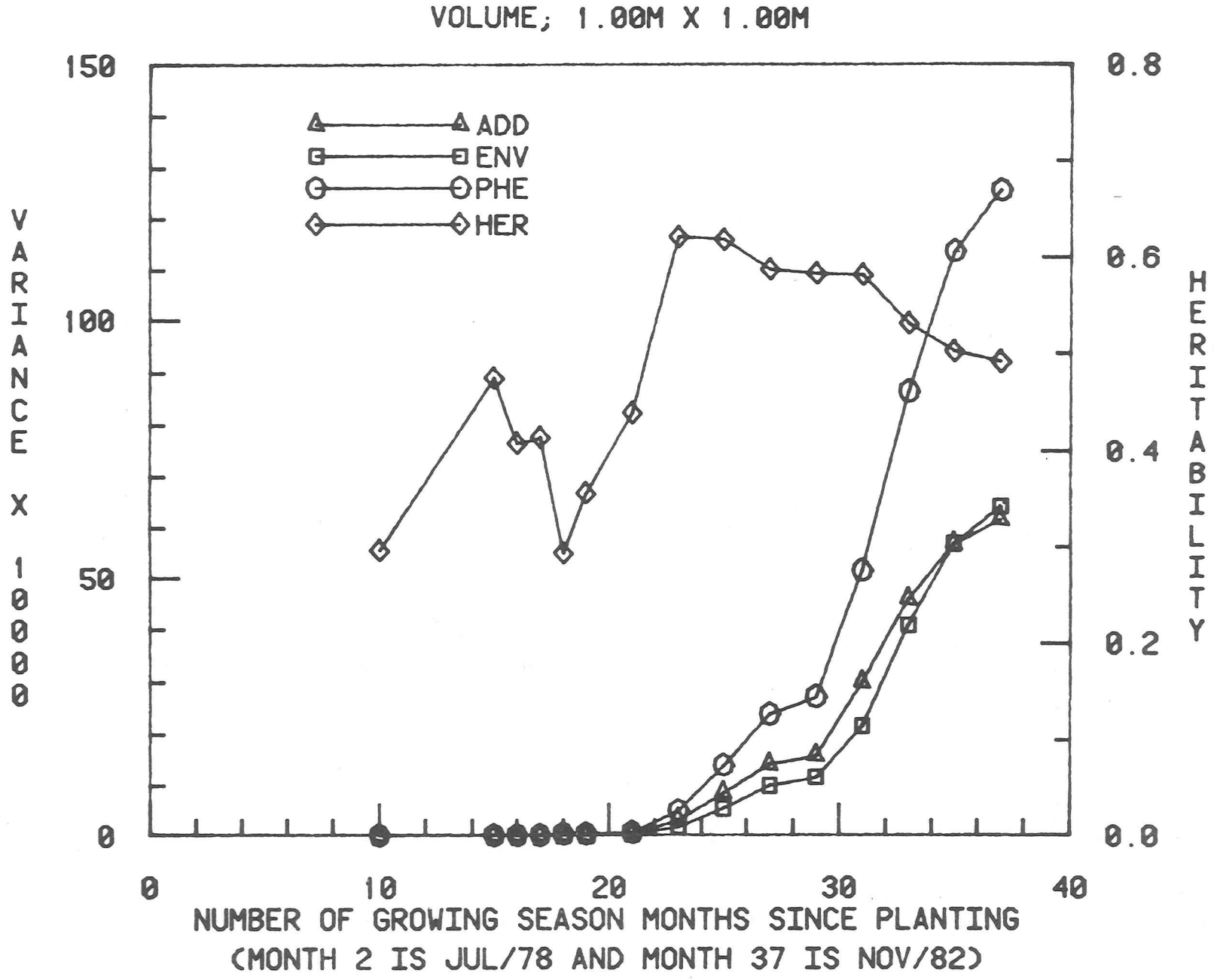


Figure 4.--Trends in the additive (ADD), environmental (ENV), and phenotypic (PHE) variances, and in the heritability ratio (HER = ADD/PHE) of volume of 35 loblolly pine families growing at a 1-meter square spacing through 37 growing months.

The 4 corner trees had 3 sibling and 5 nonsibling competitors. The 8 internal trees on the outside rows had 5 sibling and 3 nonsibling competitors. The 4 internal trees had all sibling competitors (Fig. 5). Analyses of variance were run for all traits and spacings at 37 months and repeated for the 33 cm spacing at 25 months. Results showed no differences between sibling competitor groups. Regression of growth parameters on increasing numbers of sibling competitors per group failed to demonstrate any trends.

DISCUSSION

The hypothesis under test was that for purposes of genetic interpretaion and testing, families of trees grown at very close spacings in a short period of time would mimic the development of stands of those same families grown at conventional spacing, over a much longer period of time.

Under this hypothesis based on the model (Fig. 1), the following would be expected if the hypothesis was acceptable:

1. A distinct phase change from the juvenile genotypic to mature genotypic phase marked by a rapid increase in additive genetic variance from a level hardly varying from nil.

2. A relatively high but decreasing heritability in the juvenile genotypic phase.

3. A very rapid rise in heritability to a distinct peak early in the mature genotypic phase, then a gradual decline toward the codominance-suppression phase change.

4. A sharp decline in additive genetic variance marking the boundary of the codominance-suppression phase accompanied by a plummeting heritability.

With only one minor exception (footnote 2), trends for each trait at each spacing fit perfectly through item 3. Thus, the results obtained so far are consistent with the hypothesis, but are inconclusive, because results have not reached the boundary of the codominance-suppression phase.

Comparing the behavior of the variances for the short-term tests with those of the longer-term tests, the scale indicates that development in the short-term test is well into the mature genotypic phase. Indeed, the rapid decline of the additive genetic variance is expected to occur soon. The closer the spacing the sooner the decline is expected. At the 33-cm spacing, 15% of the families have 10 or fewer trees remaining out of the original 64. When whole families start dropping out, the



Figure 5.--Competitive spacial relationships between sibling and nonsibling trees with a 16-tree square plot: $S_{1,2,3,4}$ have 3 sibling 5 nonsibling competitors; $S_{5,6,7,8,9,10,11,12}$ have 5 sibling, 3 nonsibling competitors, $S_{13,14,15,16}$ have 8 sibling competitors.

additive genetic variance is expected to plummet. This trend is expected in each spacing as mortality increases (Table 2).

These results are interesting but what is the practical significance of short-term testing? Can these tests be used to pick families which are genetically superior under conventional silvicultural regimes? This topic will be developed in a subsequent paper. Preliminary results indicate that short-term tests will be useful but that the choice of parameters to express superiority will be critical. More emphasis must be placed on yield per unit area rather than individual tree superiority or the superiority of families based on the average tree. For example, a family which combines fast growth and good survival against competition is expected to produce somewhat smaller but more uniform trees and higher yields per unit area than a family with poor or erratic survival leading to production of a few large trees. If silvicultural techniques such as planting at wide spacing are to be used, where competition is not an important environmental parameter, short-term tests at close spacing may not be appropriate in the development of genetic strains for that use.

Sibling Versus Non-sibling Competitive Ability

The apparent lack of differences between groups of trees with varying numbers of sibling versus nonsibling competitors is not unexpected with the relatively low level of genetic control obtained with orchard open-pollinated families. With full-sib families real effects may be found, and with certain clonal combinations real effects will almost certainly be found. Whether those effects will be large enough to be important remains to be demonstrated.

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Progeny Test Plantation Establishment and Maintenance in Region One

by Gerald C. Franc

There are three types of tests established in Region One tree improvement programs. The most common are the long-term field trials established in natural sites for the purpose of evaluating growth and performance over a relatively long period of time. These tests are most often established on planting sites that were created as a result of timber sale activity.

In addition to long-term field tests, the tree improvement plans for some species call for the establishment of early growth selection trials. Early selection trials are established at close spacing on intensively prepared and managed sites. Their main purpose is to provide early data on growth so that superior genotypes can be identified for quick seed orchard establishment. In western white pine, tests are also established to screen material for resistance to white pine blister rust. Both the early growth selection trials and white pine resistance testing are established in a nursery type setting where maximum care can be provided.

Test plantation sites for long-term field tests are selected from a list of proposed sites offered by the cooperators. Sites are selected to sample the particular environmental gradients specified in the species plan (i.e., elevation, latitude, etc.). Proposed sites on National Forest land are checked by the Species Director and the Selective Breeding Specialist or someone on his staff.

Site preparation is the responsibility of the District on which the site is located and is usually accomplished with funds collected from the timber sale. Once a site has been selected for a test plantation, the District Silviculturist or one of his employees is designated the plantation manager. Very often, the plantation manager is someone who is enrolled in Region One's GENE program and the establishment of the test plantation is one of his or her GENE projects.

Prior to the establishment of the test plantations, the plantation managers are given training in test plantation layout and establishment. This training is conducted by the Cooperative with input by the Regional Tree Improvement Staff. The training frequently includes a trip by all of the plantation managers to the site of the first plantation to be established at the beginning of planting. The plantation establishment training is part of a series of Region One training sessions called "Skills for Tree Improvement Workers."

The sorting and/or randomization of test seedlings, prior to planting, is usually done by the nursery at which the trees are being grown. Sometimes, cooperator help is requested. Test seedlings are container grown and are identified with the family number written in indelible ink on the cell or by preprinted plastic tags inserted into the cell.

Test plantations are laid out in a series of square, 100-tree grids. Rows and columns are numbered consecutively from the upper left hand corner of the upper left most grid. The first row and column in each grid is marked with a permanent post. The post is identified with the appropriate row and column number.

Planting is done by hand with planting mattocks or some other similar type of planting tool. Dibbles are not used. The numbered cells or pre-numbered markers are inserted into the ground beside each tree as it is planted. A map is made of each grid as it is planted.

Every tenth tree along either the rows or columns is marked with a wooden stake upon which an aluminum tag with the tree number is stapled. When the tree is large enough (usually at the time of the fifth year measurement), the aluminum tag is removed from the stake and wired directly to a branch of the tree itself. Under some circumstances, it may be desirable to stake every tree in the plantation.

Test plantations are fenced only as needed to protect them from livestock.

Maintenance of test plantations has been a problem. Districts are not in the habit of protecting operational plantations and, as a consequence, test plantations also suffer from inadequate maintenance and protection. Major problems have resulted from pocket gopher activity, although brush competition, insects, disease, and livestock have all contributed their share.

The Cooperative does provide some rather general guidelines for test plantation maintenance and the Regional Tree Improvement Staff is developing a "checklist" for plantation managers to use when they make an inspection.

The Forest Pest Management Group in Missoula has been very responsive in helping to evaluate damage in test plantations and to suggest control activities where appropriate. Test plantation visits are scheduled by both the Tree Improvement Staff and the Pest Management Staff but, because of the large number of tests, the major responsibility for regularly checking and maintaining test plantations rests with the District and the plantation manager.

Only a limited amount of vegetation control with chemicals has been done on test plantations and the only insect control measure tried so far has been the use of pheromones to minimize damage in ponderosa pine test plantations due to the western pine shoot borer. Private cooperators generally have a freer hand in use of chemicals on their test plantations. The National Forest test plantation managers encounter less resistance to treatment with chemicals if spot treatment is prescribed rather than broadcast spray. Fertilization has not been done on any field tests.

Thinning has not been done in any of the field tests so far, although there are several ponderosa pine test plantations where competition between trees is beginning to occur. In the older white pine test plantations thinning has been accomplished by blister rust.

The grid system of plantation layout provides uniform rows and columns which make future measurement and maintenance easier and establishes coordinates for each tree in the plantation. This makes it possible to create computer generated maps of the test plantation.

A plantation booklet is prepared for each plantation and includes not only the computer map but also a plantation establishment report, the daily planting log, location maps, site information, and any other records or information pertinent to that plantation.

Development and Maintenance of Wind-Pollinated Progeny Evaluation Plantations in the Pacific Southwest Region

by

Paul Stover Progeny Specialist

The following paper will discuss the most commonly used procedures for the development and maintenance of wind-pollinated progeny evaluation plantations in the Pacific Southwest Region (R-5). Special situations have and will continue to warrant deviations from the procedures detailed within. Common practice may also change with experience and as additional information becomes available.

There are two features of the R-5 Tree Improvement Program which should be mentioned in relationship to the objectives of the progeny evaluation plantations. First, to spread the large cost of seed orchard development, initially large, tentative "Breeding Zones" have been defined. On the west-side of the Sierra Nevada mountains of California, these zones may extend up to 100 miles in latitude and 2000 feet in elevation. Secondly, there is a major emphasis on the selection of the wild parents upon which future breeding efforts will be based. Each selection is based upon a multiple-tree comparison within the immediate neighboring stand and may cost as much as $200 per tree (Appendix 1- Superior Tree Candidate Report). A total of 200 trees are selected per species within each Breeding Zone.

Site Selection

The performance of wind-pollinated progeny of the superior selections will largely determine the final composition of the rogued seed orchards which, in turn, will provide improved seed for operational planting. Progeny evaluation plantations have four major objectives:

- Evaluate the relative genetic potential of trees selected for the program and already established in a production seed orchard;
- Evaluate the distance over which seed can be moved from its origin;
- Act as a source of additional superior individuals within the plantations for subsequent establishment in a seed production orchard, and
- Generate information to determine the genetic gains accomplished through the selection of desirable characteristics.

A total of 4-5 sites are selected sampling the geographic and elevational ranges found within a tentative Breeding Zone. Each Ranger District within the Breeding Zone is supplied with funding and criteria for the selection of 3-5 candidate sites. During the search for prospective sites, information is gathered pertinent to the following considerations;

1. Location - Test sites must be within the geographic and elevational range designated by the breeding zone for the species to be tested.

2. Site Class - The test site must be capable of producing at least 65 cu. ft/acre/year (eg. Dunning Site III). More productive sites will demonstrate genetic differences more quickly. They may also be more uniform than less productive sites. An estimation of site productivity should be made.

3. Slopes - Slopes should be no greater than 30% to facilitate equipment used during preparation and maintenance and to reduce soil erosion.

4. Accessibility - Sites should have good road accessibility. Vicinity maps and motor logs are required for reviewing potential sites.

5. Special Problem Areas - Area with specific local problems or management conflicts should be avoided. Resource specialists should evaluate potential biological, environmental, aesthetic, and cultural problems.

6. Site Uniformity and Size - The site must be relatively uniform in slope, aspect, soil type, and moisture regime to reduce environmentally caused variation among planted progeny. A descriptive soil survey is essential. Where sufficient uniform area is available and two or more species with overlapping breeding zones are compatible to the site, multiple test units are highly preferred. In cases where suitable acreage is restricted to less than 15-acres gross, it may be appropriate to subdivide the test unit of a single species by using two physically separate but environmentally similar sites.

7. Climate - Areas known to be cold pockets or accumulate and retain abnormal amounts of snow melt may prove difficult to establish and interfere with satisfactory testing. Thus, sites that are not typical climatically should be avoided.

Once the potential sites have been located and pertinent information gathered, a biological evaluation is made by representatives of the Regional Forest Pest Management Team. A final selection is made by a team of District, Forest and Tree Improvement personnel. Schedules and responsibilities are agreed to for the steps of plantation development through establishmennt.

The final step before site preparation is to run a traverse and prepare a base map of the area required to establish the test design. The base map will locate site characteristics such as present log landings, spur roads, rock outcrops, and any other unuseable areas. It may also serve well for site preparation and fencing contracts, and be used to locate future access roads and block orientations.

Experience has shown that the site selection process should begin at least two and preferably three seasons prior to planting. Some districts have comparatively few potential areas meeting all of the requirements for an evaluation plantation. Once a site is found, timber harvest may be required as well as site preparation and fencing. Logging and site preparation are

restricted too the drier summer months to protect soil quality. A site may also be inaccessible due to snowfall during part of the year. If separate contracts are required for each of the steps before planting and/or contract related problems arise, even a three year time frame can be severely tested.

Site Preparation

There are currently two zone organizations within R-5 to provide support and/or directly perform various Tree Improvement activities. The Central Zone, with a home office in Placerville, California accepts major responsibilities on the west slope of the Sierra Nevada Mountains. Major responsibilities for the North Zone group, working out of Yreka, California, are in the Douglas-fir forests of the norhtern coast and interior. In the near future an increasing responsibility will occur in the mixed-conifer forests of the Southern Cascades.

Each zone has developed different approaches to site preparation. These approaches will be described separately. The reasons for this divergence in approach and the advantages of each will then be discussed.

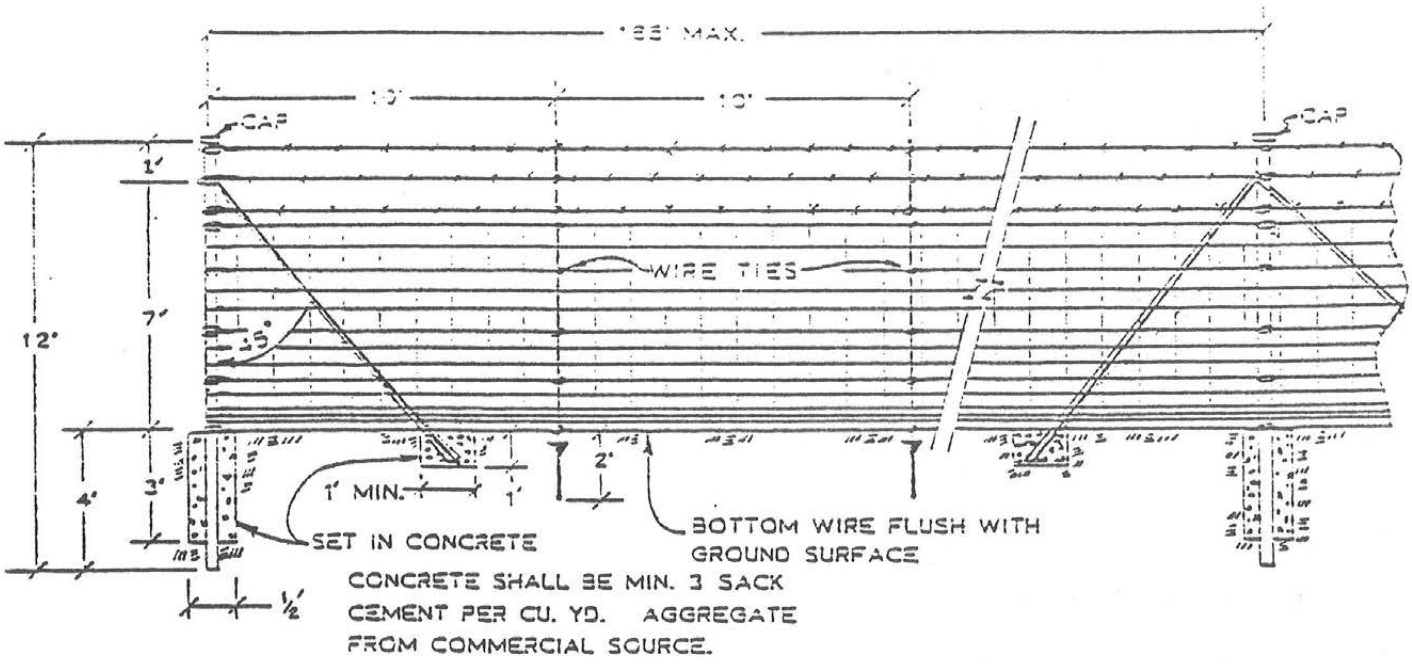
In the Central Zone, once an area is selected slash is piled away from the areas to be used and later burned. Black oak (Quercus kelloggi) stumps are then removed. Larger conifer stumps will remain. Armilariella mellea is found universally on live black oaks. Once an oak has died the disease will exist saprophytically on the remaining root system. However it may spread, infect and kill immediately surrounding conifers. After stump removal the areas are backbladed to reduce microsite variations. If part of a plantation remains fallow, disk-harrowing may be attempted to reduce competitive vegetation the summer before progeny planting.

All areas are provided with an 8-foot tall fence complete with gates which may be locked. (see Figure 1 for design diagram and Appendix 2 for contract specification). As well as excluding deer, cattle and rabbits they exclude various off-road recreational vehicles. The existence of a fence has also, on occasion reduced local resistance to using chemical vegetation control methods.

In the North Zone initial fuel loads often permit broadcast burning. In every case, all stumps will be removed from the area of planting design layout along with any residual slash. Stump removal may be accomplished by blasting or preferably by tractor-mounted stump-splitting devices. Cleared areas are then back-bladed and disk-harrowed twice at right angles to a depth of 18". (see Appendix 3 for contract specifications). Finally, as in the Central Zone, fences are constructed.

Stump Removal

The greatest initial reason for the development of two different approaches to site preparation is related to topography. Site uniformity, quality and administration are all enhanced by ground slopes of less than 20% and certainly less than 40%. There is very little land available, fitting these criteria on the North Coast or in the Siskiyou Mts. of Northern California. The lands served by the Central Zone on the western slopes of the Sierra Nevada offer more opportunities for locating large progeny evaluation sites needed for working around stumps, log landings and slash piles.



TYPICAL FENCE DETAIL

NO SCALE

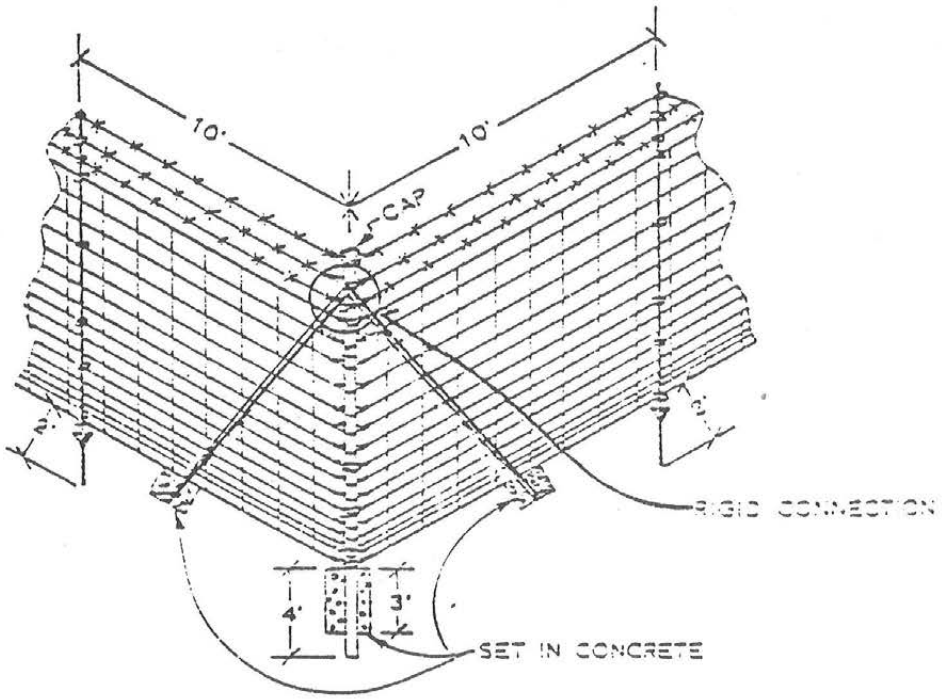


Figure 1 - Fence diagram

TYPICAL FENCE CORNER

NO SCALE

There are a number of advantages to removing stumps and disk harrowing. As mentioned, a smaller amount of area, in some cases less than half the number of gross acres are required for a test site. This may reduce the initial variability found within the site. It does substantially reduce the cost of fencing which generally run between $3-4 per linear foot when contracted. Stump removal also reduces the danger of test seedling infection by shoestring fungus (Armillariella mellea) Black-stain (Ceratocystis wagneri) and possibly even Fomes annosus.

Disk-harrowing is very beneficial in breaking-up all but the worst areas compacted during logging. Initial layout of the hexagonal planting design is made much easier on a site without stumps, skid trails and brush piles.

Once a site is prepared, data collection is made simpler and less time consuming when site to site adjustments have not been made in layout to accommodate stump locations. Without stumps, there is more often just one design arrangement to work with across all plantations.

Site maintenance is also simplified. Double disk-harrowing once after site preparation and once again the season before planting is very effective in brush control. Stump removal also allows the option of using ground-drawn booms for herbicide application.

There are also disadvantages to this approach. The removal of large stumps especially by blasting, leaves holes which are filled with loose topsoil. A "planting pot" effect is produced giving a sizeable initial advantage to seedlings planted in this situation. However leaving stumps also perpetuates site variability in nutrient and soil moisture availability, soil compaction and, as mentioned earlier, the potential for disease infection.

Another disadvantage to stump removal is increasing the task of removing often large additional amount of slash from the planting site. This figures prominently in the overall cost of site preparation which in recent experience costs $600-800/acre. This high unit cost, however, is offset by not having to clear as large of an area if the stumps remained.

Site Preparation - Logistics

As mentioned, after a test site is found, a schedule and list of responsibility and funding is agreed to between District, Forest and Tree Improvement Personnel. Site development is generally contracted. However, the opportunity exists for "force account" projects involving the use of district personnel and equipment in any or all steps of site development. In any case, specifications for all steps of the process are supplied by Tree Improvement personnel. Assistance in the application of these specifications is also provided for each site to produce the required final results.

Design Layout

Within block variability caused by environmental factors can be reduced by proper design layout. Planting designs are initially laid out orienting blocks lengthwise across slopes and avoiding breaks in the degree of slope. After the site has been prepared adjustments can be made to avoid any poor planting areas such as those with excessive rock or poor drainage.

Once the final base map has been developed with block orientation and placement, design layout is begun (Appendix 4 - Idealized Plot Layout). Base lines are established with (15") stake wire flags along the long axis of an individual or series of adjacent blocks. If several blocks are to be located in series, a transit is used not only to turn the 90 degree angles but also to take advantage of the magnification provided to ensure accurate base line placement. When fewer blocks are laid out, measuring tapes can be used to form a 3-4-5 triangle determining the 90^0 angle trigonometrically.

Once the base lines are established, two pinning lines are stretched from one base line to another. These lines are pre-marked to locate interior flag placement and establish the staggered hexagonal spacing. Within each block there are three replications of the selections being tested. These replications are identified by different colored flags. Border trees are identified by a fourth color. The final step is the location of a marker post to identify one corner of each block.

Planting Stock Development

THe first step in producing healthy progeny seedlings is cone collections from the open-pollinated superior tree candidates. The importance of cone ripeness to early and uniform seed germination, and virorous seedling development has been documented for many species. To ensure the highest level of cone ripeness, Tree Improvement personnel have always made nearly all their own collections from superior tree candidates. Cone storage, processing and seed cleaning have also been performed or directly supervised by Tree Improvement personnel.

The cumulative expense of producing open-pollinated progeny seedlings or "families" of known identity for field evaluation is considerable. The widespread occurrence of seed chalcid and occassional damage to seed in processing, has required the x-ray screening for Douglas-fir (Pseudotsuga menezii), sugar pine (Pinus lambertianna) and white fir (Abies concolor). Non-viable ponderosa pine (Pinus ponderosae) seed have been successfully reduced using air-separation. Seed lots for this species are not x-rayed.

One feature of the R-5 outplanting design is the allocation of superior tree candidates into sets of 45. Each set of open-pollinated candidates or "families" is composed of trees selected from as even a distribution as possible from within the geographic and elevational range of the Breeding Zone.

Ideally, all families to be tested within a Breeding Zone would be collected and sown for outplanting in all evaluation plantations within the same year. Unfortunately, this has not been possible for any of the Breeding Zones initiated to date. The major barrier to this approach has always been the infrequency of a truly heavy cone crop, throughout an entire Breeding Zone. An additional complication has been the locally, often repeatedly, serious influence of cone and seed insects. Finally, some of the selections themselves seem reluctant to divert from non-reproductive related growth, the energy required to produce an adequate cone crop.

Most commonly, 2-3 sets of families from a Breeding Zone are grown at the Tree Improvement Center in Chico, California. One seed is sown per 10 in 3. Leach "Super Cell" container after a 24 hour pre-soak and 30-60 day stratification.

The container used is internally ribbed to reduce root-spiralling and filled with equal quantities of peat and vermiculite. Nearly twice as many seed are sown than are needed to produce the minimum needed to outplant into the evaluation plantations. This will allow the selection of uniformly high quality progeny for outplanting. Individual families are kept separate, in four replications within the greenhouse. Each seedling container will receive a plastic marker with the appropriate family number.

Once top growth has finished in the fall, seedlings are sorted into their final plantation arrangement using computer randomized, and printed field layout maps. Many of the trees remaining after sorting will be used for border stock around the test trees. The best will be replanted into larger (40 in 3) "D-tube" containers to provide stock for replacing non-surviving progeny the first year after outplanting.

To survive the summer droughts experienced throughout California, it is essential that seedlings possess the ability to rapidly initiate root-growth upon outplanting. A continuous period of dormancy is required to develop this "root growth capacity" (Stone and Jenkinson 1970). To avoid the dormancy breaking warm interruptions experienced in Chico during the winter, seedlings are moved to cold storage facilities. Individual trays of seedlings are boxed and stored at 29-34^{o}F and 70-80% humidity. Storage may begin as early as December. Some low elevation coastal planting sites may be planted as early as February. However, higher elevation interior plantations often open as late as May.

Planting

Experience has proven spring to be the best time for plantation establishment in most regions of California. A site must not only be free of snow but possess soil temperatures on the rise and high enough to allow seedling root growth. With these conditions met, progeny seedlings are taken from storage and transported to their respective plantations. During periods of hot weather, transport may take place during the cooler temperatures of early morning. Once on the site, three trays representing each replication within a block, are carried to their predetermined location. Progeny are laid out and just before planting identities are once again checked against copies of the maps used in sorting.

Both dibble and auger planting have been used effectively. However only one method is used for a particular set planted across any group of plantations. Once the trees have been planted, the containers are retrieved to be reused at the nursery. This step also insures the planting of all progeny laid out. Finally, aluminum identification tags are positioned next to the outermost seedlings of two sides for each block in a set. These tags will more permanently assist in the location of particular trees and starting locations during data collection.

Planting crews are most commonly composed of both Tree Improvement and District personnel. This need for district man-power is emphasized early in the planning process and later quantified in project work plans. Giving district personnel an opportunity to take part in the establishment of an evaluation plantation provides a chance to answer questions about the Region's program. It will often also develop more personal individual commitments to future plantation maintenance and protection.

Plantation Maintenance

In operational plantations the reduction of competing vegetation is required to insure survival for adequate stocking and later to attain the growth rates specified in regional timber management plans. The requirements are even greater in progeny evaluation plantations. It is essential to not only attain the highest possible survival rates but also provide uniform, near optimum growing conditions.

The maintenance required to produce a successful plantation cannot be accomplished without the continued involvement of both District and Forest personnel. Progeny evaluation plantations have been established within a large number of vegetation types. The selection of the most effective and acceptable methods within the local blend of resource considerations must be arrived at through the NEPA process.

The environmental analysis (EA) of vegetation management in evaluation plantations has been approached in a variety of ways. The best approaches continue to change with the refinement of the NEPA process as guided by periodic court decisions.

Wherever possible, evaluation plantations are included in the analysis of District or Forest plantation maintenance projects. However, where different prescriptions have been required for evaluation plantations, separate EA's have been written by either Tree Improvement or District personnel. These will usually include more than one evaluation plantation over several districts. This approach is also used where local resistance to the hand-application of herbicides within fenced areas will be less than in operational district plantations.

The projected prescriptions and timing of maintenance operations are considered from the beginning of plantation development. Double disk-harrowing is usually very effective in the initial control of brush species. The largest threat to progeny survival is posed by the often rapid invasion of annual and perennial grasses and forbs. The most cost effective, commonly selected method of controlling both types of vegetation is the ground application of herbicides.

District manpower requirements are again identified with project work plans. Tree improvement personnel are often present to work directly with the crews. The products used have varied with the composition of the competing vegetation. New products will be used in the near future after first-hand experience has been gathered in operational district use. In most cases, however, progeny seedlings are protected to reduce the chance of differential reactions to the chemical treatment. Manual spot treatment often follows on missed areas or unaffected vegetation.

Plantation Protection

Again the objective of plantation protection is to reduce the controllable random influences which might interfere with determining the genetic potential of the tested progeny. The influence of both large and small animal browsing is effectively controlled by fencing the evaluation sites. The fence has also eliminated the previously experienced damage from recreational vehicles and

Christmas tree cutters. In some cases the fence has been extended 18 inches below ground to reduce the immigration of gophers into the test areas. This approach, in concert with reducing habitat within the fences, has proven to be generally effective.

Insect control poses another problem. Many insect problems may be avoided by maintaining a healthy plantation. Exceptions to this rule have not yet been viewed as a serious problem in any progeny plantations. In the event such problems manifest themselves, attempts will be made to control them. However, in any case, the level of control would be limited to the manpower and budget available for such activities. The complete exclusion of all such influences will remain impossible.

Plantation Culture

Fertilization has not been practiced in progeny evaluation plantations except on a separate trial basis. This practice is not anticipated to be an important feature in the Regions future timber management practices. Furthermore, differential family related responses to nitrogen fertilizers have been demonstrated for a number of species.

Thinning will be practiced. As mentioned, each of the eight blocks testing a set of families at a plantation, have three replications. This allows the plantation to be systematically thinned twice without losing the representation of any of the original families. Plantations will start with a 6 x 6 foot spacing and eventually end with a 10.4 x 10.4 foot spacing. However, the timing of these thinnings will vary from normal precommercial practice.

The paper, "Time Trends in Genetic Control of Height Growth in Ponderosa Pine" (Nomkoong and Conkle 1976) sheds light on the appropriate time for thinning in a progeny evaluation plantation. Three growth stages were identified, within this paper, for a plantation after 29 years of family specific growth data. It was observed that some families which performed well in the initial "exponential stage", free of interspecific competition, did not perform as well during the second "steady growth" or third "declining growth" stages. The second stage is hypothesized to have begun with crown closure. Progeny responded to increasing cohort competition and to weather and other macrosite factors. The third period represents the onset of intense tree-to-tree competition.

None of the progeny evaluation plantations established in R-5 with a design permitting systematic thinning are past the first stage of growth previously described. Thinning will be delayed past the time which would insure the highest rate of diameter growth. This will induce the progeny to respond to cohort competition and more macrosite factors. The timing of the first thinning will be considered on an individual family set and plantation basis. A timing criteria being considered is that no more than 10% of the individual trees have less than 50% crown ratios. At no time should stocking exceed the limits for maintaining a high level of vigor in the overall plantation.

The final disposition of the progeny evaluation plantations will be their management and final harvest as commercial stands. However, before that time they may act as an additional limited source of genetic material for second generation seed orchards. After the plantations have lost their ability to provide family specific data, they will still provide longer range zonal data. In addition they may serve as District seed collection areas.

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APPENDIX 1

Superior Tree Candidate Report

USDA-FOREST SERVICE R-5 TREE IMPROVEMENT PROGRAM

SUPERIOR TREE CANDIDATE REPORT

(1) RECORD TYPE 1

(2)	TREE NO. 00000	(9)	SEED ZONE	312	
(3)	SPECIES 122	(10)	ELEVATION	41 (4080)	
(4)	FOREST 14	(11)	ASPECT	1 (N)	
(5)	DISTRICT 52	(12)	SITE INDEX	139	
(6)	COMPART. ---	(13)	TREE INDEX	148	
	LATITUDE	(14)	BREED. ZONE	5	
(7)	40°40'8"N.	(15)	SEED CROP	2	
	LONGITUDE	(16)	OWNERSHIP	01	
(8)	123°50'3"W.	(17)	DATE	1083	

—FIELD USE—
SPECIES PP
TREE NO. 00000
AREA Hiamoom
T. 3N R. 7E S. 32
CREW DB. & M.D.
R. P. DF
DBH 12"
BEAR. 341°E
DIST. 2 chains
DECLIN. 17°E

(1) Record Type 2 (2) TREE NO. 00000

TREE NO.	AGE	HEIGHT TOT.	HEIGHT AV/YR	DIAMETER DBH	DIAMETER DIB	DIAMETER BT	VOL	VOL/YR	SP. GR.	REMARKS
1	75	131	1.75	25.1	21.4	1.85	138.6	1.85		sweep
2	72	126	1.75	22.4	19.2	1.60	107.3	1.49		logging damage at base
3	78	115	1.47	20.1	16.6	1.75	73.2	0.94		
4	73	137	1.88	24.4	20.8	1.80	136.9	1.88		
5										
TOT	225	372	4.97	67.6	57.2	5.20	319.1	4.23		
AVE	75	124	1.66	22.5	19.1	1.73	106.4	1.43		
SUPER TREE	(3) 073	(4) 137	1:88	(5) 24:4	20:8	1:80	(6) 0136:9	(7) 01:88	(8) ---	
% SUPER			(9) 13					(10) 31		

TREE NO. 4 IS THE SUPERIOR TREE NUMBER OF LADDERS 6

REMARKS:
#4 was selected because it has better height growth than #1. It also has a straighter stem and smaller diameter limbs. Heavy cone crop for 1984.

Cone Collection Date			Pollen Collection	Date	Scion Collection	Date	Progeny Test	YR.

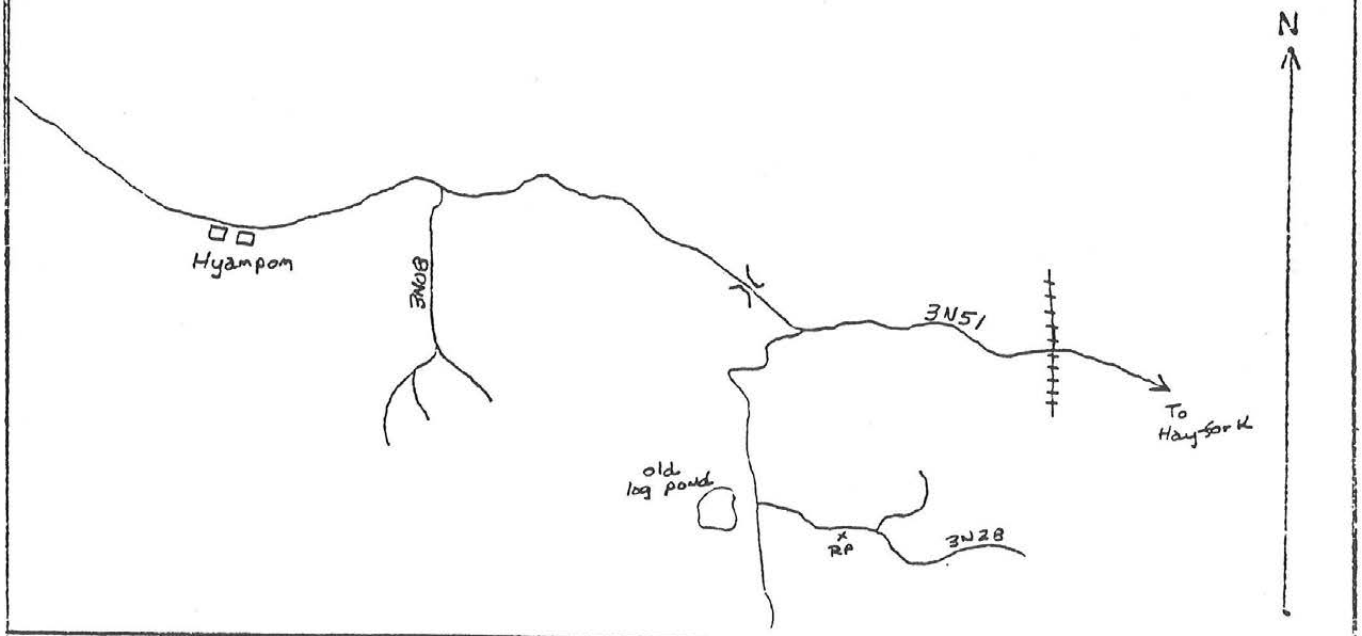
R5-2400-146
(Rev. 5/77)
6/80

TREENO: 00000

MOTOR LOG TO REFERENCE POINT:

From the jct. of Hyampom road & Fir Root road (3N21) drive south on Fir Root road 2.8 miles, turn left onto 3N28 & go 1.6 miles to R.P on the right side of road.

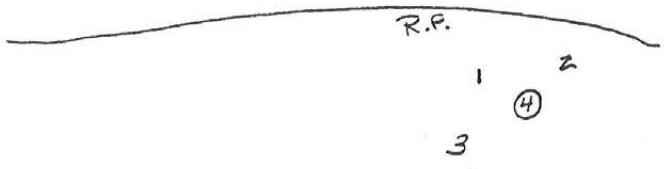
MAP ROUTE TO REFERENCE POINT:



SEND ORIGINAL TO:

CHICO TREE IMPROVEMENT CENTER
NIMSHEW STAGE BOX 29A
CHICO, CA. 95926

MAP OF INDIVIDUAL TREES:



APPENDIX 2

Fencing - Contract Specifications

SCHEDULE OF ITEMS

PROJECT: FENCING EVALUATION
PLANTATION

FOREST: NATIONAL FOREST

BIDDERS PLEASE NOTE: BEFORE PREPARING PROPOSAL, READ CAREFULLY "INVITATION FOR BIDS" AND "INSTRUCTIONS TO BIDDERS". BIDDERS ARE FURTHER CAUTIONED TO INSPECT THE CONSTRUCTION SITE AND INVESTIGATE TRANSPORTATION, WEATHER AND LOCAL LABOR CONIDTIONS.

ITEM NO.	ITEM DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	AMOUNT
1.	Evaluation Plantation, Ranger District, Construction of deer fence and associated gate.		L.F.	$_____	$_____

SECTION 01010
SUMMARY OF WORK

PART 1 GENERAL

1.01 Scope--Work performed under this contract consists of constructing an 8-foot fence with associated 12-foot entrance gate around an evaluation plantation at the location shown on the vicinity map.

1.02 Measurement and Payment--Work performed under this contract will be paid for as specified in Section 02750-Fencing. Payment will be made only for those items of work actually performed.

1.03 Variation in Quantities--The contractor is referred to Forest Service General Provisions Section 60, paragraph three, which addresses the rights and responsibilities of both parties in the event the Bid Schedule quantities differ from the actual constructed quantities by more than 25 percent.

1.04 Substitution of Materials--All requests for substitutions must be approved by the Contracting Officer.

SECTION 02750
FENCING

PART 1 GENERAL

1.01 Scope--The work in this section includes the construction of an 8-foot fence with associated entrance gate as shown on the drawing and outlined in the specifications.

1.02 Measurement and Payment--Fence will be measured at ground level around the entire enclosure, but deducting the width of the completed gate and gate posts. Payment will be made for the actual number of linear feet. No separate payment will be made for the gate.

PART 2 PRODUCTS

2.01 Corner Posts

12 feet x 2 7/8 inch full weight steel posts braced and concreted 3 feet in the ground as shown on drawing. Tops of of posts shall have steel caps.

2.02 In-Line Support Posts

12 feet x 2 7/8 inch structural steel posts braced and concreted 3 feet in the ground as shown on drawing. Tops of posts shall have caps.

2.03 Corner and In-Line Support Braces

10 1/2 feet x 1 7/8 inch structural steel pipe braces rigidly attached to corner and In-Line support posts concreted one foot in the ground as shown on drawing.

2.04 Tee Posts

10 foot, 133 Tee Posts in line every 10 feet.

2.05 Rabbit/Hog Field Fencing

6-foot galvanized fencing; 6-inch stay spacing, 12 ½ gauge top and bottom wire, 14 ½ gauge line stay

2.06 Barbed Wire

3 top wires, 12 ½ gauge galvanized barbed wire, Sears Cat. No. 32R41007N or equal.

2.07 Gate

Two 6-foot long X 8 foot high sections of commercial chain link gate. Frames 1 5/8 inch full weight with 9 gauge fill. Two hinges per gate section.

PART 3 EXECUTION

3.01 Corner and in-line support posts shall be set in concrete footings conforming to the details shown on the drawing and crowned at the top to shed water. The maximum distance between in-line support or corner posts is 165 feet. Corner and in-line posts shall be capped on top.

All corner and in-line support posts shall be provided with braces that shall extend from 7 feet and at approximately a 45 degree angle to one foot below the natural ground level. Braces shall be set in concrete footings, rigid attachment to posts, and crowned at the top to shed water (see details on drawing).

Tee posts shall be spaced at not more than 10-foot intervals measured from center to center of posts, except where a corner or in-line support post is needed. In general, in determining the post spacing measurements shall be made parallel to the slope of the natural ground. All posts shall be placed in a near to vertical position.

The 6-foot rabbit/hog field fencing shall be stretched and securely fastened to the tee posts with five fence fastners. One fastner will be located at ground level and another on the top strain of the field fencing the other three will be evenly spaced between the top and bottom of the field fencing. Field fencing shall be wrapped around corner or in-line support posts with the wire ends twisted around the field fencing. New rolls of field fencing shall be woven into the wire ends of the last roll. Any irregular areas between tee posts shall be filled or scraped by the contractor to insure that the bottom wire on the field fencing is flush with the ground.

APPENDIX 3

Site Preparation - Contract Specifications

STANDARD FORM 36, JULY 1960
GENERAL SERVICES ADMINISTRATION
FPR (48 CFR) 53.110(a)(101)

CONTINUATION SHEET

REF. NO. OF DOCUMENT BEING CONTD.

Solicitation No.

PAGE OF

NAME OF OFFEROR OR CONTRACTOR

ITEM NO.	SUPPLIES/SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	PART II - SHCEDULE OF ITEMS				
	Site Preparation in accordance with the attached specifications, Government-furnished Offset disc plow to be performed at Progeny Test Plantations on the Forest. Services to be performed include removal of logging debris and stumps to designated disposal sites within the units. Some blasting will be necessary.				
1.		EST	ac.	$_____	$_____
					$_____
	AWARD WILL BE MADE TO ONE BIDDER. BIDDER MUST BID ON AL ITEMS TO BE CONSIDERED FOR AWARD.				

* U.S. GOVERNMENT PRINTING OFFICE : 1980 O - 311-133 (1-481)

CONTINUATION SHEET - SF-36

TIME OF PERFORMANCE

The estimated starting date will be between _____ It is required that all work be completed within _____ calendar days after effective date of Notice to Proceed.

COMMENCEMENT OF WORK

Commencement of work is desired within one calendar day but required within seven calendar days after effective date of notice to proceed.

If the contractor fails to start work within the required number of calendar days after effective date of notice to proceed, the Contracting Officer may terminate the contract and issue a default notice to the Contractor.

PROTECTION OF CULTURAL RESOURCES

Location of known extant, historic, or prehistoric materials such as Amerind artifacts and/or historic mining or fur trapping remains, protected by the American Antiquities Act (16 U.S.C. 433) will be identified on the ground. Upon discovery by either party (Government or Contractor) of additional cultural materials during operation, activity in the area shall cease and the find shall promptly be reported to the other party. Materials identified on the ground during project operations may result in modification of the project or rescheduling of the operations so that assessment of the significance of the artifacts can be made and provision for their protection and conservation implemented.

SPECIFICATIONS FOR SITE PREPARATION

PROGENY TEST PLANTATION

DIVISION 100 - GENERAL SPECIFICATIONS

110 - Scope of the Job

Furnish all labor, equipment (except Government-furnished property), transportation, and incidentals necessary to prepare sites by the removal of stumps and debris and discing for use as progeny test plantations for superior trees.

120 - Description and Location

The units and work areas will be designated by the Government with blue and yellow flagging. The attached maps are intended to show only the general size and locations of the units and are not intended to be accurate as to shape and dimensions.

130 - Government-Furnished Property

The Government shall deliver to the Contractor the following listed materials, supplies, property, or services (hereinafter referred to as "Government-furnished property") at the places and times specified below. The Contractor shall be liable for all loss or damage of such delivered Government-furnished property until completion and final acceptance of work required under this contract. If the Government fails to make timely delivery of such Government-furnished property suitable for its intended use, and upon written request from the contractor, the Contracting Officer shall make an equitable adjustment of contract delivery or performance dates or contract price, or both, pursuant to the "Changes" clause of the General Provisions of this contract.

1. Offset disc plow

140 - Time of Performance

141 - Stump removal, debris removal, and plowing shall be done at any time during the required number of calendar days except under the following conditions: (1) weather predictions indicate a hazardous fire condition warranting curtailment of operations and may be specified elsewhere in this contract; (2) soil conditions are such that the equipment cannot be operated properly without causing excessive soil compaction; i.e., excessive soil moisture.

142 - The Government will specify a priority of work during the period of the contract.

150 - Contractor Furnished Supplies and Equipment

151 - Crawler-type tractor with a minimum 120 net engine horsepower at flywheel that has the necessary hydraulics and is capable of pulling the Government's offset disc plow.

152 - The Forest Service reserves the right to inspect all equipment prior to award to determine suitability and condition. The decision of the Contracting Officer as to acceptability will be final.

153 - The Contractor shall bear the expense of moving his equipment to the jobsite and returning the equipment to his place of business after completion of the job.

DIVISION 200 - TECHNICAL SPECIFICATIONS

210 - Definition of Terms

CONTOUR - A constant elevation of the surface of the ground.

DISC - A piece of equipment, generally known as an offset disc, that is drawn by a tractor through the ground surface.

DISCING - Drawing a plow to its maximum capabilities so as to completely disc the soil, uprooting and mixing the vegetation with the soil.

DISCING STRIP - A plowed area the width of the plow, but varying in length.

DEBRIS - Any brush, roots, logs, lifted stumps; or other loose vegetative material that exceeds 24 inches in length and/or exceeds four inches in diameter.

UNIT - An individual area of land as outlined and identified on the attached maps.

WORK AREA - Area within a unit that shall have all tree stumps and debris removed.

220 - Stump Removal

221 - Only the work areas within unit boundaries shall have all tree stumps removed. This includes both conifer and hardwood stumps.

222 - All stumps 30 inches or larger in diameter at ground line shall be removed by either blasting them with dynamite or splitting them with a tractor equipped with a stump splitter or ripper.

223 - Stumps less than 30 inches in diamaeter at ground line may be removed by above methods or with a tractor equipped with a dozer blade or brush rake.

230 - Debris Removal

231 - All debris (as defined under Subdivision 210 - Definition of Terms) shall be removed from the work areas to disposal sites (within work unit boundary) designated by the Contracting Officer.

240 - Debris Burning

241 - Forest Service will be responsible for burning all debris in the designated disposal sites.

250 - Tractor Plowing

251 - Contractor shall disc on the contour after completion of the debris removal.

252 - Each disced strip shall overlap the previous strip by approximately 10 percent (one foot). The total ground area within each work area shall be disced.

253 - The offset of the disc gangs shall be as wide as ground conditions will allow to obtain the best job in one pass. If an area is disced at less than optimum offset, the Government will require the area to be disced again.

254 - After completion of tractor plowing the contractor will backblade a 8-12 foot path around the work area for a fence line.

255 - Cleanup

All rubbish created in performing this work shall be hauled away by the Contractor. Rubbish includes but is not limited to such items as oil cans, oil filters, broken hoses and cables, etc. Rubbish meeting county regulations shall be placed in the county drop box.

DIVISION 400 - MEASUREMENT AND PAYMENT

410 - Method of Measurement

411 - Acreage as shown for each unit, using compass, Abney level, topographic tape, was measured on the horizontal plane.

412 - The Contractor may, in writing, at any time after award, request re-measurement of any unit(s) under this contract if he feels that the acreage as listed is incorrect. The re-measurement shall be made within the existing perimeter(s), as laid out on the ground for this contract, will be allowed.

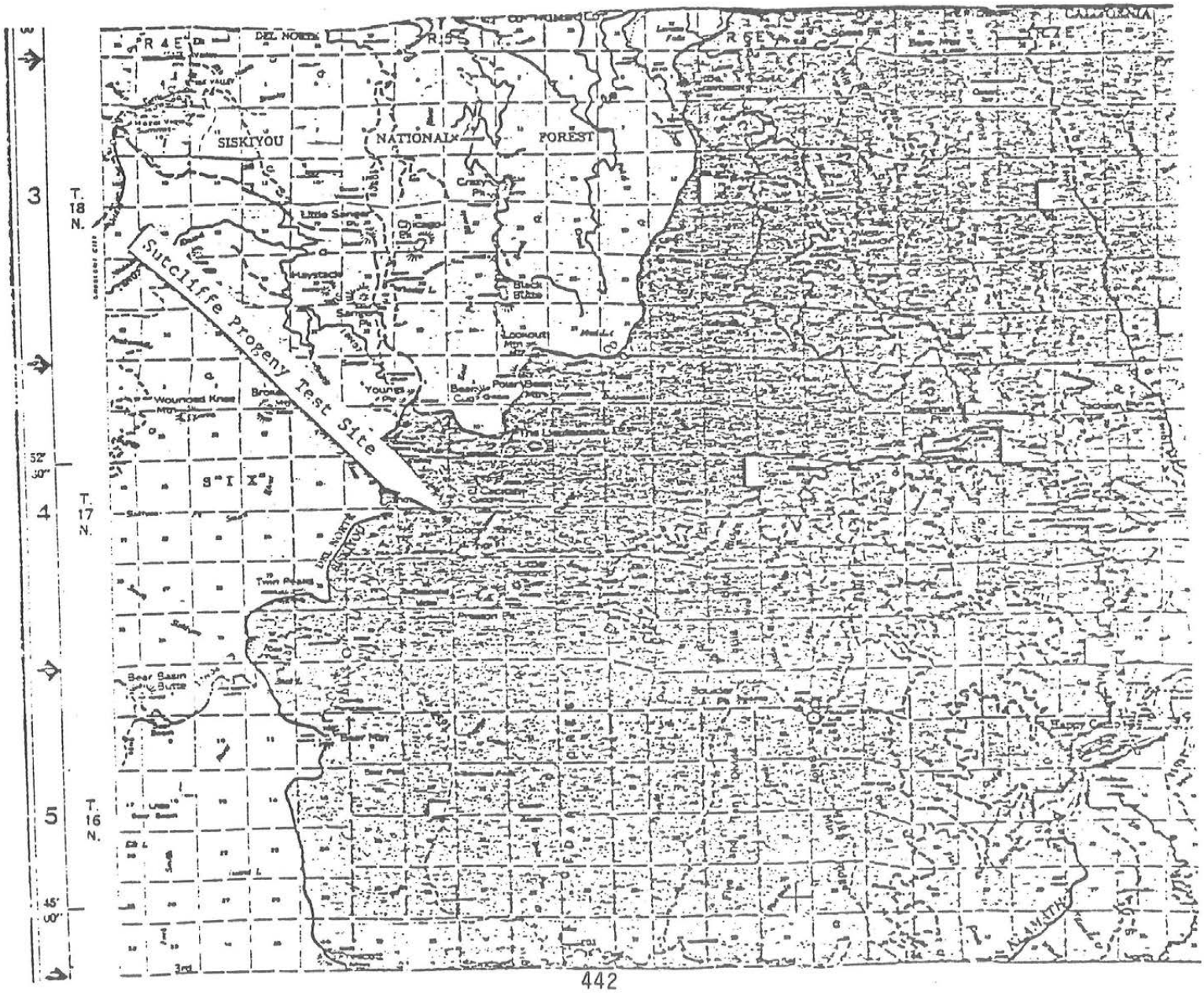
413 - If re-measurement indicates that a variance of five percent or less exists on units of more than five, but less than 20 acres, or of three percent, or less, on units of 20 acres or larger, the contractor shall pay for the actual costs of the re-measurement. If the re-measurement indicates that the actual acreage varies by more than the above factors, payment will be made on the acreage as re-measured, less any percentage for unacceptable work, and the Government will pay the cost of the re-measurement.

420 - Basis of Payment

Payment will be made on the basis of the number of acres satisfactorily completed, as determined by the Government. A Contract Payment Estimate Invoice form will be completed by the Government, signed by the Contractor, and submitted to the Contracting Officer for approval.

Solicitation No.

Sutcliffe progeny site is located on Happy Camp District in T18N, R6E, Section 20, elevation 4400 feet. Project area located on relatively flat ground (0 - 20% slope)



APPENDIX 4

Idealized Plot Layout

R5 EVALUATION PLANTATION

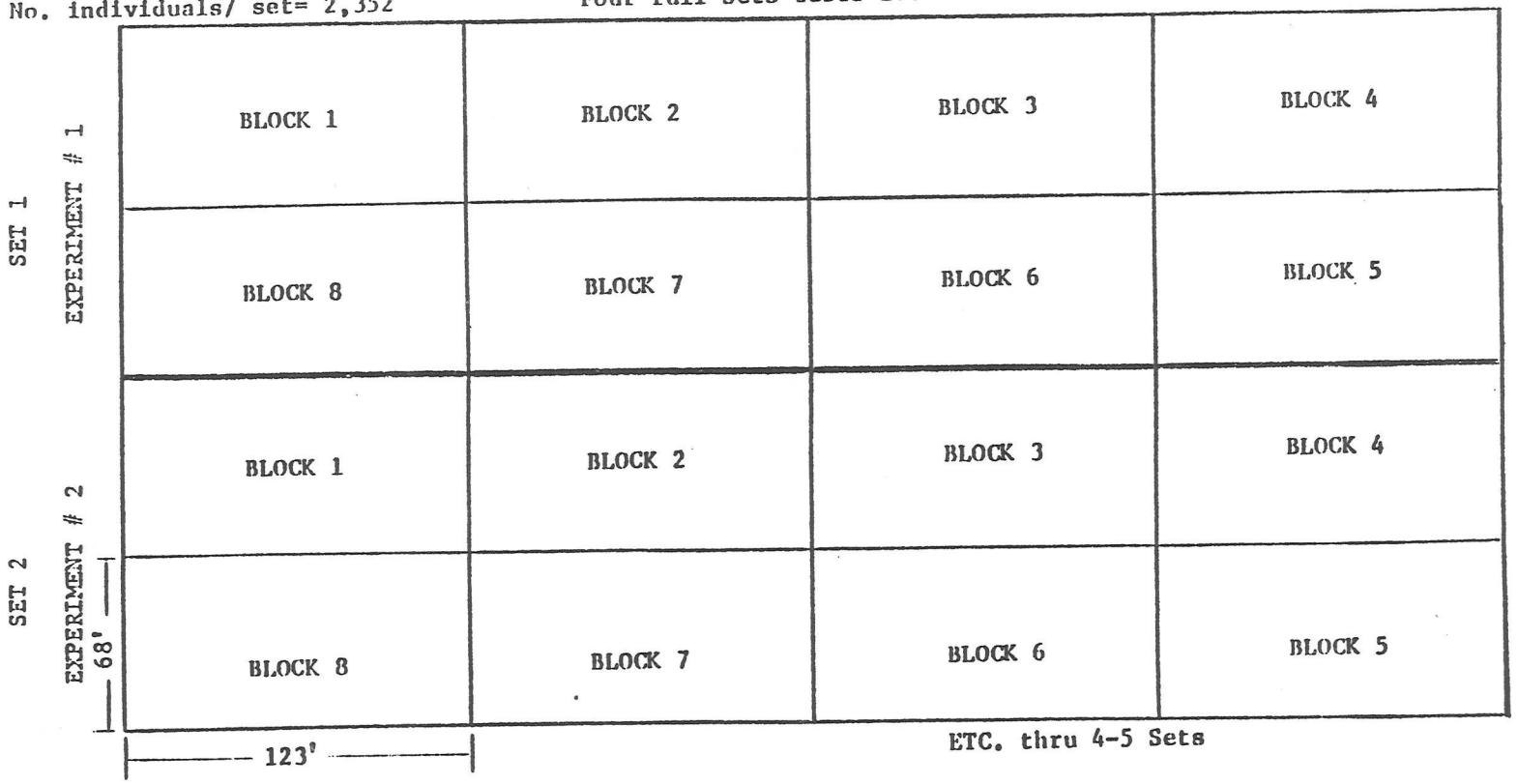
IDEALIZED LAYOUT

Spacing= 6'X 6' hexagonal
No. sets/plantation= 4-5
No. blocks/set= 8
No. families/set= 49
  45 test families+4 controls
  1 local source
  1 general source
  2 full sib families
No. individuals/family/block= 6
No. individuals/family/plantation= 48
No. individuals/block= 294
No. individuals/ set= 2,352

Sets are formed by selecting 45 well-distributed superior families in a breeding zone plus 4 controls 3 of which will be common to all plantations within a breeding zone. Local sources maybe common to more than one plantation but not to all plantations within the breeding zone.

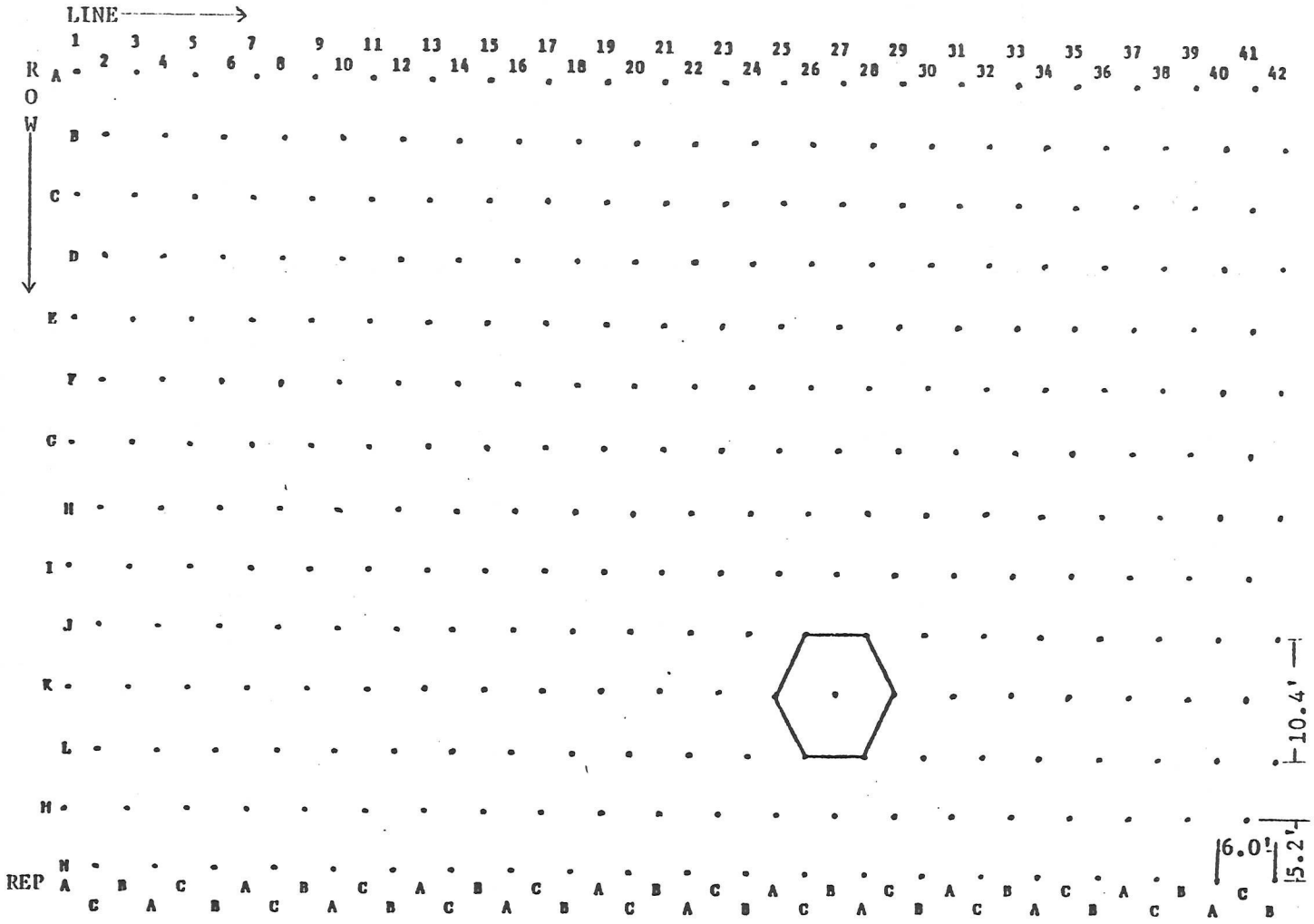
Sets (of families) represent separate experiments tied together only by 4 common control per site. Sets or experiments are physically separated and may also be separated by different planting years.

Each experiment or set requires 1.54 acres net or approx. 2 acres gross
Four full sets tests 180 test families on approximately 8 acres gross



R5 EVALUATION PLANTATION

HEXAGONAL BLOCK DESIGN


LINE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
ROW
A
B
C
D
E
F
G
H
I
J
K
L
M
N
REP
A B C A B C A B C

Region 6 Progeny Test Establishment and Management

Sheila Martinson, Gifford Pinchot National Forest

A. Who Performs Tasks.

1. PNW Forest & Range Experiment Station (PNW). Scientists provide genetic and statistical guidance to tree improvement cooperatives in the Progressive Tree Improvement Cooperative Program for design of field and nursery progeny tests. One or more scientists from PNW is in attendance at co-op meetings when important testing decisions are being made. The PNW also has the facilities for analyzing growth data from progeny field and nursery tests. In addition, PNW researchers interpret the results of growth data analyses for the Cooperatives. PNW scientists provide written procedures for nursery test establishment and measurements for those co-op programs utilizing a nursery test.

2. Industrial Forestry Association (IFA). The Tree Improvement Division of this non-profit organization coordinates Cooperative meetings for the Co-ops in the Progressive Tree Improvement Cooperative Program. Duties include: arrange times and places for meetings, draft and mail minutes of meetings to cooperators, facilitate meetings, coordinate through discussion, with cooperators the order and number of progeny tests each cooperator will establish, and attempt to keep cooperator relationships harmonious. The IFA grows containerized tree seedlings at Nisqually, Washington, for use in westside Cascade progeny tests. IFA is also hosting a nursery test site at its Greeley, Washington, facility.

3. Area Geneticists. On the westside, Area Geneticists provide guidance for statistical design and genetic questions which arise on the National Forests during implementation of cooperative progeny testing. The Area Geneticists participate in cooperative meetings when progeny testing decisions are being made. The Area Geneticist is designated by the Forest Supervisor to make resource commitments for National Forests which do not have a Forest Geneticist. For these forests, the Area Geneticist must also provide technical direction for implementation of progeny tests.

On the east side of the Cascades, many of the National Forests are not in the Progressive Tree Improvement Cooperative Program. Area or Forest geneticists, or the Regional Geneticist, provide all the genetic and statistical guidance, as well as the coordination, for establishment of progeny tests for these National Forests.

4. Forest Geneticist. The Forest Geneticist attends all co-op meetings and is the person designated by the Forest Supervisor as responsible for making resource commitments for the National Forest. The Forest Geneticist synthesizes co-op meeting information and provides technical direction to the National Forest for implementation of progeny tests programs. Technical direction is provided by the Forest Geneticist in the following areas: site selection, site preparation, fencing, staking, layout, mapping, planting, maintenance, growth measurements, and data input.

The Forest Geneticist is responsible for budgeting for progeny test establishment and maintenance costs. The Forest Geneticist is the contracting officer's representative for seedling production contracts for the progeny tests. Finally, the Forest Geneticist evaluates proposed progeny test sites for suitability before the sites are recommended to the cooperative. The Area Geneticist, in combination with the Forest Silviculturist, will perform these duties if there is not a Forest Geneticist position on a particular National Forest.

5. District Personnel. District tree improvement personnel under the responsibility of the District Silviculturist and with the technical direction from the Forest and/or Area Geneticist(s), establish and maintain the progeny tests on the National Forests. Duties include: locate sites which meet co-op criteria; accomplish site preparation, either through a separate contract or force account; construct fences through contract or force account; stake plantations; lay out progeny test design; draft an accurate map of test design layout; organize planting crew; perform required maintenance of progeny tests, including survival surveys, replacing first year mortality; perform fence maintenance; maintain accurate records for each progeny test; take growth measurements at years 5, 10, and 15; and input growth data for analysis.

B. Who Conducts Training.

1. The Industrial Forestry Association, in conjunction with the PNW Forest and Range Experiment Station conducts training for all cooperators in the Progressive Tree Improvement Cooperative Program. This training is provided on site selection, progeny test establishment and maintenance, growth measurements procedures, and growth data input.

2. Area and Forest Geneticists provide training to District personnel on all aspects of progeny test establishment and maintenance. On the westside, this training is in conjunction with, and in addition to, that provided through IFA and PNW. Area and Forest geneticists provide all training for eastside forests not in the Progressive Tree Improvement Program. Area and Forest geneticists provide Forest training sessions, followed-up by training sessions with individual districts.

3. The annual Regional Tree Improvement Workshop also provides lecture and field training in progeny test establishment and maintenance for all Region 6 tree improvement personnel. In addition, Regional tree improvement training papers are available to Region 6 Tree Improvement Program personnel on many aspects of progeny test establishment and maintenance.

C. Site Selection Process.

1. The cooperative decides on breeding zones, number of test sites per breeding zone, number of test sites per cooperator, size of test sites, and timing of progeny test establishment.

2. District personnel with Area and Forest Geneticist guidance look for available plantations which meet the Co-op criteria. The primary criteria besides those determined by the Cooperative is that the site must have uniform environmental conditions.

3. If existing plantations are unavailable, district personnel look for forested areas which meet Co-op criteria and which have uniform environmental conditions.

4. An array of proposed sites are evaluated by the Forest or Area Geneticist for suitability. The best sites are proposed for use to the Cooperative. A co-op field trip is organized and the sites are evaluated and selected by the entire Co-op.

To date, it is rare to have an overabundance of sites to select from for progeny test establishment. This is due to a very short lead time between Co-op decisions and progeny test establishment. This trend is changing, in that cooperatives are attempting to set a schedule of progeny testing in advance, so that cooperators can lay out timber sales on more environmentally uniform sites.

Progeny test sites are selected to sample the maximum range within a breeding zone of elevation, slope, aspect, soil types and ecoclasses. Progeny test sites are examined by pathologists to avoid root rot areas prior to final selection.

Eastside forests not in co-ops go through the same site selection processes within the National Forest System, under the guidance of the Regional/Area/Forest geneticists.

D. Site Preparation.

A light broadcast burn is preferred for progeny test site preparation for both eastside and westside sites.

On the westside, we may reluctantly use machine-piled and burned plantations because of lack of availability of better sites within the time constraints imposed by the Co-op. Machine piled and burned sites are undesirable, due to loss of site uniformity from soil disturbance and compaction, various levels of residual vegetation, and loss of planting spots within pile locations from incomplete combustion of slash. In addition, there is an imbalance of soil nutrients between piled areas and the remainder of the plantation. Pile locations also become the depository for topsoil that used to exist throughout the plantation.

Region 6 forests do not plan to do mechanical site scarification or stump removal on progeny test sites due to loss of site uniformity following this type of practice. Aerial applications of herbicides are applied to plantations with severe vegetation problems prior to planting, especially in southwest Oregon.

Eastside forests have utilized machine piles and windrows, although broadcast burning is generally preferred. If windrows are used, they are laid out so that replications of the progeny tests can fit between the windrows. Incompletely burned windrows or slash piles become excellent wildlife habitat. Another eastside site preparation practice is disking. This is generally used to break up sedges and grasses to reduce competition in the first years of seeding establishment.

E. Progeny Test Layout.

The entire plantation is staked at the spacing determined by the co-op. Spacing is usually 8' x 8', 8-1/2' x 8-1/2', 9' x 9', or 10' x 10'. We use cull (32") arrow shafts which are cut in two (16") pieces and are dipped in orange paint on one end to mark each test seedling location. The procedure for test site staking is to lay out several intersecting baselines within the plantation. We then fill in between the baselines at the required spacing.

After staking, we overlay the progeny test design on the grid, using metal pins with various-colored flags to mark replication and set boundaries. Once we are satisfied with the layout, we monument replication and set corners with a 6-foot length of rebar, a metal roadside stake, or a Carsonite roadside stake. Whichever material we use, it is visible from all portions of the replication.

The layout is then accurately mapped on a coordinate grid system for the entire plantation.

All layout work is completed prior to planting.

F. Planting.

Westside Procedures

1. Douglas fir seedlings are grown for 1 year in 10 cu. in. superleach containers. Noble fir seedlings are grown 1 year in the superleach containers and are then transplanted to Deepots (30 cu. in.). These containerized seedlings arrive from IFA or the Bureau of Land Management (BLM) already sorted by replication and set and individually labeled by family number.

2. One person lays the trees at the designated planting spot, marked by the arrow shafts. The planting crew follows and hand plants the seedlings, using a hoe or a shovel. One person follows the planting crew, picking up containers and ensuring that all trees are planted.

3. A mapping crew follows the planting crew, usually the same day, to map identity and location of each test seedling within the progeny test design. We produce pre-made maps (which indicate set/rep boundaries and coordinate identities) on Rite-in-the-Rain paper. Each tree seedling location has a blank square on these pre-made maps. The mapping crew records the tree seedling number, which is imprinted on the seedling label, in the blank provided for the appropriate planting spot.

4. A cross-check is made between the map and the shipping list of families per set/rep. We do this to be sure that 4 seedlings per family are planted and to detect handwriting errors which usually take the form of illegitimate family numbers.

5. Permanent tags are installed at each tree seedling location during the first growing season. We use aluminum stakes with a pigtail end. An aluminum tag embossed with family number, set/rep information, coordinate designation, and plantation name is slipped over the pigtail. Permanent tags can also be affixed to the arrow shafts which mark each tree location. The back-up to the tagging is, of course, the map of each plantation, which also identifies each seedling location within the plantation.

Eastside Procedures

Bare root seedlings are used for progeny testing on the east side of the Cascades. Tree sorting is done at the nursery in the packing shed. Seedlings are grouped by the appropriate set/reps designated by the test design. Seedlings are sorted into tubs lined with wet burlap which is folded over to cover free roots during sorting. Once a tub contains the correct seedlings, the seedling bundle is placed with sphagnum moss in a tree storage bag and transferred to the cooler until planting time. The primary management concern using bare root seedlings is to keep the seedling roots at the proper moisture level so they are "jelly-rolled" in burlap before planting. Seedling planting on the eastside is normally done using a mechanical auger to create planting holes.

G. Maintenance of Progeny Tests.

District personnel maintain the progeny tests. The plantations are visited at least once every two weeks to check on the test seedlings and the fence condition. Maintenance work needed is performed by District personnel. The District is responsible to keep accurate records for the progeny tests as a part of progeny test maintenance.

A survival examination is done on every seedling at the end of the first growing season. First year mortality is replaced by District personnel the spring following the original planting.

H. Animal Control.

An eight-foot animal enclosure is built around progeny tests in wildlife winter range or otherwise heavily-used wildlife areas. This animal enclosure includes a chicken wire mesh which is buried one foot down and one foot out to exclude rodents from the progeny test.

Animals excluded on the westside include deer, elk, rabbits, mice, pocket gophers, and mountain beaver. Eastside forests try to exclude porcupines and cows in addition to those animals excluded on the westside.

We have not fenced our high elevation noble fir progeny tests, and have experienced no animal damage at those sites.

We use Vexar tubing for seedling protection in high use areas only if we are forced to plant prior to fence construction. Vexar tubing can cause seedling deformity and introduce unnecessary environmental variation to the progeny test. We take the Vexar off the seedlings once fence construction is completed.

Gopher baiting in the form of buried, strychnine-coated oats is also practiced where needed.

I. Release.

1. We use an aerial application of Roundup in August to release trees from vineleaf maple and similar hardwood competition. This method is best used on progeny sites that have a continuous brush problem over at least 2 acres of the progeny test site. Trees are covered with Kraft paper bags prior to treatment. The bags are removed following treatment.

2. Progeny test sites which have scattered clumps of hardwood vegetation such as big leaf maple are treated with a hand, basal spray of Garlon 4A during the growing season. Trees adjacent to the treated clumps are covered with paper bags during treatment.

3. Hand cutting of vegetation is done in areas such as domestic watersheds, to reduce vegetative competition in progeny test sites. This treatment is very expensive and must be repeated annually until the test seedlings overtake the competing vegetation.

J. Thinning.

Progeny tests sites currently established are not designed to accommodate thinning. Some future test plantations will be designed to allow systematic thinning. A few plantations may even utilize the random-interlocking design.

Attempts to allow for thinning without loss of the test design will be a good source of juvenile/mature correlation analysis for height and diameter growth.

K. Fertilization.

We do not fertilize our forest stands on a production basis, and hence we do not fertilize our progeny tests.

L. Insect and Disease Control.

We have not done insect control work on any Westside progeny tests to date due to lack of an insect problem (knock on wood).

We try to select progeny test sites which do not have root rot.

M. Identity Control.

Identity control is made through use of permanent tags at each seedling location, and progeny test mapping showing each test seedling location by grid coordinates.

PROGENY TEST ESTABLISHMENT AND MANAGEMENT IN REGION 8 1/

(Round Table Discussion)

by

Timothy La Farge, Zone Geneticist
USDA, Forest Service, Region 8

In Region 8, progeny test establishment and management involve a coordination of a number of activities from the Regional Office to each Ranger District in which progeny tests are established. I will briefly try to summarize these activities and responsibilities.

Who Performs Various Tasks

The Regional Geneticist is responsible for the overall administration and management of the Tree Improvement Program. The Zone Geneticists provide technical advice, supervision and management of all tree improvement operations in the Seed Orchards and progeny tests. An exception to this is that the Regional Geneticist directs the Net Retrieval System now being implemented in four seed orchards. The Zone Geneticists' responsibilities include allocation of seed lots and crossing groups to the appropriate forests and districts and approval of sites selected by the Forest Silviculturist. The Zone Geneticists are frequently called upon to supervise the layout and planting of progeny tests, although, on some forests, these responsibilites are handled by the Seed Orchard Managers and their staffs.

The establishment of each progeny test plantation is performed by the silviculturist or other district forester assisted by technicians or other district personnel. Although this work is frequently done under the supervision of the Zone Geneticist or Forest Silviculturist, some districts have had enough experience to perform this work without higher supervision. Progeny test measurements are also performed by district personnel with assistance and/or supervision from the Zone Geneticist and Forest Silviculturist when needed.

The planning and design of the data handling and analysis system is being developed by Ralph Lewis, Planner and Biological Scientist, Regional Office.

Data storage is handled on the computer by Florence Garrison, our Silvicultural Assistant, Timber Staff Unit, Silviculture Group, in the Regional Office.

The Regional Geneticist and Zone Geneticists are all involved in the training of district personnel as the need arises. The Forest Silviculturist is also responsible for passing along new methods to the districts. In addition, annual "Seed Orchard Managers' Workshops" are held to bring all seed orchard and progeny test personnel up to date on the latest developments in seed orchard and progeny test management. On at least one occasion in the past, forest and district people have attended the Tree Improvement Short Course given periodically by North Carolina State University.

1/ Presented at the USDA, Forest Service, Servicewide Genetics Workshop, Charleston, S.C., December 5-9, 1983.

PROGENY TEST ESTABLISHMENT AND MANAGEMENT IN REGION 8
(Round Table Discussion)
by Timothy La Farge
(cont'd)

Site Selection

The Zone Geneticist notifies the Forest Silviculturist of the progeny tests in each species to be established each year. The Silviculturist selects certain districts and notifies them of the need to set aside a few clearcut acres for progeny tests. Together, the Zone Geneticist and the Silviculturist inspect each site to determine its suitability for a given test.

Site Preparation

Site preparation methods vary with the prevailing practices in the forests and districts on which the tests will be located. However, the most common methods are chopping and prescribed burning, or a combination of these. Bulldozing and KG blading are also sometimes used under exceptional circumstances.

Test Layout

The progeny test area is surveyed with a hand compass and a 200-foot tape. A colored flag is placed at every point at which a tree is to be planted. Ten-tree row plots are color-coded by alternating two colors (e.g., red and yellow) within a replicate. Replicates are color-coded by using different color combinations for different replicates (e.g., red and yellow in replicates I, III and V, blue and white in replicates II and IV). Each test has five replicates of 10-tree row plots and two border rows around the whole test. On hilly sites, the rectangular shaped replicates are laid out along the contour, with the row-plots running up and down the slope.

Planting

All planting in progeny tests is done by the dibble method. Usually, the randomization of families is done in the field. Temporary tags mark the beginning and end of each row.

Maintenance

The Forest Silviculturist or a district forester checks survival after one year. If survival is adequate, the temporary tags are replaced by permanent tags. Additional test checks are usually made once each year until age 5 years.

Animal Control

Animal damage has rarely been a serious problem. However, rabbit damage became severe on the Ouachita National Forest in 1982. Thiram was then used as a repellent.

Release

Most release is being done by hand. Chemicals have been used with success, but some districts have experienced damage to seedlings, apparently from drift. Release is usually no longer needed after age 5.

Thinning

No thinning has yet been performed in any progeny tests.

Fertilization

Fertilizers are not applied to any progeny tests.

Insects and Diseases

Normally, we do not attempt to control these problems in progeny tests. We do record their presence when collecting data to determine if there might be genetic variation for resistance, or to determine if any part is becoming a severe problem in that test.

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Measurements Taken in Region One Progeny Tests

by Gerald C. Franc[1/]

Total height in centimeters, as an expression of tree growth, is the principle measurement for all species in the Region One Tree Improvement Program. In tests where early selection is to be made for growth, baseline measurements are made after the trees have become established (usually after the first or second growing season depending upon the species, site conditions, etc.). In long-term field tests, subsequent height measurements are made at 5-year intervals. In more intensively managed early selection trials the final height measurement will be taken as soon as differentiation in height growth can be reliably measured. This may be anywhere from 3 to 10 years depending upon species and site.

How long the long-term field tests will continue to be measured is uncertain. Measurements in the future will probably be made as long as it is felt that useful information will result. Some 28-year-old white pine test plantations are still being measured, but not at regular 5-year intervals. As the trees become large and more difficult to measure for height, then it may be more desirable to measure diameter.

1/ Selective Breeding Specialist, Region One.

Douglas-fir is a species that is particularly vulnerable to frost damage. Seedlings in the Douglas-fir early selection trials will be scored for hardiness as well as growth. Hardiness will be measured by ranking trees by date of bud burst, date of bud set, or presence of second flush. The data will be used to develop a Douglas-fir growth/hardiness index so that seed orchard selections can be made in a manner that will minimize the risk of maladaptation.

In the Western White Pine program, selections are made for resistance to blister rust as well as for growth. To screen for resistance, two-year-old progeny are inoculated with rust basidiospores in a controlled environment designed to optimize infection. Rust inspections are made the spring and fall of the first year after inoculation and again the fall of the third year after inoculation. Seedlings and families are scored for six different horizontal and vertical resistance mechanisms. After the third year measurements, the resistance data and growth data from an early growth selection trial are used to select the best individuals from the best families for seed orchard trees.

Long-term test plantations are measured for survival after the first and second growing season and again when height measurements are taken. Damage to insects, diseases, animals, and environment are also noted when survival and/or growth measurements are made.

PROGENY TEST MEASUREMENTS IN THE ROCKY MOUNTAIN REGION

Richard M. Jeffers [1/]

Since 1970 five genetics plantings have been established in the Rocky Mountain Region (Region 2). In four of these plantings only survival and total height have been evaluated. In the fifth planting, which contains open-pollinated progenies of ponderosa pine from selections made on the Black Hills National Forest, survival, total height, basal diameter, and crown width were evaluated 10 years after planting. This planting which was established by the Rocky Mountain Forest and Range Experiment Station in 1971, was the first progeny test established in Region 2. Since establishment, the planting has not been adequately maintained and very few good trees remain. Consequently, this planting is no longer retained as a progeny test.

Because so little data has been collected in genetics plantings in Region 2, evaluations that will be made in progeny tests to be established in Region 2 are summarized in the following sections.

SEED

Currently, the only data that are maintained for progeny test seed is yield of seed per cone from each parent tree and total seed per family in storage. These data are being maintained by hand on superior tree seed records at the nursery. However, they will be computerized when computer facilities are available at Mt. Sopris.

[1/] Regional Geneticist, Rocky Mountain Region, Lakewood, Colorado.

Bareroot - Region 2 will use bareroot seedlings in progeny tests only when super-seedlings of Engelmann spruce, selected in two- or three-year-old bareroot nursery beds, are used to establish plantings that will be utilized as seed orchards. In the spring of 1981 two small plantings of Engelmann spruce super-seedlings were established at 10,500 feet elevation on the Rio Grande National Forest in southern Colorado. At time of selection total heights of both super-seedlings and controls were taken. All selected seedlings had to have good general vigor and needle color, good stem caliper in proportion to height, a single main stem, and a healthy appearing terminal bud. Although stem caliper was not measured on these selections, it will be taken on any future super-seedling selections. The ratio of height to stem caliper can then be used as another measure of seedling quality.

Greenhouse - Except for Engelmann spruce super-seedlings, all other progeny test seedlings in Region 2, will be grown in containers in Forest Service greenhouse facilities. Germination percent and seedling survival will be taken periodically during seedling production in the greenhouse. At the conclusion of the seedling production phase progeny test seedlings will be evaluated for total height and stem caliper. Branching may also be evaluated if variation within or among families occurs in this trait during seedling production.

Survival - Many sites in Region 2 are difficult to plant successfully because of one or more limiting environmental variables such as poor soils, low precipitation, poor distribution of precipitation in growing season, little site protection, and high elevation. Consequently, survival counts are the most important data to be evaluated in all planting projects. For progeny tests, survival will be determined at least once a year for the first five years after planting. Thereafter, survival will be determined when each major measurement is taken; for example, at ages 10, 15 and 20 years.

Growth - Initial total heights will be determined either immediately after planting or at the end of the first growing season when initial height and first growing season height growth can be estimated. Thereafter, total heights will be taken at 5, 10, 15 and 20 years after planting. Measurement of total height after 20 years will depend upon further development and disposition of the progeny tests.

Stem diameter measurements will be taken near groundline at age 10 and 20 years after planting. At a later date diameters at mid-tree height may be taken and used in estimating stem form. Additional measurements of diameter may also be taken depending upon growth patterns within individual tests.

Stem Form will be evaluated when stem diameters are measured at 10 and 20 years after planting. Estimates of stem straightness and cross-section shape will be made visually. The scoring systems used will be developed

on the basis of variation in these traits within each progeny test. Mid-tree height diameters may also be taken and the ratio of this diameter to basal diameter used as another estimate of tree form.

Branching characteristics such as number of branches per unit tree height, numbers of branches per whorl, branch diameter, and branch angle, will be scored visually at 10 and 20 years after planting. The kinds and magnitude of variation in these traits in the progeny tests will be used in development of the scoring system used to assess these traits. Average crown width, measured at 10 and 20 years, will be used as an estimate of branch length.

Flowering and Seed Production - Time of initial flowering and seed production will be noted when it occurs. When adequate numbers of females and males are present on selected individuals within a test, controlled pollinations will be made according to the breeding scheme developed for each species. Estimates of the magnitude of flowering and seed production will be made when a majority of trees in a test are producing reproduction structures of either or both sexes.

Pest Incidence will be noted when other traits are evaluated. Detailed scoring of pest incidence will be made when observable variation occurs among individuals within and/or among families.

DATA COLLECTION AND ANALYSES

To date, relatively little data has been collected in the five genetics plantings in Region 2. All data that has been collected has been hand recorded on cumulative data summary sheets (columnar paper). Ten year data from the Black Hills ponderosa pine progeny test and an Engelmann spruce provenance test were summarized and analyzed by computer at the Rocky Mountain Forest and Range Experiment Station. All other data has been summarized on a TI 55 hand calcultor. Tentatively, data to be collected in future progeny tests will, most likely, be entered directly into portable field data recorders. Data collected from the Engelmann spruce super-seedling plantings and future progeny tests will be summarized and analyzed by computer, utilizing available state of the art progeny test analysis techniques.

DATA NEEDS

Region 2 has a history of limited success in plantation establishment. Typically plantation failures have been attributed to poor site selection, inadequate site preparation and control of competing vegetation, use of the wrong seed source, poor quality planting stock, improper stock handling, poor planting techniques, poor soils, lack of precipitation, and inadequate protection against damaging pests. However, because very few plantation establishment and even fewer performance records, have been maintained, it has been very difficult to determine the reasons for individual plantations failures. Consequently, much of the data collected in progeny tests will contribute significantly to our knowledge and experience in plantation establishment and management.

Data from selection programs and progeny test programs will also increase our general knowledge of growth, flowering and seed production of species included in Region 2 tree improvement programs when tested under local conditions.

In addition, nearly all data from progeny tests will increase our knowledge of genetic variation in populations of Region 2 species, which is currently extremely limited. And, ultimately all accumulated progeny test data will be useful in the further development and implimentation of Region 2 tree improvement programs.

Progeny Data Collection and Measurement
Steven P. Grass
Central Zone Tree Improvement
Pacific Southwest Region

1. Purpose: The purpose of progeny data collection and measurement is twofold. First and foremost, is to obtain growth, form, and injury information that best describe genetic differences between the progenies and/or provenances in evaluation test plantations. Second, is to identify areas on the ground that need special maintenance attention for competition, animal, insect or disease control.

2. Data Collection Timetable:

Year In Field	Type of Data Collected
0	Planting Notes
1	Survival and Condition
2	Survival and Condition
3	Total Height and Condition
5	Total Height and Condition
7	Total Height, Diameter, Tree Form, and Condition
8	First Thinning
10	Total Height, Diameter, Tree Form, and Condition
12	Total Height, Diameter, Tree Form, and Condition
13	Second Thinning: Taper and Specific Gravity
15	Total Height, Diameter, Tree Form, and Condition

Planting notes include:

a. Date of planting
b. Planting method; dibble, auger, hoedad, etc.
c. Tree spacing
d. Block design; rectangular or hexagonal
e. Condition of planting stock
f. Identification of poor or outstanding individuals
g. Mapping microsite differences
h. Recording soil temperature
i. Noting planting conditions; soil moisture and texture, competition, weather, etc.

Data collection for diameter and tree form will occur only on the faster growing plantations at year seven, but should include all by year ten.

Total height measurements at the end of the fifteenth year may be very difficult to obtain on some of the faster growing sites. Ponderosa pine may be averaging 2-3 feet of growth per year with many trees forty feet tall or more. It is possible that the last measurements to be taken on

these sites will be in year twelve or on the thinned trees in year thirteen. Measurements on these downed thinned trees could just include the growth in year thirteen and later added to the previous total heights taken in year twelve. Measure of taper and specific gravity can be more easily determined on these downed trees.

Measurement intervals were chosen based on:

a) Measurements are more easily done in the early years.
b) Need to observe more frequently in the early years due to rapid changes occurring, i.e., instability in survival, greater injury risk, greater effect from other competing vegetation, etc. Maintenance needs can then be brought to attention early and tended to when the need is most critical in the early years.
c) To Generate a growth curve for each family with as many data points as feasible.
d) To obtain growth information for silviculture in intensively managed plantations.
e) To obtain data for juvenile-mature correlations and family rank changes.

3. Condition Codes

Qualitative evaluations of each tree are accomplished by using a two letter tree status code. The first letter generally indicates the broad classification of the trait being observed and the second letter the more specific cause. Some examples to illustrate this are codes such as DG which indicates the tree was dead having been killed by a gopher, or TI which indicates the terminal bud has been killed by an insect. (See examples, page 3.)

Status codes are very critical to the veracity of any subsequent quantitative measurement in genetic evaluation plantations. They temper survival and growth measurements to exclude those that have obvious non-genetic biases. Examples for exclusion would be man-caused or gopher-caused mortality, or height measurements from trees that were girdled by porcupines, etc. Statistical evaluations will not be made on "dirty data" so that conclusions can be drawn with more confidence towards a genetic implication.

TREE STATUS CODES

Live Healthy	OK	Living Tree
Dead	DO	Death of tree due to drought or unknown agent
	DG	Gopher mortality
	DR	Rabbit mortality
	DD	Dear mortality
	DH	Mortality caused by human activities
	DM	Missing - assumed dead
Browsed top	BO	Top browsed by unknown agent
	BG	Top browsed by gopher
	BR	Top browsed by rabbit
	BD	Top browsed by deer
Internode (bole) damage	IO	Stem scarred by unknown agent
	IG	Stem scarred by gopher
	IR	Stem scarred by rabbit
	ID	Stem scarred by deer
	IP	Stem scarred by porcupine
	IH	Stem scarred by human activity
Terminal bud	TI	Insect killed terminal bud - new
	TM	Terminal bud missing - no competing fork as yet
	TH	Terminal or top lost by human activities
Needle	NL	Needle loss
	NC	Needles chlorotic
	NB	Needles browsed - insect
	NH	Needles affected by human activities - air pollution, herbicide effects, etc.
Other	TD	Top dead (or top dieback by unknown cause)
	TR	Top dead or dieback due to porcupine and other rodents
	FK	Fork - new forking c[illegible]d fork still in terminal competition. Termin[illegible] bud is either missing, killed, or suppressed
	GA	Gopher activity near tree
Lammas second flush	LL	Lammas growth on terminal - no bud visible
	LB	Lammas growth on terminal - well established bud
	LP	Proleptic growth - laterals only
Frost damage	FL	Damage on laterals only
	FT	Damage on terminal - few laterals
	FS	Severe damage on terminal and many laterals
Snow damage	SL	Damage on laterals only
	ST	Damage on terminal - few laterals
	SS	Severe damage on terminal and many laterals
	XX	Other observations of interest
	YY	Other observations of interest
	ZZ	Other observations of interest
	PN	Pruned

Tree form codes have not been used in Region Five progeny tests yet. Criteria for evaluation will be subjectively evaluated within certain degrees of trait variation relative to the particular species involved. Examples to be included in form classification are:

A. Stem form

1. Straightness

a. straight
b. crooked
c. sweep
d. sinuous
e. forked

2. Taper

a. fast)
b. intermediate) or quantitatively measured
c. slow)

B. Branch form

1. Branch angle

a. flat
b. intermediate
c. accute

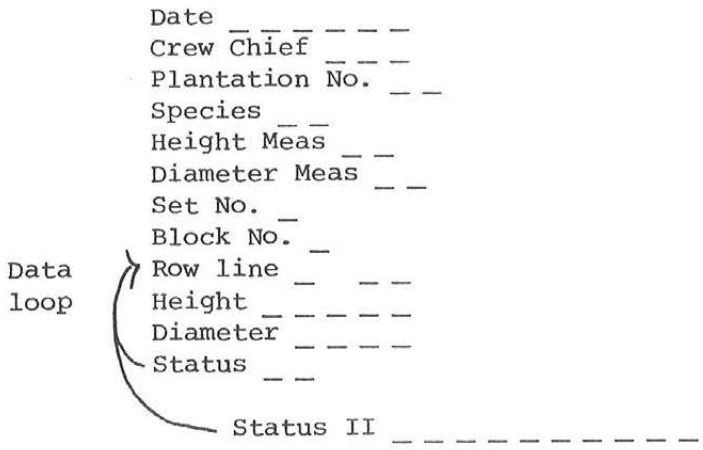
2. branch diameter
3. branch length
4. number branches/whorl

C. Crown form

1. narrow
2. intermediate
3. spreading

4. Data Collection:

Data is soon to be collected on MSI portable data recorders (PDR). These recorders are pre-programmed to ask for information on each tree by a means of prompts. The prompts start by asking for basic information which in part identifies the plantation, set, and block. Data is recorded henceforth in a block for each tree in accordance with a four prompt programmed loop. The order of prompts follows:



A special key is pressed to loop back to the Set No. Prompt to gather data in a different block or set. This program is flexible to enable data collection on any size or shape of block, rectangular or hexagonal, where each tree can be assigned its own unique row and line number.

The PDR will take longer than collecting the information on paper. This longer time in the field will be immensely rewarded by later time saving of the computer that will collate and rearrange the data into the proper form for employing the various statistical analysis program packages at the Fort Collins Computer Center. In addition, data transcription errors will be avoided.

Field data collected with the PDR will be transmitted daily onto diskettes either over phonelines to a receiving computer or directly into a portable computer. Before the PDR is cleared for reuse, a printed hardcopy must be made to determine if there were any errors in transmission.

Survival and condition code data collection from the first two years of the test alternatively might be collected on paper in the field, if time is short, and then entered into the PDR at the office. Collecting height and diameter information takes longer in the field and would be more efficient to collect the data on the PDR in the field.

5. Complexity and Scale:

The amount of data collected and analysed is on a grand scale in progeny testing. The following is a breakdown of the number of trees and frequency of data collection on each incurred for one species in one set of one plantation over a fifteen year test life.

2,352 trees/set with data collected on all trees in years 1, 2, 3, 5 and 7.
(2,352 x 5 = 11,760)

1,568 trees/set after the first thinning with data collection in years 10 and 12.
(1,568 x 2 = 3,136)

784 trees/set after the second thinning with data collection in year 15.

Total tree data records for one species in one set of one plantation then equal 15,680.

Region Five will test four major species; ponderosa pine, sugar pine, Douglas-fir, and white fir. Each species is tested in four to five breeding zones of four to five plantations each. Within each breeding zone each species is tested in four-set units. Total tree data records for one species in one breeding zone will exceed 312,500. With Region Five's average of four breeding zones per species it comes to over 1.25 million. Multiplied by four species, we will have in excess of 5 million tree data records.

6. Measuring Tools:

Height measuring tools that work well are 1 to 2 meter measuring sticks that measure tree heights in centimeters, ours are homemade with alternating black and white centimeter units for easy reading. When the trees start averaging over head high, the measuring units change to decimeters (year 7 or 10) and telescoping measuring poles are used. Telescoping poles of 7.5 meters are used for reading heights directly near breast height, 1.5 meters from the ground.

Proper measuring techniques are needed to ensure precision. Some rules are:

1. Avoid leaning the pole into the tree at an angle and hold the pole as close to the bole as possible.

2. Make sure the pole is on the true ground at the base of the tree, not in a hole, on a small log, rock or limb.

3. Measure on the uphill side of the tree.

4. Make sure that two sections of the telescoping pole aren't locked together. Readings can be off by more than a meter.

5. Measure to the top of the terminal bud, not the needles. If the terminal is dead, measure the highest lateral.

Diameter measuring tools include calipers for small trees and a diameter tape for larger trees.

7. Other Considerations:

A. Salvaging damaged test trees:

Trees that have been: girdled by rodents, have had the terminal killed by insects, broken by snow, killed or growth retarded by improperly applied herbicide, etc., need not always be excluded from comparisons with other unaffected test trees. Total height comparisons of these severely damaged trees can never be made with undamaged trees unless the damage had occurred early on in the first

few years. Annual growth and tree form information can still be valid.

For annual growth information to be better compared, growth should be directed into a single rather than multiple terminal. Pruning may be the only answer to convert a "bush" or "candelabra" tree into one with one true terminal. Tree form can still be valid in giving information on branch angle, crown form, etc.

B. Lamma versus Proleptic Growth:

In Region Five many of the ponderosa pine have been commonly renewing growth in mid to late summer in the early years of progeny establishment. Growth on the terminal (lammas) and growth on the laterals (proleptic) has been observed in every plantation and from observation is not consistant within a family or to a trend of elevational or seed zone origin.

Evaluating height and condition information on some of these trees is complicated when some trees of a family have a new terminal flush of lammas growth while others have set their bud after one whorl. The trees with the lammas flush are often taller with a smaller terminal bud size compared to others that did not flush. Which is the more desireable trait?

Another condition that occurs is when proleptic flushing occurs on the laterals but no lamma flushing on the terminal. The laterals have set a new whorl of buds above the terminal. The next year many of these trees are forked and a few have suppressed the true terminal and have taken over. Are these true forks? Are total height comparisons adversely affected by these competing forks?

Both lammas and proleptic flushing seem to be decreasing with the age of the trees. Year seven has much less flushing than earlier. The effects of forking and terminal suppression are still apparent and lasting, however.

C. Thinning:

The evaluation plantations are typically planted on a 6 x 6 hexagonal design. Two systematic thinnings will be necessary. The first thinning is anticipated at age 8 and the second at age 13. The trees being planted at this close spacing come into inter-tree competition early. Thinning is delayed to promote this competition to force the trees out of their juvenile growth stages into more mature stages to hopefully attain earlier stability in family rankings. However, thinning will not be delayed to the point of less than 40% live crown ratio.

Survival and growth data will be the primary basis on deciding which interlocking replications will be thinned out.

Forest Genetics Workshop
December 5-9, 1983
Charleston, SC

PROGENY TEST MEASUREMENTS
Region Six

William Randall

The progeny testing program for Region 6 is based upon the promise that trees of the Pacific Northwest are quite closely adapted to their local geographic area. From within a local area, perhaps 20 by 20 miles, 300 or more parent trees are selected and 120-140 progeny from each are evaluated at 8 to 12 sites. A lot of trees to measure, 36 to 40 thousand in a breeding zone. The chief characters are survival and growth. Recordings are usually made at five year intervals with first growth measurements taken at age five years.

These measurements are analyzed by analysis of variance and regression of progeny performance on parent location information. The purpose of which is to determine and map genetic variation within the breeding zone, eliminate poor parent trees from seed orchards and reforestation seed collections, and to generate a new population for seed orchards and future testing.

CHARACTER	AGE	HOW	PURPOSE
Survival	2	Visual record on map	Replace mortality Continue w/site
Damage	5	Visual record on 80-column sheet	Eliminate families Continue w/site
Total Height	5	Measurement pole 80-column sheet	Eliminate families Determine genetic variation in zone
Total Height	10	80-column sheet	Eliminate families.
		Measurement pole	Refine variation within
Diameter (B.H.)	10	D-Tape or caliper	zone. Crosses among top
		80-column sheet	parents. Selection based
Damage	10		on volume.
Total Height	15	pole or altimeter	As above. Establish new
Diameter	15	D-Tape or caliper	seed orchard with
Damage	15	80-column sheet	combination of family and within family selection

Other characters measured as need arises:

deer browsing	volcano damage	frost damage
root weevil damage	herbicide damage	mouse girdling
forking	hare and mountain beaver clipping	

Other insect, disease, and environmental damages are measured when they occur. A special set of blister rust evaluations are taken on western white and sugar pine plantations.

MEASUREMENTS 1/

(Round Table Discussion)

by

Timothy La Farge, Zone Geneticist
USDA, Forest Service, Region 8

In Region 8, we started collecting data in our five-year-old progeny tests for the first time last winter. So far, we have tried to develop a data recording system which is simple, yet flexible, and can be easily stored in our computer system.

Characteristics Measured

At age one, we record the First Year Survival (FYS), i.e., whether each tree is alive or dead, including codes as to the possible cause of death (e.g., animal damage, poor planting, drought, insect or disease problems, etc.)

At age 5, we make our First Interval Evaluation (FIE). The traits measured are: (1) height; (2) the crown-width/height ratio; and (3) problem codes (e.g., cronartium galls, chlorosis, tip moth, web worm, brown spot, competition, etc.).

At ages 8-10, we perform our Second Internal Evaluation. The traits measured will include: (1) height; (2) dbh; (3) problem codes (to be determined); and (4) probably stem straightness.

Ages at Which Traits are Measured

As I have stated above, the measurement ages currently planned are 1, 5 and 10 years. However, these are not necessarily fixed and can be altered at the discretion of the Zone Geneticist.

How Measurements are Made

At FIE, height is measured by means of a pole graduated in feet and tenths (e.g., a stadia pole). At SIE, height will be measured by a Suunto, Blumleiss or Haga Altimeter, or by an Abney Level. Diameter will probably be measured with a caliper.

The crown-width/height ratio is measured by means of a transparent plexiglass stencil through which each tree is viewed and framed within vertical and horizontal lines from which the ratio is read.

The problem codes are determined from visual observations.

1/ Presented at the USDA, Forest Service, Servicewide Genetics Workshop, Charleston, S.C., December 5-9, 1983.

MEASUREMENTS
(Round Table Discussion)
by Timothy La Farge
(cont'd)

Purpose of Measurements

Height and d.b.h. are measured to determine the genetic control of growth rate, so that gains can be estimated, and to select families for second generation breeding. A secondary purpose will be to rogue the clonal seed orchards.

Problem codes have two purposes. If any insect or disease problems become epidemic, we will then have a basis to determine if they are under genetic control, so that we can select resistant families. If the problem becomes so serious as to threaten the plantation, we can apply control measures, but this measure has not yet been needed.

The crown-width/height ratio is a catch-all quality trait. In research at Macon (Southeastern Station) over the years, we found it to be quite heritable. There were usually strong family differences. A narrow crowned tree seems generally to represent good form, including a tendency to have small, wide-angled branches and a straight stem.

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FOREST GENETICS WORKSHOP

DEC. 5-9, 1983

CHARLESTON, SOUTH CAROLINA

Round Table -- Measurements -- what, when, how, why?

By -- Ross Melick, Central States Zone Geneticist, R-9.

INTRODUCTION

Region 9 has three Tree Improvement Zones, with varying emphasis on hardwoods and softwoods.

1. Lakestates Zone (MN, WI, MI) - Mostly conifers (pines, spruce, tamarack) with some hardwood work, primarily hybrid poplars .

2. Eastern Zone (VT, NH, PA & WV) - Mostly hardwoods (yellow birch, black cherry, sugar maple, black walnut, tulip poplar).

3. Central States Zone (MO, IL, IN, OH) - Mostly hardwood tests (75%) (black walnut, cottonwood, northern red and white oak, green ash, tulip poplar) with several recent shortleaf pine tests in MO to date. (Loblolly pine tests planned for Southern IL and Southern MO, eastern white pine tests planned for IL through OH).

WHAT, WHEN, WHY

The differences in species priorities result in somewhat different types and timing of field measurements between zones. In general, in the Eastern and Central States Zones, with a present preponderance of hardwood tests, we score survival and damage and measure heights at ages 1, 2, 3 and 5. Good site prep and early care, especially weed control, are so critical in hardwood plantation establishment that these early measurements force us to take a close look at plantation conditions and needs. Need for release of individual trees is often recorded in these early measurements. It is hoped that these early measurements will also provide useful juvenile/ mature correlations and help identify early starters.

In the Lake States Zone, survival is recorded after the first winter. Height is also recorded, if thought to be important enough to warrant the extra time required. No other measurements are taken until age 5, although an annual review of each plantation is made to see if any cultural work or protection is necessary.

In the Central States we attempt to get as-planted height measurements immediately after planting in our shortleaf pine and oak tests for the following reasons:

1. Shortleaf Pine - great size differences occur between families in the nursery. We also know that drought tolerance in shortleaf is increased by deep-planting, so shortleaf seedlings are often set one to three inches deeper than they were in the nursery, often with the lower whorl of branches below the soil surface. The as-planted heights in shortleaf, then, will be used to try to correlate effects of seeding size/seedling height above soil surface with later measurements and survival data.

2. In oak tests, family size differences are often large and shoot dieback is often experienced for several years after planting. It is hoped that as-planted heights or stem caliper (in the case where shoots are purposely clipped back to about 15 cm to facilitate planting and provide better shoot/root ratios) will provide useful correlations with later measurements.

After ages 1 to 3, all three zones regularly schedule subsequent measurements at 5 year intervals at ages 5, 10, 15 and 20. At these times, in addition to height, survival and damage, parameters such as DBH, flowering, stem form and branching habit are measured as appropriate. For instance, in the Central States we start taking cottonwood DBH's at age 3. By age 5 we have had heights of 16.4 m (54') and diameters of 22 cm (almost 9"). In the Lake States,jack pine flowering observations can often be made at age 5.

In hardwood progeny tests in the Central and Eastern Zones, because of the importance of stem form and branching habit on tree quality and value, (e.g., forking is a major source of volume loss in hardwoods) these parameters are scored as soon as practicable (age 5 or 10). Subjective stem quality scores are also often recorded. We are interested in determining the effectiveness of these early subjective and prescriptive estimates in predicting subsequent hardwood stem quality. Appendix A is a tatem aid used in the Central States Zone. It shows the basic characters usually considered in Region 9 and the basic scoring methods used. Specific items can be used or not, or modified as needed to closely fit or describe almost any plantation situations encountered. Appendix B is a hardwood grading scheme now on trial in the Eastern Zone.

The standardized remeasurement schedules for each zone, along with the specification that measurements normally will be taken after growth cessation in the fall and before resumption in the spring, serve only as basic guidelines. After severe storms or weather, or high incidence of other damage vectors, all zones attempt to opportunistically record damage. Examples may be breakage following severe wind, ice or snow storms; drought and heat damage, such as observed in new Central States shortleaf tests after the 1980 and 1983 droughts; the winter damage, especially to southern clones observed in Central States cottonwood tests after the severe winters of 1977 to 1979; or observations of damage by late or early frosts, the latter usually observed as damage to new spring growth.

HOW

In Region 9, most measurements are metric. Some typical items measured or scored and the basic scoring methods are shown in Appendix A.

Standard instruments and measuring devices are used. In the Central States, until trees reach DBH greater than 10 cm, wedge-cut diameter gauges with a neck strap are used rather than calipers. Thus, only one man with a fairly short measuring pole (up to about 8 m) can also take diameters, a second person records data. After trees exceed 10 cm DBH, calipers are used and a three-man crew may be necessary. (A caliper requires 2 hands [1 person], heights of caliper-measured trees are such that if a pole is used, it is so tall that the person holding it will need 2 hands just to control it safely at all times [1 person] and recorder). As heights exceed 10 meters, we switch from poles to clinometers. By attaching a steel-core (no stretch, yet smooth, flexible) clothes line (of 33', 50' or 66' length as desired) to the belt of the clinometer person, the recorder or caliper-operator can hold the other end at bole mid-point to quickly achieve clinometer distance-control.

A special case of what and how is the Lake States Zone's blister rust resistance testing of eastern white pine. The replicated pallet design is used to test approximately 100 families per year using about 10 "susceptible" control lots to check on the success of inocculation. About 10 other "resistant" control lots are used as standards against which test individuals can be compared.

Portable data recorders (PDR's), such as the MSI-77 are used entirely for this blister rust progeny screening. PDR's are used from 10 to 25% of the time in normal field tests and will be used even more in the future.

TREE IMPROVEMENT TATEM AID 12/76 ram

6 SURVIVAL (#'s 1-5) — # Digits: 1
1 - Tree Dead
2 - Fair Growth
3 - Excellent Growth
4 - Position Vacant
5 - Permanently Vacant

7 TOTAL HEIGHT
To nearest centimeter or decimeter

8 INSECT & DISEASE DAMAGE (#'s 1-0) — 1
1 - No damage
2 - Stem, shoot & root insects(weevil, wood borers, grubs, tip moths, bark beetles)
3 - Defoliators(Sawfly, leafroller, caterpillar, grasshopper, leaf beetles, leaf miners, etc.)
4 - Gall insects(Mites, wasps, aphids, etc.)
5 - Sap-sucking insects(Aphids, scale, midges, spittlebugs, etc.)
6 - Flower, fruit, seed & cone insects
7 - Leaf diseases
8 - Stem & root diseases
9 - Other
0 - Unknown

9 ANIMAL & MECHANICAL DAMAGE (#'s 1-0) — 1
1 - No damage
2 - Ice/snow damage
3 - Chemical damage
4 - Fire
5 - Machinery
6 - Wind
7 - Rodent
8 - Deer
9 - Birds
0 - Unknown or other

1=Dead
2=Fair Growth
3=Excellent Growth
4=Position Vacant
5=Permanently Vacant
B=Broken Near Ground
S=Rootstock Sprout has become main Stem(use only in Clonal Orchards)

10 FLOWERING (#'s 1-4) — 1
1 - No flowers
2 - Female flowers
3 - Male flowers
4 - Both male & female flowers or perfect flowers

11 CONTROLLED POLLINATION (#'s 1-2) — 1
1 - No
2 - Yes

12 BLISTER RUST (#'s 1-2) — 1
1 - No
2 - Yes

13 LAMMAS GROWTH (#'s 1-2) — # Digits: 1
1 - No
2 - Yes

14 FROST DAMAGE (#'s 1-3) — 1
1 - No damage
2 - Terminal Damage
3 - Terminal & lateral damage

15 HEIGHT TO FORK — 2
To nearest Decimeter(1/10th meter)

16 CULTURAL WORK Can get Map, Not Worklist — 2
Assign 2-digit code & submit with data forms

18 STEM FORM (#'s 1-7) — 1
1 - Single stem to tip
2 - Single fork above DBH
3 - Multiple forks above DBH
4 - Single fork below DBH
5 - Multiple forks below DBH
6 - Multiple stems, 1 dominant
7 - Multiple stems, no dominant (Bush)

19 DBH
To nearest centimeter or 1/10". Specify unit of measure.

20 NEED FOR RELEASE (#'s 1-3) — 1
1 - None
2 - Moderate
3 - Severe need

21 YEAR OF ESTABLISHMENT (Alpha/Num) — 1
# of growing seasons since planted. Can assign own alpha/numeric code as tickler for next measurement.

22 EXTRA (#'s 1-0) — 1
Enter own heading & code. Use code 1 for no or none

23 EXTRA (#'s 1-0) — 1
Same as Item 22 above.

24 EXTRA (Enter own 2-digit code) — 2
The summary of data in these columns will list mean, range & % of test mean.

25 EXTRA (Enter own 2-digit code) — 2
Same as Item 24 above.

APPENDIX B

Guidelines for Use of Stem Form Codes of Hardwoods in Progeny Test Observations

These stem form codes are based on the frequency and location of forks. Sweep and crook are not considered because almost all sweep and crook seems to be associated with forking and because of the difficulty of judging the severity of these defects in sapling sized trees.

The criteria given here do not have much correlation with subjective stem quality judgments when used on trees less than 3 metres tall. Neither these guides nor subjective judgments appear to be very meaningful on trees less than one metre tall. All hardwood progeny tests ten years or older when being measured should have stem form and height to the first fork included with the other observations. All trees over 2 metres will be given a stem form code as defined on these sheets and a subjective judgment of stem quality using only 1 - good, 2 - average, and 3 - poor categories. These numbers will be recorded in column 23.

The judgment as to whether a branch forms a fork should be based on whether it fits the criteria on these sheets when the observation is made and not upon a prediction of what the tree will look like some time in the future.

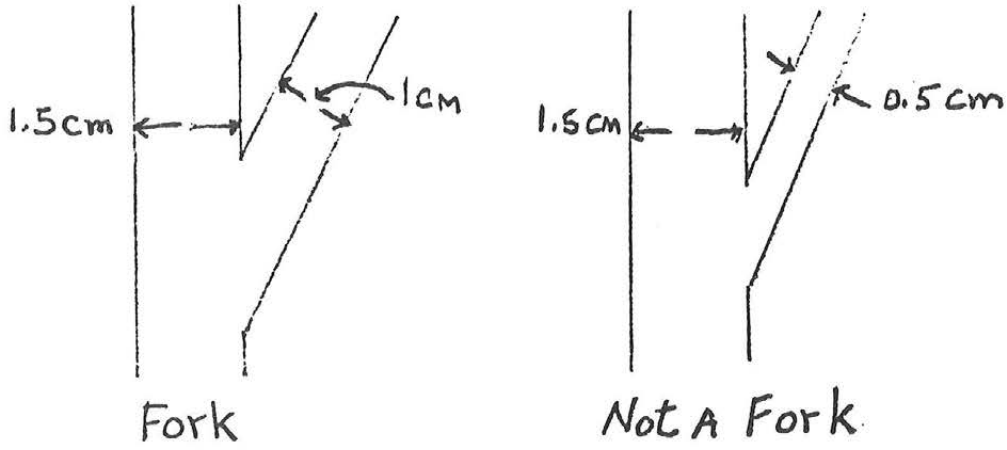
When total height is measured, it will be the height above ground of the highest point on the tree, disregarding forking or what is considered to be the main bole.

Any branch below 1.3 metres above the ground will be considered to be below the DBH point, even if the tree is so short (2.6 metres) that the 50% point is less than 1.3 metres.

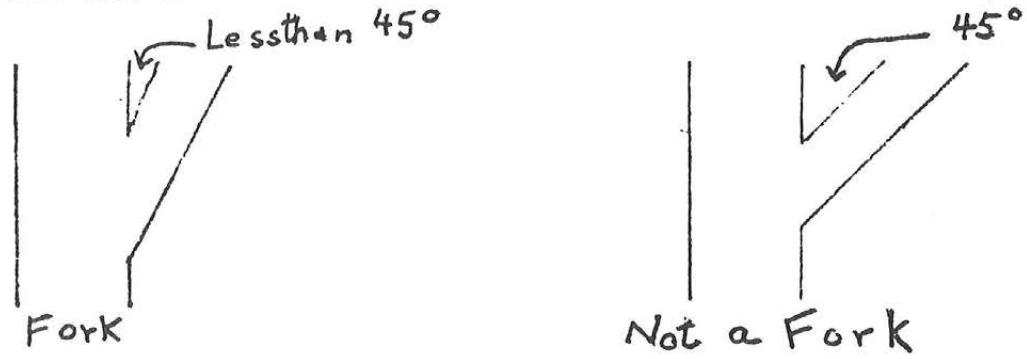
Definition of Forking

To have a fork all of the first 3 conditions must exist or condition 4 must exist

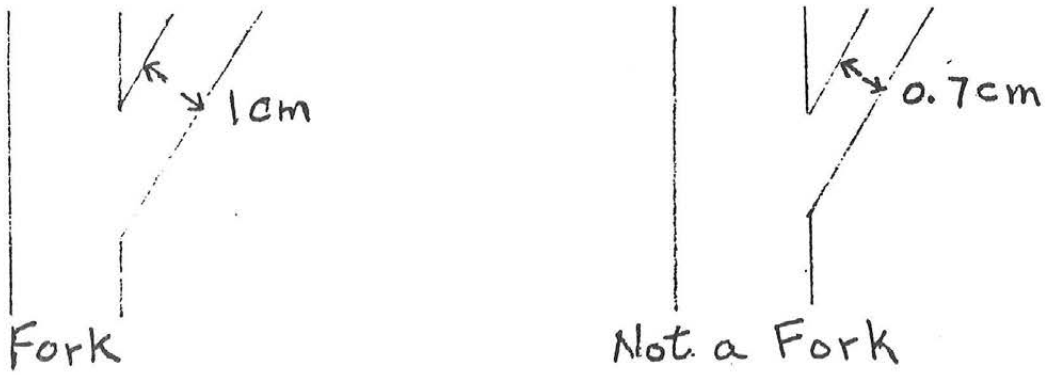
1. Diameter of branch must be over ½ the diameter of main stem just above point of juncture



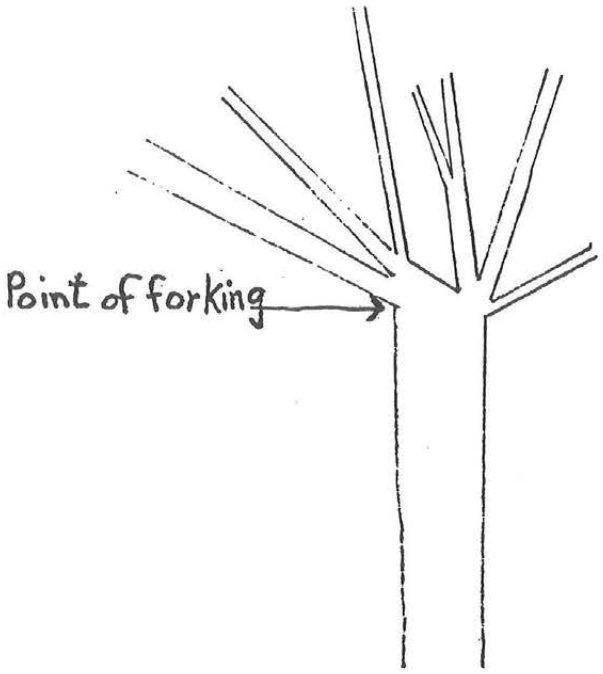
and 2. Angle between main stem (or vertical line) and branch must be less than 45°



and 3. Branch must be over 1 cm in diameter



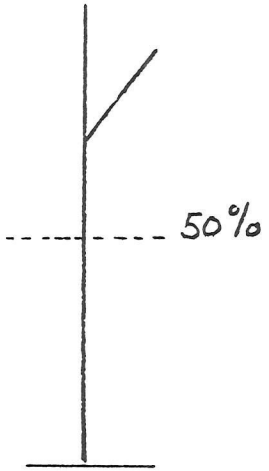
4. No central stem exists beyond this point -





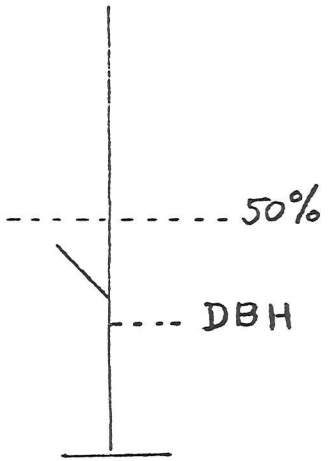
Code 1

No Forks



Code 2

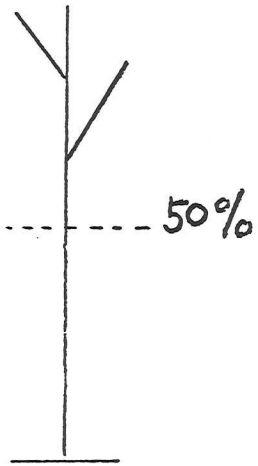
One fork above 50% of total height; none below this point



Code 3

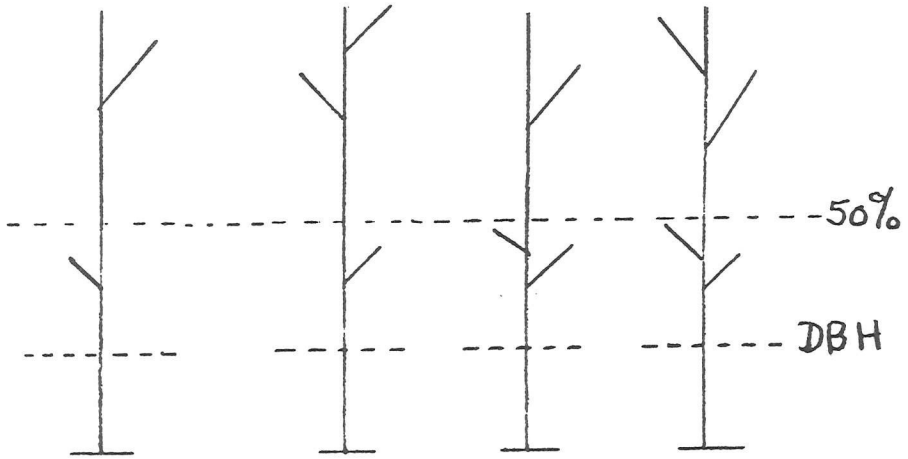
One fork below 50% pt, but none below DBH pt (1.3m)

OR



Code 3

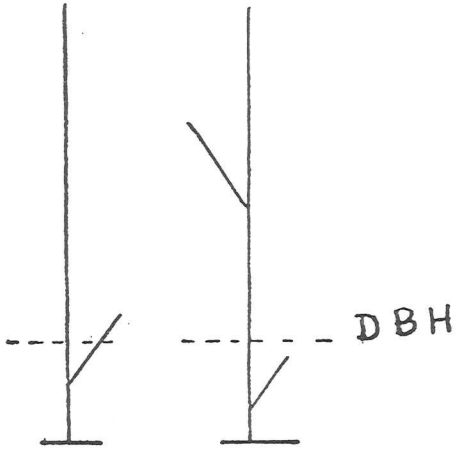
Two or more forks above 50% mark



Code 4

One or more forks above 50% and one or more forks below 50%, but none below DBH

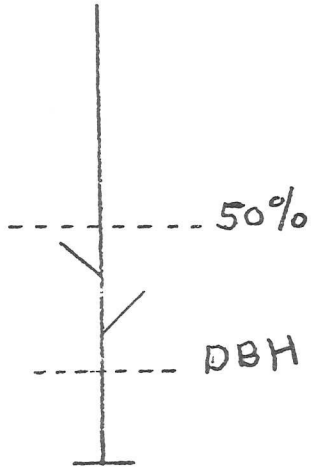
or



Code 4

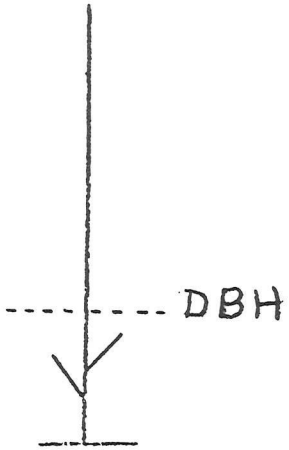
One fork below DBH, and one or none above DBH

or



Code 4

Two forks below 50%, but none above 50% and none below DBH



Code 5

Two or more forks below DBH

or



Code 5

Multiple (2 or more) stems

SYSTEM OF HANDLING AND TRACKING CONTAINERIZED GENETIC STOCK FROM NURSERY THROUGH FIELD ESTABLISHMENT

Jay H. Kitzmiller 1/

Introduction

Genetic improvement of seed from production orchards depends largely on obtaining reliable progeny performance information from evaluation plantations. These plantations are designed and managed to identify those parents in orchards that have the highest genetic worth for breeding and to define the zone where improved orchard stock will be used in reforestation.

Accurate evaluation of the genetic stock is contingent on careful planning and implementation of a whole chain of events that must occur over a period of several years. The process is complicated by the fact that genetic stock must be moved from location to location several times while concurrently progressing through various plant development stages and various management activities.

Perhaps the most critical step is progressing from the nursery through field establishment. This is based on two factors: nursery stock quality and handling can strongly influence survival and growth; and an experimental design must be chosen and implemented to meet the objectives for field testing.

Experimental Design

The experimental design provides the framework for the potential amount and quality of information. It integrates the type, number, and arrangement of genetic stocks with the environments to be planted. Complex designs may have strong theoretical advantages and yet be impractical to implement on-the-ground. The more common approach has been to use a simple design because it is easy to carry out. However, experience has shown the need to improve the design of long-term field tests due to the multitude of uncontrollable influences.

1/ Regional Geneticist, USDA Forest Service, Pacific Southwest Region

In 1979, the PSW Region adopted a novel, relatively complex, and highly efficient design for genetic evaluation plantations. The field layout is described as random, non-contiguous plots in interlocking replications (Libby and Cockerham, Silvae Genetica 29, 5-6, 1980). Within each field block independently randomized replications are interlocked and plot members are arranged non-contiguously. Interlocking replications allow for systematic thinning without loss of balance of family information (i.e., all families are present and equally represented after each thinning of a replication). Non-contiguous arrangement of plots (family members) achieves the efficiency advantage of small plots. Moreover, a hexagonal pattern of spacing economizes that land area requirement by allowing approximately 15% more trees per acre and more complete utilization of the site environment. After the final (second) thinning a uniform spacing exists among all trees.

Container System

This field layout had not been widely used in large field tests due to the difficulty in sorting, handling, and tracking nursery stock, especially the bare-root type. However, the PSW Region has developed a unique system of stock handling, field layout, and record keeping which uses Leach Super-Cell containers and computerized mapping. 1/ A main feature is the operational linkage between the container nursery system and the field design for efficient handling of stock and records.

The Leach Super-Cell container system is well-suited for growing high quality nursery stock, is widely used in the nursery industry, and is conducive to physical handling of individual containers. Tray size and configuration of individual removable containers make it readily adapted to our predetermined experimental design criteria (Figure 1). Therefore, we developed a computerized mapping and sorting system specifically for these containers. This provides the opportunity to "load" a tray with genetic stock in the nursery so that it corresponds exactly to the desired layout of a replication in the field. 2/

1/ Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the US Department of Agriculture is implied.

2/ The same procedure could be adapted to any container type that is compatible with the desired field design.

Thus, after sorting the genetic stock in the nursery a tray exactly represents a field replication (i.e., genetic stocks occupy the same relative position in the tray as they will in the field replication). Because of this, a map of the future outplanting can be generated on the computer prior to sorting in the nursery. This map then dictates the placement of genetic stock into trays. The procedure shifts randomization and mapping jobs from field to nursery to save time and reduce error.

The major steps to implement this system are:

1. Grouping genetic stock into sets (genetic design)
2. Sowing and growing genetic stock
3. Generating tray and field coordinate locations for genetic stock
4. Sorting genetic stock into trays
5. Field layout and marking tree locations
6. Planting

Step 1. Grouping Genetic Stock into Sets (Genetic Design)

The goal is to select 200 to 220 superior trees per zone and to obtain enough seed to progeny test about 180 W-P families. After seed has been collected and processed, genetic stock is assigned to sets. Each of the four sets is composed of 45 wind-pollinated (W-P) test families plus four control lots. At least three alternate W-P families are also sown per set to provide replacement if some families fail in the nursery.

W-P families are assigned to sets such that each set is a representative sample of the entire breed zone. Sets are arranged in the field environments such that comparisons within sets are more accurate than those among sets. Thus, each set is an evaluation unit. The accuracy of comparing among sets depends on the magnitude of micro-site differences and the amount of G x E interaction exhibited by the standard control lots that are common to all sets. The use of control lots as common links among sets is especially important when all four sets cannot be planted in the same year.

Control lots are:

1. two full-sib families (environmental monitor across sets and plantations),
2. one general source lot (environmental monitor across sets and plantations and genetic monitor for gain estimation),
3. one local lot from the plantation locale (environmental monitor across sets on that site and genetic monitor for local origin).

Step 2. Sowing and Growing Genetic Stock

Seed for each W-P family is sown in four complete trays. Each tray has 98 (7 x 14) cells using 2 ft^2 of area. Families are handled and sown one at a time. Each cell is sown with a single filled seed. Trays are marked for family identification. After sowing, trays are arranged for germination in the greenhouse such that families of a given set are in an RCB design. Three blocks are surrounded by the fourth block of border trays.

After germination is complete, trays of each family are brought back into the headhouse and empty cells are pulled, discarded, and replaced by seedlings from block 4. After consolidation, a plastic tag, which identifies the family, is placed in each cell. Stock is then returned to the original design for completion of the growing phase.

Since 392 seeds (4 x 98) are sown to get 240 plantable seedlings per family and since germination losses and mortality rarely exceed 10%, approximately 25-30% of the seedlings can be culled out in the sorting operation. The plantable "culls" are later outplanted as border stock in the field test. However, a few from each family are repotted and grown another year in the nursery to replace trees that die the first year after outplanting.

A similar process is used with the control lots except they require different quantities for outplanting. For example, a W-P family occurs in one set in five plantations, while the full-sibs and general lots occur in all sets of all plantations, and a local lot occurs in all sets of one plantation. For five plantations, five local lots are needed.

Step 3. Generating Tray and Field Coordinate Locations for Genetic Stock

Since each tray has 98 cells and each set has 49 genetic lots, a tray can hold exactly two individuals per lot. Thus, the tray corresponds to a rep, and three trays (reps) compose a field block. Eight blocks are used in each of four or five plantations.

Locations within a tray can be designated using the 14 columns and 7 rows of cells (Figure 1). Thus, each lot can be given two coordinate locations in a tray. The field design required randomization of lots and their members.

Initially, a "dummy" set was randomly assigned two coordinate locations in each rep (tray) of the first block. Then randomization was repeated for Reps A and B for each of the remaining seven blocks. Since Rep C will be thinned and it is interlocked with A and B, it did not need re-randomization for each block. Also, randomization was done for only one plantation, so that genetic lot locations are the same for all plantations. This is a major efficiency advantage in sorting. This randomization was a one-time job.

To generate a field map, the locations within trays have to correspond to field locations. Figure 2 illustrates this correspondence. Note that the three Reps (A,B,C) interlock and form a hexagonal pattern in a field block. Tray columns correspond to field lines, and tray rows correspond to field rows. The Rep sequence (shown at the bottom) is A,B,C,. Rep (tray) A is shaded for illustration. For example, Tray-Rep A coordinate 4-2 is Family 3350 at field coordinate D-10. Family 3350 occurs again at Tray Coordinate 10-1, field coordinate B-28 in that same rep. The interlocking of three reps requires three field lines (columns) for each tray column. The hexagonal arrangement requires two field rows for each tray row. Thus, tray (input) coordinates must be translated to field (output) coordinates in the computer program to generate the field map.

When a new set is formed, the actual lots are arranged in numerical order and linked with the "dummy" coordinate list. Linkage is done by the computer to generate the outplant map. The outplant map can be printed for each rep separately ("By Rep" map) or together ("Composite" map).

The "By Rep" map is also a tray map. So, it can be used to check the accuracy of placement after sorting into trays is complete and when containers are being pulled from trays in the field just before planting. "By Rep" maps satisfy a double checking purpose.

FIG. 1. "Super Cell" Leach Tray

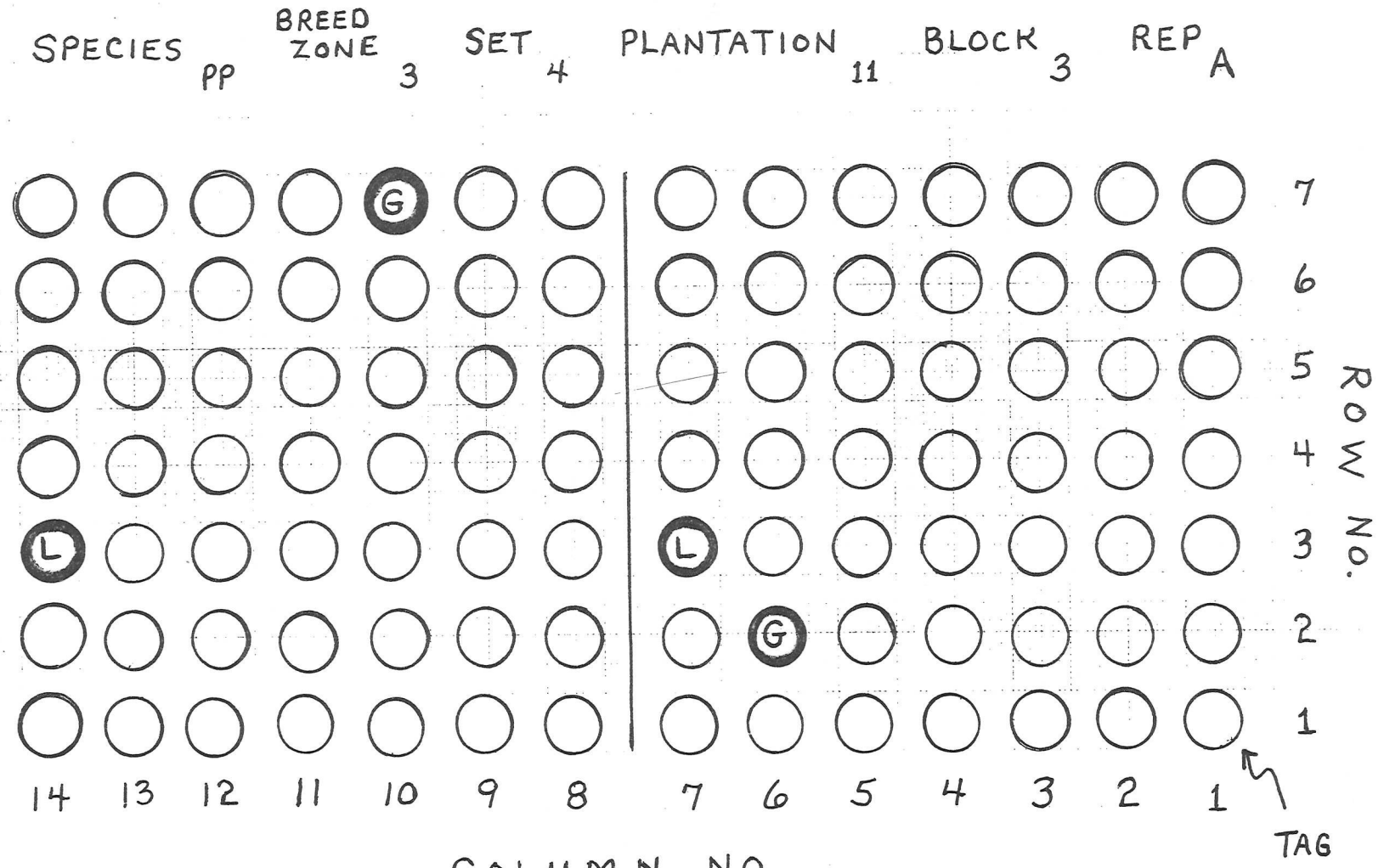


FIG. 2.

EVALUATION PLANTATION FIELD MAP - USFS PACIFIC SOUTHWEST REGION - 18 MAR. 1982 AT 21:11:19

SPECIES PP PLANTATION 11 BADGER HILL (PLACERVILLE)

BREED ZONE 3 SET 4 BLOCK 3

TRAY COLUMN NUMBER AS RELATED TO FIELD BLOCK LOCATION

TRAY ROW NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
	L 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41														
	R I 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42														
	O N														
	W E														
	A	3091 3415	3174 3419	3323 3230	3314 3347	3046 3004	3005 3091	3321 3232	3001 3043	3043 3308	3312 3046	3003			A
1	B	3035 3035	3319 3356	3357 3174	3062 3357	3409 3407	3393 3095	3363 3350	3230 3049	3319 3189	8X9 3049	3003			
	C	3415 3342	3043 3043	3004 3098	3005 G531	3356 3312	3350 3415	3232 8X9	3312 3174	3415 3064	3393 3004	G531			C
2	D	3347 3323	3062 3347	3350 3407	3323 G531	3186 3403	7X5 3008	3321 3409	3403 3319	3189 3357	3350 3035	3095			
	E	3409 3363	3419 3407	3098 3409	3347 7X5	3005 L	3304 3363	3314 7X5	3342 3308	3350 3005	8X9 3316	3007			E
3	F	3064 3046	3319 3085	3091 3419	3308 3098	3357 3304	3316 3031	3393 3347	3342 3186	3230 3312	3316 L	3085			
	G	3363 3174	3008 3342	3398 3008	3031 3046	3003 3230	3393 3314	3062 3031	3186 3308	G531 3046	8X9 3398	3398			G
4	H	3407 3031	3312 3098	3363 3316	3095 3304	3008 L	3007 3403	3232 3008	3035 3004	3186 3419	3415 3398	3189			
	I	3304 3186	3085 3001	3323 3043	3419 3098	3316 3356	3035 3091	3008 3356	3357 3356	3304 3232	3064 3001	3323			I
5	J	3304 3405	3003 8X9	3085 3064	7X5 3005	3091 3319	3415 3321	3007 3342	3405 3031	3174 3407	3393 3004	3232			
	K	3319 3321	3321 3049	3064 3049	3001 3347	3230 3405	L 3095	3003 3049	3314 3085	L 3031	3403 3007	3357			K
6	L	3004 3398	3062 L	3046 3356	3419 3232	3230 G531	3403 3005	3174 3098	3308 3342	3321 3308	7X5 3407	3091			
	M	3007 3405	3405 7X5	3001 3350	3003 3314	3189 3064	3007 3409	3397 3314	3312 3189	3049 3035	3316 3397	3001			M
7	N	3189 3095	3409 3397	3397 8X9	3062 3095	3393 3403	3186 3363	3398 G531	3043 3405	3062 3085	3397 3323	3397			
	REP	A C B	A C B	A C B	A C B	A C B	A C B	A C B	A C B	A C B	A C B	A C B	A C B	A C B	
		B A C	B A C	B A C	B A C	B A C	B A C	B A C	B A C	B A C	B A C	B A C	B A C	B A C	

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The "Composite" map is the complete outplant map of a block and it is used for post-planting observations such as survival checks. A "Composite" map is usually printed only after actual planting locations have been verified. Along with each map is printed a map coordinate index which shows locations of each family member (Figure 5a, b).

Step 4. Sorting Genetic Stock into Trays in the Nursery

Sorting is done in the headhouse after the growth period is complete and prior to cold storage (mid-October to mid-December). The sorting process involves selection and placement of test stock in their proper locations in trays for subsequent cold storage and then outplanting.

Placement of stock into trays is guided by the "Tray Coordinate Index". This worksheet shows coordinate locations of each family by rep and block. Families are listed in numerical order beside their tray coordinates (Figure 3).

The physical setup is illustrated in Figure 4. The four nursery block trays of each family are placed together just outside the headhouse and families are arranged in numerical order. Families are brought into the headhouse and processed in assembly-line fashion one at a time. One area of the headhouse is set up for pulling the better trees of the family group (selection phase) and placing them in 1-gallon pots for distribution to the second area of the headhouse where trays are loaded (placement phase).

In the "selection phase", 1-gallon pots labelled by rep and block (i.e., 1A) are set on a cart in an arrangement that corresponds with that of the "placement phase" set up. Each pot receives two trees for each plantation. The best trees (based on stem caliper and bud development) are put in pots for the first blocks of Reps A and B. Trees of lesser quality end up in the last blocks of Rep C. This stratification was chosen to create more uniformity within blocks and because Rep C will be removed in thinning.

The physical set up in the "placement phase" consists of three long rows of trays on tables. Rows represent reps A, B, and C trays. Each tray is labelled by its unique block, rep, and plantation with a tag at coordinate 1-1 (one tag is attached to the tray; a second is placed in the cell). Thus, Block 1, Rep A would have four trays in a linear group representing four different plantations. The pot placed at that station would then contain 8 trees. Two trees would be placed in each tray using the Tray Coordinate Index worksheet (Figure 3). The

FIG. 3.

1979 NURSERY PROGENY

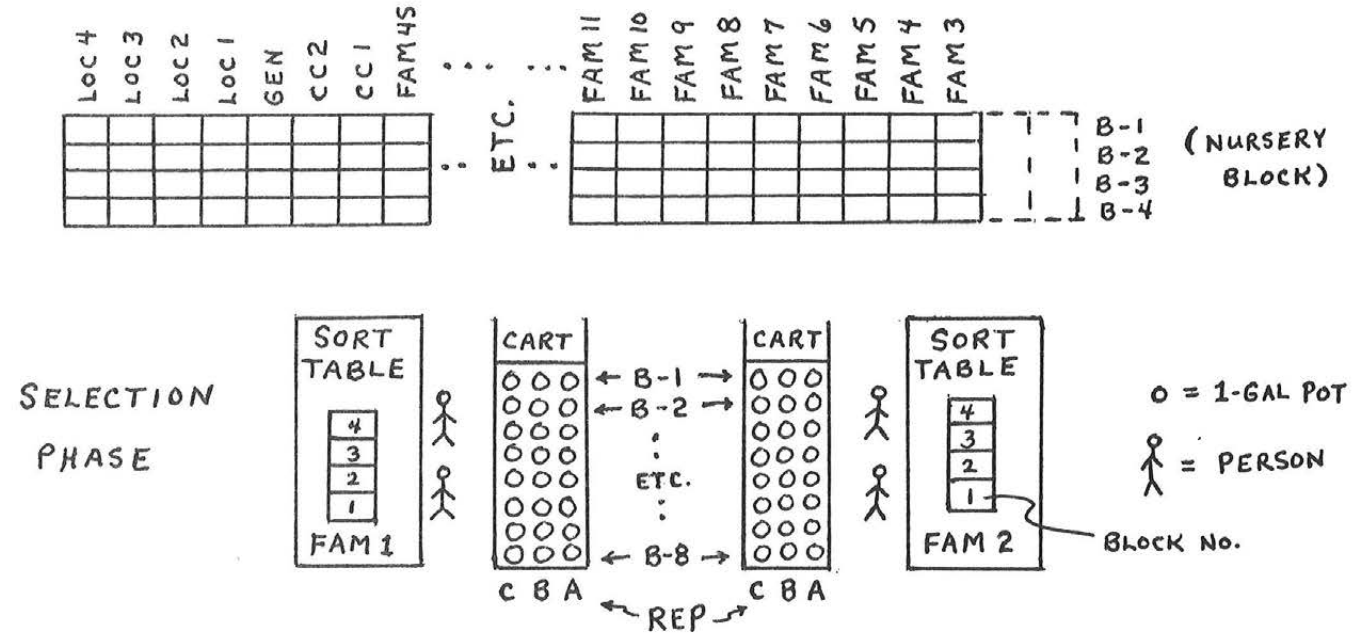
SPECIES PP
BZ 3
SET 4

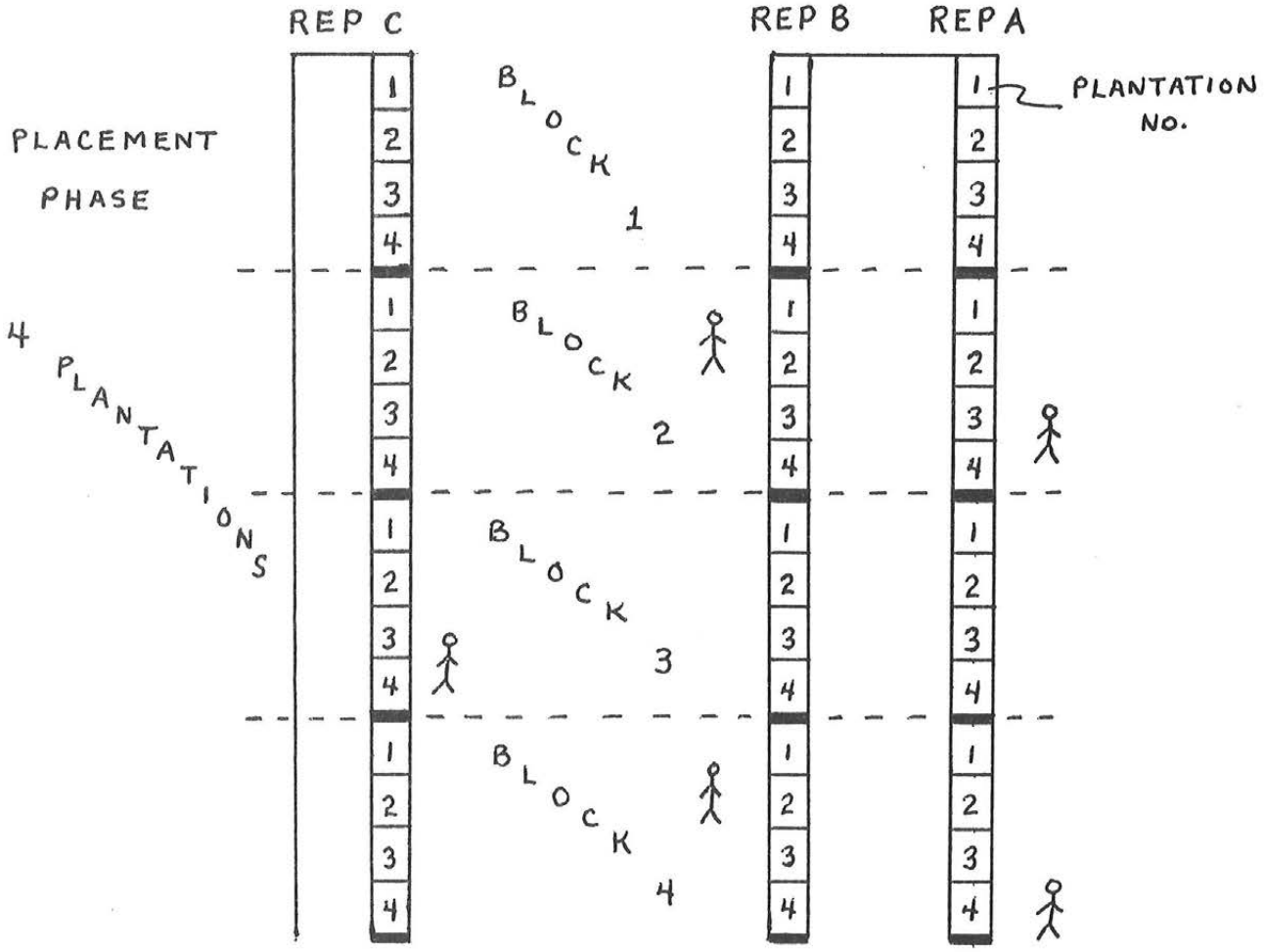
TRAY COORDINATE INDEX

PLANTATION 11
BLOCK 3

FAMILY	REP A	
	Col - Row	Col - Row
3001	3-5	5-6
3003	9-6	5-7
3004	7-1	14-5
3005	5-2	6-5
3007	8-4	1-7
3008	10-4	9-5
3031	2-4	5-4
3035	2-1	14-2
3043	11-1	3-2
3046	2-3	4-6
3049	14-1	3-6
3062	9-4	12-7
3064	13-5	7-7
3085	4-5	11-6
3091	1-1	4-3
3095	2-7	6-7
3098	6-3	10-6
3174	11-2	12-5
3186	8-7	12-4
3189	12-2	11-7
3230	12-3	7-4
3232	9-2	6-6
3304	6-4	1-5
3308	11-3	11-4
3312	13-1	7-2
3314	5-1	9-3
3316	8-3	13-7
3319	12-1	1-6
3321	9-1	12-6
3323	2-2	14-7
3342	3-4	10-5
3347	5-3	10-3
3350	10-1	4-2
3356	7-5	11-5
3357	4-1	6-1
3363	1-4	4-4
3393	13-2	8-1
3397	4-7	9-7
3398	14-4	2-6
3403	8-6	13-6
3405	2-5	7-6
3407	3-3	14-6
3409	10-2	1-3
3415	1-2	8-5
3419	3-1	5-5
CC 705	8-4	3-7
CC 809	13-3	13-4
G 531	6-2	10-7
L	7-3	14-3

Fig. 4. Physical layout for sorting genetic test stock.





ETC. THROUGH BLOCK 8

same two coordinate locations would be used in each plantation tray for a given family. Once a family has been processed for all blocks, reps, and plantation trays, another family is processed. When all families of a set have been placed, every cell in every tray is filled and the "check phase" begins.

The "check phase" involves physically checking the location of each tree against the "By Rep" map to make sure no mistakes were made in loading families into trays. Since all plantations are the same within a given rep-block, this phase is expedited. One person reads aloud family numbers from the "By Rep" map while others check the tags in the trays. Any mistakes are corrected at this time.

Next is the "measurement phase". Usually, 24 individuals of each family are measured for epicotyl length for the four plantations for Block 1 of all three reps. Data is recorded on the "By Rep" map sheets. These data form the basis for a) evaluating nursery performance of families, and b) tracking specific individuals from nursery through field performance.

At our facility this sorting process is most efficiently done with 13 people, although 12 is adequate. One set can be completed in one day with 13 people. Our best arrangement was:

1. Selection phase - 6 people, 3 per family (work 2 families but maintain numerical sequence)
2. distributing loaded pots, collecting empty pots and arranging pots on carts and "trouble-shooting" - 1 person
3. placement phase - 8 people, 3 for Rep A, 3 for Rep B, and 2 for Rep C.

Close coordination and teamwork are required to maintain a steady, continuous flow of material in proper sequence along the "assembly-line". The "check" and "measurement" phases require about 2 hours to complete when working with two crews of five or six people each (one map reader plus one person per plantation).

Occasionally, it is necessary to use control lots to replace test families when test families have insufficient members for all trays. When this occurs, revisions must be made on the computer before outplanting, so that an accurate map is available for outplanting.

Step 5. Field Layout and Marking Tree Locations

Each plantation consists of four sets each in an RCB design with eight blocks. Sets are laid out as separate experiments. A block includes two border rows. Blocks are ca. 90 x 150 ft (0.3 acre). The hexagonal pattern has 6 ft between trees. See Figure 5a for sample field map. Where possible, blocks are joined together thus eliminating the need to border each block separately. This reduces stock and space requirements.

In preparing each site the objective is to create uniform conditions in areas that approximate increments of block size. This reduces "dead" space, makes efficient use of site land, and facilitates layout.

Colored flags attached to metal pins are used to premark tree locations. Usually different color flags are used to distinguish border rows, Rep A, Rep B, and Rep C. This avoids confusion during planting.

One corner of each block is marked with a permanent stake labelled with set and block number. This corner designates the "starting point" and corresponds to tray coordinate 1-1.

Step 6. Planting

Trees are transported from the nursery to cold storage and finally to the field in boxes built especially for the super-cell tray. Boxes are marked by plantation, block, and rep.

In the field, the Rep A tray is removed first, carried to the block corner stake, and oriented so the tray corner label corresponds to the block corner stake. While maintaining this orientation, trees are pulled from the tray in sequence and laid by the flag where they'll be planted. Tree tags are also read and checked against the map to assure proper location. This is repeated for Rep B tray and then C in corresponding rows.

Next, trees are planted and work is completed in that block. Trees are planted consistently on one side of the flags to maintain the spacing pattern.

Flexibility in Design Variations

This system may appear rigid due to the strong linkage with Leach containers. As long as the Leach containers are used, there exists several possibilities for varying the overall design, although some efficiencies may be sacrificed. The

number of plantations and blocks can vary as desired. Also, a square or rectangular field spacing pattern could be used in place of the hexagonal.

Another important flexibility is in the total number of genetic lots in a set. A full set consists of 49 lots. However, partial sets of 42 lots, 35, 28, etc, in increments of seven could be used. For example, if 42 lots were used, tray and field coordinates would be reassigned such that the last two columns of each rep would be omitted both in the tray and in the field block.

More than four control lots may be used as long as the number of test families is reduced accordingly. If minor imbalances can be tolerated, control lots can replace test families in certain reps and blocks. For example, Figure 6a shows a reduced block size of the 42 lot version. However, close inspection of Figure 6b reveals that only 37 (instead of 38) test families and four control lots are included. However, Lot "LOC" was also used to completely replace one family and to partially replace Families 3045, 3082, and 3472 which were short of seedlings for Rep C.

FIG. 5a. EVALUATION PLANTATION FIELD MAP - USFS PACIFIC SOUTHWEST REGION 18 MAR. 1982 AT 21:11:19

SPECIES PP PLANTATION 11 BADGER HILL (PLACERVILLE)

BREED ZONE 3 SET 4 BLOCK 3

ROW	L 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	ROW
A	3091	3415	3174	3419	3323	3230	3314	3347	3046	3004	3005	3091	3321	3232	3001	3043	3043	3308	3312	3046	3003	A
B	3035	3035	3319	3356	3357	3174	3062	3357	3409	3407	3393	3095	3363	3350	3230	3049	3319	3189	8X9	3049	3003	B
C	3415	3342	3043	3043	3004	3098	3005	G531	3356	3312	3350	3415	3232	8X9	3312	3174	3415	3064	3393	3004	G531	C
D	3347	3323	3062	3347	3350	3407	3323	G531	3186	3403	7X5	3008	3321	3409	3403	3319	3189	3357	3350	3035	3095	D
E	3409	3363	3419	3407	3098	3409	3347	7X5	3005	L	3304	3363	3314	7X5	3342	3308	3350	3005	8X9	3316	3007	E
F	3064	3046	3319	3085	3091	3419	3308	3098	3357	3304	3316	3031	3393	3347	3342	3186	3230	3312	3316	L	3085	F
G	3363	3174	3008	3342	3398	3008	3031	3046	3003	3230	3393	3314	3062	3031	3186	3308	G531	3046	8X9	3398	3398	G
H	3407	3031	3312	3098	3363	3316	3095	3304	3008	L	3007	3403	3232	3008	3035	3004	3186	3419	3415	3398	3189	H
I	3304	3186	3085	3001	3323	3043	3419	3098	3316	3356	3035	3091	3008	3356	3357	3356	3304	3232	3064	3001	3323	I
J	3304	3405	3003	8X9	3085	3064	7X5	3005	3091	3319	3415	3321	3007	3342	3405	3031	3174	3407	3393	3004	3232	J
K	3319	3321	3321	3049	3064	3049	3001	3347	3230	3405	L	3095	3003	3049	3314	3085	L	3031	3403	3007	3357	K
L	3004	3398	3062	L	3046	3356	3419	3232	3230	G531	3403	3005	3174	3098	3308	3342	3321	3308	7X5	3407	3091	L
M	3007	3405	3405	7X5	3001	3350	3003	3314	3189	3064	3007	3409	3397	3314	3312	3189	3049	3035	3316	3397	3001	M
N	3189	3095	3409	3397	3397	8X9	3062	3095	3393	3403	3186	3363	3398	G531	3043	3405	3062	3085	3397	3323	3397	N
REP	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	REP

FIG. 5b. EVALUATION PLANTATION FIELD MAP - USFS PACIFIC SOUTHWEST REGION - 18 MAR. 1982 AT 21:11:19

SPECIES PP PLANTATION 11 BADGER HILL (PLACERVILLE)

BREED ZONE 3 SET 4 BLOCK 3

MAP COORDINATE INDEX

FAMILY	NO TREES	A RW	A LN	A RW	A LN	B RW	B LN	B RW	B LN	C RW	C LN	C RW	C LN
3001	6	I	7	K	13	A	29	M	41	I	39	M	9
3003	6	K	25	M	13	A	41	G	17	B	42	J	6
3004	6	A	19	J	40	H	32	L	2	C	9	C	39
3005	6	C	13	J	16	E	17	E	35	A	21	L	24
3007	6	H	22	M	1	E	41	J	26	K	39	M	21
3008	6	H	28	I	25	G	5	G	11	D	24	H	18
3031	6	H	4	G	13	J	32	K	35	F	24	G	27
3035	6	B	4	D	40	B	2	M	35	H	30	I	21
3043	6	A	31	C	7	C	5	I	11	A	33	N	30
3046	6	F	4	L	10	A	17	G	35	A	39	G	15
3049	6	B	40	K	7	B	32	K	11	K	27	M	33
3062	6	G	25	N	34	B	14	N	14	D	6	L	6
3064	6	I	37	M	19	C	35	F	2	J	12	K	9
3085	6	J	10	K	31	F	8	I	5	F	42	N	36
3091	6	A	1	F	10	A	23	I	23	J	18	L	42
3095	6	N	4	N	16	H	14	K	23	B	24	D	42
3098	6	F	16	L	28	C	11	H	8	E	9	I	15
3174	6	C	31	J	34	A	5	L	26	B	12	G	3
3186	6	N	22	H	34	F	32	G	29	D	18	I	3
3189	6	D	34	M	31	M	17	N	2	B	36	H	42
3230	6	F	34	G	19	A	11	K	17	B	30	L	18
3232	6	C	25	L	16	H	26	I	35	A	27	J	42
3304	6	H	16	I	1	F	20	J	2	E	21	I	33
3308	6	E	31	G	31	A	35	F	14	L	30	L	36
3312	6	A	37	C	19	C	29	M	29	F	36	H	6
3314	6	A	13	E	25	G	23	K	29	M	15	M	27
3316	6	F	22	M	37	F	38	I	17	E	39	H	12
3319	6	B	34	K	1	D	32	J	20	B	6	F	6
3321	6	A	25	L	34	D	26	K	5	J	24	K	3
3323	6	D	4	N	40	D	14	I	41	A	9	I	9
3342	6	G	7	J	28	E	29	L	32	C	3	F	30
3347	6	E	13	F	28	D	2	D	8	A	15	K	15
3350	6	B	28	D	10	D	38	M	11	C	21	E	33
3356	6	I	19	I	31	B	8	C	17	I	27	L	12
3357	6	B	10	B	16	I	29	K	41	D	36	F	18
3363	6	G	1	H	10	B	26	E	23	E	3	N	24
3393	6	C	37	B	22	J	38	F	26	G	21	N	18
3397	6	N	10	M	25	N	8	N	38	M	39	N	42
3398	6	H	40	L	4	G	41	N	26	G	39	G	9
3403	6	L	22	K	37	D	20	N	20	D	30	H	24
3405	6	J	4	K	19	M	5	N	32	J	30	M	3
3407	6	E	7	L	40	B	20	H	2	D	12	J	36
3409	6	D	28	E	1	E	11	M	23	B	18	N	6
3415	6	C	1	J	22	C	23	H	38	A	3	C	33
3419	6	A	7	I	13	E	5	L	14	F	12	H	36
7X5	6	D	22	M	7	J	14	L	38	E	15	E	27
8X9	6	E	37	G	37	B	38	J	8	C	27	N	12
G531	6	D	16	N	28	C	41	L	20	C	15	G	33
L	6	E	19	F	40	H	20	L	8	K	21	K	33

FIG. 6a. EVALUATION PLANTATION FIELD MAP - USFS PACIFIC SOUTHWEST REGION - 8 NOV. 1983 AT 20:04:00

SPECIES PP PLANTATION 11 BADGER HILL (PLACERVILLE)

BREED ZONE 3 SET 6 BLOCK 1

ROW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	ROW
A	3162	LOC	3229	3116	3386	3418	3402	3408	3171	3178	3066	3066	3311	3355	3080	3066	3162	3082																											A
B			3368	3418	3383	G531	3472	3315	3385	3341	3034	3175	3348	3229	3385	3386	3348	3034	3370	3341																									B
C	3082	3402	3471	3066	3047	3171	3123	3370	LOC	3386	3418	3116	3315	3187	3187	3045	3171	5X7																											C
D			3364	3318	3176	3178	G531	LOC	3386	3116	3318	3311	3080	LOC	LOC	3175	G531	8X9	3082	3465																									D
E	LOC	3471	3187	3047	3311	3424	3402	5X7	3047	3385	3358	3358	3341	3047	3176	LOC	3418	3362																											E
F			3355	3187	3383	3175	3358	3080	3178	3370	3465	3383	3408	3116	3116	3034	3402	3188	3045	3364																									F
G	LOC	3315	3472	3188	8X9	3383	3176	3171	3311	3348	LOC	3364	3465	3116	3408	3355	3188	3355																											G
H			3318	3385	3364	3082	3123	3370	3229	3472	LOC	8X9	3178	G531	3315	3424	3123	3465	3171	5X7																									H
I	3471	3318	3472	3034	3386	3162	3383	3311	3188	3465	3123	3123	3188	3424	LOC	3358	3358	3424																											I
J			3034	8X9	LOC	3402	3171	3178	3370	3311	3188	3471	3187	3385	5X7	8X9	LOC	G531	3383	LOC																									J
K	3355	3385	3176	3418	3178	3318	3229	3408	3162	LOC	8X9	3408	3315	3175	LOC	3364	3229	3348																											K
L			3368	3229	3176	3341	3368	3424	3358	3362	3348	3418	3364	3066	3386	3162	3362	3045	3318	3362																									L
M	3362	LOC	3402	3175	3034	3465	G531	3368	3066	3176	3080	3362	5X7	3368	3080	5X7	3175	3315																											M
N			3348	3047	3355	3123	3368	3341	3370	3080	LOC	3045	3424	3471	3341	3408	3162	3047	3471	3187																									N
REP	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	REP

FIG. 6b. EVALUATION PLANTATION FIELD MAP - USFS PACIFIC SOUTHWEST REGION - 8 NOV. 1983 AT 20:04:00

SPECIES PP PLANTATION 11 BADGER HILL (PLACERVILLE)

BREED ZONE 3 SET 6 BLOCK 1

MAP COORDINATE INDEX

FAMILY	NO TREES	A RW	A LN	A RW	A LN	B RW	B LN	B RW	B LN	C RW	C LN	C RW	C LN
3034	6	F	28	I	7	J	2	B	32	B	18	M	9
3045	4	C	31	F	34	L	32	N	20				
3047	6	E	7	N	4	E	17	N	32	C	9	E	27
3066	6	A	31	C	7	A	23	M	17	A	21	L	24
3080	6	D	22	N	16	A	29	M	29	F	12	M	21
3082	4	C	1	D	34	A	35	H	8				
3116	6	A	7	D	16	C	23	F	26	F	24	G	27
3123	6	C	13	H	10	I	23	N	8	H	30	I	21
3162	6	A	1	L	28	I	11	K	17	A	33	N	30
3171	6	J	10	H	34	A	17	C	11	C	33	G	15
3175	6	D	28	M	7	B	20	F	8	K	27	M	33
3176	6	G	13	M	19	E	29	K	5	D	6	L	6
3178	6	A	19	H	22	D	8	F	14	J	12	K	9
3187	6	F	4	J	22	C	29	E	5	C	27	N	36
3188	6	G	7	I	25	F	32	I	17	J	18	G	33
3229	6	L	4	K	13	A	5	H	14	B	24	K	33
3311	6	J	16	A	25	D	20	G	17	E	9	I	15
3315	6	C	25	K	25	H	26	M	35	B	12	G	3
3318	6	D	4	L	34	H	2	K	11	D	18	I	3
3341	6	B	16	E	25	L	8	N	26	B	36	N	12
3348	6	B	22	G	19	N	2	K	35	B	30	L	18
3355	6	G	31	K	1	F	2	G	35	A	27	N	6
3358	6	F	10	I	31	E	23	L	14	E	21	I	33
3362	6	L	16	M	1	E	35	M	23	L	30	L	36
3364	6	K	31	L	22	G	23	D	2	F	36	H	6
3368	6	L	10	N	10	B	2	L	2	M	15	M	27
3370	6	B	34	F	16	J	14	N	14	C	15	H	12
3383	6	I	13	J	34	F	20	G	11	B	6	F	6
3385	6	E	19	H	4	B	14	B	26	J	24	K	3
3386	6	B	28	C	19	D	14	L	26	A	9	I	9
3402	6	A	13	E	13	J	8	M	5	C	3	F	30
3408	6	F	22	N	28	G	29	K	23	A	15	K	15
3418	6	B	4	K	7	A	11	L	20	C	21	E	33
3424	6	H	28	N	22	E	11	I	35	I	27	L	12
3465	6	G	25	I	19	H	32	M	11	D	36	F	18
3471	6	I	1	N	34	C	5	J	20	E	3	N	24

FAMILY	NO TREES	A RW	A LN	A RW	A LN	B RW	B LN	B RW	B LN	C RW	C LN	C RW	C LN
3472	4	B	10	H	16	G	5	I	5				
5X7	6	M	25	M	31	J	26	C	35	E	15	H	36
8X9	6	J	4	J	28	D	32	H	20	K	21	G	9
G531	6	D	10	M	13	B	8	J	32	D	30	H	24
LOC	18	E	31	K	19	I	29	K	29	J	30	M	3
		E	1	G	1	C	17	D	26	D	12	J	36
										A	3	J	6
										D	24	H	18
										G	21	N	18

TREE IMPROVEMENT COMPUTER SYSTEMS - REGION 6

by Sharon T. Friedman 1/

Region 6 has opportunities and concerns in the use of computers which may differ from other Regions because most of the tree improvement jobs are performed at the ranger district level. There are approximately 94 ranger districts in the Region, and 19 forests, plus Dorena and the Regional Office, so that 115 units may want to use or understand any given tree improvement computer program. Thus, ease of use is a prime concern in any computer system.

At present, the following programs are used in Region 6.

1. Selected Trees

These are kept in INFO-990 a) with register and status as two separate datasets, b) with register and status combined into one dataset, and c) at F.C.C.C. in S2K with status and register in one data base. There are R-6 mandatory fields and many optional fields. All fields used in S2K in the Region are maintained in a data dictionary in Data Management in the Regional Office. For S2K questions contact Marge Levesque ((503) 221-2505) Regional Office Data Management; for general questions and handouts contact Sharon Friedman ((503) 447-6247). One of the fields is a yes or no for whether a tree has alias numbers; the actual numbers are most often kept on lists.

2. Breeding Arboretum and Seed Orchard Data Base

An informal survey showed that people use INFO-990, other computers, and SPSS report generator at F.C.C.C. to generate reports on their seed orchards, and most data were not computerized at all. These data bases have in common the fact that each orchard position is a record, and that the clone at each position is recorded. Other than that, people keep track of whatever is important in each specific orchard. For information on which fields have been used in a operational seed orchard, contact Bill Randall, Sisulaw National Forest ((503) 757-4550).

1/ Area Geneticist, U.S.D.A. Forest Service, Prineville, Oregon

3. Tree Improvement Seed Data Base

The tree improvement seed data base is kept at Dorena on their TI-990 in INFO-990. It is described in an attachment to a Washington Office letter of September 30, 1983. Information on seed from controlled pollination is also stored. Contact Judie Wilson at Dorena Tree Improvement Center ((503) 942-5526).

4. Program Planning, Priority Setting, Budgeting and Accomplishment Data Base

This information is presently on INFO-990. This data base is basically designed to transmit budgetary information downward and accomplishment upward, and to ensure that budgeting is accomplished according to Regional priorities. Accomplishments are organized by district, breeding zone and work item. This is difficult on INFO-990 due to the problems of merging floppy disks. When this data base is put on FLIPS, its utility should greatly improve. For information and handouts, contact Sharon Friedman.

5. Evaluation Plantation Data Base

This program will use a data base management system to generate reports on progeny tests. It will also produce maps to be used for data recording in the field, and facilitate conversion to PNW format for data analysis. Thsi program is in the development stage, to be coordinated with the FLIPS Data Base Management System. For information and handouts, contact Sheila Martinson and Shel Weinberg, Gifford Pinchot National Forest ((206) 696-7506).

6. Statistical Programs for Analysis

People who are in the IFA-PNW coops generally have the PNW analyze their progeny test data. Other people analyze their own, using the PNW progeny test analysis program now at Ft. Collins (described in W.O. letter 9/30/83). For other analyses and other types of studies (such as rust resistance) the statistical packages SPSS and BMDP at Ft. Collins are used. For genetics questions on the analysis program contact Nancy Mandel at P.N.W., Corvallis ((503) 757-4434); for computer questions and handouts contact Ron Briggs at F.C.C.C. ((303) 493-2801).

7. Seed Orchard Design

The "COOL" permutated neighborhood seed orchard design program (G.D. Bell and A.M. Fletcher, Silvae Genetica 27(6): 217-256, 1978) has been used to design many of the newer seed orchards in the Region. This program takes the tree numbers and total numbers of ramets and randomizes them subject to the constraints that 1) each clone occurs next to another a minimum number of times, 2) each clone is at least a minimum distance from another ramet of itself. It handles irregular shaped orchards, different numbers of ramets for different clones, and generates orchard maps with the correct tree numbers for a cost of about $3.00 if run in batch (an example is $2.44 for an 18 acre, 150 clone orchard). For genetic questions and handouts, contact Sharon Friedman; for computer questions contact Bill Cannon, Umpqua National Forest ((503) 672-6601).

8. Sowing Randomization

This is a program which randomizes families for sowing in the rust resistance testing program. It is located at F.C.C.C. For further information, contact Judie Wilson, Dorena Tree Improvement Center ((503) 942-5526).

Data recorders have not been used in Region 6 as in other regions. One reason may have been the diversity of hardware, and the need to have someone program the interface between the recorder and whatever computer is available. Another reason may be that with the large number of progeny tests we have, and present restrictions on personnel, we may be forced to contract measurements. Generally the process works this way:

1) contractors or employees use field sheets,
2) field sheets are keypunched mostly by contract from Regional Office or sometimes on forest,
3) files are checked by forest level data management or forest level tree improvement.

Tom Tibbs of the Siskyou has suggested that the contract include inputting the data such that the product of the measurement contract would be a tape with the data on it, which could be inspected and then shipped to P.N.W. This would leave the use of data recorders up to the contractor.

While a certain level of computerization has been successfully implemented in the Region, there are several National Forests which feel that there is a need for centralized support for tree improvement computer programs. As can be seen by looking at the names and locations of the contact people listed above, they are a diverse group located throughout the western United States. Often they support programs without having that support an official duty of their position. Geneticists are not generally good support personnel because they are in the field, not near the phone, because they have their own work to do, and frequently their computer skills are rusty because they spend relatively little of their time using computers. Forest level computer personnel have the skills, but may also have different priorities from tree improvement people.

Several other problems result from decentralized support. A computer system grows randomly, and no one looks at the overall structure and function of the system. This is most evident in the interfaces between programs, which are generally non-existent, and in duplication of efforts for that reason (Fig. 1). For example, in the programs mentioned above, the seed orchard design program contains a matrix of row, column, and clone, which it uses to produce a map. This could be copied to begin the seed orchard data base (with corrections where trees are misplanted). At present, the map is used to plant trees, and then the row, column, and clone are re-entered by hand. Using the same program as an example, some people prefer randomized block to permutated neighborhood designs. People either use no programs or might go to the trouble to convert another program. A simpler approach would be to assess the needs of different units and have one program, with a choice of design. In most of these decisions there are not a tremendous array of choices, and, in fact, most units would have similar needs. A final point in favor of centralizing support is that conversion from INFO-990 to FLIPS will be very slow if carried out on a forest-by-forest basis.

We feel support for tree improvement computer programs should be centralized at the Washington Office level. For Region 6, due to the sheer volume of units involved, centralized support at the Regional Office would also be necessary. These support people would preferably be located in the office a high proportion of the time and work directly for Timber Management.

The development of a fully coordinated and staffed GENESIS system we propose would be a two stage process:

1) A systems analyst and a committee of geneticists would look over all the activities in tree improvement and design a tree improvement system which would fully utilize the capabilities of FLIPS and serve the needs of all regions.

2) A person should be given responsibility for implementing the system designed above. This person's responsibilities would include:
   a) writing the necessary programs and converting data from present systems to the new system,
   b) writing interface programs,
   c) supporting, documenting, and training on all programs.

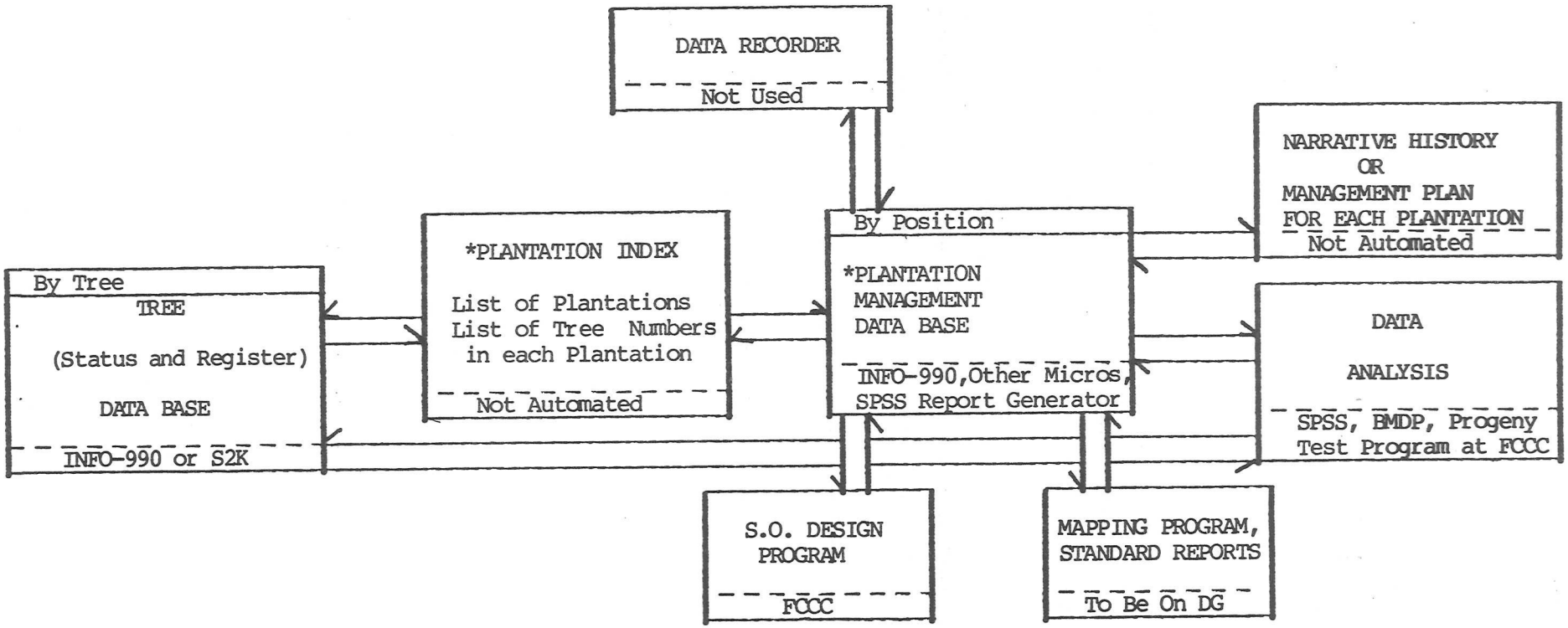
The Region 6 support person would step in after the system is developed and be responsible for:

1) Training on the new system, and conversion for the many units in Region 6,
2) developing programs for problems unique to Region 6.

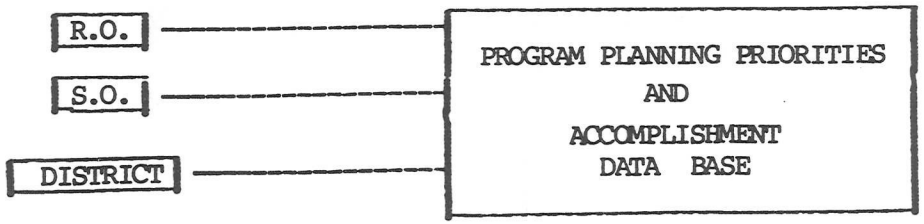
Examples of programs likely to be unique to Region 6 would include the Planning and Program Management Data Base, and a program to optimize thinning in noncontiguous plot designs not designed for thinning.

In summary, we feel that by carefully designing an overall information system, and centralizing support at appropriate levels, the work of tree improvement can be carried out in the most cost-effective manner.

GENESIS IN R-6 (NOW AND POTENTIAL FOR THE FUTURE)



* Plantation refers to seed orchards,clone banks,progeny tests breeding arboreta, and nursery studies.



R-8 TREE IMPROVEMENT PROGRAM - COMPUTER SYSTEMS

Ralph A. Lewis, Forester, Southern Region
Betty Thompson, Computer Programmer, Southern Region

I. Introduction

The Southern Region has one of the largest individual tree improvement programs in the South. Currently, over 1200 acres of seed orchards (1st generation) are maintained with approximately 65,000 trees, (58,000 ramets and 7400 seedling-origin trees). We have 112 progeny tests established with another 52 programmed for establishment this year. Thus, we are currently tracking 150,000 test trees (an average test will have approximately 1500 trees) with another 80,000 planted this year.

These figures are presented to indicate the size of the task in data collection, maintenance and analysis. At present, R-8 is using two systems to maintain data for the Regional Tree Improvement program.

The first system is called Seed Orchard Inventory (ORCH). As its name indicates, this system is primarily an inventory system for the first generation orchards. It was brought into full operation in 1977 and revised in 1979. It now contains data on all R-8 orchards-both clonal and seedling.

The second system is called Progeny Evaluation and Testing (PET). Its primary functions are to maintain, process, summarize, and update data collected on progeny test plantations in the Southern Region. The system became operational in 1982. The backlog of data from established tests is now being entered into the data base.

Both systems reside on the Univac Computer at the Fort Collins Computer Center (FCCC) in Fort Collins, Colorado. Each system is independent with no interactive function between the two. The data bases for these systems are large and no move to FLIPS equipment is contemplated because of the size of the data bases.

II. The Orchard Inventory System (ORCH)

The ORCH system was designed to provide detailed information on individual trees as well as summaries on clone and block status. Two versions of this system are used, one for the clonal orchards and the other for the sand pine seedling orchard.

A. Characteristics

The data bases are organized by species with no interaction between species. All programs are written in ASC II FORTRAN with front end programs to prompt the user and simplify running of multiple programs. Updates can be made on an individual tree (ramet) basis. The format is relatively rigid to maximize efficiency of routine runs.

B. Data Elements - Headers

1. Seed Orchard
2. Species
3. Breeding Population
4. Geographic Origin
5. Block
6. Row
7. Inventory Date

C. Data Elements - Individual Tree (Ramet)

1. Point Number
2. Orchard Number
3. Forest Number
4. Forest Number - Alternate
5. Age (computed by establishment date)
6. Status (height)
7. Status Modifiers
   a. Mechanical damage
   b. Animal damage
   c. Disease damage
   d. Insect damage
   e. Physiological problems
   f. Removal codes
8. Diameter
9. Crown Score
10. Form Score
11. Cone Score
12. Flowering - Female
13. Flowering - Male
14. Remarks - Denote presence of remarks on the field data sheets.

D. Programs - The following programs are part of this system.

1. Build (ORCBLD) - Creates file by species and geographic origin. This program sets the maximum dimensions of the individual file. Any changes must be made through an update or another build program (where dimensions must be changed).

2. Update (ORCUPD) - Updates file after any changes are made in individual records. Most updates result from man's activities such as thinning or natural forces such as a hurricane.

3. Utility (ORCUTL) - User defined criteria is used to sort records and print them out in either a long or short listing. A long listing will provide all available data from each record selected while a short listing gives only identity (clone and forest number), location (block, row and point number), age, height and diameter.

4. Calculations - Arithmetic means for age, height, diameter and (ORCCAL) all scores are calculated by this program. The percentages of damages from all status modifiers are also calculated by clone. A subroutine (ORCRNK) will rank the clones from best (1) to worst (N) for all means and percentages calculated. Predicted heights and diameters, based on the entire data set for the clone, are calculated and each individual ramet is compared to the clonal means to facilitate within clone growth comparisons for orchard thinning purposes.

5. Plot - (ORCPLT) Orchard blocks are plotted out with this program. Clone numbers are shown at each tree location. If the tree is dead or missing, a cause code is also displayed.

6. List - (ORCLST) This program allows the selective listing of data for individual rows or blocks. It may also be used to obtain extra printouts of the entire geographic source.

E. Discussion

The orchard Inventory System has worked well in the purposes for which it was designed. It has been a valuable management tool for orchard thinning operations and similar activities where detailed data was required.

III. Progeny Evaluation and Testing (PET) System

The PET system is designed to maintain, process, summarize, update and retrieve (for analysis) data collected on progeny tests planted in the Southern Region.

A. Characteristics

The PET system is a System 2000 (S2K) Data Base Application. It was brought operational in 1982.

There is a standard R-8 format for progeny test layout (randomized complete block with 5 reps and 10 tree row plots). PET follows the basic format with some allowance for deviation. Since there is no interaction between species, each species is a separate data base. Within each data base, it is possible to extract virtually any combination of data for analysis by other statistical packages such as SPSS and STATJOB.

Due to the large data bases that are being developed (with periodic additions of data that will further increase size and complexity), the PET system is being designed and implemented in phases. Phase I, which covers all activities from initial establishment to the first mandatory measurement (First Interval Evaluation - FIE), is fully operational, Phase II, which will include the second mandatory measurement (Second Interval Evaluation -SIE) and custom analysis programs (where statistical packages cannot handle data in terms of format or volume), is now being designed.

B. PET Schema and Data Elements - See Page A-2 of the User's Handbook.

1* NFTEST - National Forest Test
2* NF - National Forest Code
3* NF NAME
4* TEST - Number
5* SPECIES - Code
6* SPEC NAME
7* RD - Ranger District Code
8* DIST NAME
9* COMPT - Compartment Number
10* STAND - Number
11* B. POP - Breeding Population
12* STATUS
13* ESTAB MO - Month of Establishment
14* ESTAB YR - Year of Establishment
15* FY - Fiscal Year
16* SPAC1 - Spacing (within row)
17* SPAC2 - Spacing (between row)
18* LF-1 - Land form (of test site)
19* LF-2 - Land form (of test site if more than one LF is involved)
20* PROD CL - Productivity Class of the Test Site
21* SITE PREP - Site Preparation Methods used on the Test Site
22* ACRES - Acres involved in the test (including border rows)
23* RMKS - Remarks
24* CUL-DAM1 - Cultural Practices or Damage Code (1st entry)
25* YR1 - Year of 1st entry
26* CUL-DAM2
27* YR2
28* CUL-DAM3
29* YR3
30* CUL-DAM4
31* YR4
32* CUL-DAM5
33* YR5
40* ROWS
  41* LOCATOR
  42* REP - Replication
  43* ROW - Row Number
  44* X-GRP - Crossing Group Number
  45* F-PARNT - Female Parent Number
  46* M-PARNT - Male Parent Number
  47* FAM - Family Code (Assigned for eacn pair of parents regardless of which is male and female)
  50* POINTS
    51* PTLOC - Point Location
    52* PT NO - Point Number
    53* FYS - First Year Survival Code
    54* EM-MO - Early Measurement (Month)
    55* EM-YR - Early Measurement (Year)
    56* EM-HT - Early Measurement Height
    57* EM-PROB1 - Early Measurement Problem Code #1

58* EM-PROB2 - Early Measurement Problem Code #2
59* FIE-MO - First Interval Evaluation - Month
60* FIE-YR - First Interval Evaluation - Year
61* FIE-DIA - Diameter Measurement
62* FIE-HT - Height Measurement
63* FIE-CND - Condition (Crown-Height Ratio)
64* FIE-PROB1 - Problem 1
65* FIE-PROB2 - Problem 2

C. Breakdown of Schema

Data are normally added on a sequential basis. The individual test is defined in the file by the establishment information. This data includes items 1-50 on the schema. (Note that items 34 - 39 are not listed because these are for future expansion.) Data items 51-53 are then added after the initial survival check. Data items 54-58 are optional for any early measurements that are taken. Data items 59-65 are measurements and coding associated with the first mandatory evaluation that normally comes after the end of the fifth growing season. A more detailed discussion of these data and their collection will be given in the next section.

D. Programs General Overview

1. The PET system is a data system that allows the creation of certain summary and specified information reports. It also allows the formation of files through the combining and/or selective retrieval of information from one or more tests. These data can then be used in various statistical analyses that are available and appropriate.

2. Establishment

The system creates a test file which carries essential information on the location and layout of the test. This information serves as header data for the test throughout its lifetime. Layout date includes number of reps, number of families, identity of families by row within reps.

3. First Year Survival (FYS)

Records all dead trees and provides information to determine which tests are adequately stocked to provide a valid test of the progeny. Also tracks problems associated with mortality - defines probable cause of death.

4. Early Measurement (EM)

An optional evaluation that can take place anytime after FYS to the fourth year (assuming a five year FIE). Data elements include height and problems. Purpose is to give some Forests a chance to take a close look at the test before FIE.

5. First Internal Evaluation (FIE)

The first mandatory evaluation after FYS. FIE will normally be done at the end of the fifth growing season for most species, the timing may be varied from species to species. One example is sand pine where a four or even three year measurement may be best.

FIE data includes height, condition (measured by crown-height ratio) and problems. The problems are divided into a number of categories such as insects, disease, mechanical damage, etc. Each category has a number of specific items with provisions for expansion as other important problem sources are identified. Diameter measurements are provided for in the program but data is not being collected on this trait for FIE.

6. Updates for Test Status, Cultural Practices and Test Problems

Certain information will be generated for each test on an irregular basis. For example, a given test is not furnished with permanent tags until after the results of the first year survival check have been evaluated and the test declared valid. Installation of the permanent tags should be done sometime during the second year after establishment but delays may be experienced. A change in the status code will be made after the field has notified the RO that the permanent tags have been installed. Provisions have also been made to track other significant influences on each test.

Some tests may require cultural practices such as a release of the test seedlings from competition. A few tests may have serious damage due to fire or other causes. Such data will provide a historical profile of the test. Comparisons of these profiles should have utility in any analysis of test data especially where significant shifts in family rankings are encountered.

E. Analysis of Data

The PET system is set up to allow data to be pulled from various parts of the file (for example, the same families from several different tests) and brought together for examination and/or analysis. The PET system does not have any internal capabilities for statistical analysis but relies on the statistical packages now up on the computers at Fort Collins. Nevertheless, several of the reports generated provide valuable summaries.

1. Reports - The following is a listing of the current reports for the PET system:

AVAILABLE REPORTS FOR "PET" AS OF 11-83

REPORT NAME	DESCRIPTION OF REPORT	TYPE OF REPORT
LST-EST	LISTING OF ESTABLISHMENT DATA	RW
LST-CROSS	LISTING OF NUMBER OF TREES BY CROSS OR CHECK - SINGLE TEST	RW
LST-PAR	LISTING OF PARENTS BY TEST & FY	RW
RW-FILE	PRODUCES A FILE TO BE USED WITH EMDOC OR FIEDOC	RW
LST-FYS-REC	LISTING OF FYS RECORD (SOURCE DOCUMENT)	RW
LST-FYS	LISTING OF FYS DATA	RW
LST-FAM-FYS	LISTING OF FAMILY CODES & FYS DATA	RW
FYS-REP	FYS SUMMARY BY REP - SINGLE TEST	RW
FYS-FAM	FYS SUMMARY BY FAMILY - SINGLE TEST	RW
FYS-FAM-FY	FYS SUMMARY BY FAMILY, YR, TESTS-MULTIPLE TESTS	RW
FYS-FY	FYS SUMMARY BY FY - MULTIPLE TESTS	RW
FYS-PAR	FYS PARENT SUMMARY BY TEST AND BY CROSS	PLEX
FYS-PAR-NF	FYS PARENT SUMMARY BY TEST AND BY CROSS AND BY PARENT FOR A SINGLE NF	PLEX
EMDOC	PRODUCES EM SOURCE DOCUMENT	FTN
LST-EM	LISTING OF EM DATA	RW
EM-SUR-REP	EM SURVIVAL - REP SUMMARY - SINGLE TEST	RW
EM-SUR-FAM	EM SURVIVAL - FAMILY SUMMARY - SINGLE TEST	RW
FIEDOC	PRODUCES FIE SOURCE DOCUMENT	FTN
LST-FIE	LISTING OF FIE DATA	RW
FIE-SUR-REP	FIE SURVIVAL - REP SUMMARY - SINGLE TEST	RW
FIE-SUR-FAM	FIE SURVIVAL - FAMILY SUMMARY - SINGLE TEST	RW
FIE-SUR-RF	FIE SURVIVAL - FAM WITHIN REP SUMMARY - SINGLE TEST	RW
FAMLIS	LIST OF FAMILIES IN SPECIES FAMILY FILE	FTN
CUL-DAM-REC	STATUS, CUL TREAT., DAMAGE RECORD (SOURCE DOC)	RW

RW = S2K REPORT WRITER PLEX = S2K PLEX PROGRAM
FTN = ASCII FORTRAN

Descriptions and other information about most of the reports are contained in Appendix A. A few of the reports have not been thoroughly tested and these are currently under evaluation.

2. Statistical Analysis

As previously noted, the system is designed to interface with current statistical packages. The full array of desirable analyses cannot be predicted at this time.

Considerable work has yet to be done before a standard analytical procedure is defined for use with FIE (and later measurements) data. Current work will be limited to four statistical packages now operational at FCCC:

a. STATJOB
b. Statistical package for the social sciences (SPSS)
c. BMDP
d. PNW & R-6 stat package.

A preliminary examination of these packages indicated that each has some shortcomings that will be critical to a complete analysis. Both SPSS and STATJOB appear to have adequate capabilities to define frequency distributions and perform least squares regression. For an analysis of variance, SPSS apparently cannot accommodate nested designs. STATJOB does not indicate a basic capability to do covariance analysis. The BMDP (83 version) has not been fully evaluated. The PNW Region 6 program has limitations on the number of tests which may not be large enough for some species -geographic source analysis. Thus, none of the packages can be considered adequate to meet all needs. Certain programs with desired features will be selected from each package in order to do the complete analysis.

F. Future Development

The previous sections represent only Phase I of the system. One or more additional phase will be required to fully meet the future needs for data collection and analysis.

Projected requirement include:

1. Second Internal Evaluation (SIE) - This is the second mandatory test measurement and evaluation. Timing (probably 8-10 yrs) and specific data elements to be collected have not yet been fully defined.

2. Third Interval Evaluation (TIE) - This is the third mandatory test measurement and evaluation. Timing (probably around the 12th - 15th year) and specific data elements have yet to be defined.

3. Custom Programs for Analysis of Data - Although the system has considerable flexibility under the S2K data base, some custom programming may be required for statistical analysis and reporting. Existing statistical packages will be utilized whenever possible but some data sets may not fit within existing program limits. Development of such programs will be done only when the requirements can be well defined.

IV. Portable Data Recorders

The operational use of portable data recorders to collect field data has not been initiated in R-8. It is not a matter of desirability but rather a combination of several separate factors that have not been fully reconciled. With the introduction of several new portable machines on the market, most if not all of the current problems should be resolved.

At present, the Region's Timber Management staff unit has two portable data recorders, MSI, Model 88f. These were originally purchased to collect progeny test data. This is still an option if trained crews are used and provisions are made for telephone linkages to computer equipment in Atlanta. Nevertheless, the state-of-the-art has developed to a point where these machines have comparatively limited capabilities which could best be used in rather routine applications. Thus, the current plans are to develop procedures for using these recorders at the Ashe Nursery for inventory work.

This still leaves the R-8 Tree Improvement Program without an immediate solution to the increasing data processing workload. Handwritten field data sheets will be the primary data collection method for at least the next year. This will provide an opportunity for evaluations of the newer equipment including several small hand-held computers. The primary features that are desirable for an operational machine are:

A. Adequate memory to hold at least two day's data collection.

B. Programable in a common but efficient language to enable in-house programming for prompting of data entry, editing, format changes and any other specific application changes that are necessary to ensure minimum complexity of operation combined with maximum efficiency and accuracy. This should also allow the machine to be utilized for a variety of other activities such as timber marking, road construction, etc.

C. Downloading capabilities to reduce data entry requirements and increase editing options.

D. Compatability with FLIPS.

Several of the new portable computers appear to have capabilities that approach or meet this criteria. Of the machines surveyed, a computer, the NEC PC-8201, made by the Nippon Electric Company appears to have the best capabilities relative to its size and listed cost. Other machines made by Radio Shack, Hewlett Packard and others also appear to have good potential especially if some features such as memory capacity are expanded. With recent advances in improved chip capabilities and reduced power requirements, the number and variety of machines that will meet our basic requirements should greatly expand in the near future.

V. Conclusions

There is no question that the use of computers (from mainframe to hand-held portables) is a necessity if the tree improvement programs are to efficiently collect and effectively utilize their data. With expanding programs and static or shrinking personnel levels, the future needs for automation become even more critical. The real challenge will be to maintain the awareness and flexibility to take advantage of state-of-the-art improvements as they become available.

LST-EST

Description: Single test report. An S2K report writer which prints all data loaded into the data base from the R8-2400-38 and the R8-2400-39. Three report pages are printed on each computer printout page to reduce total number of output pages.

Sorted by: C51 (i.e., point number within row, within rep, within test, within NF).

Selection criteria: None. Selects and lists every point record in the data base by test. User may control selection of tests with the GENERATE command.

LST-CROSS

Description: Single test report: This report writer calculates the number of points within each cross or check within a test. It also calculates total number of points within a test and total number of crosses and checks within a test. These totals are printed along with species code, NF code, test number, FY, breeding pop, crossing group and internal family code (FAM C47).

Sorted by: FAM (C47) code in data base.

Selection criteria: None. Selects every record within a test. User may control selection of tests with the GENERATE command.

LST-PAR

Description: Multiple test report. This report writer lists each female parent showing test number and fiscal year where it is planted. Also shows sub-total count of total number of tests with that parent and grand total of number of tests included in report. Then the same report is produced showing each male parent.

Sorted by: Test number within NF, within FY, within parent code.

Selection criteria: None. Selects every record within every test. User may control selection of tests with the GENERATE command. If invalid tests are NOT to be included, this must be stated in the GENERATE command (i.e., GENERATE ALL WH C12 LT 7 and -------).

RW-FILE

Description: This report writer produces a formated file which is used as input data to ASCII FORTRAN programs EMDOC and FIEDOC. The report writer retrieves the following data items from the data base and writes them to the file: species code, NF code, test number, Ranger District, replication number, row, point number, female parent, male parent, FYS code, test status code, and remarks. The only output is the file; no report is produced.

Sorted by: Row within rep, within test, within NF

Selection criteria: None. User has complete control as to which records are selected from the data base with the GENERATE command.

LST-FYS-REC

Description: Single test list. This report writer produces the field document for recording FYS data. The document is by replication with up to 23 row on one page. Data items from the data base that are printed on the document are: species code, NF code, Ranger District code, test number, replication number, remarks, row, female parent, male parent. Point numbers 1-10 are generated across the top of form.

Sorted by: Row within rep, within test, within NF.

Selection criteria: None. The user has complete control over which tests are slected with the GENERATE command.

LST-FYS

Description: Single test report. This report writer prints the following data items from the data base: species code, Ranger District code, compartment number, stand number, breeding pop, acres, date established, test status code, NF code, test number, rep number, female number, male parent, and FYS code. No calculations are made. Two report pages are printed on each computer printout page to reduce total number of output pages.

Sorted by: C51 (i.e., point number within row, within rep, within test, within NF).

Selection criteria: None. Program selects and lists every point record in data base by test. User may control tests listed with the GENERATE.

LST-FAM-FYS - To be written after further testing.

FYS-REP

Description: Single test report. This report writer determines the number of trees with FYS code (C53 GT 0 and LT 90). It then determines number of live trees (C53 EQ 1) within a replication. Percent survival is calculated and printed for each rep. Average survival for the entire test is also printed.

Sorted by: Rep within Test, within NF.

Selection criteria: Selects record if FYS code (C53) exists and if FYS code is less than 90. This eliminates points coded as short row, split row and permanently vacant. The GENERATE command controls which tests are selected.

FYS-FAM

Description: Single test report. This report writer calculates and lists number of living seedlings (C53 EQ 1) and percent survival within a family.

Sorted by: Low FAM code (C47) within test number, within NF.

Selection criteria: Selects record if FYS code (C53) exists and if FYS code is less than 90. This rejects points coded as short rows, split row, and permanently vacant. The GENERATE command controls which tests are selected.

FYS-FAM-FY

Description: Multiple test report. This report writer calculates and lists number of living seedlings (C53 EQ 1) and percent survival within a family much the same as FYS-FAM does for a single test.

Sorted by: Test number within FY, within FAM (C47) code.

Selection criteria: Selects record if FYS code (C53) exists and FYS code is LT 90. This eliminates points coded as short row, split row and permanently vacant. The GENERATE command controls which tests are to be included in report. If invalid tests are NOT to be included, this must be controlled in the GENERATE command (i.e., GENERATE ALL WH C12 LT7 and -------).

FYS-FY

Description: Multiple test report. This report writer calculates percent survival of a test based on FYS code. Printed data items include FY, test number, Forest name, Ranger District name, compartment number, stand number, acres, and percent survival.

Sorted by: Test number within NF, within FY.

Selection criteria: Selects record if FYS code (C53) exists and if it is less than 90. This eliminates points coded as short row, split row, and permanently vacant. The GENERATE command controls which tests are to be selected.

FYS-PAR

Description: Multiple test report for entire data base. This report is generated by an ASCII FORTRAN PLEX program, not a report writer. When the program is executed, it reads at least 2 control records.

The first control record must be the data base name (i.e., PETxxx with xxx being the species code).

The second control record must be in the following format:

```
X,NNN,NNN,NNN,NNN, ----------------NNN/
      X   = number of parent codes to be selected, up to 1000
      NNN = parent code to be selected
```

Parent codes may continue onto as many control records as needed until the total number listed equals the number for 'X', Each line should end with a slash.

The generated output is two reports. The first report is 'Individual Parent Survival Summary - by Test'. This report prints the parent code, the cross, type of cross, FY, forest name, test number, live tree count of cross for each test, and percent survival of cross for each test.

FYS-PAR (Cont'd)

The second report is 'Individual Parent Survival Summary - by Cross'. This report prints the parent code requested, the cross, total number of tests containing the cross, the total number of living trees per cross, and the percent survival of the cross.

Note: The same test may be included in more than one cross, if both parent codes are requested.

Sorted by: FAM (C47) code within test, within NF.

Selection criteria: The program will reject a test with a 0 (zero) in test status code (C12) in the data base. However, at this time it does not reject an invalid test.

FYS-PAR-NF

Description: Multiple test report for a single NF. This is an ASCII FORTRAN PLEX program, not a report writer. When the program is executed, it reads at least 2 control records.

The first control record must be the data base name (i.e., PETxxx with xxx being the species code.

The second control record must be in the following format:

```
NF,X,NNN,NNN,NNN,NNN,---------------NNN/
      NF  = administrative unit code
      X   = number of parent codes to be selected, up to 1000
      NNN = parent code to be selected
```

Parent codes may continue onto as many control records as needed until the total number listed equals the number for 'X'. Each line should end with a slash.

The generated output is three reports. The first report is 'Individual Parent Survival Summary - by Test'. The data items listed are parent code, cross, type of cross, FY, test number, live tree count of cross within each test, and percent survival of cross within each test. The species name and NF name are printed in the report heading. This report is the same as the first report of FYS-PAR except FYS-PAR selects all tests in the data base and FYS-PAR-NF selects tests on only one NF.

The second report is 'Individual Parent Survival Summary - by Cross'. This report prints the parent code, the cross, total number of tests in cross, live tree count of cross, and percent survival of the cross. This report is the same as the second report of FYS-PAR except FYS-PAR includes all tests in the data base and FYS-PAR-NF includes only tests for a single NF.

FYS-PAR-NF (Cont'd)

The third report is 'Individual Parent Survival Summary - by Parent'. This report prints the parent code, the live tree count of the parent for one NF, the percent survival of parent for one NF, the ranking of percent survival with #1 rank being the best.

Note: The same test may be included in more than one cross, if both parent codes are requested.

Sorted by: FAM (C47) code within test, within NF.

Selection criteria: Selects only the tests with NF code (C2) the same as NF code in the control record. The program will reject a test with a 0 (zero) in the test status code (C12) in the data base. However, at this time it does not reject an invalid test.

EMDOC

Description: Produces EM source document. This is ASCII FORTRAN program, not a report writer, to produce field documents for early measurement (EM). The program reads data from a file that has been created with report writer RW-FILE. The data items read from the file are: species code, NF code, test number, Ranger District code, rep number, row, point number, female parent, male parent, FYS code, test status code and remarks.

If the FYS code for a point is not a 1 (live tree), a code '9' will be preprinted on the EM document in the first problem code field.

Sorted by: The data read in from file is already in the proper sequence: row within rep, within test, within NF.

Selection criteria: None. The selection is controlled by the user at the time the file is created with the report writer RW-FILE.

LST-EM

Description: Single test report. This report writer lists the following data items from the data base: species code, Ranger District code, compartment number, stand number, breeding pop, acres, date established, test status code, NF code, test number, rep number, female parent, male parent, FYS code, EM month & year, EM height, EM problem 1 and 2. No calculations are made. Two report pages are printed on each computer page to reduce total number of output pages.

Sorted by: C51 (i.e., point number, within row, within rep, within test, within NF).

Selection criteria: None. Program selects and lists every point record in data base by test. User may control data listed by the GENERATE command.

EM-SUR-REP - To be written after further testing.

EM-SUR-FAM

Description: Single test report. This is an Early Measurement (EM) survival report BY FAMILY within a single test. This report writer selects records by FYS code (C53). A record is selected if FYS code exists and if it is less than 90. The report writer calculates and lists by family percent survival and average EM height. Also a live tree count is listed. For each live tree (i.e., has EM height shown) a percent of incidence of each problem code is calculated and listed.

Sorted by: To be written after further testing.

Selection criteria: To be written after further testing.

FIEDOC

Description: Produces FIE source document. This is an ASCII FORTRAN program, not a report writer, to produce field documents for first interval evaluation (FIE). The program reads data from a file that has been created with report writer RW-FILE. The data items read from this file are: species code, NF code, test number, Ranger District code, rep number, row, point number, female parent, male parent, FYS code, test status code and remarks.

If the FYS code for a point is not a 1 (live tree), a code '9' will be preprinted on the FIE document in the condition code field and in the first problem field.

Sorted by: The data read in from the file is already in the proper sequence: row within rep, within test, within NF.

Selection criteria: None. The selection is controlled by the user at the time the file is created with report writer RW-FILE.

LST-FIE

Description: Single test report. This report writer lists the following data items from the data base: species code, Ranger District code, compartment number, stand number, breeding pop, acres, data established, test status code, NF code, test number, rep number, female number, male parent, FYS code, FIE month and year, FIE height, FIE problem 1 and problem 2. No calculations are made. Two report pages are printed on each computer page to reduce total number of output pages.

Sorted by: C51 (i.e., point number within row, within rep, within test, within NF).

Selection criteria: None. Program selects and lists every point record in data base by test. User may control data listed by the GENERATE command.

FIE-SUR-REP

Description: Single test report. This report writer calculates BY REPLICATION the live tree count, the percent survival, the average height, and the average condition score. Also the percent of incidence of problem codes by rep is calculated and listed. This percent of incidence is calculated only on live trees (i.e., trees showing height for FIE).

Sorted by: Replication, test and NF.

Selection criteria: To be written after further testing.

FIE-SUR-FAM

Description: Single test report. This report writer calculates and lists BY FAMILY the following: live tree count, percent survival, average height and average condition score. Also the percent of incidence of problem codes by family is calculated and listed. This percent of incidence is calculated only on live trees (i.e., trees showing a height for FIE).

Sorted by: Male parent, female parent, test, and NF.

Selection criteria: Selects records with FYS code greater than 0 and less than 90. This eliminates points in the data base designated as short row, split row, or permanently vacant. Only points with a FIE height greater than 0 are used in the calculations. User controls which tests are selected with the GENERATE command.

FIE-SUR-RF - To be written after further testing.

FAMLIS

Description: File report. This is an ASC II FORTRAN program generated report which lists all families represented in a species file. No sort or selection functions are available.

CUL-DAM-REC

Description: Single test report. This report writer produces a field document for recording changes in test status, cultural treatment or test damage. Changes are input as updates and each update becomes part of a new document that shows current test status and all cultural treatments applied to the test. This report will be run as needed after an update is made on a test.

The Politics of Progeny Testing

Ralph A. Lewis, Forester
Southern Region

The vital role of progeny testing in most tree improvement programs is well recognized, but certain parts of this role are often taken for granted or totally ignored. For want of a better term, I will call one of these neglected parts, the politics of progeny testing.

When most people are faced with a large, complex and time-consuming task such as progeny testing, it is natural to focus on the mechanics of doing the job. They often overlook the fact that the value of the project is not obvious to everyone and little effort is made to educate those outside of the project on its worth. But such a project requires resources, manpower, money, land, etc., and as such, it will always have interested observers, competitors, sceptics, critics and even enemies. Tree improvement programs do not hold any special claims on manpower and money. They can and should compete with other programs in the Forest Service.

Thus, we should not leave the display and understanding of the merits of tree improvement to chance. Progeny testing offers excellent opportunities for showing the results of the program and explaining their meaning in understandable terms. Such opportunities should be actively pursued whenever possible. Here are a few of the ways that opportunities can be enhanced or even created.

1. Get the tests into the ground and growing as soon as possible. Most people can more readily understand and believe what they can see and feel rather than what they read or hear. There is no substitute for on-the-ground displays of program products.

2. Whenever the opportunity arises for you to present information about a test or the entire program, do not hesitate to take it but be sure that what you say is understandable and has meaning to the audience. Usually only the geneticists and people that work closely with the program are interested in the more technical details of operation. On the other hand, most other people will be interested in a general overview of operations and results put in terms that they can understand. For example, progress in breeding is often expressed in terms of genetic gain. Be prepared to follow these figures with more tangible data on what this means in terms of increased volume per unit of time, quality improvements, relationship with the environment and other resources and some estimation of economic worth. If other people talk about the program, be sure they have the facts and understand them.

3. Create opportunities by establishing tests whenever possible near seed orchards, nurseries, Ranger or Supervisors' Offices and other facilities. Such installations are natural draws for tours, show-me trips, reviews, inspections, etc., and the proximity of the tests will create opportunities for effectively communicating results to these visitors.

4. Pay attention to such things as layout and accessibility when choosing any test sites. There may be good reasons why it would be desirable to establish tests in remote locations, but for purposes of fire protection, maintenance, measurements and visits, easy access and viewing may be highly desirable.

There are many other considerations and practices that should serve to enhance the appreciation and understanding of a tree improvement program. The primary consideration is that we do not remain passive in this area and allow more aggressive programs of lesser merit to overshadow us.

FOREST GENETICS WORKSHOP

December 5-9, 1983

Charleston, South Carolina

COMPUTER SYSTEMS FOR KEEPING TRACK OF PLANT MATERIALS AND DATA ANALYSIS

REGION NINE
JOHN D. MURPHY, REGIONAL GENETICIST

INTRODUCTION

All computer systems for keeping track of plant materials and data for analysis start out with an idea. This idea leads to some form of desired data output. Before the actual programming is done, the idea and desired output should be evaluated to insure the output is in fact going to be useful, and affordable, or is it just something that would be nice to have. Once the idea has been accepted and programming completed, the user must be ready to make adjustments to compensate for many unforeseen problems.

THE REGION 9 SYSTEM.

The Region 9 Tree Improvement computer system basically consists of the following areas.

a. Superior Tree Register and Status Report.

b. Pollination and Seed Record.

c. Evaluation Plantation and Seed Orchard Data Processing.

In our entire system the following procedures must be followed:

a. ALL R-9 TREE IMPROVEMENT MATERIAL, (SEED, SEEDLINGS, TREES, POLLEN, CLONES, ETC.), MUST BE ENTERED IN THE SUPERIOR TREE REGISTER AND STATUS REPORT WITH A UNIQUE ACCESSION NUMBER.

b. ALL MATERIAL THAT IS RECEIVED FROM ANOTHER AGENCY WITH AN IDENTIFICATION NOT COMPATIBLE WITH THE R-9 NUMBERING SYSTEM MUST BE ISSUED A R-9 NUMBER AND ENTERED IN THE ALIAS LIST.

c. ALL R-9 MATERIAL TRANSFERRED TO OTHER AGENCIES WHO IDENTIFY IT WITH A NUMBER OTHER THAN THE R-9 NUMBER MUST BE ENTERED IN THE R-9 ALIAS RECORD, INDICATING THE AGENCY NUMBER.

Computers Used

Our computer system programs are in the Fort Collins Computer Center (FCCC). All data is input by either cards, terminal entry, or portable data recorders to terminals to FCCC. We have a TI990 (TI) at the Oconto River Seed Orchard and have had some of our basic programs at FCCC programmed for the TI so that portable recorder data can be reformatted prior to transmitting to FCCC for complete processing.

Superior Tree Register and Status Report. (See Appendix A-C)
This superior tree and status reports are two separate listings generated from the same data file. The basic input document is the Superior Tree form R-9-2400-86. This form is used for both conifers and hardwoods and is filled out for any material that is in the program. If only pollen is obtained from a tree, the form is filled out even if some data is unknown. It should be noted, that on the back of the form the minimum standard for superior trees is given. The intensity of the program and species involved determine the intensity of selection standards.

The status report is usually updated once a year. At the present time pollination and seed collection records and EP data are not automated to update the status report. Both the status report and superior tree register can be sorted by forest by species or by species by forest.

Pollination and Seed Record. (See Appendix D-H)
The pollination and seed record is an independent data file using R9-2400-95 as the input document. Computer generated versions of this form can also be used. The back of each 2400-95 has an area for describing the pedigree and seed use. Each seed lot is assigned a number which can be either alpha or numeric. Seed collected from the same mother tree in different years will be assigned different numbers.

The record is updated annually by adding new seed lots and indicating the amount of seed removed from lots all ready in the record. The weight of seed in storage is then automatically updated.

The records can be sorted by species by forest or by forest by species. Seed lots which no longer have seed in storage are placed in a separate area of the printout. An additional printout of only the seed lot numbers, female numbers and male numbers can be obtained. A separate list is maintained for control crosses that produce no seed. Seed lot numbers and tree numbers have been designed so that future pedigree-search programs could be developed. i.e. a tree selected from seed lot number 1234 would be assigned a tree number of 1234A.

In addition the Timber Management Information Systems (TMIS) and our nurseries use the same numbering system for seed and seedlings. Different seed lots planted in the same stand can be tracked using the Seed Lot numbers and TMIS. (see appendix G&H).

Evaluation Plantation and Seed Orchard Data Processing. (See Appendix I-T) Our seed orchards are designed using a computer program which can provide for double and single isolation rings. Tree numbers are assigned manually to the computer generated map numbers.

Once a seed orchard or evaluation planting has been established a grid is established with 2 alpha digits for each row and 3 numeric digits for each column. The upper-left position is always AA001 and the lower-left position of a 26 row orchard is always AZ001. This prevents mirror image computer maps.

The grid and tree number are the key factors for the data collection system. Our computer generated data sheets have the items listed in Table 1 with title, number of codes and digits, and the summary that they will be listed in. Each data item has standard codes established but different meanings can be assigned if desired.

Once data has been collected and entered into a file the following output can be obtained using the file and our GENETA*ORCHARD. program system.

a. Blank forms can be obtained with 3 options. They also can have previous dbh and height printed on the right side of the new blank forms.

b. Five different summary programs have been established, the summary used depends on the data item needed. Summaries can be by FAMILY, FAMILY BY BLOCK, BLOCK, AND BLOCK BY FAMILY. The summaries listing DBH, Height, Height to Fork, and items 24 and 25 will list the mean, percent of mean, high and low data for each unit (family or block). Summary 5 will compute volume as D*D*H.

c. Planting Maps can be produced with 26 rows and 21 columns per computer sheet. Maps can be made of Family Numbers, Survival, I&D, Height and Others. The height map will print tree numbers over a specified height. A series of height maps can be made if desired.

d. An analysis of variance program is available which can be run on most of the data items such as height, dbh, insect and disease, and frost damage. A summary by family sorted by family mean is produced including number of live trees, family mean, standard error, standard deviation, and coefficient of variation. Missing plots are permissible.

e. Work lists can be generated for most data items. The work list for survival will list by family by position each tree that is coded 1, 4, or 5 (dead, permanent vacant or vacant). Work lists for other items will list trees with codes 2 or higher since code one normally is used for "none" or "no".

f. Correlation analysis can be done with most items. A new file has to be created using data from the summaries. The program computes coefficient of determination and correlation coefficient for X and Y variables.

g. A GENETA*NURSERY. program is also available which uses the same grid tree number system as our ORCHARD. program. This program is based on all EP trees in a nursery being measured by height class from 1-10 by family and rep. The program will indicate how far down the scale you must come to get the number of trees needed for the EP. This distance is divided into 4 units with the same number of trees per unit. Four tree plots are assembled by measuring each tree after lifting and taking 1 tree from each of the 4 units to make a plot. In theory each 4 tree plot is the same average height from the bigger trees in the family.

Table 1. LIST OF DATA FORM ITEMS

ITEM #	TITLE	#DIGITS	CODES	SUMMARY
1	Orchard or EP number	3	999	-
2	Replication	2	99	-
3	Tree or clone no.	5	-	-
4	Position No.	5	-	-
6	Survival	5	1-5	1
7	Height (XX.XXX)	5	-	1,5
8	Insect & Disease Damage	1	1-0	2
9	Animal and Mechanical Damage	1	1-0	2
10	Flowering	1	1-4	1,5
11	Controlled Pollination	1	1-2	1
12	Blister Rust	1	1-2	2,4
13	Lamas Growth	1	1-2	1
14	Frost Damage	1	1-3	1
15	Height to Fork	2	99	3
16	Cultural Work	2	99	-
17	Year of Measurement	2	-	-
18	Stem Form	1	1-7	3
19	DBH (XX.XX)	4	-	3,5
20	Need for release	1	3	3
21	Year of Establishment	1	1-0 or A-Z	
22	EXTRA	1	1-0	4
23	EXTRA	1	1-0	4
24	EXTRA	2	99	3
25	EXTRA	2	99	3

ALIAS LIST

A system has been set up using computer cards to list vital tree information (accession number, forest, tree no. etc) for all trees in the superior tree list having an alias. If seed, scion, or pollen is given to or received from another agency, the agency code and material ID numbers are listed. This type of system could easily be adopted to computer programs, or word processing systems.

PORTABLE DATA RECORDERS

We have been using portable data recorders to some degree for the past several years. Our present system uses MSI 77 or 88D units. These do not have alpha capabilities so all alpha/numeric data must be programmed as a 2 digit number (i.e. A=11 1=01). A format statement is entered first indicating which items of data are to be taken and in what sequence. The data is then entered.

Entered data can be transmitted to a terminal such as TI990 by phone or by direct connection. The data is then processed through a reformat program in the TI or at FCCC. The reformated data is in the same format as the paper data sheets and can be processed in ORCHARD.

This system is very flexible in that only the items that you want data for have to be entered. We have been working with the MSI88s, which gives prompts and has digit checks. At this time we have not been able to obtain the flexibility and speed that we desire.

The use of portable data recorders can be a time and money saver. It is also new and ever progressing. This results in some levels of frustration and ground work is required to overcome unknown problems. A proper attitude is required, for it is certain if personnel do not think it will work, it won't!

PROTECTION OF DATA

We have recognized that we have large quantities of data that we have assembled over the years and that it might be impossible or very costly to recover lost data. We use the systems below to prevent data loss.

Superior Tree Lists

a. R-9-2400-86 forms retained by Forest, Zone Geneticist and Regional Geneticist.

b. Superior tree data is on a tape at FCCC.

c. A backup tape is maintained at FCCC.

d. Copies of printouts are maintained at the Regional and Zone Geneticist Office.

Orchard and EP data.

a. Data is entered in a disk at FCCC.

b. A computer listing of data is maintained by the Zone Geneticist.

c. A micro film copy of the computer data listing is maintained at the Regional Office.

d. When the cost of maintaining data in the disk reaches $10.00 per week, the disk is copied to a tape. The next time the disk is copied the last tape and the disk are merged into a new tape. The 1st tape is retained until a third tape is made. (See Figure 2).

SUMMARY

Our Tree Improvement Computer processing systems has been developed over a number of years. We feel this system is economical and provides most of the information we need. We recognize that new ideas and needs will always develop. We would recommend that any new additions to our system or a national systems be developed so that they comply with the GENESIS standard formats as much as possible while maintaining applicability to existing Regional systems.

JOHN D. MURPHY
Regional Geneticist

Figure 2: DATA PROTECTION

A.

DATA INPUT TO DISK
977
979



B.

DATA INPUT TO DISK
988

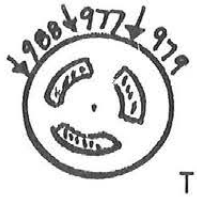


C.

DISK COST = $20.+

CREATE TAPE 1
AND CLEAR DISK





T 1

D.

DATA INPUT TO DISK
976





T-1

E.

DISK COST = $20.+

CREATE TAPE 2
AND CLEAR DISK





T-2



T-1

F.

WHEN TAPE 3 IS CREATED
PURGE TAPE 1

APPENDIX INDEX

	PAGE
Select Tree Candidate Report R-9-2400-86	A
Select Tree Status Report	B
Select Tree Register	C
Pollination and Seed Collection Record Printout	D
Pollination and Seed Collection Input Document	E, F
Plantation Map with Two Seed Sources	G
TMIS-S2K Document R-9-2400-15	H
R9 ADP Request Form	I
80/80 Listing of Data	J
Blank Data Sheets for a New Planting	K
Blank Data Sheets from an Existing Data File	L
Summary 1 Option 1	M
Summary 1 Option 1 in percent	N
Summary 1 Option 2	O
Summary 5 Option 2	P
FAMILY MAP	Q
SURVIVAL MAP	R
Survival Worklist	S
Alias List	T

USDA Forest Service

APPENDIX A

SELECT TREE CANDIDATE REPORT

Accession No. (2-6) ____

Tree No. (7-12) ____ Species (13-16) ____

Section ____ T ____ R ____

State (17-18) ____ County (19-21) ____

National Forest/Agency (22-24) ____ Ranger District (25-26) ____

Originator (27-29) ____ Seed Zone (30-32) ____

Longitude Deg. (33-35) ____ Min. (36-37) ____

Latitude Deg. (38-39) ____ Min. (40-41) ____

Tree Located By:

Title/Date:

Tree is marked with ____ (Color) paint, ribbon (cross out one)

Other ____ (Describe mark)

Bearing and distance from reference point:

Name and address of landowner:

SELECT TREE RATING

3 Largest Trees (Same species within 66 feet)	(1) Age (At DBH)	(2) Total Height (Feet)	(3) Merch. Height (Feet)	(4) DBH (Nearest 1/10 inch)	(5) Stem Volume (cu. ft.)
A					
B					
C					
Total					
Average					
Select Tree	(42-44) ___	(45-47) ___	(48-49) ___	(50-52) ___	(53-55) ___
% Superiority		(56-57) ___	(58-60) ___		(61-63) ___

COMPLETE THE FOLLOWING FOR SELECT TREE ONLY

(6) Apical Dominance . . . . . (64-65) ___

(7) Selection Objective: Primary . . (66) ___

Secondary . (67) ___

(8) Type of Stand . . . . . (68) ___

(9) Seed Crop/Sex . . . . . (69) ___

(10) Elevation . . . . . (70-71) ___

TO BE COMPLETED BY ZONE GENETICIST

(11) Status:

Alive-Dead-Grafts-Cuttings . . . . . (72) ___

Seed Orchard . . . . . (73) ___

Breeding Arboretum-Reserve-½ Sib Seed . . (74) ___

Full Sib Seed-½ & Full Sib Eval. Plant. . . (75) ___

Sufficient Seed-Alias . . . . . (76) ___

Special Notes-Special Eval. Plant. . . . . (77) ___

OTHER DATA ON SELECT TREE

(14) Crown Length . . . . . ___

(15) Crown Diameter . . . . . ___

(16) Branch Angle . . . . . ___

(17) Self Pruning . . . . . ___

(18) Roundness Ratio . . . . . ___

(19) Decay Ratio . . . . . ___

(20) Cambial Activity Ratio . . ___

FINAL SCREENING

☐ Accepted ☐ Rejected

Examined By ____

Title ____ (12) Date (Year) (78-79) ___

(13) Control Code (80) ___

REMARKS

(over)

R9-2400-86 (11/77)

INSTRUCTIONS

(Reference Tree Improvement Handbook, FSH 2475.1 R-9, Chapter 120)

This report form is to be used for reporting all conifer and hardwood select tree candidates. Send original and one copy to Zone Geneticist - Zone Geneticist will send one copy to Timber Management Staff, USDA, Forest Service, 633 West Wisconsin Avenue, Milwaukee, Wisconsin 53203.

ACCESSION NUMBER. Leave blank. RO will assign numbers in sequence.

TREE NUMBER. Assigned by Forests. Use letter prefix shown in 2475.1.

SPECIES. Use three digit codes. Blank for column 13 is reserved for identifying hybrids.

CODE NUMBERS. For State, County, National Forests/Agency, Ranger District, Originator, and Seed Zone see Tree Improvement Handbook (FSH 2475.1 R-9)

LONGITUDE AND LATITUDE. Report to nearest degree and minute.

MAP. Draw or trace a simple map showing reference point, direction, and distance to location of selected tree, and its relationship to comparison trees. Indicate township, range, and section. Eastern Forests use County, Political Subdivision and Tract Number, or when available use quadrangle number and tract number. A copy of the Forest Map showing tree location can also be used.

COMPARISON TREES: Three largest dominant trees of same species and age (± 5 years) within one chain. Comparison trees will be paint marked with the letters A, B, and C respectively, to retain their identities. For certain species, not growing in pure stands, comparison trees more than one chain from the candidate will be acceptable providing that the sites can be considered similar.

SELECT TREE RATING.

Item (1) - Age at DBH: Determined by increment core which has intercepted pith. Save increment cores. Place in soda straw, label with tree number. Hold for final acceptance by Zone Geneticist. Do not bore black walnut candidates.

Item (2) - Total Height: Measure total height to nearest foot with a clinometer such as a Sunto, Speigel relaskop or Haga altimeter.

Item (3) - Merchantable Height - Hardwoods Only: Measure to eight inch top. Leave blank if tree is under 8".

Item (4) - DBH: Measure diameter at 4½ feet above ground.

Item (5) - Stem Volume: CONIFERS — Use Table 3 in the Timber Management Fieldbook, page 1.32. Round DBH to nearest inch, interpolate table to nearest foot for tree height, and record volume to nearest cubic foot. HARDWOODS — For trees over eight inches, use R-9 Cubic Foot Volume Table - Sawtimber in the Timber Sale Preparation Handbook 2409.24, 203--3. Interpolate using tenth inch DBH and nearest foot merchantable height, and record volume to nearest cubic foot. For trees less than 8 inches, use R-9 Cubic Foot Volume Table - Cordwood in the Timber Sale Preparation Handbook 2409.24, 203--4.

Item (6) - Apical Dominance - Hardwoods Only: Candidate must maintain a central stem to one half its total height or 33', whichever is greater. Measure the length of the stem to first fork or point where definite central stem is no longer apparent, whichever is the shortest. Record as the percentage of total height.

Item (7) - Selection Objective: Use the following codes:

1 Total Height	4 Apical Dominance	7 Insect Resistance
2 Merchantable Height	5 Stem Straightness	8 Abundant Seed Producer
3 Volume	6 Disease Resistance	9 Small Diameter Branches
		0 Other (note in remarks)

Item (8) - Type of Stand: Use following codes:

1 Native Stand	4 Provenance Test	7 Evaluation Plantation
2 Plantation	5 Ornamental Planting	8 Seed Orchard
3 Shelterbelt	6 Wildlife Planting	9 Other (note in remarks)

Item (9) - Seed Crops/Sex: Use following codes:

1 No Crop	3 Medium Crop	5 Cannot be determined at this time
2 Light Crop	4 Heavy Crop	6 Male Tree

Item (10) - Elevation: Indicate elevation of select tree to nearest hundred feet above sea level.

Item (11) - Status: Zone Geneticist will insert proper code.

Item (12) - Date: Zone Geneticist will insert last two digits of year.

Item (13) - Control Code: Zone Geneticist will insert control code.

1 New Addition	2 Update	3 Delete Record

NOTE: Items (14) through (20) will not appear on Select Tree Register, but should be completed.

Item (14) - Live Crown Length: Measure length of effective live crown to nearest foot.

Item (15) - Crown Diameter: Measure long and short diameter on line through stem. Record average diameter to nearest foot.

Item (16) - Branch Angle: Consider the angle of the majority of branches in lower third of live crown. Record: 1 for branches 60^{o} - 90^{o} and 2 for less than 60^{o} or more than 90^{o}.

Item (17) - Self Pruning: Count the number of branches and stubs over ½" diameter on the best quarter face to 17'.

Item (18) - Roundness Ratio: Measure long and short diameter. Divide smaller number by the larger number. Record as a decimal to the nearest hundreth (0.00).

Item (19) - Decay Ratio: Measure resistance 10 cm directly above wound (A) and make a second measurement 5 cm to the side of the first (B). Use drill and twisted-wire probe to make measurement at 3 cm into the wood. Divide B into A for item 19.

Item (20) - Cambial activity ratio: Measure cambial activity with dual needle probe on select tree (S) and on comparison trees (C). Divide average of C's into S for item 20.

PERCENT SUPERIORITY. Divide value of the selected tree by the average value of the three comparison trees to obtain the percent superiority. Use the following formula:

$$\% \text{ Superiority} = \left[100\left(\frac{S}{C}\right) - 100\right]$$

Where: S = Value of trait for selected tree

C = Average value of same trait for comparison trees

MINIMUM SELECTION STANDARDS. Select tree candidate should meet or exceed the following standards. Trees which do not meet minimum standards may be submitted; a statement for the reasons for selecting these trees must be made in the space reserved for remarks.

1. All species should show at least five percent height superiority and twenty percent volume superiority.
2. Be free of sweep or crooks or spiral grain. (A straight line from the merchantable top to the ground will not leave the bole at any point).
3. Dominant to co-dominant crown class. Should not exceed the average for live crown length and width, branch angle, and self pruning.
4. Equal or exceed the average for seed crops. (This may be impossible to determine at time of selection).
5. Have vigorous branch tips for scions.
6. Forking - CONIFERS - No ramiform branches or forking. HARDWOODS - No forks below 33'. Forking occurs when: (a) the branch exceeds 1/3 of the diameter of the main stem, (b) the main stem is deflected more than 10% at the juncture, and (c) the angle between branch and main stem is less than 30^{o}.
7. Roundness Ratio should exceed 0.90.
8. Show no evidence of serious disease, insect, or weather injury.

SELECT TREE STATUS REPORT BY FOREST, SPECIE, ACCESSION NUMBER
JAN 5, 1978

ACCESS NO.	S P E C	SEED ZONE	ST-CTY-NF/ AGE NCY-	R ORIG D- IN ATOR	TREE NO.	TREE ALIVE SPEC. NOTE	VEGETATIVE PROPAGATION GRAFT	CUT	SEED ORCHARD CLO NAL	1/2 SIB	FULL SIB	BRED AMOR ETUM	RES- ERVE	SEED 1/2 SIB	STOK FULL SIB	EVAL 1/2 SIB	PLAN FULL SIB	SPEC 1/2 SIB	EVAL FULL SIB	ALIAS NO.
1468	129	5	26- 71-907-	3-900	0100	YES-	G					A	R	M	FS	M	F			
1469	129	5	26- 71-907-	3-900	0101	YES-	G					A	R	M	F		F			
1470	129	5	26- 71-907-	3-900	0102	YES-	G					A	R	M						
1471	129	5	26- 71-907-	3-900	0103	YES-	G					A	R							
1472	129	5	26- 71-907-	3-900	0104	YES-	G					A	R		F					
1473	129	5	26- 71-907-	3-900	0105	YES-	G					A	R							
1474	129	5	26- 71-907-	3-900	0106	YES-	G					A	R	M	F		F			
1475	129	5	26- 71-907-	3-900	0108	YES-	G					A	R							
1476	129	5	26- 71-907-	3-900	0109	YES-	G					A	R							
1477	129	5	26- 71-907-	3-900	0110	YES-	G					A			F		F			
1478	129	5	26- 53-907-	6-900	0111	YES-	G					A		MS	F	M				
1479	129	5	26- 71-907-	3-900	0112	YES-	G					A	R	M	FS	M	F			
1480	129	5	26- 71-907-	3-900	0113	YES-	G					A		M	FS	M	F			
1481	129	5	26- 71-907-	3-900	0114	YES-	G					A	R	MS	F	M				
1482	129	5	26- 71-907-	3-900	0115	YES-	G					A	R	M	F	M				
1483	129	5	26- 71-907-	3-900	0116	YES-	G					A	R	MS	F	M				
1484	129	5	26- 53-907-	6-900	0117	YES-	G					A	R	MS		M				
1485	129	5	26- 53-907-	6-900	0118	YES-	G					A		M	F					
1486	129	5	26- 53-907-	6-900	0119	YES-	G					A			F					
1487	129	5	26- 71-907-	3-900	0122	YES-	G					A	R	MS	F	M	F			
1488	129	5	26- 71-907-	3-900	0123	YES-	G					A	R	M	F					
1489	129	5	26- 71-907-	3-900	0124	YES-	G					A	R	MS	F					
1490	129	5	26- 71-907-	3-900	0125	YES-	G					A		MS	F	M	F			
1491	129	5	26- 71-907-	3-900	0126	YES-	G					A	R	M	F	M				
1492	129	5	26- 71-907-	3-900	0127	YES-	G					A	R							
1493	129	5	26- 71-907-	3-900	0128	YES-	G					A	R							
1494	129	5	26- 71-907-	3-900	0129	YES-	G					A			F		F			
1495	129	5	26- 71-907-	3-900	0130	YES-	G					A	R		F		F			
1496	129	5	26- 71-907-	3-900	0131	YES-	G					A		M	F	M	F			
1497	129	5	26- 71-907-	3-900	0132	YES-	G					A	R	M	F	M	F			
1498	129	5	26- 71-907-	3-900	0133	YES-	G					A	R							
1499	129	5	26- 71-907-	3-900	0134	YES-	G					A	R							
1500	129	5	26- 71-907-	3-900	0135	YES-	G					A	R							
1501	129	5	26- 71-907-	3-900	0136	YES-	G					A	R	MS		M				
1502	129	5	26- 71-907-	3-900	0138	YES-	G					A	R							
1503	129	5	26- 53-907-	6-900	0139	YES-	G					A								
1504	129	5	26- 53-907-	6-900	0140	YES-	G					A								
1505	129	5	26- 53-907-	6-900	0141	YES-	G					A		M	F	M				

SELECT TREE REGISTER BY FOREST, SPECIES, AND ACCESSION NUMBER
JUL 6, 1978

ACCESS NO.	SP EC	SEED ZONE	ST-CTY-NF/AGENCY-RANGER-ORIGINATOR	TREE NO.	AGE	HEIGHT TOT ME RCH (FEET)	DBH (IN)	STEM VOL (CU FT)	APC DOM (%)	% TOT HT	SUPERIOR MER HT	CF VOL	SEED CROP SEX	SEL OBJ 1 2	BTND	LIVE	LONGITUDE DEG MIN	LATITUDE DEG MIN	ELEVATION HDFT	YR SEL
1468	129	5	26-71-907-3-900	0100	56	61	16.0						1	6	1	YES				65
1469	129	5	26-71-907-3-900	0101	56	66	19.6						1	6	1	YES				66
1470	129	5	26-71-907-3-900	0102	45	52	12.9						1	6	1	YES				66
1471	129	5	26-71-907-3-900	0103	50	55	14.4						1	6	1	YES				66
1472	129	5	26-71-907-3-900	0104	45	47	12.4						1	6	1	YES				66
1473	129	5	26-71-907-3-900	0105	45	42	10.0						1	6	1	YES				66
1474	129	5	26-71-907-3-900	0106	45	44	10.9						1	6	1	YES				66
1475	129	5	26-71-907-3-900	0108	45	47	12.9						1	6	1	YES				66
1476	129	5	26-71-907-3-900	0109	45	46	12.8						1	6	1	YES				66
1477	129	5	26-71-907-3-900	0110	45	47	14.3						1	6	1	YES				66
1478	129	5	26-53-907-6-900	0111	52	54	13.9						1	6	1	YES				65
1479	129	5	26-71-907-3-900	0112	52	57	14.2						1	6	1	YES				66
1480	129	5	26-71-907-3-900	0113	50	55	13.6						1	6	1	YES				66
1481	129	5	26-71-907-3-900	0114	50	48	12.5						1	6	1	YES				66
1482	129	5	26-71-907-3-900	0115	50	52	11.1						1	6	1	YES				66
1483	129	5	26-71-907-3-900	0116	45	43	11.2						1	6	1	YES				66
1484	129	5	26-53-907-6-900	0117	76	68	14.4						1	6	1	YES				65
1485	129	5	26-53-907-6-900	0118	48	62	14.4						1	6	1	YES				65
1486	129	5	26-53-907-6-900	0119	45	53	12.1						1	6	1	YES				67
1487	129	5	26-71-907-3-900	0122	59	69	14.1						1	6	1	YES				65
1488	129	5	26-71-907-3-900	0123	56	63	13.3						1	6	1	YES				65
1489	129	5	26-71-907-3-900	0124	53	60	13.7						1	6	1	YES				65
1490	129	5	26-71-907-3-900	0125	65	65	16.8						1	6	1	YES				66
1491	129	5	26-71-907-3-900	0126	64	70	14.6						1	6	1	YES				66
1492	129	5	26-71-907-3-900	0127	58	66	12.5						1	6	1	YES				66

POLLINATION AND SEED COLLECTION RECORD 9/23/78

1--LOCATION		2--FEMALE DATA			3--MALE DATA			4--ISOLATION AND POLLINATION DATA								5--SEED DATA						
10	11 12	20	21	22 23	30	31	32	40	41	42	43	44	45	46	47	50	51	52	53	54	55	
SEED ORCH EVAL PLAN	NAT FOR STA IE	SEED ZONE	FEMALE PARENT NO.	POSIT G SPEC N	MALE FE= MALE	MALE PARENT NO.	G SPEC N	MALE	TYP ISO MAT	NO. ISO BAG APP	DATE ISO FEM M/DD	AGE OF ISO POL	YR POL	DATE POL M/DD	NO. POL COLL	NO. FLO CONE	SEED LOT NO.	GRAMS PER M SEED	NO. FULL SEED CONE	% GER	TOTAL WEIGHT SEED STOR	WEIGHT SEED MEM STOR
	907	19	0141	0	129	00000	0	129	1			9	68		6		5280	281	15.2	32		0.6	1.8
	907	19	0101	0	129	00000	0	129	1			9	66		18		5356	357	10.0	51		2.5	1.1
	907	19	0111	0	129	00000	0	129	1			9	66		31		5357	358	11.1	46	1	5.2	1.1
	907	19	0113	0	129	00000	0	129	1			9	66		39		5358	359	12.3	41	13	4.6	2.6
	907	19	0114	0	129	00000	0	129	1			9	66		36		5359	360	11.0	46		12.7	5.4
	907	19	0123	0	129	00000	0	129	1			9	66		27		5360	361	13.7	37		8.2	5.5
	907	19	0102	0	129	00000	0	129	1			9	69		7		5383	384	16.7	28		1.1	1.9
	907	19	0112	0	129	00002	0	129	4	11	6/14	0	69	7/01	50	15	5385	386	33.3	5		2.3	.4
	907	19	0118	0	129	00000	0	129	1			9	70			2	5429	430	24.4	41		2.0	
	907	19	0123	0	129	00002	0	129	4	6	6/14	0	70	6/21	23	5	5432	433	30.4	5		0.7	
	907	19	0125	0	129	00000	0	129	1			9	70			45	5433	434	25.0	31	2	15.1	1.4
	907	19	0126	0	129	00002	0	129	4	6	6/14	0	70	6/22	57	1	5435	436	19.0	21		0.3	.1
	907	19	0141	0	129	00002	0	129	4	3	6/16	0	70	6/22	30	1	5439	440	18.2	11		0.2	
	907	19	0141	0	129	00003	0	129	4	5	6/16	0	70	6/22	53	1	5440	441	18.2	11		0.2	
	907	19	0100	0	129	00000	0	129	1			9	66				5545	550	3.0			1.9	1.4
	907	19	0100	0	129	00002	0	129	3			0	66		51		5546	551	14.5	28		19.0	2.0
	907	19	0100	0	129	00003	0	129	3			0	66		58		5547	552	14.5	29		16.4	1.1
	907	16	0136	0	129	00000	0	129	1			9	73		34		6542	1250	20.0	35		21.1	2.4
	907	5	0117	0	129	00000	0	129	1			9	73		60		6544	1252	19.0	30		32.6	1.9
	907	16	0111	0	129	00000	0	129	1			9	73		58		6548	1256	16.0	20		15.9	2.4
	907	16	0124	0	129	00000	0	129	1			9	73		50		6551	1259	21.0	23		22.8	1.4
	907	5	0114	0	129	00000	0	129	1			9	73		60		6552	1260	15.0	15		8.7	1.3

CONES COLLECTED FROM TREE IN FOREST

USDA – FOREST SERVICE

POLLINATION AND SEED COLLECTION RECORD
(FSM-2470)

R9-2400-95
(4/1/80)

1. LOCATION

10. Seed Or. or Progeny Test No. (1-3) ___
11. National Forest Code (State) (4-6) 906
12. Seed Zone (7-9) 19

2. FEMALE Parent

20. Tree No. (10-15) N23
21. Position No. (16-20) ___
22. Generation (21) 0
23. Species (22-25) 129

3. MALE Parent

30. Tree No. (26-31) 000000
31. Generation (32) 0
32. Species (33-36) 129

4. ISOLATION and Pollination

40. Material (37) ___
41. No. Applied (38-39) ___
42. Date Isolated* (40-41) ___
43. Age of Pollen (42) 9

44. Year Pollinated (43-44) 76
45. Date Pollinated* (45-46) ___
46. No. of Flowers Pollinated (47-49) ___
47. No. of Cones Collected (50-53) 75

5. SEED DATA

50. Seed Lot No. (54-58) 1234
51. Container No. (59-62) 21
52. Grams/M Seed (63-66) 18.0
53. % Germination (67-68) ___
54. Total WT. of Seed in Storage (Grams) (69-73) 50.0
55. WT. of Seed Removed from Storage (G) (74-78) ___

56. Month (Letter) (79) A
57. 1 = New; 2 = Update (80) 1

* = Days from 1st Day of Month

APPENDIX E
140
Aug 80

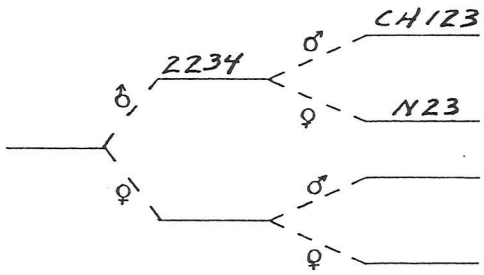
SEED AND POLLINATION RECORD

2 2 3 4
SEED LOT No.

WT. (G) IN STORAGE	WT. REMOVED	DATE	FOR OR TO (REMARKS)
48.0		10/1/77	
BALANCE			

CONTROLS: YES ☐ NO ☐
COLOR CODE

OTHER POLLEN: YES ☐ NO ☐



REMARKS:

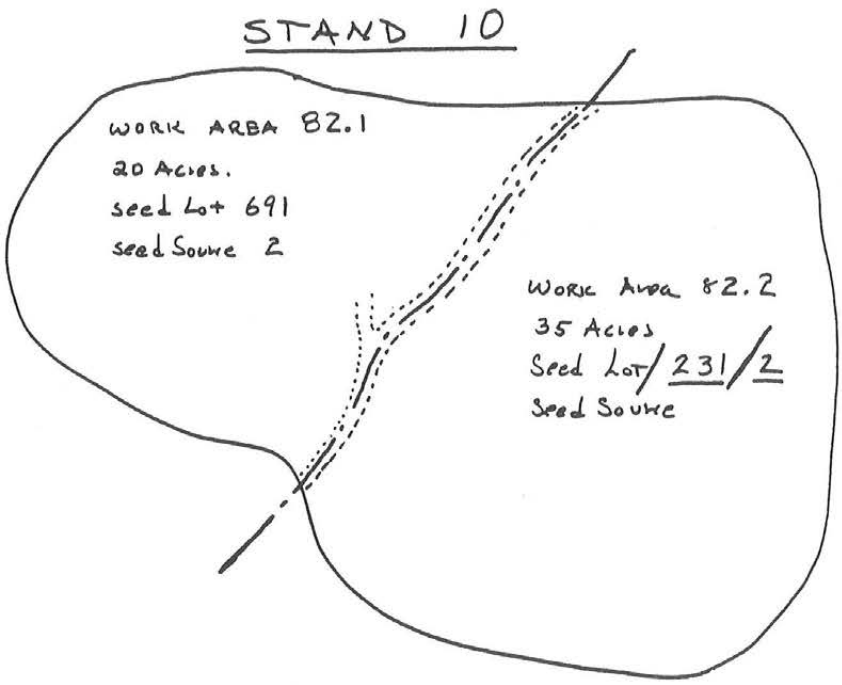
541

1442
Aug 80

EXAMPLE OF A PLANTATION MAP WITH TWO SEED LOTS.

FOREST 03
DISTRICT 02
Comp 126
STAND 10

1982 PLANTING OF
WHITE SPRUCE
3-0 STOCK



Seed Lot 691 from Taconey Nursery Seed Zone 3
Seed Lot 231 from Eveleth Nursery Seed Zone 2

H

TMIS-S2K
PLANNING & ACCOMPLISHMENT DOCUMENT

NAME: _____

DATE: _____

ACTIVITY & ACTION BLOCK

ACTIVITY ID					WORK AREA	ACTION CODE	COMPLETE
FOREST	DISTRICT	COMP NO.	STAND NO.	ACTIVITY			
03	02	126	010	4311	82.1	2	0
03	02	126	010	4311	82.2	2	1
1 2	3 4	5 6 7	8 9 10	11 12 13	14 15 16 17	18	19

"CRITICAL" COMPONENT FOR ACT., PLANNED, & ACCOMP. RQ

"CRITICAL" COMPONENT FOR BOTH PLANNED & ACCOMP. RQ.

PLANNED BLOCK

CARD CODE	FUND	F.Y.	ACRES	SPECIES	NO. PER ACRE	PRIORITY	METHOD	P ACTIVITY
1								
1								
1								
20	21 22	23 24	25 26 27	28 29 30	31 32	33	34 35 36	37 38 39

"CRITICAL" COMPONENTS FOR PLANNED RQ ONLY

ACCOMPLISHED BLOCK 1 of 2

CARD CODE	DATE	ACTIVITY	FUND	ACRES	COST/ACRE	METHOD	LUC	FS TYPE
2	823	4311	PM	020		100	500	91
2	823	4311	PM	035		100	500	91
2								
20	21 22 23	24 25 26	27 28	29 30 31	32 33 34	35 36 37	38 39 40	41 42

"CRITICAL" COMPONENTS FOR ACCOMP. RQ.

ACCOMPLISHED BLOCK 2 of 2

CONTRACT NO	SPECIES	NO PER ACRE	TYPE STOCK	SEED LOT	SEED SOURCE	PEST-ICIDE	PEST	CHEMICAL LBS/AC AI.	CONTROL %	% STOCK NG	DAMAGE
	094	06	1	0691	2						
	094	06	1	0231	2						
43 44 45 46	47 48 49	50 51	52	53 54 55 56	57	58 59 60	61 62 63	64 65 66	67 68	69 70	71 72 73

REMARKS: _____

(THESE WILL NOT BE STORED)

USDA-Forest Service FS-2400-15 (6/80)

I

R-9
ADP REQUEST FORM
FOREST TREE IMPROVEMENT

151t replace
151 JDM

DATA Attached:_____ DATA Previously Sent:_____ DATE SUBMITTED _____

SPECIES:_____ ORCHARD/PLANTATION NAME and NUMBER_____

NATIONAL FOREST_____ DISTRICT_____

ESTAB:_____ No. Families/Clones:_____ No. Reps:_____ No.Trees/Plot_____

TOTAL TREES:_____ TOTAL POSITIONS:_____ Name of Area:_____

DATE DATA COLLECTED:_____ NO. PAGES of DATA:_____

ITEMS	PROGRAM TITLE	OPTION	NO COPIES	REMARKS
BLANK	FORM	1		
STRAIGHT	FORM*	2		
CHANGE		3		
*w/Ht.DBH	YES NO	4		
I 6,7, 10,11,13 and 14	SUM 1	1		
		2		
	SUM 1A	1		
		2		
BR (YES)(NO) % ALSO (YES)(NO)				
ITEMS 8, 9 and 12	SUM 2	1		
		2		
	SUM 2A	1		
		2		
BR (YES)(NO) % ALSO (YES)(NO)				
I 15,18,19 20,24,25	SUM 3	1		
		2		
	SUM 3A	1		
		2		
ITEMS 22, 23 and 12	SUM 4	1*		
		2		
	SUM 4A	1		
		2		
	*BR	(YES)(NO)		
ITEMS 7, 19, and 10 plus volume*	SUM 5	1		
		2		
	SUM 5A	1		
		2		

PROGRAM TITLE	ITEM NO/ NAME	NO COPIES	REMARKS
MAP			
AV. or RAV OPTION			
WORK LIST			
CORR	X		
	X		
	X		
	X		

80/80 LIST

ORCHARD DESIGN: NO CLONES_____
NO. RAMETS LONG ROW_____
TOTAL NO.ROWS_____
1 or 2 isolations_____

* VOL = $D^2 * H$

CM x m. 0
IN x m. 1
CM x FT 2
IN x FT 3

OTHER_____

REMARKS_____

DATE: 122083 TIME: 135329

>@ASG,A R9TIPD.
READY
>

 @ELT,L R9TIPD.R9HYPD
ELT 9R1 S74Q1C 12/20/83 13:54:20 (0)
>@END

1.	00	998	1HYPD2AA001	30525011221213511771 3251 6150 0
2.	00	998	1HYPD2AA002	30475011221113312772 2751 8170 0
3.	00	998	1HYPD2AA003	30500011421213513771 3501 746030
4.	00	998	1HYPD2AA004	20450091421113114773 2501 534020
5.	00	998	1HYPD4AA005	1 1177 D
6.	00	998	1HYPD4AA006	20450063421113612772 3501 463050
7.	00	998	1HYPD4AA007	30600011221214813771 4001 2110 0
8.	00	998	1HYPD4AA008	30750011221216014771 4501 3120 0
9.	00	998	1HYPD6AA009	3035001122111 711774 3501 4130 0
10.	00	998	1HYPD6AA010	3025001722211 512775 2002 2110 0
11.	00	998	1HYPD6AA011	3030000831111 613774 2501 13 020
12.	00	998	1HYPD6AA012	3032501842111 614775 2751 322010
13.	00	998	1HYPD5AB001	30350011111112111772 3001 11 0 0
14.	00	998	1HYPD5AB002	30350011111112112773 2751 11 0 0
15.	00	998	1HYPD5AB003	30275011112111613774 2002 11 0 0
16.	00	998	1HYPD5AB004	20200065222121214774 1502 2110 0
17.	00	998	1HYPD1AB005	1 1177 D
18.	00	998	1HYPD1AB006	2015006222213 912775 1003 2110 0
19.	00	998	1HYPD1AB007	30200012112121213774 1503 11 0 0
20.	00	998	1HYPD1AB008	30250011112111514774 1752 11 0 0
21.	00	998	1HYPD3AB009	3017501111213 511774 1253 11 0 0
22.	00	998	1HYPD3AB010	3015005111213 412775 753 11 0 0
23.	00	998	1HYPD3AB011	3012507711213 413775 503 11 0 0
24.	00	998	1HYPD3AB012	3015001811213 414775 753 11 0 0
25.	00	998	2HYPD6AD001	3035001122111 721774 3501 2110 0
26.	00	998	2HYPD6AD002	3025002022211 522775 1752 3120 0
27.	00	998	2HYPD6AD003	3030001111111 623775 2001 11 0 0
28.	00	998	2HYPD6AD004	3032501122111 624775 2251 2110 0
29.	00	998	2HYPD2AD005	20475011111113321772 3001 11 0 0
30.	00	998	2HYPD2AD006	1 2277 D
31.	00	998	2HYPD2AD007	20475012221113323772 3001 6150 0
32.	00	998	2HYPD2AD008	30600011421214224771 3501 534020
33.	00	998	2HYPD1AD009	30250011112111521774 1752 11 0 0
34.	00	998	2HYPD1AD010	3015003611213 922775 1003 11 0 0
35.	00	998	2HYPD1AD011	30175014112131023774 1003 11 0 0
36.	00	998	2HYPD1AD012	30225014112121324774 1502 11 0 0
37.	00	998	2HYPD4AE001	30700011221215621771 4001 5140 0
38.	00	998	2HYPD4AE002	30800011411216422771 4501 665050
39.	00	998	2HYPD4AE003	30700011211215623771 3751 4130 0
40.	00	998	2HYPD4AE004	30675011111215424772 3501 11 0 0
41.	00	998	2HYPD3AE005	3020001111212 621773 1002 11 0 0

HYPO DATA BLANK DATA SHEETS
KEY IN DESCRIPTION,ETC.
DATE DATA COLLECTED / /
SHEET NO. 1

```
 2    3     4    6    7    8  9 10 11 12 13 14  15   16  18   19   20 21 22 23  24  25
REP: PLOT:POSIT:SU:HEIGHT:I :A : F:C_:B :LA:FR: HT :CUL:ST : DBH :NED:YR:  :  :   :   :
 NO:  NO :  NO :RV:GROWTH: &: &: L: P: R:HM:OS: TO :WO : EM:     :FOR:OF:  :  :   :   :
   :     :     :IV:METERS: D: M: D:  :  :AS: T:FORK: RK:FOM:     :REL:ES:  :  :   :   :
5-6: 7-11:12-16:22: 23-27:28:29:30:31:32:33:34:35-6:378: 41 :42-45:46:47:48:49:501:523:

   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
   :    :    : : . : : : : : : : : :   :  :  : . : : : : : : :
```

NEW DATA SHEET FROM EXISTING DATA FILE HYPO 998
LISTS DATA IN SAME ORDER AS IN FILE
THIS OPTION ALSO LISTS PREVIOUS DBH AND HEIGHT
SHEET NO. 1

```
 2    3     4    6    7    8  9 10 11 12 13 14  15   16  18   19   20 21 22 23  24  25
REP: PLOT:POSIT:SU:HEIGHT:I :A : F:C :B :LA:FR: HT :CUL:ST : DBH :NED:YR:  :  :   :   :
 NO:  NO :  NO :RV:GROWTH: &: &: L: R: R:HM:OS: TO :WO : EM:     :FOR:OF:  :  :   :   :
   :     :     :IV:METERS: D: M: O:  :  :AS: T:FORK: RK:FOM:     :REL:ES:  :  :   :   :OLD 7 :OLD19:
5-6: 7-11:12-16:22: 23-27:28:29:30:31:32:33:34:35-6:378: 41 :42-45:46:47:48:49:501:523:HEIGHT: DBH :

  1:HYP02:AA  1:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 5.250: 3.25:

  1:HYP02:AA  2:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 4.750: 2.75:

  1:HYP02:AA  3:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 5.000: 3.50:

  1:HYP02:AA  4:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 4.500: 2.50:

  1:HYP04:AA  5:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  : D:  :  :  :  ::  .000:  .00:

  1:HYP04:AA  6:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 4.500: 3.50:

  1:HYP04:AA  7:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 6.000: 4.00:

  1:HYP04:AA  8:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 7.500: 4.50:

  1:HYP06:AA  9:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 3.500: 3.50:

  1:HYP06:AA 10:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 2.500: 2.00:

  1:HYP06:AA 11:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 3.000: 2.50:

  1:HYP06:AA 12:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 3.250: 2.75:

  1:HYP05:AB  1:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 3.500: 3.00:

  1:HYP05:AB  2:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 3.500: 2.75:

  1:HYP05:AB  3:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 2.750: 2.00:

  1:HYP05:AB  4:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 2.000: 1.50:

  1:HYP01:AB  5:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  : D:  :  :  :  ::  .000:  .00:

  1:HYP01:AB  6:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 1.500: 1.00:

  1:HYP01:AB  7:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 2.000: 1.50:

  1:HYP01:AB  8:  :  .  :  :  :  :  :  :  :  :   :  :  :  .  :  :  :  :  :  :  :: 2.500: 1.75:
```

HYPO DATA PP3 SUMMARY 1 DP 1
LIST BY FAMILY
ITEMS 6,7,10,11,13, AND 14

CLONE OR FAM NO.	TR OR BL NO	NO. RAM OR SEED	SURVIVAL DEAD	SURVIVAL POOR GROW 2	SURVIVAL EXC GROW 3	SURVIVAL TEMP VAC 4	SURVIVAL PER VAC 5	CONT POLL NO 1	CONT POLL YES 2	FLOWERING NONE 1	FLOWERING FEM 2	FLOWERING MALE 3	FLOWERING BOTH 4	FROST DAMAGE NONE 1	FROST DAMAGE 2	FROST DAMAGE 3	LAMMAS GROW NO 1	LAMMAS GROW YES 2	HEIGHT (METERS) MEAN	HEIGHT (METERS) TALLEST	HEIGHT (METERS) SHORTEST	% OF TEST MEA
HYP01	4	16	1	1	14			14	1	13	1	1		2	7	6	15		1.933	2.500	1.000	55.
HYP02	4	16	1	5	9		1	8	6	5	5	1	3	14			6	8	5.054	6.250	4.250	145.
HYP03	4	16	1	4	11			15		14	1				1	14	15		1.467	2.000	1.000	42.
HYP04	4	16	1	2	13			5	10	3	8		4	15			1	14	6.517	8.000	4.500	187.
HYP05	4	16		2	13		1	13	2	12	2	1		13	2		15		2.983	3.500	2.000	85.
HYP06	4	16	1	3	12			5	10	2	9	3	1	15			15		3.050	3.500	2.500	87.
TOTAL		96	5	17	72		2	60	29	49	26	6	8	59	10	20	67	22	3.483	8.000	1.000	

HYPO DATA 998 SUMMARY 1 OF 1 IN PERCENT X 10
IE 75.3 PER = 753
ITEMS 6,7,10,11,13, AND 14

CLONE OR FAM NO.	TR OR BL NO	NO. RAN OR SEED	SURVIVAL DEAD	POOR GROW	EXC GROW	TEMP VAC	PER VAC	CONT POLL NO	CONT POLL YES	FLOWERING NONE	FEM	MALE	BOTH	FROST DAMAGE NONE			LAMMAS GROW NO	LAMMAS GROW YES	HEIGHT (METERS) MEAN	TALLEST	SHORTEST	% OF TEST MEAN
			1	2	3	4	5	1	2	1	2	3	4	1	2	3	1	2				
HYP01	4	16	62	62	875			933	66	866	66	66		133	466	400	1000		1.933	2.500	1.000	55.5
HYP02	4	16	62	312	562		62	571	428	357	357	71	214	1000			428	571	5.054	6.250	4.250	145.1
HYP03	4	16	62	250	687			1000		933	66				66	933	1000		1.467	2.000	1.000	42.1
HYP04	4	16	62	125	812			333	666	200	533		266	1000			66	933	6.517	8.000	4.500	187.1
HYP05	4	16		125	812		62	866	133	800	133	66		866	133		1000		2.983	3.500	2.000	85.7
HYP06	4	16	62	187	750			333	666	133	600	200	66	1000			1000		3.050	3.500	2.500	87.6
TOTAL		96	52	177	750		20	674	325	550	292	67	89	662	112	224	752	247	3.483	8.000	1.000	

HYPO DATA 998 SUMMARY 1 OF 2
LIST BY FAM BY BLOCK
ITEMS 6,7,10,11,13,AND 14

CLONE OR FAM NO.	TR: OR: BL: NO:	NO. RAM OR SEED:	SURVIVAL DEAD 1	POOR GROW 2	EXC GROW 3	TEMP VAC 4	PER VAC 5:	CONT POLL NO 1	CONT POLL YES 2:	FLOWERING NONE 1	FEM 2	MALE 3	BOTH 4:	FROST DAMAGE NONE 1	2	3:	LAMMAS GROW: NO 1	YES 2:	HEIGHT (METERS) MEAN	TALL EST	SHORT EST	% OF TEST MEAN
HYPO1	1	4	1	1	2			2	1	2	1			1	1	1	3		2.000	2.500	1.500	57.4
HYPO1	2	4			4			4		4				1	1	2	4		2.000	2.500	1.500	57.4
HYPO1	3	4			4			4		3		1			2	2	4		1.750	2.250	1.000	50.2
HYPO1	4	4			4			4		4					3	1	4		2.000	2.250	1.750	57.4
FAM		16	1	1	14			14	1	13	1	1		2	7	6	15		1.933	2.500	1.000	55.5
HYPO2	1	4		1	3				4		2		2	4			2	2	4.875	5.250	4.500	140.0
HYPO2	2	4	1	2	1			1	2	1	1		1	3			2	1	5.167	6.000	4.750	148.3
HYPO2	3	4		1	2		1	3			2	1		3			1	2	5.167	6.250	4.250	148.3
HYPO2	4	4		1	3			4		4				4			1	3	5.063	5.250	4.750	145.3
FAM		16	1	5	9		1	8	6	5	5	1	3	14			6	8	5.054	6.250	4.250	145.1
HYPO3	1	4			4			4		4						4	4		1.500	1.750	1.250	43.1
HYPO3	2	4	1	2	1			3		3					1	2	3		1.500	2.000	1.250	43.1
HYPO3	3	4		1	3			4		4						4	4		1.375	1.750	1.000	39.5
HYPO3	4	4		1	3			4		3	1					4	4		1.500	1.750	1.250	43.1
FAM		16	1	4	11			15		14	1				1	14	15		1.467	2.000	1.000	42.1
HYPO4	1	4	1	1	2				3		2		1	3			1	2	6.000	7.500	4.500	172.3
HYPO4	2	4			4			3	1	1	2		1	4				4	7.188	8.000	6.750	206.4
HYPO4	3	4			4			1	3	1	2		1	4				4	6.813	7.500	6.250	195.6
HYPO4	4	4		1	3			1	3	1	2		1	4				4	5.938	6.750	5.000	170.5
FAM		16	1	2	13			5	10	3	8		4	15			1	14	6.517	8.000	4.500	187.1

```
 D D
     ATA 998 SUMMARY 5 OP 1   COMPUTESD*D*H
THIS LIST INCLUDES HT IN FEET AND DBH IN CENT.
OTHER OPTIONS ARE H*C,H*I,F*C,AND F*I
```

CLONE: OR : FAM NO.	BLK : OR : REP NO.	HEIGHT NO.	HEIGHT MEAN	HEIGHT MAX	HEIGHT MIN	HEIGHT % OF ORCH MEAN	DBH NO.	DBH MEAN	DBH MAX	DBH MIN	DBH % OF ORCH MEAN	VOLUME NO.	VOLUME MEAN	VOLUME MAX	VOLUME MIN	VOLUME % OF ORCH MEAN	ITEM NO. 10 1	2	3	4
HYP01	TOTAL	15.	1.933	2.500	1.000	55.5	15.	1.40	2.00	1.00	57.8	15.				12.6	13	1	1	
HYP02	TOTAL	14.	5.054	6.250	4.250	145.1	14.	3.14	3.50	2.50	129.8	14.	.002	.002	.001	150.5	5	5	1	3
HYP03	TOTAL	15.	1.467	2.000	1.000	42.1	15.	.88	1.25	.50	36.5	15.				4.0	14	1		
HYP04	TOTAL	15.	6.517	8.000	4.500	187.1	15.	3.95	4.50	3.25	163.1	15.	.003	.005	.002	305.9	3	8		4
HYP05	TOTAL	15.	2.983	3.500	2.000	85.7	15.	2.43	3.00	1.50	100.5	15.	.001	.001		57.0	12	2	1	
HYP06	TOTAL	15.	3.050	3.500	2.500	87.6	15.	2.77	3.50	1.75	114.3	15.	.001	.001		73.4	2	9	3	1
ORCH	TOTAL	89.	3.483	8.000	1.000	100.0	89.	2.42	4.50	.50	100.0	89.	.001	.005		100.0	49	26	6	8

>

HYPO DATA 998 MAP OF FAMILIES OR CLONES
USING DATA FILE
1983

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
AA	HYP02	HYP02	HYP02	HYP02	HYP04	HYP04	HYP04	HYP04	HYP06	HYP06	HYP06	HYP06									
AB	HYP05	HYP05	HYP05	HYP05	HYP01	HYP01	HYP01	HYP01	HYP03	HYP03	HYP03	HYP03									
AC																					
AD	HYP06	HYP06	HYP06	HYP06	HYP02	HYP02	HYP02	HYP02	HYP01	HYP01	HYP01	HYP01									
AE	HYP04	HYP04	HYP04	HYP04	HYP03	HYP03	HYP03	HYP03	HYP05	HYP05	HYP05	HYP05									
AF																					
AG	HYP04	HYP04	HYP04	HYP04	HYP02	HYP02	HYP02	HYP02	HYP06	HYP06	HYP06	HYP06									
AH	HYP01	HYP01	HYP01	HYP01	HYP05	HYP05	HYP05	HYP05	HYP03	HYP03	HYP03	HYP03									
AI																					
AJ	HYP05	HYP05	HYP05	HYP05	HYP06	HYP06	HYP06	HYP06	HYP04	HYP04	HYP04	HYP04									
AK	HYP01	HYP01	HYP01	HYP01	HYP02	HYP02	HYP02	HYP02	HYP03	HYP03	HYP03	HYP03									
AL																					
AM																					
AN																					
AO																					
AP																					
AQ																					
AR																					
AS																					
AT																					
AU																					

HYPO DATA 998 SURVIVAL MAP
TREE NUMBERS = DEAD OR MISSING. PV = PERM VACANT
EXC= EXCELLENT GROWTH, FG = FAIR GROWTH

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
AA	EXG	EXG	EXG	FG	HYPO4	FG	EXG	EXG	EXG	EXG	EXG	EXG									
AB	EXG	EXG	EXG	FG	HYPO1	FG	EXG	EXG	EXG	EXG	EXG	EXG									
AC																					
AD	EXG	EXG	EXG	EXG	FG	HYPO2	FG	EXG	EXG	EXG	EXG	EXG									
AE	EXG	EXG	EXG	EXG	EXG	FG	HYPO3	FG	EXG	EXG	EXG	EXG									
AF																					
AG	EXG	EXG	EXG	EXG	EXG	EXG	FG	PV	FG	EXG	EXG	EXG									
AH	EXG	EXG	EXG	EXG	EXG	EXG	FG	PV	FG	EXG	EXG	EXG									
AI																					
AJ	EXG	EXG	EXG	EXG	HYPO6	EXG	FG	FG	FG	EXG	EXG	EXG									
AK	EXG	EXG	EXG	EXG	EXG	EXG	EXG	FG	FG	EXG	EXG	EXG									
AL																					
AM																					
AN																					
AO																					
AP																					
AQ																					
AR																					
AS																					
AT																					
AU																					

HYPO DATA 993 SURVIVAL WORKLIST
SURVIVAL CODES 1, 4, AND 5 LISTED
CODES 2 AND 3 NOT LISTED

CLONE OR FAM NO.	POSITION NO.	BLOCK NO.	TREATMENT CODE	SURVIVAL CODE	CONFLOWERING POLLEN	FROST DAMAGE	LAMINGROOVE DAMAGE	INSECT OR DISEASE DAMAGE	ANIMAL / MECHANICAL DAMAGE	BRANCH FORM	STEM FORM
HYP01	AB	5	1	11	1						
HYP02	AD	6	2	22	1						
HYP03	AE	7	2	23	1						
HYP04	AA	5	1	11	1						
HYP06	AJ	5	4	41	1						

>

REGION 9 - LAKE STATES

ALIAS TREE REGISTER

DATE RUN 10 JUNE 1982

NOTE: ALL CODES FOUND IN SELECT TREE REGISTER EXCEPT THOSE BELOW

ITEM 8-10 MATERIAL CODE 1ST AGENCY IS ORIGINATOR

R-9 MATERIAL TO OTHER	OTHER AGENCY TO R-9 OR OTHER
1 # SEED OR SEEDLINGS	6 # SEED OR SEEDLINGS
2 = CLONAL	7 # CLONAL
3 # BOTH SEED AND CLONAL	8 # BOTH SEED AND CLONAL
4 # POLLEN ONLY	9 # POLLEN ONLY
0 # SAME INFO AS MATERIAL CODE AT LEFT-FEMALE LEFT,MALE THIS	

ITEM 8-10 AGENCY CODES IN THIS LISTING

45 # POTLATCH	906 # NICOLET N F	
88 # UNIV WIS	960 # USFS NCFES RHINE	
500 = USFS REGION 5	902 # CHEQ N F	909 # SUPERIOR N F
600 # USFS REGION 6	903 # CHIP N F	910 # HIAWATHA N F
99 # INS PAPER CHEM	904 # HU-MAN N F	
	907 # OTTAWA N F	

ACC. NO.	SPEC	ST-- CTY- NF/AGY-DI	R-9 NO.	MATERIAL CODE-- AGENCY - AGENCY TREE NO.
1	2	3	7	8 / 9 / 10
XXXXX	XXXX	XX-XXX-XXX-XX	XXXXXX	X-XXX-XXXXXX / X-XXX-XXXXXX / X-XXX-XXXXXX
481	0094	55-003-902-02	CH 3	3-960- 2525 / - - / - -
685	0094	27-007-903-01	C 12	3-960- 2566 / - - / - -
	90	- - -	F2280	&7-960- 2280& / - - / & - - &
688	94	27- 7-903-01	C 24	&2-960- 8084& / - - / & - - &
691	94	27- 61-903-04	C 28	&2-960- 8076& / - - / & - - &
697	94	27- 61-903-05	C 37	&2-960- 8083& / - - / & - - &
694	94	27- 21-903-04	C 32	+2-960- 4885+ / - - / + - - +
704	94	27- 61-903-04	C 46	&2-960- 8086& / - - / & - - &
709	94	27- 7-903-01	C 55	&2-960- 9081& / - - / & - - &
712	94	27- 7-903-01	C 66	&2-960- 8078& / - - / & - - &
3286	94	27- 71-906-	F741	&7-960- 2511& / - - / & - - &
3287	94	55-115-906-	F742	&7-960- 1885& / - - / & - - &
3288	94	55-115-906-	F743	&7-960- 1886& / - - / & - - &
3289	94	55-115-906-	F744	&7-960- 1887& / - - / & - - &
3290	94	55-115-906-	F745	&7-960- 1888& / - - / & - - &
3291	94	55- 3-906-02	F746	&7-960- 1894& / - - / & - - &
3292	94	55-115-906-	F747	&7-960- 2517& / - - / & - - &
3293	94	55-115-906-	F748	&7-960- 2520& / - - / & - - &

HYPO DATA 998 SUMMARY 1 OP 1
LIST BY FAMILY
ITEMS 6,7,10,11,13, AND 14

CLONE OR FAM NO.	TR OR BL NO	NO. RAM OR SEED	SURVIVAL DEAD 1	POOR GROW 2	EXC GROW 3	TEMP VAC 4	PER VAC 5	CONT POLL NO 1	CONT POLL YES 2	FLOWERING NONE 1	FEM 2	MALE 3	BOTH 4	FROST DAMAGE NONE 1	2	3	LAMMAS GROW NO 1	YES 2	HEIGHT (METERS) MEAN	TALL EST	SHORT EST	% OF TEST MEAN
HYP01	4	16	1	1	14			14	1	13	1	1		2	7	6	15		1.933	2.500	1.000	55.5
HYP02	4	16	1	5	9		1	8	6	5	5	1	3	14			6	8	5.054	6.250	4.250	145.1
HYP03	4	16	1	4	11			15		14	1				1	14	15		1.467	2.000	1.000	42.1
HYP04	4	16	1	2	13			5	10	3	8		4	15			1	14	6.517	8.000	4.500	187.1
HYP05	4	16		2	13		1	13	2	12	2	1		13	2		15		2.983	3.500	2.000	85.7
HYP06	4	16	1	3	12			5	10	2	9	3	1	15			15		3.050	3.500	2.500	87.6
TOTAL		96	5	17	72		2	60	29	49	26	6	8	59	10	20	67	22	3.483	8.000	1.000	

HYPO DATA 998 SUMMARY 1 OP 1 IN PERCENT X 10
IE 75.3 PER = 753
ITEMS 6,7,10,11,13, AND 14

CLONE OR FAM NO.	TR OR BL NO:	NO. RAM OR SEED:	SURVIVAL DEAD 1	POOR GROW 2	EXC GROW 3	TEMP VAC 4	PER VAC 5:	CONT POLL NO 1	CONT POLL YES 2:	FLOWERING NONE 1	FLOWERING FEM 2	FLOWERING MALE 3	FLOWERING BOTH 4:	FROST DAMAGE NONE 1	FROST DAMAGE 2	FROST DAMAGE 3:	LAMMAS GROW: NO 1	LAMMAS GROW: YES 2:	HEIGHT (METERS) MEAN	HEIGHT (METERS) TALLEST	HEIGHT (METERS) SHORTEST	% OF TEST MEAN
HYP01	4	16	62	62	875			933	66	866	66	66		133	466	400	1000		1.933	2.500	1.000	55.5
HYP02	4	16	62	312	562		62	571	428	357	357	71	214	1000			428	571	5.054	6.250	4.250	145.1
HYP03	4	16	62	250	687			1000		933	66				66	933	1000		1.467	2.000	1.000	42.1
HYP04	4	16	62	125	812			333	666	200	533		266	1000			66	933	6.517	8.000	4.500	187.1
HYP05	4	16		125	812		62	866	133	800	133	66		866	133		1000		2.983	3.500	2.000	85.7
HYP06	4	16	62	187	750			333	666	133	600	200	66	1000			1000		3.050	3.500	2.500	87.6
TOTAL		96	52	177	750		20	674	325	550	292	67	89	662	112	224	752	247	3.483	8.000	1.000	

HYPO DATA 998 SURVIVAL WORLLIST
SURVIVAL CODES 1, 4, AND 5 LISTED
CODES 2 AND 3 NOT LISTED

CLONE OR FAM NO.	POSITION NO.	BLOCK NO.	TREATMENT CODE	SURV CODE	CONFLOWERING POL	FROSTING DAM	LAMGRO	INSECT OR DISEASE DAMAGE	ANIMAL / MECHANICAL	B R	STEM FORM
HYP01	AB	5	1	11	1						
HYP02	AD	6	2	22	1						
HYP03	AE	7	2	23	1						
HYP04	AA	5	1	11	1						
HYP06	AJ	5	4	41	1						

HYPO DATA 998 SUMMARY 1 OP 2
LIST BY FAM BY BLOCK
ITEMS 6,7,10,11,13,AND 14

CLONE OR FAM NO.	TR: OR: BL: NO:	NO. RAM OR SEED:	SURVIVAL DEAD 1	POOR GROW 2	EXC GROW 3	TEMP VAC 4	PER VAC: 5	CONT POLL NO 1	CONT POLL YES 2:	FLOWERING NONE 1	FEM 2	MALE 3	BOTH: 4	FROST DAMAGE NONE 1	2	3:	LAMMAS GROW: NO 1	YES 2:	HEIGHT (METERS) MEAN	TALL EST	SHORT EST	% OF TEST MEAN
HYPO1	1	4	1	1	2			2	1	2	1			1	1	1	3		2.000	2.500	1.500	57.4
HYPO1	2	4			4			4		4				1	1	2	4		2.000	2.500	1.500	57.4
HYPO1	3	4			4			4		3		1			2	2	4		1.750	2.250	1.000	50.2
HYPO1	4	4			4			4		4					3	1	4		2.000	2.250	1.750	57.4
FAM		16	1	1	14			14	1	13	1	1		2	7	6	15		1.933	2.500	1.000	55.5
HYPO2	1	4		1	3				4		2		2	4			2	2	4.875	5.250	4.500	140.0
HYPO2	2	4	1	2	1			1	2	1	1		1	3			2	1	5.167	6.000	4.750	148.3
HYPO2	3	4		1	2		1	3			2	1		3			1	2	5.167	6.250	4.250	148.3
HYPO2	4	4		1	3			4		4				4			1	3	5.063	5.250	4.750	145.3
FAM		16	1	5	9		1	8	6	5	5	1	3	14			6	8	5.054	6.250	4.250	145.1
HYPO3	1	4			4			4		4						4	4		1.500	1.750	1.250	43.1
HYPO3	2	4	1	2	1			3		3					1	2	3		1.500	2.000	1.250	43.1
HYPO3	3	4		1	3			4		4						4	4		1.375	1.750	1.000	39.5
HYPO3	4	4		1	3			4		3	1					4	4		1.500	1.750	1.250	43.1
FAM		16	1	4	11			15		14	1				1	14	15		1.467	2.000	1.000	42.1
HYPO4	1	4	1	1	2				3		2		1	3			1	2	6.000	7.500	4.500	172.3
HYPO4	2	4			4			3	1	1	2		1	4				4	7.188	8.000	6.750	206.4
HYPO4	3	4			4			1	3	1	2		1	4				4	6.813	7.500	6.250	195.6
HYPO4	4	4		1	3			1	3	1	2		1	4				4	5.938	6.750	5.000	170.5
FAM		16	1	2	13			5	11	3	8		4	15			1	14	6.517	8.000	4.500	187.1

DATA 998 SUMMARY 5 OP 1 COMPUTESD*D*H
THIS LIST INCLUDES HT IN FEET AND DBH IN CENT.
OTHER OPTIONS ARE N*C,M*I,F*C,AND F*I

CLONE: OR : FAM NO.	BLK : OR : REP NO.	HEIGHT NO.	HEIGHT MEAN	HEIGHT MAX	HEIGHT MIN	HEIGHT % OF ORCH MEAN	DBH NO.	DBH MEAN	DBH MAX	DBH MIN	DBH % OF ORCH MEAN	VOLUME NO.	VOLUME MEAN	VOLUME MAX	VOLUME MIN	VOLUME % OF ORCH MEAN	ITEM NO. 10 1:	2:	3:	4:
HYP01	TOTAL	15.	1.933	2.500	1.000	55.5	15.	1.40	2.00	1.00	57.8	15.				12.6	13	1	1	
HYP02	TOTAL	14.	5.054	6.250	4.250	145.1	14.	3.14	3.50	2.50	129.8	14.	.002	.002	.001	150.5	5	5	1	3
HYP03	TOTAL	15.	1.467	2.000	1.000	42.1	15.	.88	1.25	.50	36.5	15.				4.0	14	1		
HYP04	TOTAL	15.	6.517	8.000	4.500	187.1	15.	3.95	4.50	3.25	163.1	15.	.003	.005	.002	305.9	3	8		4
HYP05	TOTAL	15.	2.983	3.500	2.000	85.7	15.	2.43	3.00	1.50	100.5	15.	.001	.001		57.0	12	2	1	
HYP06	TOTAL	15.	3.050	3.500	2.500	87.6	15.	2.77	3.50	1.75	114.3	15.	.001	.001		73.4	2	9	3	1
ORCH	TOTAL	89.	3.483	8.000	1.000	100.0	89.	2.42	4.50	.50	100.0	89.	.001	.005		100.0	49	26	6	8

HYPO DATA 998 MAP OF FAMILIES OR CLONES
USING DATA FILE
1983

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
AA	HYP02	HYP02	HYP02	HYP02	HYP04	HYP04	HYP04	HYP04	HYP06	HYP06	HYP06	HYP06									
AB	HYP05	HYP05	HYP05	HYP05	HYP01	HYP01	HYP01	HYP01	HYP03	HYP03	HYP03	HYP03									
AC																					
AD	HYP06	HYP06	HYP06	HYP06	HYP02	HYP02	HYP02	HYP02	HYP01	HYP01	HYP01	HYP01									
AE	HYP04	HYP04	HYP04	HYP04	HYP03	HYP03	HYP03	HYP03	HYP05	HYP05	HYP05	HYP05									
AF																					
AG	HYP04	HYP04	HYP04	HYP04	HYP02	HYP02	HYP02	HYP02	HYP06	HYP06	HYP06	HYP06									
AH	HYP01	HYP01	HYP01	HYP01	HYP05	HYP05	HYP05	HYP05	HYP03	HYP03	HYP03	HYP03									
AI																					
AJ	HYP05	HYP05	HYP05	HYP05	HYP06	HYP06	HYP06	HYP06	HYP04	HYP04	HYP04	HYP04									
AK	HYP01	HYP01	HYP01	HYP01	HYP02	HYP02	HYP02	HYP02	HYP03	HYP03	HYP03	HYP03									
AL																					
AM																					
AN																					
AO																					
AP																					
AQ																					
AR																					
AS																					
AT																					
AU																					

HYPO DATA 998 SURVIVAL MAP
TREE NUMBERS = DEAD OR MISSING, PV = PERM VACANT
EXC= EXCELLENT GROWTH, FG = FAIR GROWTH

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
AA	EXG	EXG	EXG	FG	HYPO4	FG	EXG	EXG	EXG	EXG	EXG	EXG									
AB	EXG	EXG	EXG	FG	HYPO1	FG	EXG	EXG	EXG	EXG	EXG	EXG									
AC																					
AD	EXG	EXG	EXG	EXG	FG	HYPO2	FG	EXG	EXG	EXG	EXG	EXG									
AE	EXG	EXG	EXG	EXG	EXG	FG	HYPO3	FG	EXG	EXG	EXG	EXG									
AF																					
AG	EXG	EXG	EXG	EXG	EXG	EXG	FG	PV	FG	EXG	EXG	EXG									
AH	EXG	EXG	EXG	EXG	EXG	EXG	FG	PV	FG	EXG	EXG	EXG									
AI																					
AJ	EXG	EXG	EXG	EXG	HYPO6	EXG	FG	FG	FG	EXG	EXG	EXG									
AK	EXG	EXG	EXG	EXG	EXG	EXG	EXG	FG	FG	EXG	EXG	EXG									
AL																					
AM																					
AN																					
AO																					
AP																					
AQ																					
AR																					
AS																					
AT																					
AU																					

```
NEW DATA SHEET FROM EXISTING DATA FILE HYPO 998
LISTS DATA IN SAME ORDER AS IN FILE
THIS OPTION ALSO LISTS PREVIOUS DBH AND HEIGHT
SHEET NO.   1
 2    3     4    6    7    8  9 10 11 12 13 14  15   16  18   19   20 21 22 23  24  25
REP: PLOT:POSIT:SU:HEIGHT:I :A : F:C :B :LA:FR: HT :CUL:ST : DBH :NED:YR:  :  :   :   :
 NO:  NO :  NO :RV:GROWTH: &: &: L: P: R:MM:OS: TO :WO : EM:     :FOR:OF:  :  :   :   :
   :     :     :IV:METERS: D: M: O:  :  :AS: T:FORK: RK:FOM:     :REL:ES:  :  :   :   :OLD 7 :OLD19:
5-6: 7-11:12-16:22: 23-27:28:29:30:31:32:33:34:35-6:378: 41 :42-45:46:47:48:49:501:523:HEIGHT: DBH :

  1:HYPO2:AA  1:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 5.250: 3.25:

  1:HYPO2:AA  2:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 4.750: 2.75:

  1:HYPO2:AA  3:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 5.000: 3.50:

  1:HYPO2:AA  4:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 4.500: 2.50:

  1:HYPO4:AA  5:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  : D:  :  :  :   ::  .000:  .00:

  1:HYPO4:AA  6:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 4.500: 3.50:

  1:HYPO4:AA  7:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 6.000: 4.00:

  1:HYPO4:AA  8:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 7.500: 4.50:

  1:HYPO6:AA  9:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 3.500: 3.50:

  1:HYPO6:AA 10:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 2.500: 2.00:

  1:HYPO6:AA 11:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 3.000: 2.50:

  1:HYPO6:AA 12:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 3.250: 2.75:

  1:HYPO5:AB  1:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 3.500: 3.00:

  1:HYPO5:AB  2:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 3.500: 2.75:

  1:HYPO5:AB  3:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 2.750: 2.00:

  1:HYPO5:AB  4:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 2.000: 1.50:

  1:HYPO1:AB  5:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  : D:  :  :  :   ::  .000:  .00:

  1:HYPO1:AB  6:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 1.500: 1.00:

  1:HYPO1:AB  7:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 2.000: 1.50:

  1:HYPO1:AB  8:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 2.500: 1.75:

  1:HYPO3:AB  9:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 1.750: 1.25:

  1:HYPO3:AB 10:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 1.500:  .75:

  1:HYPO3:AB 11:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 1.250:  .50:

  1:HYPO3:AB 12:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 1.500:  .75:

NEW DATA SHEET FROM EXISTING DATA FILE HYPO 998
LISTS DATA IN SAME ORDER AS IN FILE
THIS OPTION ALSO LISTS PREVIOUS DBH AND HEIGHT
SHEET NO.   2
 2    3     4    6    7    8  9 10 11 12 13 14  15   16  18   19   20 21 22 23  24  25
REP: PLOT:POSIT:SU:HEIGHT:I :A : F:C :B :LA:FR: HT :CUL:ST : DBH :NED:YR:  :  :   :   :
 NO:  NO :  NO :RV:GROWTH: &: &: L: P: R:MM:OS: TO :WO : EM:     :FOR:OF:  :  :   :   :
   :     :     :IV:METERS: D: M: O:  :  :AS: T:FORK: RK:FOM:     :REL:ES:  :  :   :   :OLD 7 :OLD19:
5-6: 7-11:12-16:22: 23-27:28:29:30:31:32:33:34:35-6:378: 41 :42-45:46:47:48:49:501:523:HEIGHT: DBH :

  2:HYPO6:AB  1:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 3.500: 3.50:

  2:HYPO6:AB  2:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 2.500: 1.75:

  2:HYPO6:AB  3:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 3.000: 2.00:

  2:HYPO6:AB  4:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 3.250: 2.25:

  2:HYPO2:AD  5:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 4.750: 3.00:
* OUTPUT INTERRUPTED *
@@X

  2:HYPO2:AD  6:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  : D:  :  :  :   ::  .000:  .00:

  2:HYPO2:AD  7:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 4.750: 3.00:

  2:HYPO2:AD  8:  :  .  :  :  :  :  :  :  :  :    :  :  :  .  :  :  :  :  :  :   :: 5.000: 3.50:
* OUTPUT INTERRUPTED *
@@X
```

HYPO DATA BLANK DATA SHEETS
KEY IN DESCRIPTION,ETC.
DATE DATA COLLECTED / /
SHEET NO. 1

```
 2    3     4    6    7    8  9 10 11 12 13 14  15   16  18   19   20 21 22 23  24  25
REP: PLOT:POSIT:SU:HEIGHT:I :A : F:C :B :LA:FR: HT :CUL:ST : DBH :NED:YR:  :  :   :   :
 NO:  NO :  NO :RV:GROWTH: &: &: L: P: R:MM:OS: TO :WO : EM:     :FOR:OF:  :  :   :   :
   :     :     :IV:METERS: D: M: O:  :  :AS: T:FORK: RK:FOM:     :REL:ES:  :  :   :   :
5-6: 7-11:12-16:22: 23-27:28:29:30:31:32:33:34:35-6:378: 41 :42-45:46:47:48:49:501:523:
```

```
 @ELY,IL R9TIPD.R9HYPO
PROGRAM NOT FOUND
>@ELT,L R9TIPD.R9HYPO
ELT 8R1 S74Q1C 01/06/84 07:41:47 (0)
>@END
```

1.	00	998	1HYP02AA001	30525011221213511771	3251	6150	0	
2.	00	998	1HYP02AA002	30475011221113312772	2751	8170	0	
3.	00	998	1HYP02AA003	30500011421213513771	3501	746030		
4.	00	998	1HYP02AA004	20450091421113114773	2501	534020		
5.	00	998	1HYP04AA005	1	1177	D		
6.	00	998	1HYP04AA006	20450063421113612772	3501	463050		
7.	00	998	1HYP04AA007	30600011221214813771	4001	2110	0	
8.	00	998	1HYP04AA008	30750011221216014771	4501	3120	0	
9.	00	998	1HYP06AA009	3035001122111 711774	3501	4130	0	
10.	00	998	1HYP06AA010	3025001722211 512775	2002	2110	0	
11.	00	998	1HYP06AA011	3030000831111 613774	2501	13	020	
12.	00	998	1HYP06AA012	3032501842111 614775	2751	322010		
13.	00	998	1HYP05AB001	30350011111112111772	3001	11	0	0
14.	00	998	1HYP05AB002	30350011111112112773	2751	11	0	0
15.	00	998	1HYP05AB003	30275011112111613774	2002	11	0	0
16.	00	998	1HYP05AB004	20200065222121214774	1502	2110	0	
17.	00	998	1HYP01AB005	1	1177	D		
18.	00	998	1HYP01AB006	2015006222213 912775	1003	2110	0	
19.	00	998	1HYP01AB007	30200012112121213774	1503	11	0	0
20.	00	998	1HYP01AB008	30250011112111514774	1752	11	0	0
21.	00	998	1HYP03AB009	3017501111213 511774	1253	11	0	0
22.	00	998	1HYP03AB010	3015005111213 412775	753	11	0	0
23.	00	998	1HYP03AB011	3012507711213 413775	503	11	0	0
24.	00	998	1HYP03AB012	3015001811213 414775	753	11	0	0
25.	00	998	2HYP06AD001	3035001122111 721774	3501	2110	0	
26.	00	998	2HYP06AD002	3025002022211 522775	1752	3120	0	
27.	00	998	2HYP06AD003	3030001111111 623775	2001	11	0	0
28.	00	998	2HYP06AD004	3032501122111 624775	2251	2110	0	
29.	00	998	2HYP02AD005	20475011111113321772	3001	11	0	0
30.	00	998	2HYP02AD006	1	2277	D		
31.	00	998	2HYP02AD007	20475012221113323772	3001	6150	0	
32.	00	998	2HYP02AD008	30600011421214224771	3501	534020		
33.	00	998	2HYP01AD009	30250011112111521774	1752	11	0	0
34.	00	998	2HYP01AD010	3015003611213 922775	1003	11	0	0
35.	00	998	2HYP01AD011	30175014112131023774	1003	11	0	0
36.	00	998	2HYP01AD012	30225014112121324774	1502	11	0	0
37.	00	998	2HYP04AE001	30700011221215621771	4001	5140	0	
38.	00	998	2HYP04AE002	30800011411216422771	4501	665050		
39.	00	998	2HYP04AE003	30700011211215623771	3751	4130	0	
40.	00	998	2HYP04AE004	30675011111215424772	3501	11	0	0
41.	00	998	2HYP03AE005	3020001111212 621773	1002	11	0	0
42.	00	998	2HYP03AE006	2012503311213 422775	753	11	0	0
43.	00	998	2HYP03AE007	1	2377	D		
44.	00	998	2HYP03AE008	2012503911213 424775	503	11	0	0
45.	00	998	2HYP05AE009	30250048112111521774	2002	11	0	0
46.	00	998	2HYP05AE010	30350011111112122772	3001	11	0	0
47.	00	998	2HYP05AE011	30325011111111923773	2751	11	0	0
48.	00	998	2HYP05AE012	30350011111112124773	2751	11	0	0
49.	00	998	3HYP04AG001	30650011111215231771	3501	11	0	0
50.	00	998	3HYP04AG002	30700011221215632771	4001	3120	0	
51.	00	998	3HYP04AG003	30750011221216033771	4251	4130	0	
52.	00	998	3HYP04AG004	30625011421215034772	3251	473060		
53.	00	998	3HYP02AG005	30625011211214331771	3501	7160	0	
54.	00	998	3HYP02AG006	30500011211213532771	3001	9180	0	
55.	00	998	3HYP02AG007	20425013311112933772	2751	14	030	
56.	00	998	3HYP02AG008	5	3477	D		
57.	00	998	3HYP06AG009	2025001531211 531775	2752	14	030	
58.	00	998	3HYP06AG010	3030001131111 632775	3001	13	020	
59.	00	998	3HYP06AG011	3035001122111 733774	3251	3120	0	
60.	00	998	3HYP06AG012	3032501122111 634773	3251	4130	0	
61.	00	998	3HYP01AH001	3010008511213 631775	1003	11	0	0
62.	00	998	3HYP01AH002	30200033112121232774	1252	11	0	0
63.	00	998	3HYP01AH003	30225011112121333774	1502	11	0	0
64.	00	998	3HYP01AH004	30175011312131034775	1003	12	010	
65.	00	998	3HYP05AH005	30275011112111631773	2002	11	0	0
66.	00	998	3HYP05AH006	30300911112121332774	2502	11	0	0
67.	00	998	3HYP03AH009	2010003211213 331775	503	11	0	0
70.	00	998	3HYP03AH010	3012503011213 432775	753	11	0	0
71.	00	998	3HYP03AH011	3017501111213 533774	1253	11	0	0
72.	00	998	3HYP03AH012	3015001111213 434773	1003	11	0	0
73.	00	998	4HYP05AJ001	30325011111111941773	2751	11	0	0
74.	00	998	4HYP05AJ002	30350011311112142772	3001	12	010	
75.	00	998	4HYP05AJ003	30275011222111643773	2752	2110	0	
76.	00	998	4HYP05AJ004	30275011112111644773	2502	11	0	0
77.	00	998	4HYP06AJ005	1	4177	D		
78.	00	998	4HYP06AJ006	3035001122111 742774	3251	3120	0	
79.	00	998	4HYP06AJ007	2027501122211 543775	3002	2110	0	
80.	00	998	4HYP06AJ008	2027501111211 544775	2752	11	0	0
81.	00	998	4HYP04AJ009	20500013111214041772	3751	11	0	0
82.	00	998	4HYP04AJ010	30575011221214642771	4001	4130	0	
83.	00	998	4HYP04AJ011	30625011221215043771	4251	4130	0	
84.	00	998	4HYP04AJ012	30675061421215444771	4501	675060		
85.	00	998	4HYP01AK001	30200071112121241775	1752	11	0	0
86.	00	998	4HYP01AK002	30225011112121342774	2002	11	0	0
87.	00	998	4HYP01AK003	30175039112131043774	1253	11	0	0
88.	00	998	4HYP01AK004	30200011112121244774	1752	11	0	0
89.	00	998	4HYP02AK005	30500011111213541772	3251	11	0	0
90.	00	998	4HYP02AK006	30525011111213642771	3501	11	0	0
91.	00	998	4HYP02AK007	30525011111213643772	3501	11	0	0
92.	00	998	4HYP02AK008	20475011111113344774	3001	11	0	0
93.	00	998	4HYP03AK009	2012503511213 441775	753	11	0	0
94.	00	998	4HYP03AK010	3015004111213 442775	1003	11	0	0
95.	00	998	4HYP03AK011	3015001111213 443775	1253	11	0	0
96.	00	998	4HYP03AK012	3017501121213 544775	1253	2110	0	

STRATEGIES FOR MAINTAINING THE GENETIC BASE. HOW WILL ADVANCED GENERATION TESTS DIFFER FROM FIRST.

by

J. P. van Buijtenen[1/]

Objectives

For the purpose of this discussion, we need to focus on only part of the objectives of advanced generation breeding. The objectives of interest are: 1) maximizing the immediate rate of progress; 2) maximizing the long-term rate of progress; and 3) managing inbreeding.

The first two objectives are in direct conflict with each other and a reasonable compromise needs to be made. In order to maximize the rate of progress, one should have as high a selection differential as possible. This means selecting as few individuals as possible. To maximize the long-term rate of progress, one wants to do just the opposite and select as many individuals as possible. Obviously one cannot do both at the same time and one has to arrive at the number of selections that will give a satisfactory immediate rate of progress without unduly limiting the long-term rate of progress.

Key Concepts

Before delving into the meat of the topic, it may be well to focus on a few key concepts. In order to maintain a continuing breeding program, one has to regenerate the same number of trees each generation. This will, of course, not work out in practice, but in designing a theoretically sound system this is a logical simplifying assumption.

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One needs to distinguish clearly between the breeding populations (the parents one crosses to produce the next generation), the production population (the seed orchard), and the operational plantations which results from the seed orchards and which are the final product of the whole program.

Inbreeding can be tolerated or even be used to good advantage in the breeding population and the production population. However, the operational plantings should be the result of outcrossing.

The above objectives can be achieved by subdividing the breeding population into breeding groups or sublines. All crossing for breeding purposes will be done within each breeding group, causing them to become inbred over a period of time. In the seed orchard, however, the genotypes will be arranged in such a way that the seed will be outcrossed. The resulting seedlings will be used to establish operational plantings. By means of a co-ancestry matrix, one can keep track of inbreeding. It is also possible to maintain a desired rate of inbreeding (within the feasible limits) by judiciously choosing the crosses to be made. It is somewhat difficult to visualize co-ancestry relations, since one has to go back two generations, but the method lends itself very well to computer manipulation and programs are available that will do the job.

Implementation

At the current state of the art, the breeding cycle is about 16 years as shown in Table I. The first generation took us about 24 years, but with what we have learned we feel that for the following generation we can reduce it to 16 years.

Table I. Sixteen Year Breeding Cycle

Year	Activity
1-3	Selection and grafting
6-8	Control-pollination program
10	Plant seed in nursery
11	Plant seedlings in field
16	Make next generation selections

We are planning to use a complementary mating design as a crossing scheme. One set of crosses will be made using a polymix. We currently are conducting some studies to determine the best pollen mixture to use, and how many pollen parents might be needed. The second set of crosses will be a partial diallel very similar to the scheme we are using now for our first generation selections.

One of the best ways to assure long-term progress is to start with a large breeding population. We have asked each cooperator to contribute 100 trees for each orchard, which will form four breeding groups. Since we can, however, pool many orchards into one breeding population, the actual breeding population is more nearly 500 to 1,000 trees depending on the region. We have well over 3,000 trees in the program now, but they cannot all be considered one breeding population.

For the purpose of field testing the advanced generation seedlings, we are thinking of a somewhat unusual arrangement. The field design for the polymix will be identical to the one currently used for all our progeny tests, i.e. 12 reps of 6 tree row plots replicated on three locations. These tests will provide gca information and will determine which families are selected.

The partial diallels will be used for within family selection. They will be planted at two locations. Each location will consist of one rep of

49-tree square plots.

At the end of five years, or possibly ten for slow growing tests, we'll make selections. Currently we plan to select the four best trees from the six best families within a breeding group. These will be used to regenerate a new set of crosses. The best few trees from each breeding group will go into a seed orchard. The seed orchard will be divided into ten clone blocks as our current orchards, but each clone within a block will be from a different breeding group. Different blocks in the orchard can have different clones from the same breeding group, but the same position in the block will be kept for the breeding group to assure proper separation at block boundaries.

Accelerated Breeding

Sixteen years is still a very long period for a cycle and much effort is being expended on accelerated breeding studies. Breeding can be speeded up in two ways: by shortening the time needed to produce seed, and by shortening the period needed for testing. Some of our industrial members have been extremely successful in reducing the time to flowering in their acceleration facilities. By utilizing water stress treatments, gibberellins, wire girdling, and out of phase dormancy, they have been able to complete their breeding in five years. This is a saving of five years on the 16 year cycle.

Early testing is another area which we are investigating thoroughly and implementing in some cases. There are a number of traits that can be utilized right now for early testing such as stress testing, testing for rust resistance at the USDA Resistance Screening Center at Asheville, N.C., testing for brown spot resistance in longleaf, and breaking out of the gas stage early in longleaf. Testing for growth rate at an early age is more

difficult, but promising results are being obtained in that area as well. So far total shoot weight has been most indicative of growth potential.

Progeny Testing Strategies

The concept of accelerated breeding has made us rethink our strategy for progeny testing completely. Means need to be found to incorporate early tests, short-term field tests, and rotation-age field tests in one system. A step-wise screening procedure might satisfy these requirements. One could, for instance, start by screening 500 families in a stress test. The 250 best families might then be selected for submission to a rust resistance test. The 100 best families in this test might be put in a five year field test. At the end of five years, new selections could be made in this test. These selections would be put into a scion bank, accelerated breeding facility, and/or seed orchard. The families from which the selections are made would be put in a long-term field test to be carried out to rotation age. In addition it would be desirable to have seed orchard mixes and appropriate controls planted in operational tests.

I can foresee that accelerated breeding might progress to the point where we might want to try making two or three rapid breeding cycles without field testing. The step-wise screening procedure would provide an easy way to feed this material back into the main-line program through short-term and long-term field tests. Everything that is in a seed orchard should be evaluated in a rotation-length test.

The use of proper controls in all these tests is extremely important. They should be chosen in such a way that the progress made at each step in the screening process can be measured. This is essential if one is to evaluate the selection methods. In the example given above there should be a checklot composed of a few seeds of all 500 original trees, a checklot of

the 250 trees that passed the stress test, and a checklot of the 100 families that passed the rust resistance test. This would give a direct measurement of the effectiveness of each of the procedures. Similarly it would be very valuable to have checklots composed of an unrogued first generation mix, a rogued first generation mix, unrogued second generation mix, etc. In the first generation tests we were not nearly critical enough in choosing controls. For those of you still involved in first generation selection programs, this is an important point to consider.

Some very rapid changes are taking place in the field of genetics, most of which have not impacted tree improvement yet. The previous discussion is limited to conventional approaches, but the general framework developed gives the flexibility to incorporate new technology such as the generation of new genetic variation through tissue culture or genetic engineering as it becomes available.

Conclusions

In advanced generation breeding it is important to distinguish between the breeding population, production population and the operational plantations resulting from the orchards. By subdividing the breeding population into breeding groups, inbreeding can be manipulated in the breeding and production populations, but avoided in the operational plantings.

A complementary mating design can be used for progeny testing and breeding, using the breeding group structure. A polycross is used to estimate general combining ability, while a disconnected partial diallel is used to develop the populations from which selections will be made.

Flexibility needs to be maintained in an advanced generation breeding program to incorporate new strategies in accelerated breeding and early testing. Step-wise screening is advocated as a means of creating a flexible

system that will incorporate both conventional testing and breeding and accelerated breeding procedures. It would even be possible to conduct two or three breeding cycles before field testing and incorporate materials developed through high-technology approaches.

PEST CONDITIONS IN REGION 8 PINE PROGENY TESTS

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ABSTRACT

Damage surveys of 33 pine progeny tests in Region 8 revealed that reproduction weevils were responsible for the most serious pest-caused loss. Man-caused damage (planting method, release work) was severe in many tests. Pests occurring at low levels but having the potential to interfere with accurate progeny test evaluations under outbreak conditions include stem rusts, pitch canker disease, root disease, animals, white pine weevil, tip moths, and sawflies. Of these, opportunities for genetic improvement in host resistance exist for stem rusts and pitch canker disease. The remaining pests were infrequent finds or caused slight or unnoticeable damage, in spite of wide distribution and high incidence.

Current practices are largely adequate to control serious damage, though recommendations are given for modification of nursery practices, test maintenance, site selection, and test evaluation.

Relative resistance to forest tree pests is important information to consider in any comprehensive evaluation of genetically improved stock used in progeny tests. For certain pests, some damage may actually be desirable, adding another element to the process of winnowing less fit genotypes from breeding programs. However, pest damage can be a serious barrier to accurate evaluation of other tree characteristics important to the tree breeder if damage is indiscriminate of genetically controlled tree factors. Periodic reports of damage in localized areas of R-8 progeny tests caused R-8 Forest Pest Management to conduct a thorough assessment of pest conditions in some of these areas. The purpose of the surveys were to: 1) determine damage incidence and severity; 2) determine potential pest threats to accurate evaluation of progeny tests; and 3) determine if pest damage warrants changes in current practices governing progeny test establishment, maintenance, and evaluation.

During 1983, 33 progeny tests of 5 different southern pine species on 10 National Forests were surveyed. Normally, all trees were examined. Damage from all pests was diagnosed and recorded, and summaries were prepared for each test.

Pest Incidence and Damage

Pests and their damage were found in all tests, but the kinds and numbers of pests present and the level of damage they caused varied considerably (Table 1). Occasionally, man-caused injury was the most serious of all. Release work resulted in damaged stems, broken branches and tops, and debris covering test

Table 1.--Pests found damaging pine progeny tests of the Southern Region, 1983.

Pest	Host 1/	Damage Type	Primary Damage Result	Incidence	Severity	Potential for Genetic Improvement	Practical Control	
							Method	Current Need
1. Reproduction Weevils *Hylobius pales*, *Pachylobius picivorus*	all	stem feeding	mortality	moderate to high	high	no	site selection chemical	yes
2. Man (Cultural Practices) planting methods, release work	all	mechanical injury J-rooting	mortality form growth loss	variable	high	no	education	yes
3. Fusiform and Eastern Gall Rust *Cronartium quercuum* f. sp. *fusiform* and f. sp. *quercuum*	all, except E. white	stem rust	mortality form	variable	moderate	yes	chemical	no-field yes-nurse
4. Pitch Canker Disease *Fusarium moniliforme* var. *subglutinans*	slash, shortleaf, Virginia	shoot dieback	growth loss form	low	low	yes	-	no
5. Root Disease *Heterobasidion annosum*, *Armillariella mellea*	all	root decay	mortality growth loss	low	low	no	site selection	no
6. Animal Damage mice, rabbits, groundhogs, deer	all	stem, branch shoot feeding	growth loss form mortality	variable	moderate	no	site selection	no
7. White Pine Weevil *Pissodes strobi*	E. white	leader dieback	growth loss form	moderate	moderate	no	-	no
8. Tip Moths *Ryacionia frustrana*, *R. subtropica*	all, except E. white	shoot and tip dieback	growth loss form	high	low	no	chemical	no
9. Sawfly *Neodiprion lecontei*	all, except E. white	defoliation	growth loss	moderate	low	no	chemical	no

Table 1.--con't

Pest	Host	Damage Type	Primary Damage Result	Incidence	Severity	Potential for Genetic Improvement	Practical Control	
							Method	Current Need
10. Brown Spot Needle Blight *Scirrhia acicola*	slash (longleaf)	needle injury (defoliation)2/	none (growth loss mortality)2/	low	low	no (yes)2/	- (site selection chemical)2/	no (no)2/
11. Pitch Moth *Dioryctria* spp.	all, except E. white	stem, branch dieback	top, branch kill	low	low	no	-	no
12. Pine Webworm *Tetralopha robustella*	all	defoliation	none (possible growth loss in small seedlings)	high	low	no	chemical	no
13. Spider Mites many genera	slash	needle chafing sucking	vigor reduced	variable	low	no	chemical	no
14. Tortoise and Needle Scale *Toumeyella numismatica*, *Phenacaspia pinifoliae*, and others	all	shoot and needle sucking	vigor reduced	variable	low	no	chemical	no
15. Aphids many genera	all	shoot sucking	vigor reduced	variable	low	no	chemical	no
16. Pitch and Needle Midges many genera	all, except E. white	needle injury shoot injury	none	low	low	no	-	no
17. Bagworm *Thyridopteryx ephemeraeformis*	all	defoliation	none	low	low	no	chemical	no
18. Needle Rust *Coleosporium* spp.	Virginia, slash	needle injury	premature needle cast	variable	low	no	weed control	no

Table 1.--con't

Pest	Host	Damage Type	Primary Damage Result	Incidence	Severity	Potential for Genetic Improvement	Practical Control	
							Method	Current Need
19. Tip Blight Diplodia pinea	Virginia, E. white	shoot dieback	none	low	low	no	-	no

1/ Host indicates species where pests were observed, not potential hosts.

2/ Longleaf pine only. No field tests currently in place.

trees. In one test, exposure after overstory removal resulted in needle burn and twig dieback. In several tests, J-rooting was causing trees to grow at severe angles from vertical due to lack of root support, with mortality sometimes resulting.

Injurious pests (causing or having the potential to cause serious growth loss, form damage, or mortality) were found in most tests. Incidence was usually low, but some tests had severe damage that compromised all or large portions of some repetitions (blocks). Pests occurring with moderate to high frequency and causing important damage include reproduction weevils, fusiform and eastern gall rust, animals, and white pine weevils. Reproduction weevils are attracted to newly created pine stumps for breeding purposes and then feed on newly planted pine seedlings planted nearby. The amount and distribution of damage is dependent on the distribution of newly created pine stumps in the planting area. Entire plantations can be devastated, requiring substantial replanting efforts. In R-8 progeny tests, injury was frequently found and mortality was common. Large portions of individual families and occasionally entire blocks (repetitions) were severely damaged.

Fusiform rust is the most important disease in the South and is the subject of intensive tree improvement efforts. It and the closely related eastern gall rust cause stem galls and may kill trees outright or predispose trees to stem breakage from wind or other stand disturbance. Many rust galls were in a position that suggested infection occurred in the nursery.

Animals were locally damaging in some tests. Trees were killed by mouse or vole gnawing at or slightly below the groundline, and groundhogs caused large stem and branch wounds and some top kill in sapling-sized tests. Rabbits clipped the tops from seedlings, sometimes causing tree mortality, while deer caused mainly form damage by repeatedly browsing older seedling tops.

White pine weevil only attacks eastern white pine. Damage was limited to dieback of at least one year's height growth from the activities of larvae feeding in the leader. Heavy adult feeding and oviposition alone can result in top kill.

Some pests (tip moths, sawfly, pine webworm, scale, aphids, and needle rust) were observed in many tests and when present were often found in great abundance. In spite of this, their damage was considered minor.

The remaining pests were only occasional finds and caused little noticeable damage.

Threats to Accurate Test Evaluation

In order for pests to interfere with accurate test evaluations, their damage would have to be indiscriminate of genotype and mask or otherwise interfere with trees' abilities to express their genetic potential. Entire tests could be affected by excessive mortality or growth reductions caused by pests, or damage could be confined to blocks, families, or individual trees. If enough variability is introduced from these factors or if the number of observations is reduced because of tree mortality, correct assessment of valuable genetic characteristics is compromised. On the other hand, pests differentially attacking some genotypes provide important information for tree selection.

Surveys showed that reproduction weevils and man-caused damage are currently causing enough damage to be considered as threats. Damage is indiscriminate of genotype. Control of reproduction weevils can be obtained through the use of registered insecticides, but is more efficient through proper site selection. Former pine lands should be spring planted with pine seedlings, only if the planting site was harvested and site prepared prior to June 1. Stumps are thereby given enough time to deteriorate to the point where they are no longer attractive as breeding sites.

Careless planting and release work also results in damage to all trees, regardless of genotype. Education of field crews to the value of progeny tests and the importance of careful work can limit this type of damage.

Other threats to accurate evaluations of some test parameters may arise if conditions develop that favor pest outbreaks. These include:

1. Fusiform and eastern gall rust
2. Pitch canker disease
3. White pine weevils
4. Tip moths
5. Root diseases
6. Animal damage
7. Sawflies

Of these, rust and pitch canker are known to show differences in virulence to different loblolly, slash, and shortleaf pine families. Epidemic pitch canker can make accurate height measurements impossible and even depress growth. Rust is included as an important component of loblolly and slash pine breeding programs in the South, while individual trees and regional populations of slash pine show varying resistance to pitch canker. Because gains are possible from tree improvement, control of these diseases in field plantings is not desirable. In the case of rusts, however, management of the disease in seedbeds is imperative. Seedlings infected in the nursery are exposed to only one local inoculum source and under conditions most favorable for infection. Exposure to inoculum sources local to the planting area under field conditions (1-0 spring planted bareroot stock) could result in vastly different infection levels. Chemical control of fusiform rust is standard practice in loblolly and slash pine seedbeds in the South, but this may have to be extended for eastern gall rust of Virginia and shortleaf pines used for progeny testing.

Preferences for ovipositing are expressed by white pine weevil and, to some extent, tip moths, but it is unclear if these preferences can be effectively exploited in breeding programs. Chemical control with registered insecticides can be accomplished but is unnecessary, except in the most extreme cases.

As far as is currently known, the root diseases found are indiscriminate antagonists of trees, and no benefit can be derived from their occurrence in progeny tests. Careful site selection can help in assuring that root diseases do not interfere with correct interpretation of progeny tests. In forest stands in the southern and western U.S., bark beetle spots are known to be frequently associated with root diseased areas. In all tests where root disease mortality was found, there was evidence that bark beetles had been active in the previous stand. By avoiding sites salvaged because of bark beetle attacks, the chances for progeny test losses to this cause are lessened.

Site selection can also aid in limiting animal damage. Areas with dense herbaceous ground cover (former pastures or agricultural land, certain forest sites) often harbor high populations of mice, voles, rabbits, and groundhogs and may attract deer. Avoidance of these areas or special site preparation may be required to control damage. Trapping, poisoning, or hunting is probably not justified, except in extreme cases.

In outbreak areas, sawfly larvae populations may be high enough to cause complete defoliation, resulting in branch or tree mortality and growth reduction. No such conditions were observed during our surveys, but have periodically occurred in R-8 National Forests. Properly timed applications of registered insecticides have been effective in managing sawfly damage.

Evaluation of Current Practices

For the most part, current practices governing progeny test site selection, establishment, and maintenance in R-8 are adequate to meet existing pest conditions. Recommendations for increased emphasis include:

1. Better rust control in nursery seedbeds growing progeny test seedlings.

   a. Triadimefon fungicide sprays recommended.

2. Clearer guidelines on site selection to avoid losses to reproduction weevils and root diseases.

   a. Avoid establishing tests on sites harvested and site prepared after June 1. If such sites must be used, plant chemically treated seedlings or establish a monitoring and insecticide spray program.

   b. Avoid establishing tests on sites where the previous stand was salvaged because of bark beetle activity.

3. Additional training for crews responsible for tree planting and test maintenance, emphasizing test value and the importance of careful work.

4. Improved monitoring of tests so pest problems can be detected and controlled before excessive damage is done.

   a. Where reproduction weevils are a hazard, seedlings should be examined for damage within a few weeks of planting, with weevil traps (fresh cut and split pine bolts or disks placed close to cut stumps attract adults that can be found on the underside in morning) added as a monitoring tool.

   b. Annual evaluations for general pest conditions could detect developing problems.

   c. Involve FPM personnel in routine test evaluations and supplemental monitoring of newly established tests. Four to eight tests in each category from different National Forests would provide an adequate view of current conditions.

d. Heighten awareness of district personnel to pest conditions and factors governing outbreaks through training programs with special emphasis on progeny test pests.

Other Pest-Related Tree Improvement Activities in the Southern Region

Field testing for resistance to various disease problems requires that many sites be established and maintained for several years (5-7 for most diseases). Rust disease can be used to illustrate the vagaries of field tests of relative resistance. Exposure to the pathogen can be highly variable, and the conditions for infection are absent in some years. If enough rust infection occurs to evaluate the relative susceptibility of families, then other data such as growth and form are usually lost. Because of these factors and the importance of fusiform rust in the South, the Fusiform Rust Resistance Screening Center was established at Asheville, N.C. Forest Pest Management operates the facility for the rapid and inexpensive screening of seedlots from tree improvement programs, forest industry, and federal clients.

The client may choose from loblolly and slash pine inoculum collection areas to match the location closest to their field planting area. The screening process revolves around the life cycle of the fungus that has four different spore stages alternating between pine and oak. Concentrations of spores far in excess of natural inoculum loads ensure a high incidence of infection. Several sizes, shapes, and types of galls indicate varying levels of susceptibility. Reliable results can be inexpensively obtained in 7 months instead of the 5 or more years required for field tests that may or may not become infected to sufficient degree to evaluate rust. Correlations have been established between field results and this artificial screening method that ensure correct evaluation of rust resistance in the field.

Operational procedures have been developed for a similar screening of longleaf pine for brown spot needle blight. Currently, it is only available for seedlots from the National Forest system. No operational field tests have been established to date, but research tests verify the accuracy of the screening procedure.

Potential applications include screening for pitch canker disease, white pine blister rust, and air pollution sensitivity, but procedures for these screenings have not yet been developed.

High-Resolution Mapping of Inherent Growth Variation in Coastal Douglas-Fir

Roy R. Silen[1/]

Six high-resolution maps of genetic height variation for small breeding zones in western Oregon are presented in this paper. Production of such maps is becoming routine. Two maps were presented in the April 1983 issue of the Journal of Forestry (Silen and Mandel 1983). Since then four more have been produced as part of an analysis package as 5-, 10-, or 15-year data are processed for progeny tests of breeding zones for the Progressive Tree Improvement Program (Silen and Wheat 1980). Full or partial data on 26 more breeding zones in Washington and Oregon are scheduled for analysis in 1984. Within a reasonably short period, the 1.3 million acres now mapped may expand to over 3 million acres. Total height, or incremental height, is the only genetic trait now routinely mapped. My purpose is to display the maps, describe the data base and analysis, briefly discuss computer processing and enhancement, and highlight patterns of geographic genetic variation common to the six maps. Implications for genetic programs are not covered.

Coverage

Figure 1 shows 8.2 million acres in western Washington and Oregon in the Progressive Tree Improvement Program. There are 90 breeding zones of 100,000 to 300,000 acres. Within zones, the sampling of parent trees is fairly dense--usually two trees per square mile of forest ownership. For these six maps the number of parent trees ranges from 161 to 900. In other words, there are a lot of sample points per map. Parents are evaluated at 5-year intervals from metric height measurements of progeny on 6 to 12 sites, each with 12 to 20 progeny. With over 100 progeny per parent the family mean is a fairly precise statistical estimate of performance. This large number of individuals per family probably accounts for the clarity with which patterns of geographic genetic variation often appear when unprocessed family means are plotted on a map. Sometimes the patterns are improved by computer enhancements, and sometimes not.

Highlighted on the figure are five presently mapped Douglas-fir cooperative program areas--Vernonia, Molalla, Burnt Woods, Gold Beach, and Dallas. The sixth map applies to a program in western hemlock--the Tillamook Hemlock Tree Improvement Program.

Vernonia Tree Improvement Cooperative

Figure 2 shows a 350,000-acre forest area directly west of Portland, Oregon, of this Cooperative mainly owned by Crown Zellerbach Corporation, Longview Fibre Corporation, International Paper Corporation, and the State of Oregon, known as the Vernonia Tree Improvement Cooperative. The basic procedure for constructing the genetic maps is to plot the family mean height at its coordinate location, then draw in isoheight contour lines. The Vernonia map, the first such map, was prepared by hand. With 900 parent trees to be plotted

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and with decisions needed about map scales and background information such as topographic contours, rivers, roads, and towns, the several trials of various alternatives proved to be tedious. For the map shown, we used the height growth increment from years 7 to 10 as the plotted variable, mainly to eliminate the large variation in heights in the first 7 years caused by animals, brush competition, and frost.

Without applying any computer enhancement techniques, the basic data itself provides clear geographic patterns. Note that in the hilly area south of the Nehalem River, nearly all family height growth over 200 cm can be included in a 1- to 6-mile-wide band on the rolling ridgetop, at 1,200-1,500-feet elevation, and that two parallel bands 1- to 6-miles wide downslope include the 190-199 cm, and then the 180- to 189-cm trees in this valley bottom. On this gentle, 10-mile slope there is a genetic cline from the Nehalem River bottom to the ridgetop. Note the similar band of 200+ cm growth on the ridge that parallels the Columbia River north of the Nehalem River. The parentage at the western edge of the Willamette Valley and in the lowlands northward to Vernonia are relatively slower growing. A most striking feature concerns the 70 families on the south end of the map located at 1,500- to 2,400-feet elevation on the southeast flank of Saddle Mountain, all with below average growths of 178 to 190 cm.

Computer Aids

All this former handwork, except drawing of the isoheight lines, is now done by computer. Cooperators are asked for coordinates of parent tree using the military grid found on all U.S. Geological Survey (USGS) Quadrangle sheets. The metric grid on USGS maps is shown in 10,000-meter marginal tic marks. The 0,0 origin is somewhere in the Pacific Ocean to assure that all coordinates are positive. The 10,000-meter grid (6.2 x 6.2 miles) will be prominent on most subsequent maps. Up to 900 points were impossible to plot on a map of useful scale, so the number of points was reduced by plotting the mean of all families with parents in a 500-meter square. The density of points also made necessary the coding of heights into classes represented by single digits. Typically the range of heights is divided into five to ten classes represented by the digits 0 through 9.

Computer maps are plotted on a 1:250,000 scale to correspond with a convenient USGS map series. The coded values and a coordinate grid are plotted directly on acetate sheets so that they can be overlaid on the USGS contour maps. The isoheight lines are drawn on Xerox copies of the map plus overlay.

As with the processing of satellite data, systematic and random variation can sometimes be reduced by computer techniques. Krieging, a procedure that uses a moving average, sometimes helps in smoothing out statistical variation. The main statistical smoothing and data strengthening has been done with multiple regression to predict an expected family height at the parents latitude, longitude, and elevation. The method is described in a previous paper (Silen and Mandel 1983). The method produces a response surface for which isoheight contours are mapped.

Maps from Multiple Regression

The next map of the Vernonia area (figure 3) is based on parent tree values estimated by multiple regression for their coordinate location. In this data set there were significant effects of latitude and elevation squared. The

response-surface map shows that parents in the north half would be expected to perform better than average. The better performance on the hills south of the Nehalem River is also shown, as well as the poor performance of those southeast of Saddle Mountain. The map becomes somewhat absurd in its prediction that trees from the northeast corner should be 7-1/2 percent better than average--a case of carrying trends too far.

The next map (figure 4) generated from multiple regression techniques applies to the Molalla Cooperative. This cooperative of four landowners is located southeast of Portland in the foothills of the Cascade Range and east of the Willamette Valley. The forests range from about 1,000 feet to 2,600 feet. The 375 selected parent trees are not well distributed and only about 40 percent of the mapped area is owned by the four landowners. But the data is generally excellent and a number of factors were significant in multiple regression analysis (latitude squared, latitude times elevation, elevation squared, longitude times elevation, and longitude squared). The result was a response surface of considerable complexity that fit the basic data reasonably well.

The map shows a strong trend of better parent performance to the north. Parallel bands representing a change of 2-1/2 percent in total height at 10 years are spaced at 2- to 5-mile intervals. Best performance in the north is at 1,000 feet along the edge of the Willamette Valley. Performance drops off upslope to about 1,800 feet, then improves again at elevations up to 2,500 feet. At the south end of the map the poorest performance is from parentage on the valley edge. Performance there rises as parent elevation increases. This is quite a complex geographic pattern. A feature of the Molalla Cooperative data is that the top 10 of the 375 parent trees originate in a 1- by 2-mile rectangle at 1,000 feet elevation near Colton, Oregon.

Burnt Woods Cooperative

The remaining four maps were constructed from basic data. No attempt has been made at computer enhancements because newer data will soon become available from 10- or 15-year measurements.

The Burnt Woods Cooperative (figure 5) tested only 161 parent trees on 70,000 acres owned by the State of Oregon and Starker Forests. The lands lie west of Corvallis in an east-west oriented pair of drainages with flanking highlands to north and south. Several points about the isoheight contouring are of interest.

As with the Molalla Cooperative map, the top-performing parentage is confined to a small area. One such area is south of Blodgett at 1,200 feet elevation. Other areas of good parentage are associated with coves near the top of low hills in the main drainages. At the northeast corner is a major ridge. A clinal banding of the successively poorer growing parents occurs on the east side of this ridge that forms the forest edge of the Willamette Valley, a similar pattern to the Vernonia Cooperative map. The isoheight lines are mainly oriented east to west paralleling the drainage pattern.

Gold Beach Cooperative

Several features seen in maps from the Gold Beach Cooperative (figures 6-8) are unusual. The area is located astride the Oregon-California border and

includes a 15-mile-wide strip along 50 miles of the Pacific coastline. Two major drainages are included--the Rogue River at the north and the Chetco River at the south of the mapped area. The nine landowners in the Gold Beach Cooperative own about 80 percent of the forest land. Sampling of 1,066 parents is more uniform than for any other of the six maps. This is shown in figure 6 in which the coded values in each sampled 500-meter square range from 2 to 6 with 4 the average value.

An enlargement of the Oregon-California border area is next shown with isoheight lines (figure 7). The pattern of these lines is complex, but some simplifications become obvious. The "average-growth" parentage along the coast grades inland into "above-average" parentage, and then into islands of "top" parentage, finally grading eastward into "average" and "below-average" parentage.

Figure 8 covers the pattern for the 50-mile stretch of coastline. There is a 5- to 15-mile-wide band of average parentage (slant shading) that parallels the coastline. The eastern edge of the sampled area has below-average parentage (vertical shading). Each of the two major drainages has a basically simple pattern. The east-west orientation of the Rogue River is characterized by slow-growing parentage at the river mouth, then relatively fast-growing parentage (heavy shading) for about 15 miles upstream in the valley bottom. On either side of this faster growing band is a 1- to 4-mile-wide band of average-growth parentage, and still more distant from the river is a band of slow-growing parentage. This pattern is like that for the east-west drainage in the Burnt Woods Cooperative map. The Chetco River, with north-south orientation, has the same banding pattern except that the valley bottom has slow-growing parentage banded by average, then slow-growing parentage to the west and fast-growing parentage to the east and south.

The most interesting feature has to do with location of the fastest growing parentage. Other than an area of such parentage described for the Rogue River, nearly all such parentage occurs either near the Oregon- California border, or on a ridge paralleling the ocean north of the Rogue River. Note how the small areas of best growing parentage are within island-like isoheight contours of better than average parentage. Of these two areas, the one nearer the Oregon-California border is interesting because it delineates nearly all the extension of the range of coast redwood into southern Oregon. An ecologist from the Siskiyou National Forest, USDA Forest Service, has suggested that the coastal strip of average parentage corresponds to the narrow range of western redcedar along the southern Oregon Coast. Figure 9 shows the isoheight lines drawn on a 1:250,000-scale USGS map of the type sent to each Cooperator.

Dallas Tree Improvement Cooperative

This cooperative (figure 10) of seven landowners is located south of the Vernonia Cooperative and west of Salem, Oregon. It fringes the Willamette Valley for about 40 miles. About 300 parent trees at elevations below 1,500 feet provide the data base. Only about 35 percent of the land area is sampled leaving large gaps with no parent tree sampling.

Even so, the pattern is consistently one of increasingly slower growing parentage as sampling approaches the edge of the Willamette Valley. We see an isoheight line following the forest edge that includes all the below-average

parentage. The band of average parentage is 3- to 6-miles wide, with better growing parentage generally westward. This is the similar pattern as reported for the Vernonia and Burnt Woods Cooperatives. With so much of the forest area unsampled, a lot of the isoheight lines are shown as dashes between solid lines where sampling occurred.

Tillamook Hemlock Tree Improvement Cooperative

A cooperative involving five landowners of western hemlock forests along the north coast of Oregon (figure 11) provides 5-year data for the last map. The coastal strip sampled with 300 trees varies from 0 to about 12 miles in width along 70 miles of coastline. The pattern seems quite clear: Virtually all parentage of below average performance can be delineated with a band paralleling the coastline extending into each estuary about to the limit of tidewater. Inland from this tidewater line are parent trees of average performance. At intervals along the coast are island-like isoheight lines that delineate the above-average parentage. Most of these islands of faster growing parentage involve upland basins, ridges, and south-facing slopes somewhat back from the coastline.

Discussion

There are some features in common to all six maps that support the concept of a highly precise adaptation to local environments (Silen 1982):

1. Clinal variation is the rule. There are clear examples of gradual changes of inherent growth along gradients of moisture or temperature.

2. Fastest or slowest inherent growth rates are geographically localized. There are clear examples in each of the six cooperative areas.

3. The correspondence of genetic isoheight lines with topographic features is clear in many cases, and best where sampling of locales is dense. Prime examples are the gradient of lesser growth toward the timber edge of the Willamette Valley, the tidal relationship of slower growth in the western hemlock area, the cline associated with the slope of the Cascades, the band of similar performance along the 50 miles of coastline near the Oregon-California border, and the faster growing parentage associated with the redwood area in Curry County.

4. The north-south orientation of many isoheight bands follows predictions from general regional studies. East-west valleys of the Burnt Woods and Gold Beach cooperatives, however, demonstrate the overriding effects of local topography.

5. All six cooperative maps display a 10- to 15-percent difference in progeny height associated with geography. How much of this genetic variation is applicable to use for upgrading growth in the area of poorer growth on each map is a major question.

There is ready acceptance by geneticists of stable racial differences in growth rate occurring along major latitudinal or elevational transects where pollen exchange is unlikely. Here is added evidence that clinal variation is maintained over distances so short that pollen exchange must occur. Any of

the six cooperative areas have as great or greater environmental variation as might occur over whole states in the eastern United States. Obviously the species would benefit from a similar precise genetic and environmental matchup as occurs along the major environmental gradients. It would appear that such a matchup is occurring even though the mechanism isn't understood.

Most Ranger Districts in the Pacific Northwest will soon have high-resolution maps of inherent growth variation.

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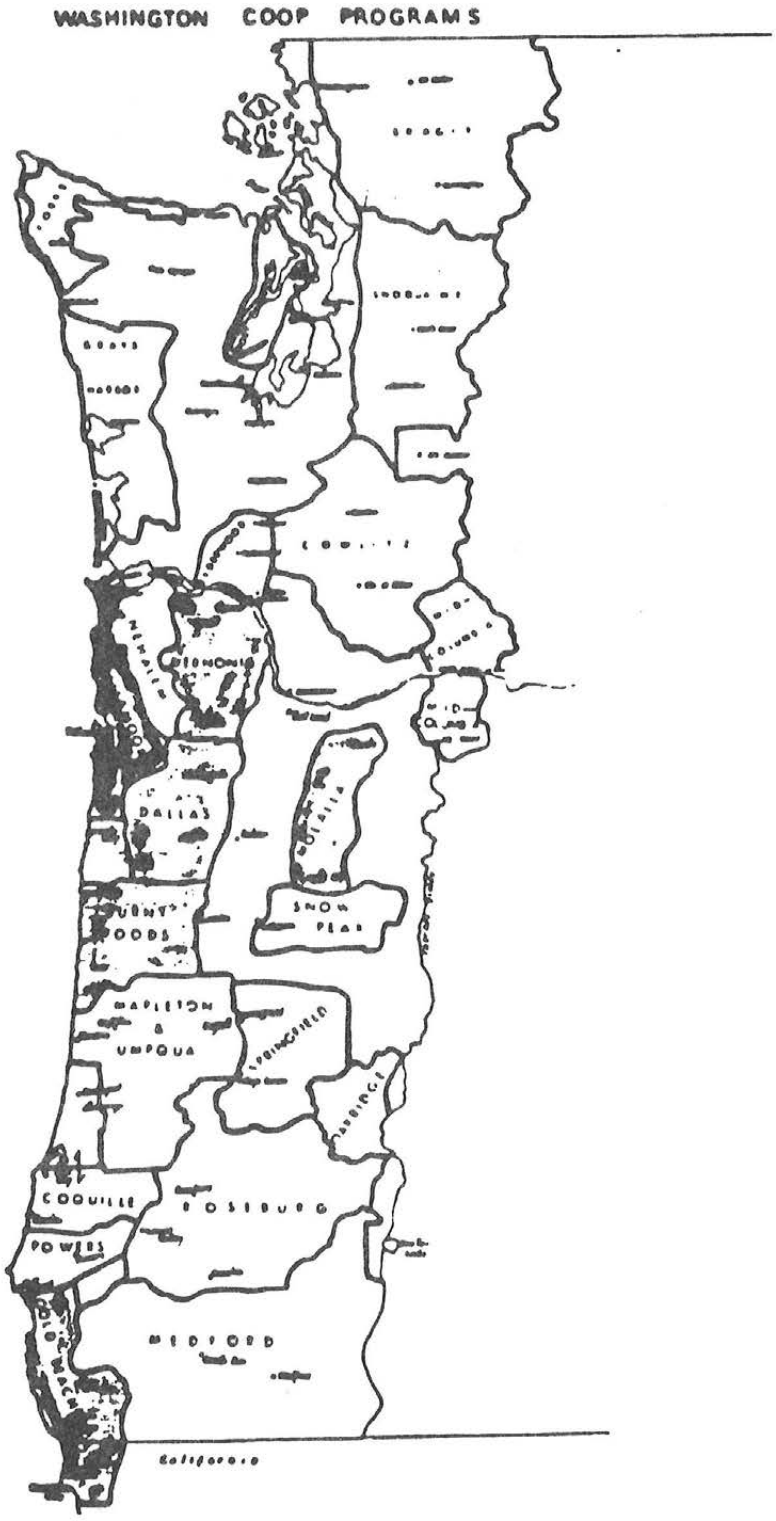


Figure 1.--Twenty-three tree improvement cooperatives are outlined in western Oregon and Washington, involving 8.2 million acres and 44 landowning organizations. Cooperatives for which maps of genetic variation are presented are shaded. Progeny test data from 161 to 1,066 parent trees were used to prepare the six maps.

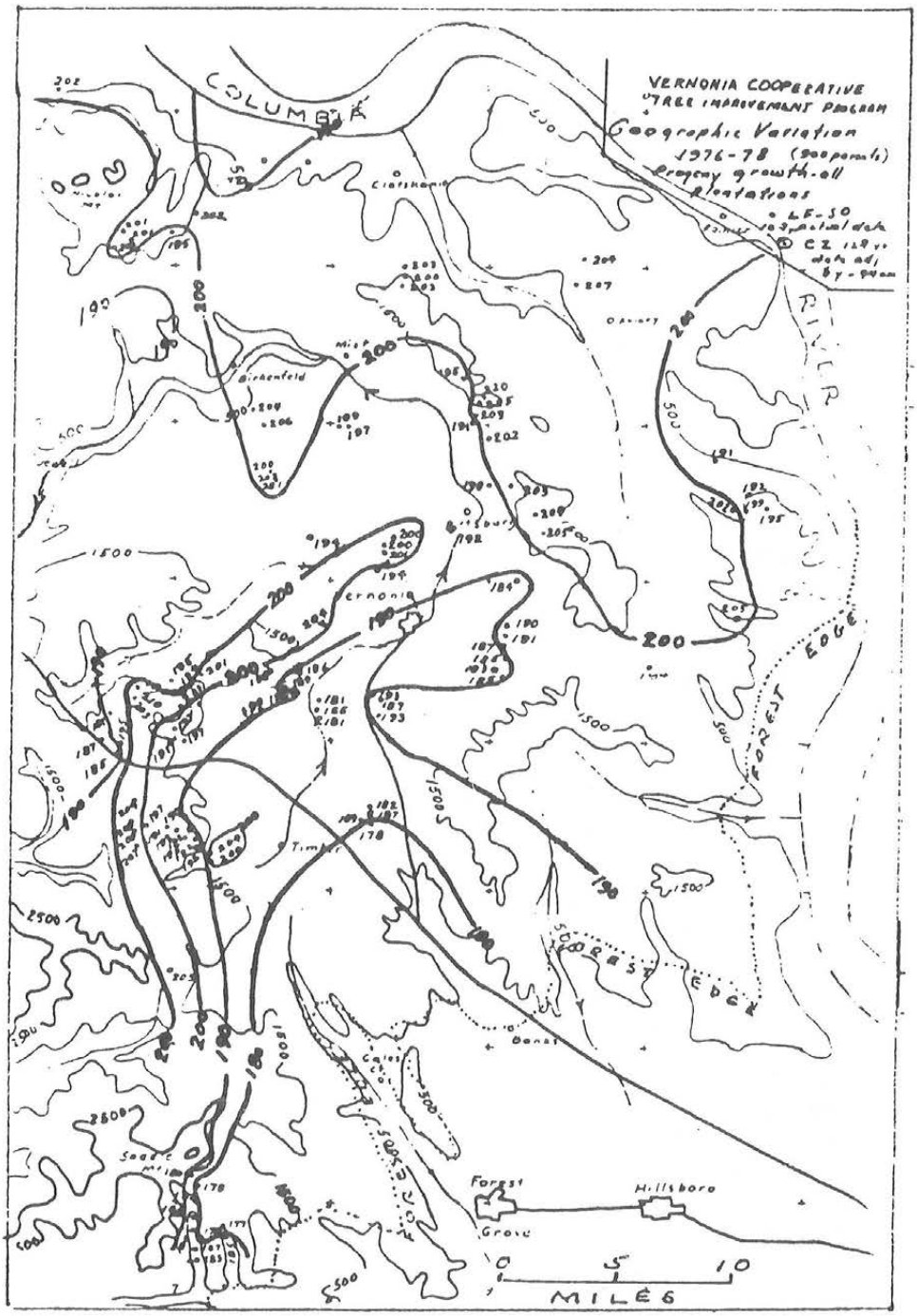
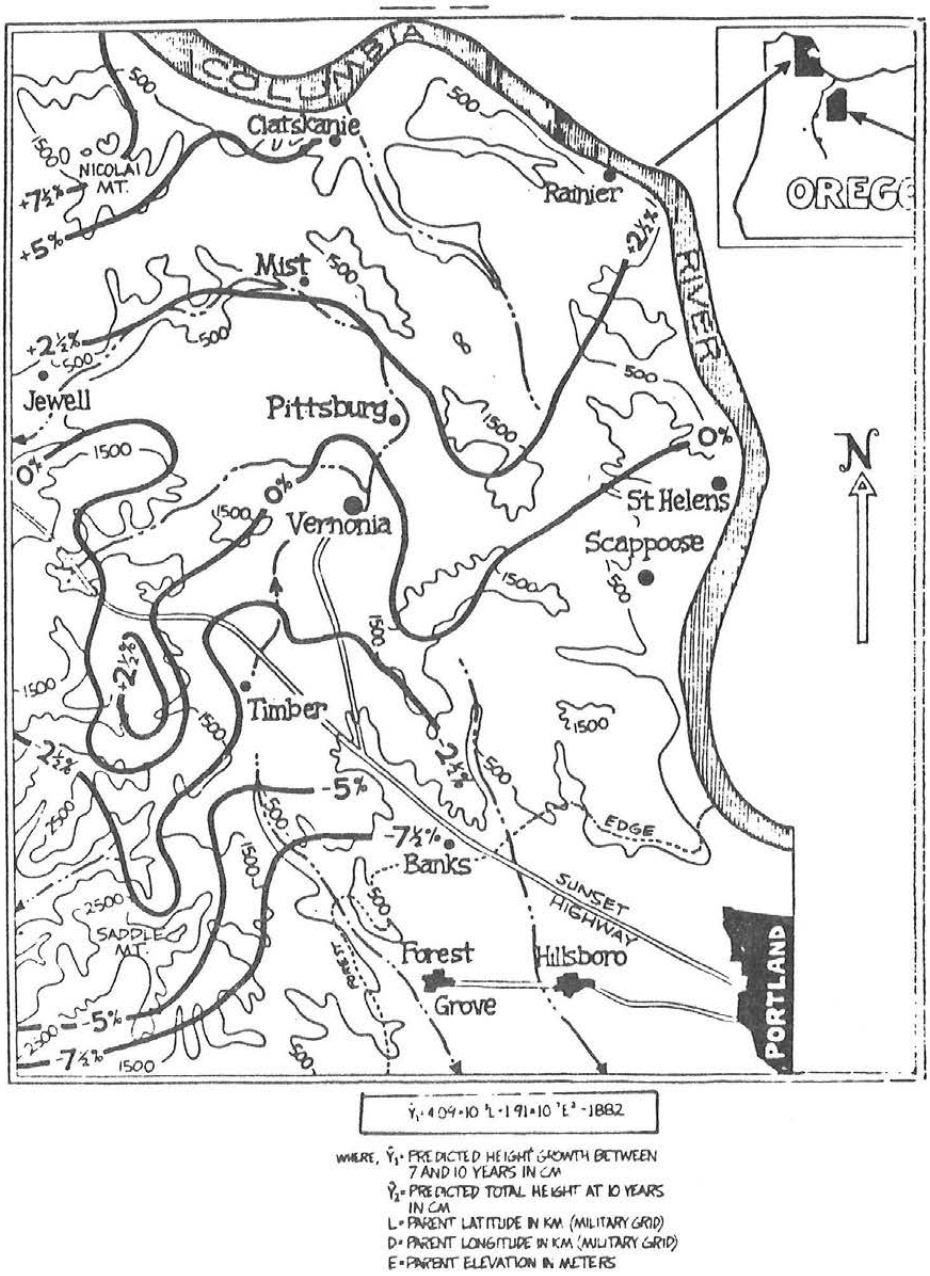


Figure 2.--Vernonia Cooperative in the Coast Ranges west of Portland involved 900 parent trees tested on 12 sites by four landowners. This was the first map attempted, so was prepared by hand methods. Decreasing progeny heights in a cline from the hills of the Coast Range to the edge of the Willamette Valley is a prominent feature of the map. Figures are centimeters of incremental growth from 7 to 10 years.



$\hat{Y}_1 = 4.04 + 10^{-5}L - 1.91 + 10^{-7}E^2 - 1882$

WHERE, $\hat{Y}_1$ = PREDICTED HEIGHT GROWTH BETWEEN 7 AND 10 YEARS IN CM
$\hat{Y}_2$ = PREDICTED TOTAL HEIGHT AT 10 YEARS IN CM
L = PARENT LATITUDE IN KM. (MILITARY GRID)
D = PARENT LONGITUDE IN KM. (MILITARY GRID)
E = PARENT ELEVATION IN METERS

Figure 3.--Vernonia Cooperative map was prepared from 7- to 10-year incremental growth predicted for each parent location by the regression equation shown in the box below the map. The equation reduces statistical variation, thus smoothing the data of the previous map which shows the unprocessed data.

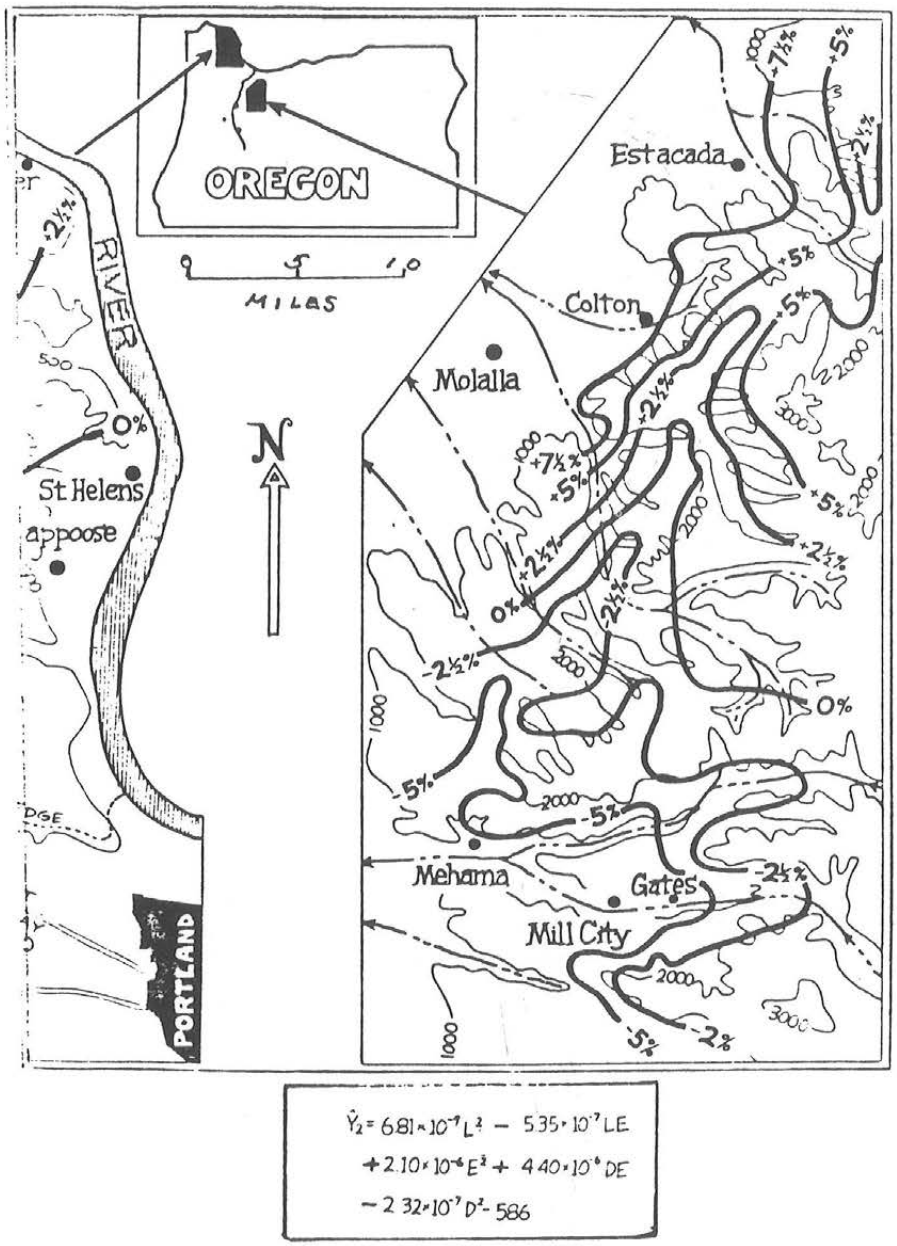


Figure 4.--Molalla Cooperative is in the foothills of the Cascade Range southeast of Portland. Progeny from 375 parents were tested on nine sites. The 10-year total heights produced the multiple regression equation in the box below the map. The equation was used to estimate heights at parent coordinates. Note that northern parents show superior heights. Clinal variation is displayed up the slope of the foothills.

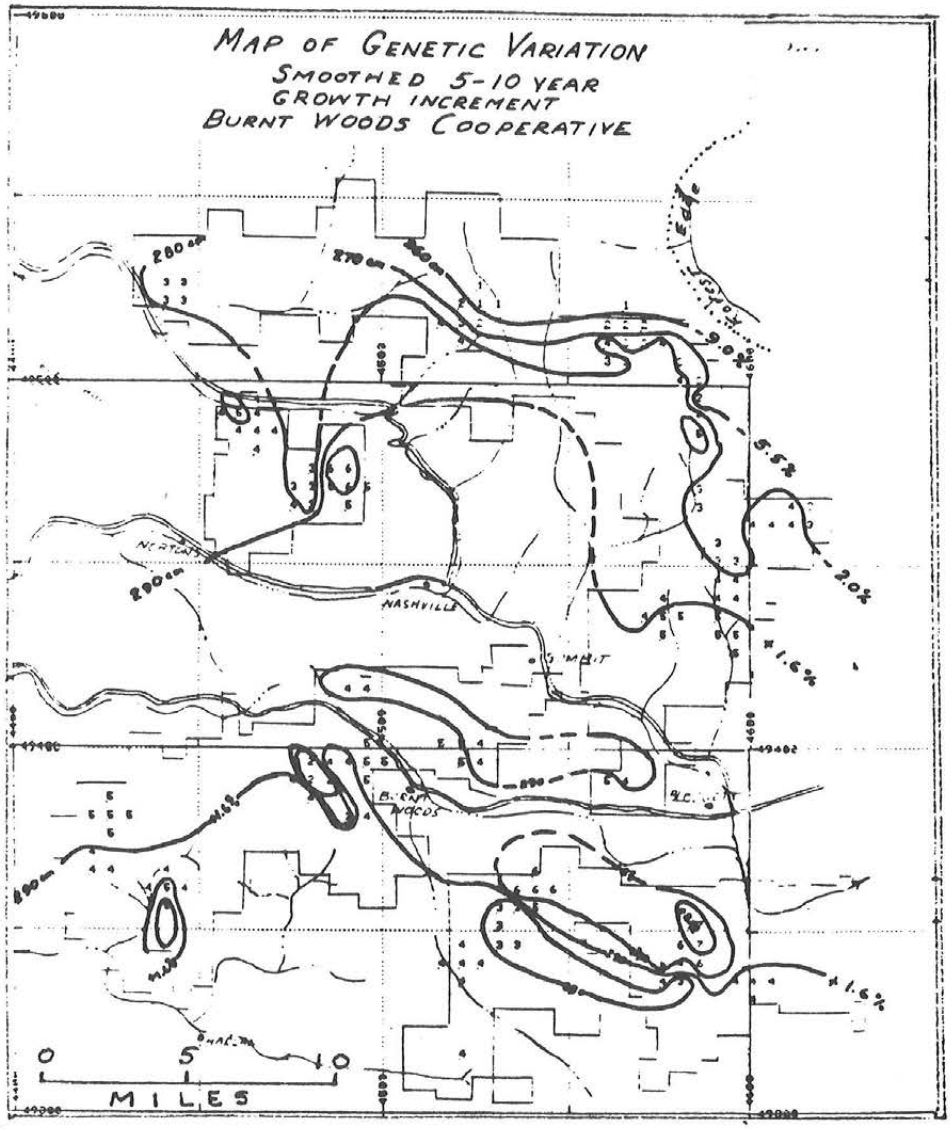


Figure 5.--Burnt Woods Cooperative in the hills of the Coast Range west of Corvallis displays coded 5- to 10-year progeny height in 10-cm increments based on 161 parents tested on eight sites (1=260 cm; 7=320 cm). Drainage orientation and isoheight lines are mainly east-west. Note concentrations of fastest growing families south of Blodgett and steep clinal variation in northeast corner associated with the rain shadow created by Little Grass Mountain.

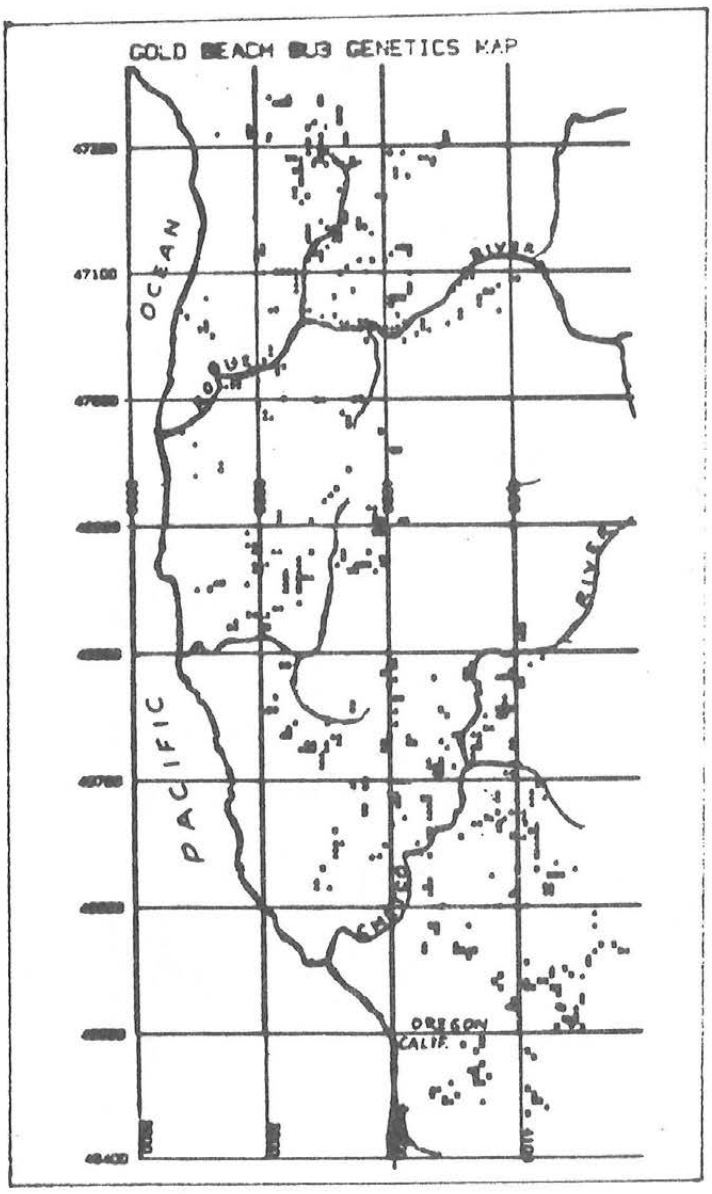


Figure 6.--Gold Beach Cooperative along the Oregon and California Coasts embraces acreage of nine landowners with 1,066 tested trees. The better distribution of parents is shown by the coded progeny heights. Note the east-west alignment of the Rogue River and northeast-southwest alignment of the Chetco River for details explained in the text.

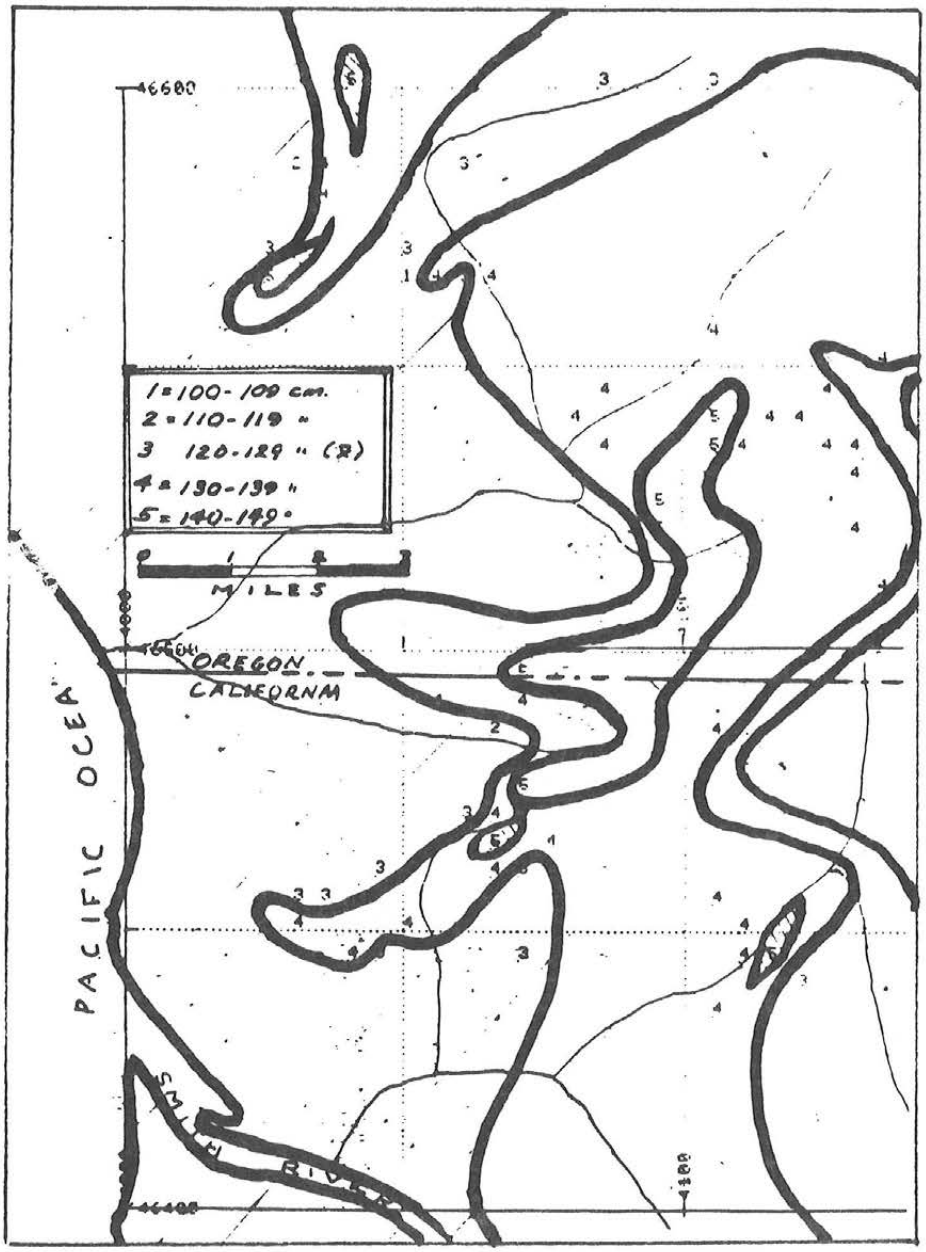


Figure 7.--An enlargement of figure 6 in the area of the Oregon-California border. Isoheight lines delineate locations of above-average (4's) and top-performing (5's) parent trees. Average parentage are in a 3- to 6-mile coastal band, with top-performing parentage inside islands of above-average percentage.

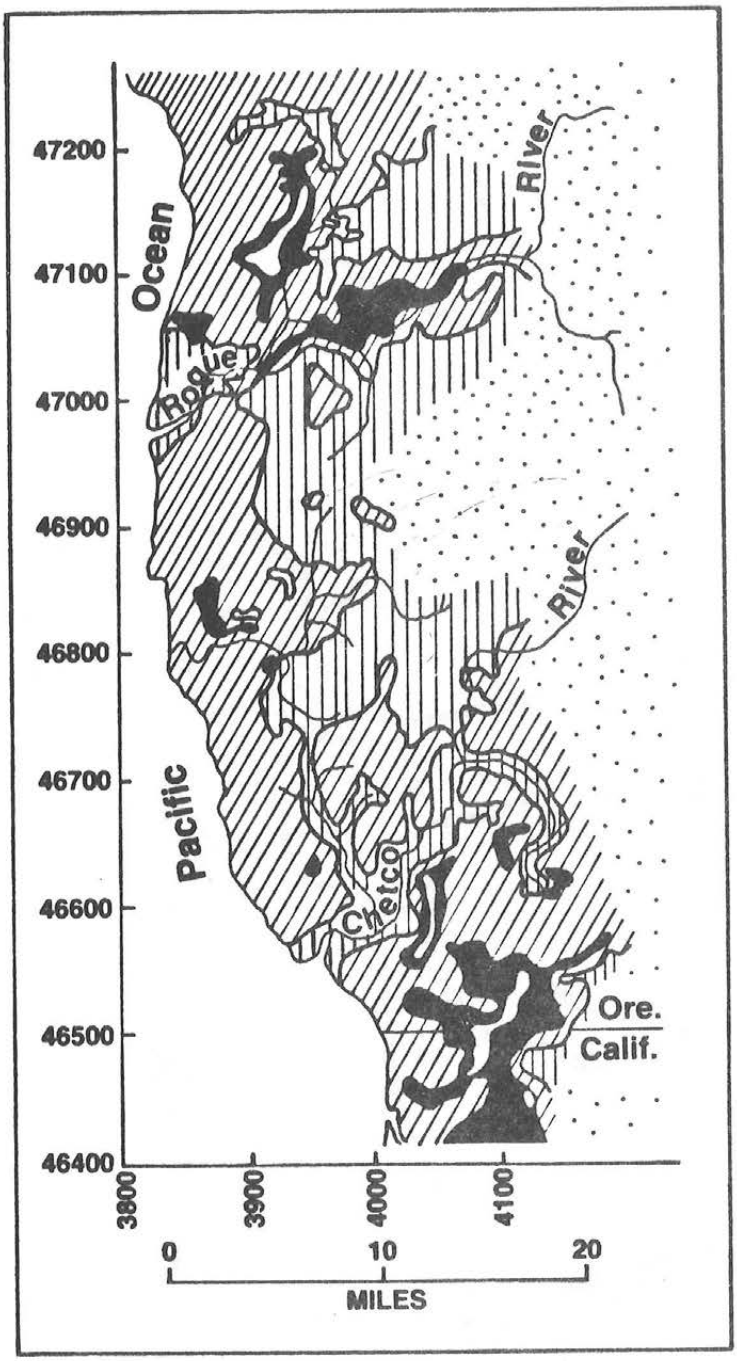


Figure 8.--Gold Beach Cooperative. Mapping for about 50 miles of coastline forests displays the band of average-growth parentage along the coast, a contrasting pattern for the Chetco and Rogue valleys, and islands of above-average parentage near the California border and on a ridge north of the Rogue River.

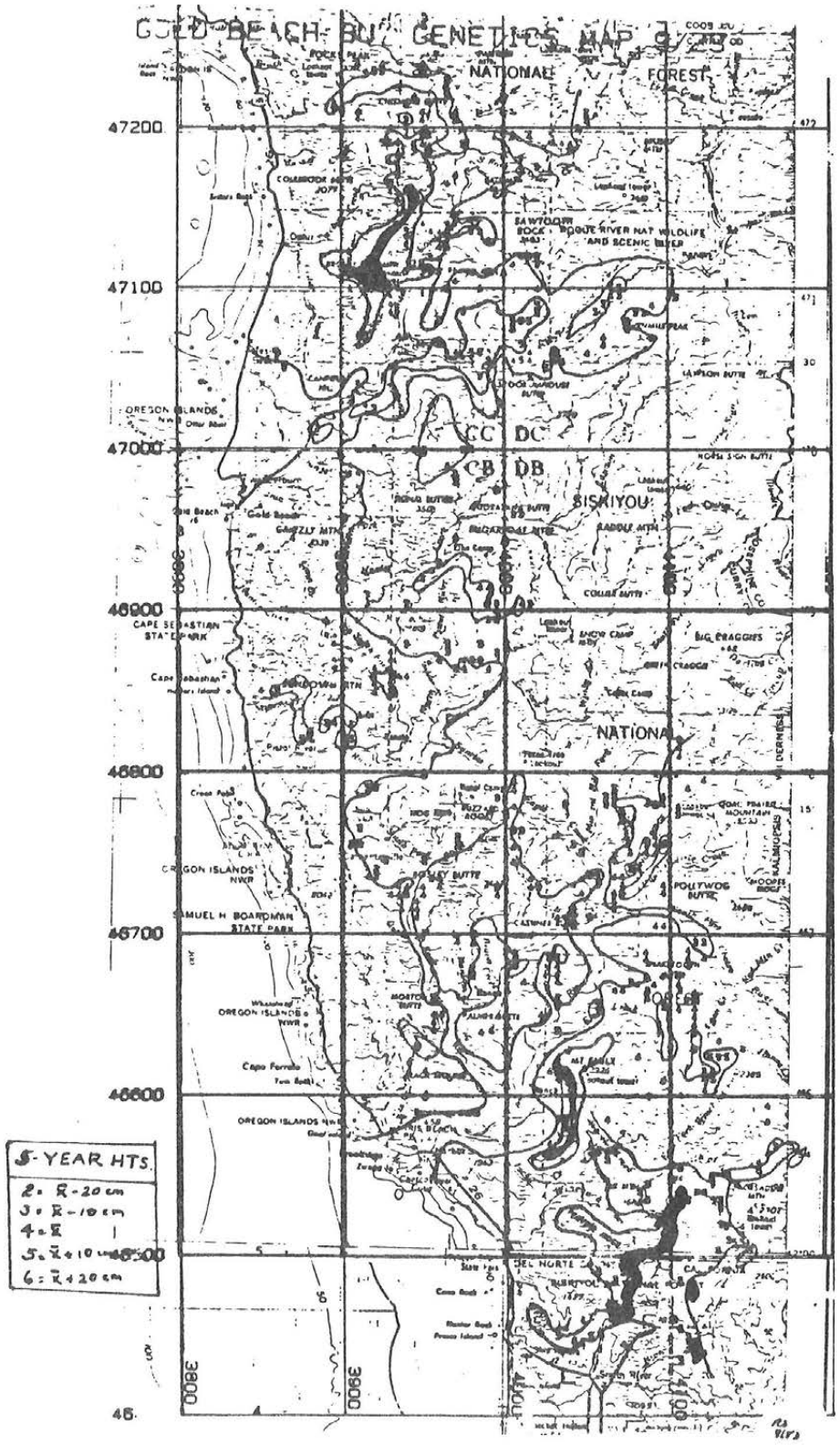


Figure 9.--All cooperative members receive more detailed maps of the kind in this figure. Coded parental information and isoheight contours are drawn on a USGS 1:250,000-scale topographic map.

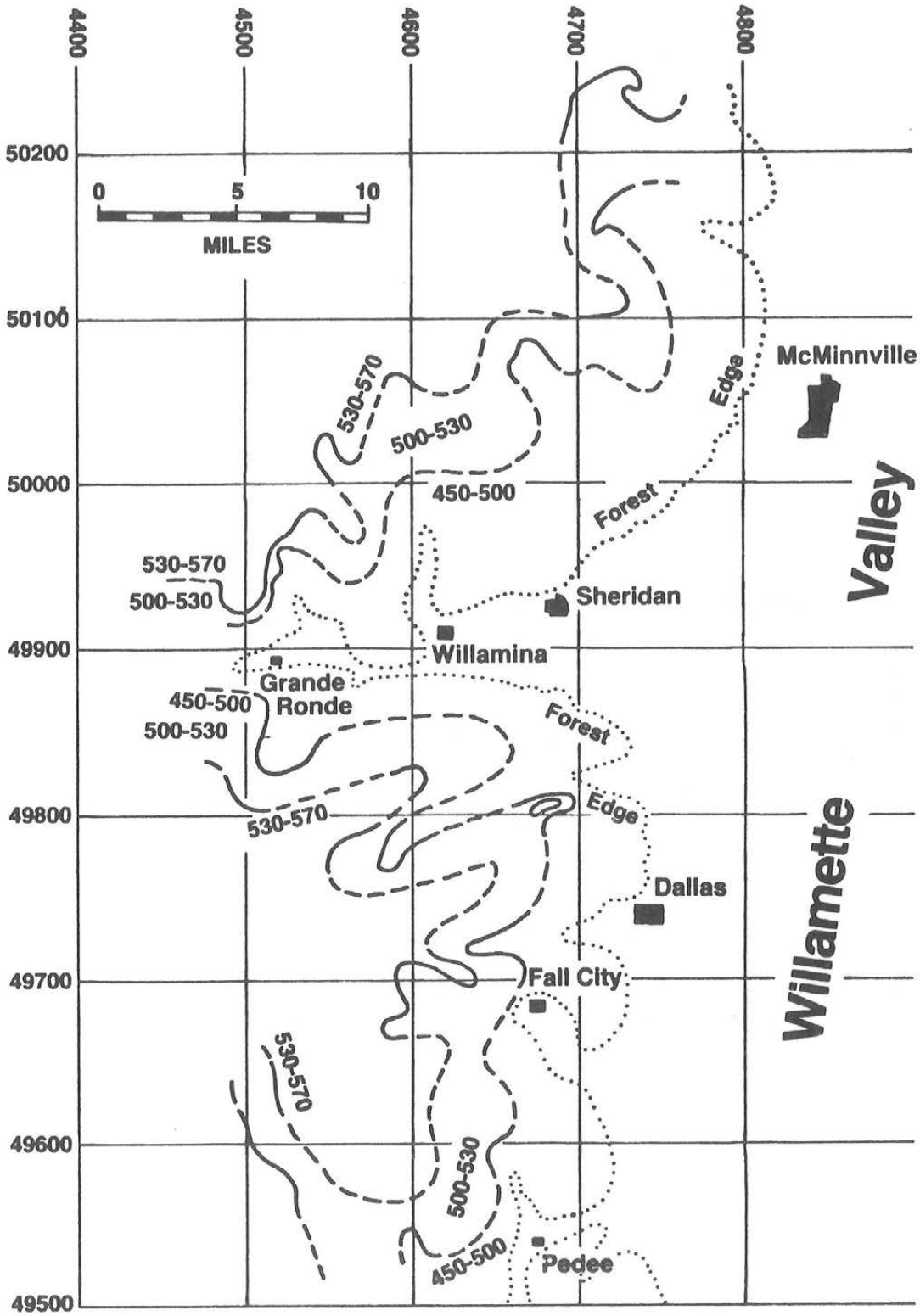


Figure 10.--Dallas Valley Cooperative. The map, like that of the Vernonia Cooperative area, displays a banding of below-average parentage fringing the Willamette Valley. Successive bands of average growth and above-average growth are indicated westward into the Coast Ranges.

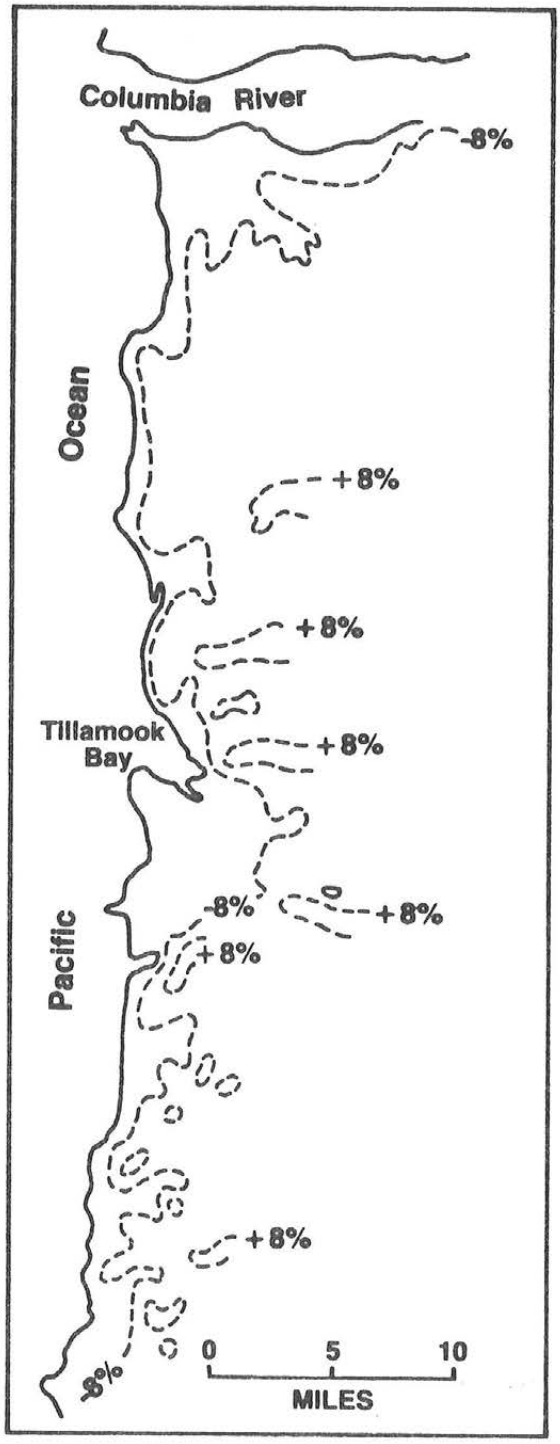


Figure 11.--Tillamook Hemlock Cooperative. Below-average parentage can be delineated by a line along the coast into each estuary to about the limit of tidewater. Average-growth parentage is found inland of this line. Several scattered island-like areas of parentage with above-average growth occur in basins, south slopes, and ridges somewhat back from the coast.