NORTHWEST TREE IMPROVEMENT COOPERATIVE

ANNUAL REPORT 2001

JUNE 2002

OREGON STATE UNIVERSITY
COLLEGE OF FORESTRY

Members of the Northwest Tree Improvement Cooperative for the year 2001

Avery Interests
Boise Cascade Corp.
British Columbia Ministry of Forests
USDI Bureau of Land Management
Canadian Forest Products, Ltd.
Cascade Timber Consulting, Inc.
Crown Pacific, Ltd.
Hampton Tree Farms, Inc.
John Hancock Life Insurance Co.
International Paper Pacific Timberlands, Inc
Longview Fibre Co.
Menasha Corp.
Miami Corp.
Moore Mill Timber Company
Oregon State Department of Forestry
Plum Creek Timberlands L.P.
Pope Resources
Port Blakely Tree Farms L.P.
Quinault Indian Nation
Rayonier Timberlands Operating Co.
Roseburg Resources Co.
Simpson Timber Co.
South Coast Lumber Co.
Starker Forests, Inc.
Stimson Lumber Co.
The Campbell Group
The Timber Company
Timber West Forest, Ltd.
USDA Forest Service, Region 6
Washington Department of Natural Resources
Western Forest Products Ltd
Willamette Industries, Inc.

Cover photo – Dan Cress at the Mill City site of the Molalla Genetic Gain Trial, fall 2001
(Photo by Brad St. Clair)

Northwest Tree Improvement Cooperative

Annual Report

2001

by Keith Jayawickrama, Department of
Forest Science, Oregon State University,
Corvallis, OR 97331

June 2002

Contents

Cooperative Second-Generation Breeding and Testing of Coastal Douglas-fir

NOCTIC seedlings sorted, packed and ready for planting.

The year 2001 was marked by intense activity in cooperative breeding and testing of Douglas-fir. The North Oregon Cascades (NOCTIC) metacooperative established six sites testing 234 full-sib crosses recombining parents selected from 13 first-generation programs.

The Vernonia/Ryderwood meta-cooperative established five sites in the northern part of the Oregon Coast range continuing into the state of Washington, testing 254 full-sib crosses recombining parents selected from three first-generation programs. Summer drought was an issue in their first growing season, and it is hoped the effect on survival and growth will not be too severe.

The South Central Coast (SCC) metacooperative grew test seedlings at Pelton Nursery in British Columbia; by December 2001 over 52,000 seedlings from 287 crosses and controls were ready for lifting for the tests. By then six sites had been prepared for the mainline tests, and three smaller test sites were prepared to test 50 top-ranked families for ability to grow in the presence of Swiss Needle Cast disease. The SCC combined selections from six first-generation breeding units.

The Puget Sound metacooperative sowed its Phase I tests at the IFA nursery in Nisqually, WA in December 2001. Puget Sound was the first metacooperative to in-

Bureau of Land Management – Coos Bay test site for the South Central Coast meta-cooperative immediately after burning.

Stimson test site for Vernonia/Ryderwood metatcooperative.

corporate non-local crosses from other metacooperatives, and was able to sow over 140 families as a result.

With input from NWTIC, members of the North Cascades and South Cascades second-generation programs decided to merge the programs and form a single Washington Cascades metacooperative.

Crossing got underway in spring 2001 for a new Washington Coast program; this program got off to a flying start partly due to the work done on identifying, stimulating and crossing elite parents for NWTIC's Grays Harbor Genetic Gain trial.

Crossing took place for all seven the second-generation programs listed above, in orchards from Whidbey Island in Washington near the Canadian border to south of Eugene in Oregon. The overall progress and status is summarized in in Table 1.

Recognition is due to those cooperators leading these efforts; special mention is made of Al England (Bureau of Land Management – Coos

Table 1. Status of / plans for cooperative second-generation Douglas-fir breeding populations as of December 2001.

	Status	Number of Local & Semi-Local Elite Crosses		Test Sites		
		Target	Already Tested or Sufficient Seed	Target no.	Start planting in spring of	Complete planting in spring of
Washington Cascades	Crossing	361	[a]150	10	[a]2004	[a]2007
Puget Sound	Planting 5 sites in 2003 (Phase I, 143 crosses)	94	81	10	2003	[a]2005
Washington Coast	Crossing	176	40	6	[a]2006	[a]2006
Vernonia/ Ryderwood	Planted 5 sites in 2001 (Phase I, 254 crosses)	404	272	10	2001	2004
North Oregon Cascades	Planted 6 sites in 2001 (Phase I, 234 crosses)	414	317	12	2001	2004
Trask (Coast + Inland + Swiss Needle Cast elite)	Crossing	764	222	24	2004	2006
South Central Coast	Planting 6 sites in 2002 (283 Crosses) + 3 Swiss Needle Cast sites	310	283	6	2002	2002[1]
TOTAL		**2,423**	**1,365**	**78**		

[1] Assuming no Phase II sowing

Bay) for his dedication and patience in steering the SCC through a very demanding year as SCC prepared for test establishment. Al's accomplishments included recruiting three new members to the meta-cooperative (The Campbell Group, Lone Rock Timber Co. and Moore Mill Timber Co.)

NWTIC contributed to second-generation breeding by training support (listed in more detail later), drafting breeding strategies for three of the breeding strategies, and coordinating making and exchanging non-local crosses.

Tom Williams on HEMTIC test site, February 2001

Cooperative Second-Generation Breeding and Testing of Western Hemlock

The level of activity for western hemlock matched that for Douglas-fir, as the second-generation breeding population grown at the IFA nursery at Nisqually was lifted and planted. The 342 full-sib families belonging to the Mainline Local Diallels (in which parents from first-generation local breeding zones were crossed) were planted on four sites; the 166 full-sib families belonging to the Elite Partial Diallels (in which top parents were crossed across first-generation zones) were planted on five sites. There was sufficient over-run to allow planting a further local diallel site in British Columbia (adding to the five sites successfully established there in 1997 and 1998), 155 family blocks in Oregon and Washington, and a further 126 in British Columbia. As shown in Table 2, the second-generation population is now

Table 2. Summary of cooperative second-generation western hemlock (HEMTIC) trials.

Location	Type of Trial	Year Planted (spring of)	Number of Families	Number of Sites	Number of Test Trees Planted
British Columbia	Local Diallel	1997	316	2	12,640
	Local Diallel	1998	334	2.5	15,544
	Local Diallel	2001	332	1	6,640
	Elite Population	1999	143	4	11,440
	Full-Sib Family Blocks	2001	126	1	3,150
Oregon & Washington	Local Diallel	1998	330	2	13,100
	Elite Population	1998	15	1	300
	Elite Population	1999	155	1	4,167
	Local Diallel	2001	342	4	27,360
	Elite Population	2001	166	5	20,750
	Full-Sib Family Blocks	2001	155		15,500
Total					130,591

Table 3. Least squares means five years after planting for the NWTIC Molalla Genetic Gain Verification trial .

Trait		Overall	Site				
			Colton	Estacada	Mill City	Molalla	Silver Falls
Height	Elite Genetic treatment(cm)	190.7	209.2	186.8	269.8	138.3	149.6
	Unimproved control (cm)	180.0	194.1	184.5	253.1	132.8	135.7
	% difference (Elite - Control)	5.9	7.8	1.3	6.6	4.1	10.3
	p-value for (Elite - Control)	0.0005	0.01	0.78	0.075	0.246	0.0012
	1.8 m spacing (cm)	190.3	207.2	182.7	273.6	138.3	149.9
	3.6 m spacing (cm)	179.8	198.9	178.9	249.6	135.1	136.4
	% difference (1.8 m – 3.6 m)	5.9	4.2	2.1	9.6	2.3	9.9
	p-value for (1.8 m-3.6 m)	0.048	0.142	0.560	0.038	0.551	0.071
Dbh	Elite Genetic treatment(cm)	1.44	1.633	1.470	2.329	0.937	0.854
	Unimproved control(cm)	1.34	1.468	1.406	2.103	0.904	0.814
	% difference (Elite - Control)	7.88	11.22	4.51	10.75	3.67	4.90
	p-value for (Elite - Control)	0.007	0.017	0.541	0.108	0.544	0.429
	1.8 m spacing(cm)	1.42	1.561	1.429	2.335	0.923	0.859
	3.6 m spacing(cm)	1.34	1.569	1.350	2.055	0.928	0.801
	% difference (1.8 m – 3.6 m)	6.02	-0.51	5.85	13.6	-0.54	7.24
	p-value for (1.8 m-3.6 m)	0.189	0.900	0.413	0.094	0.773	0.368
Volume	Elite Genetic treatment (cm^3)	791.0	869.0	651.0	1987.0	262.0	186.0
	Unimproved control(cm^3)	619.0	689.0	561.0	1475.0	212.0	157.0
	% difference (Elite - Control)	27.8	26.1	15.9	34.7	23.8	18.5
	p-value (Elite - Control)	0.003	0.032	0.407	0.067	0.241	0.341
	1.8 m spacing (cm^3)	739.0	758.4	589.3	1919.4	235.1	190.5
	3.6 m spacing (cm^3)	641.0	820.4	526.6	1467.8	240.7	149.4
	% difference (1.8 m – 3.6 m)	15.2	-7.56	11.9	30.8	-2.33	27.5
	p-value (1.8 m – 3.6 m)	0.331	0.427	0.524	0.089	0.563	0.300

complete with over 130,000 test trees (not including fillers and buffers) planted.

Jim Hargrove (Quinault Indian Nation) continued his long service as HEMTIC chair in this busy year.

Genetic Gain Verification Trial

After many years of planning and execution, the Molalla Genetic Gain trial finally yielded valuable information upon its first measurement (namely, the first published estimates of realized gain from large-plot trials, for coastal Douglas-fir in the USA) . All five sites as well as the Study Area were measured during September – October 2001, at the end of their fifth growing season.

Across all five locations and both spacings, the difference between the elite population (10 pair-crosses between highly ranked parents from the Molalla breeding population) and the unimproved populations was 5.9% for height, 7.9% for dbh and 27.8% for volume. This difference was statistically highly significant for all three traits. Neither the interaction between genetic population and location, nor between genetic population and spacing were statistically significant. Realized gains matched expected gains (7.5%, 6.9% and 25.0%) closely for the elite population, but were lower than expected gains for the intermediate population. This study, as well as the strongest published work on realized genetic gain in a forest tree species (radiata pine in New Zealand), indicates that realized gains in stem volume may be five times as large as realized gains in height.

It should be noted that the expected gains for this group of 20 parents was not the maximum possible even for the Molalla breeding zone, nor is it by any means an upper limit for gain from first-generation breeding programs or elite 1.5 generation orchards.

The second phase of the Genetic Gain trial was planted in spring 2001, on five sites in the Noti breeding zone in the Oregon Coast Range. Over 32,600 seedlings were planted in this trial. The seedlings faced a challenging dry first spring and summer, and their progress will be watched.

Data Management

NWTIC staff started implementing the plan approved by the membership at the October 2000 annual meeting. NWTIC contributed to the purchase of a new server by the College of Forestry. This powerful new machine has an eight-processor server, 4 GB of RAM and a large expandable storage system.

Work has progressed furthest on the parent-tree geographic information. We expect to get data from 29,776 parent trees. During 2001 we brought the number of records present to 26,751 (90% of the total) and complete data to 25,844 (87% of the total). Parent- tree records are complete for 40 of 115 first-generation breeding zones.

Over 16,500 data and analysis files (with over 2.5 GB information) were transferred from diskettes and compact disks to the hard drive's NWTIC directory. These were sorted into 647 appropriate folders (directories / subdirectories), and checked that files with duplicate names but different dates were renamed accordingly.

The database design was fine-tuned to include information for contacts, programs, sites and sowing schedules, parent tree and cross-breeding info, orchard sowings, progeny measurements, and plantation and family results. The process of loading data into SQL Server was started. Work also began on a NWTIC web page, with the objective of providing cooperators with better and faster access to data and other information.

Table 4. Summary of data analyses and reports completed in 2001

Breeding Unit	Second-Generation Breeding Plan Generated
Cowlitz: Breeding Unit 1	Yes
Cowlitz: Breeding Unit 3	Yes
Port Gamble	Yes
Skagit: North-High	Yes
Skagit: North-Low	Yes
Skagit: South-High	Yes
Skagit: South-Low	Yes
Grants Pass: Breeding Unit 2	No
Cave Junction: Breeding Unit 1	No
South Umpqua Breeding Unit 2	No

Data Analyses and Reports

NWTIC maintained emphasis on data analysis, completing analyses and reports for 10 first-generation breeding units. The data analysis protocol was reviewed at a Technical Committee meeting held at OSU in July, and some adjustments were made. The data analysis protocol is to be fully documented in 2002 and circulated as an NWTIC technical document. Cooperators are now provided a more detailed analysis and a report to help interpret the findings. Given how long it takes to properly evaluate the families, and how much time and expense is involved establishing, maintaining and measuring tests, proper analysis and reporting are obviously vital for the interests of members. NWTIC made a special effort to obtain completed datasets and provide analyses to the Mapleton, Medford, Powers and Roseburg cooperatives from southwest Oregon.

Training and Information Transfer

NWTIC held a workshop on progeny test site selection in September 2001. The objective behind this workshop was to help cooperators maximize the benefits of second-generation test establishment, by identifying uniform test sites with the minimum future difficulties. The workshop was attended by representatives of nine NWTIC members. NWTIC also gave input and support into establishing the HEMTIC sites (planting and mapping), and site selection, test design, nursery randomization and packout for the South Central Coast program. A new section ("Guidelines for cooperative second-generation testing for Douglas-fir and western hemlock") was added to the NWTIC Tree Improvement Handbook and circulated to members.

Getting Genetic Gain In Operational Plantations

Recognizing that investment in testing and breeding alone do not guarantee realizing genetic gain in plantations, NWTIC increased its involvement in deployment (with formal approval by membership at the annual meeting to spend up to 20% of effort in this area). A workshop held in Portland on November 14 on this topic, (with the same title "Getting Genetic Gain In Operational Plantations") attracted 48 participants from Oregon, Washington, British Columbia and Idaho. Topics covered included cooperator expectations and attitudes toward genetic gain, the ingredients for successful transfer of genetic gain to plantations, the relationship between number of parents and genetic gain and diversity, rooted cuttings for Douglas-fir and western hemlock, tree improvement as compared to other tools to boost productivity, and managing tree improvement for gentic gain.

Perhaps the most significant and exciting activity in this area was NWTIC's involvement in establishing a high-gain "1.5" generation seed orchard (Interim Dallas orchard) at the J.E. Schroeder Seed Orchard complex. The best selections from nine first-generation programs (containing a total of nearly 2,000 tested families) were selected, with a strong emphasis on parental ("backwards") selections. Members of the orchard cooperative went to great efforts to locate parent trees and collect supplementary wood specific gravity information where needed. The orchard is to be grafted in February 2002. Members of the Burnt Woods seed orchard cooperative decided to similarly upgrade the Burnt Woods Interim Orchard, with help from NWTIC. This project will begin in 2002.

NWTIC also gave the Oregon Department of Forestry a recommendation on deploying genetically improved western hemlock seed in the Astoria and Tillamook districts, and input to a western hemlock seedling seed orchard to be established by Crown Pacific.

Sitka Spruce Program

A cooperative program to develop to develop genetically improved Sitka spruce for planting in coastal Oregon and Washington finally got underway. The approach adopted was to test selections from OR and WA (undamaged phenotypes with potential resistance to the white pine weevil) and weevil-resistant selections from British Columbia, and select for growth rate and lack of weevil attack. Discussion with breeders in British Columbia continued on gaining access to weevil-resistant spruce. Some selections have already been made by Oregon Department of Forestry, Willamette Industries, Inc. and the Bureau of Land Management. Much of the interest and enthusiasm for this program was provided by Oregon Department of Forestry (Astoria and Tillamook districts) and Willamette Industries, Inc.

Membership Changes

NWTIC ended 2001 with one less member than it started. Two memberships were lost due to the merger of The Timber Company and Plum Creek, and the sale of IP Pacific Timberlands (whose assets were bought by a client of The Campbell Group). However NWTIC was pleased to welcome Moore Mill Timber Company as an active member during the year, and Lone Rock Timber Company stated its intent to join from the beginning of 2002.

Cooperators

Randall Greggs (Simpson Timber Co.) was re-elected NWTIC Chair at the 2001 annual meeting.

NWTIC members voted to disband the Steering Committee at that same meeting.

NWTIC representatives for 2001 were:

Pete Mastenbroek (Avery Interests)

Don Wales (Boise Cascade Corp.)

Charlie Cartwright (BC Ministry of Forests, Research Branch)

Liang Hsin (Bureau of Land Management)

Patti Brown (Canadian Forest Products)

Howard Dew (Cascade Timber Consulting)

Jim Unsell (Crown Pacific--Hamilton Division)

Steve Loy (Crown Pacific -- Olympic Division)

Beth Fitch (Hampton Tree Farms)

John Davis (John Hancock Life Insurance Co.)

Erik Lease (Longview Fibre Co.)

Ron Durham (Menasha Corp.)

Joe Steere (Miami Corp.)

Brett Weidemiller (Moore Mill Co.)

Rosemary Mannix (Oregon State Department of Forestry)

Loren Hiner (Plum Creek Timber lands L.P.)

Bryan Schulz (Pope Resources)

Brandon Austin (Port Blakely Tree Farms)

Jessica Josephs (Rayonier Timberlands)

Dave Walters (Roseburg Resources)

Randall Greggs (Simpson Timber Company – WA and OR operations)

Mark Diegan (Simpson Timber Company – Cal Ops)

Marc Halley (South Coast Lumber)

Dick Powell (Starker Forests)

Margaret Banks (Stimson Lumber Co.)

Jim Hargrove (Quinault Indian Nation)

Jeff Madsen (The Campbell Group)

Jim Smith (The Timber Company)

Tim Crowder (Timber West Forest)

Sheila Martinson (USDA Forest Service, Region 6)

Jeff DeBell (Washington Department of Natural Resources)

Annette van Niejenhuis (Western Forest Products)

Greg Johnson (Willamette Industries, Inc.).

Staff

Dan Cress was recruited as NWTIC Analyst / Coordinator in June 2001. Keith Jayawickrama continued as Director and Denise Steigerwald as Information Manager.

Overview of Cooperative Testing and Second-Generation Breeding and Testing of Douglas-fir

First-Generation Testing

The IFA-PNW Progressive Tree Improvement System was launched in 1966 with the formation of the Vernonia cooperative in northwest Oregon. The concept took firm hold among the forestry industry and agencies in Oregon, Washington, and California, till 21 first-generation local cooperatives were formed and the Douglas-fir zone west of the Cascades was blanketed with over 100 separate breeding units. Test establishment finally ended in 1993 with the second sowing of the Skagit cooperative, in the Skagit and Whatcom counties in northern Washington.

Second-Generation Breeding

A second-generation task force was formed in 1984-85 to explore requirements for a second-generation program. Key participants were Bob Campbell and Roy Silen (USDA Forest Service PNW Research Station), Mike Bordelon (Oregon State Department of Forestry), Rich Kelley and Liang Hsin (USDI Bureau of Land Management), and Tim White and Greg Johnson (International Paper).

The South Central Coast program was formed around 1986 to consolidate the Umpqua, Mapleton, Coquille, Noti, and Reedsport first- generation breeding programs. Around 1987-88, Vernonia developed a second- generation breeding plan combining the original Vernonia breeding unit, International Paper's Ryderwood program, and the Vernonia Southeast program. However, progress on breeding was slow in both programs for a number of reasons.

The BZERC Strategy

The Breeding Zone Restructuring and Restructuring Cooperatives (BZERC) strategy was developed between 1996 and 1997. This strategy could be applied, depending on interest, to cooperative second-generation breeding of Douglas-fir from northern California to southwestern British Columbia. The BZERC prospectus outlined a genecological, multi-population approach and a regionalized breeding strategy for second-generation program development. Details of the BZERC strategy can be found in Jess Daniels' report of the BZERC committee, and the BZERC final recommendations are also included in Johnson (1998).

Using the BZERC recommendations, Jess Daniels (NWTIC), Randy Johnson (USFS-PNW Research station), David Todd (Champion International) and others drafted preliminary breeding plans for the north Oregon Cascades, Oregon Coast Range and the western Washington regions in 1997 and 1998.

The objectives of program restructuring were:

- Reduce breeding and testing costs to cooperators.
- Provide opportunities to reduce orchard costs.
- Increase genetic gain potential for important traits.
- Maintain adaptability of breeding and production populations.
- Minimize risks of deployed seed not meeting expectations.
- Retain flexibility to change strategies in a timely manner.

Key questions asked in structuring the breeding programs were:

- What will the operational seed/plant propagation system be?
- What trait or trait combinations will be selected?
- What should be considered a breeding zone?
- How many clones must be in a seed orchard or how many clones will be deployed if clonal forestry is an option? (How much genetic diversity is needed in the production forest?)
- What is considered as the gene resource population and how will it be maintained (in situ, or in the breeding population)?

The BZERC group came up with the following, termed "A Multiple-Population (Genecological) Breeding Approach":

- Geographically adjacent breeding programs may merge for purposes of sharing genetic material in the next round of breeding and testing. This shared set of selections makes up the breeding population.
- Breeding groups are used to confine relatedness, manage inbreeding, and create multiple populations for purposes of genetic conservation.
- Breeding groups are structured such that members of a breeding group are genetically similar with respect to adaptive traits. To accomplish this, groups should be defined on the basis of geographic proximity and/or climatic similarity, or based on knowledge of genetic architecture.
- The top 10-20 percent of parents within a breeding population could also be assigned to special breeding groups to form an elite population for the purpose of generating higher genetic gains for economically important traits or trait combinations.
- There should be at least nine breeding groups within a given testing zone should be at least nine to allow for effective crossing among members of different breeding groups in a wind-pollinated seed orchard. (Fewer might be used if control-pollination or supplemental mass pollination technology will be routinely used for operational seed production.)
- Breeding population size for any merged programs should be in the order of at least 300-400 selections.
- Breeding group size should be in the order of 20-40 to allow a slow approach to inbreeding and sufficient genetic gain within any single breeding group.

Proposed BZERC Strategy for Restructuring Co-op Breeding Programs:

The working group recommended that each existing breeding zone formed four to eight second-generation breeding groups of 25-30 selections. Each new testing zone was to utilize all of the families from "local" breeding groups and only the most elite selections from breeding groups originating further away from the testing zone. Each testing zone would test a proportion of families from breeding groups which are two "breeding zones" away. Elite populations could be created whenever additional genetic gains are desired.

Families were to be tested on a minimum of four sites within a testing zone. If elite populations were used, this number could be decreased for the main population. Cooperators in some testing zones had the option to further subdivide their land base because of extreme uncertainty as to whether the area as a whole is truly one breeding zone (e.g., high- and low-elevation subunits). In such cases, each sub-unit should test families on at least two, but preferably three, sites.

The Testing Program

The BZERC committee proposed a combination of three types of tests, each with a specific purpose and design: family-ranking/selection tests; long-term stability tests; and adaptability-screening tests.

Family-Ranking/Selection Tests

These tests were designed to give precise estimates of family means and family-site interactions (genotype x environment interactions = G x E). "Alpha" designs with 20 trees per family per site, in single-tree plots comprising a total of 20 replications, were recommended, and 8 ft. x 8 ft. spacing .

Long-Term Stability Tests

These tests were designed for long-term assessment of adaptability/stability of families (a life span of approx. 25 years). They would be different from family ranking / selections in that they would employ a conventional randomized complete block design, 2-tree interlocking blocks, and would be designed to have balanced numbers of trees after thinning, from an initial 680 trees/acre to 340 trees/acre. The information taken from these tests, before thinning, could also be used for inferences on family ranking and selection.

Adaptability-Screening Tests

The BZERC committee suggested using additional tests to get early data on the adaptational characteristics of the selected trees. Traits in this category included cold-hardiness, date of bud flush, and drought tolerance; some were to be assessed in the field and some in laboratories.

Implementing the BZERC Strategy and Subsequent Modifications

The Molalla and Snowpeak programs were combined into the North Oregon Cascades (NOCTIC) metacooperative in 1998 based on the BZERC strategy, and become the first Douglas-fir metacooperative. Also in 1998, the Vernonia program was converted into a meta-cooperative, with slight changes to the breeding plan to align it with BZERC. The Trask metacooperative, combining the BLM, Burnt Woods, Dallas, Sunday Creek, Nehalem, Alsea, Hebo, and The Timber Company programs, was formed in 1999. The South Central Coast second-generation program also adopted the BZERC strategy. In Washington, the Puget Sound metacooperative has made the most progress in terms of formal structure and sowing; crossing has begun for a Washington Cascades metacooperative and a Washington Coast metacooperative although formal agreements are yet to be made. In the process of combining first-generation programs, several previously independent programs (e.g., Washington Department of Natural Resources, The Timber Company) joined NWTIC and contributed their independently improved selections.

The rule of thumb for "Local x Local" crosses has been a 1 in 10 selection intensity; the large number of first-generation selections tested in the region allowed this luxury while still keeping the population size big enough for many cycles of selection. The term "Elite Semi-Local" was later coined to signify crosses within the metacooperative but between first-generation breeding zones (e.g. Cowlitz BU-1 x Cowlitz BU-2). In the Washington programs, around three to five parents have been used per program. Similarly, the term "Alien" was replaced by "Non-Local". Non-Local crosses have been categorized as "Adjacent" (closer / more similar to the metacooperative) and "Intermediate". A 1 in 25 selection intensity is used in selecting parents from “Adjacent” zones and 1 in 50 for “Intermediate” zones. The full structure of the second-generation metacooperatives and their constituent first-generation breeding zones is shown in Table 5.

These tests are being established using both alpha and sets-in-replicates experimental designs. In one case alpha designs were used in a thinable configuration. Both 8 ft ¥ 8 ft for and 9 ft ¥ 9 ft spacings have been used. Tests established to date have had five or six sites, with 20 replicates per site.

As of 2001, there was no agreement to continue many of the first-generation breeding zones from southwest Oregon into a second generation of breeding and testing. This was largely due to decreased harvesting and reforestation on federal timberland in this area. Given the fact that over 10,000 parents have been tested in these first-generation cooperatives and given that there are hundreds of thousands acres of industrial timberland in the area, there are obviously opportunities for other NWTIC members in terms of second-generation breeding and testing. These breeding units are listed in Table 6.

Reviewing both tables, it is worth noting that over 26,000 parents have been tested in 109 first-generation breeding zones.

Glossary Used in the Original BZERC Strategy

Breeding zone - A geographic-elevational subdivision of a local co-op program area (e.g., the Snow Peak Coop’s High-Elevation zone) within which a group of parent trees was originally selected and progeny tested as the basis for first-generation seed orchards (i.e., the existing NWTIC breeding zones/units).

Breeding population - The group of parents that will be crossed to produce full-sib families to test within a deployment unit. These parents need not be limited to the area encompassed by the deployment unit. Breeding zone evaluation depends upon the willingness of cooperators to test families from beyond their local deployment units (i.e., wide testing). The farther from the deployment unit, the more selective one will be in choosing parents to be tested (i.e., only the most elite selections will be wide-tested across substantial geographic/climatic distances). While deployment units are geographically distinct, breeding populations will have considerable overlap. Two adjacent deployment units could be testing most of what is in the other’s breeding population.

Breeding group - A group of 20-30 parents which is used to generate full-sib families for testing. This is a subset of the breeding population. Parents within a breeding group are from the same geographic area; therefore, they are expected to have very similar adaptational characteristics because, presumably, they have evolved under similar selection pressures. These groups are also formed to ensure that breeding groups are unrelated. All breeding population crosses are made within breeding groups. This accomplishes two things: (1) the multiple populations that are formed help conserve genetic diversity and maintain any co-adapted gene complexes; and (2) outcrossed seed can always be produced to overcome any inbreeding depression by crossing parents from different breeding groups.

Deployment zone - The planting area (i.e., a set of planting environments) for which a landowner (or group of cooperators) chooses to develop a production population (e.g., a seed orchard) from selections made in second-generation tests.

Ecoregion - A subdivision of the range of coastal Douglas-fir which is perceived to be significantly different from other such subdivisions in terms of overall climatic and ecological conditions in-

Table 5. Details on second-generation metacooperatives and their constituent first-generation breeding zones.

Second Generation Meta-cooperative	First Generation Program		Elevation	Tested Parents*	Second Generation Meta-coops							
					WA Coastal	Puget Sound	WA Cascades	Veronia Ryderwood	TRASK Coast	TRASK Inland	South Central Coast	NOCTIC
WA Coast	Rayonier	Forks Douglas-Fir	< 1,000'	211	**18**	5	3	5	5	3	3	
WA Coast	DNR	Forks	0-1,600	120	**15**	4	2	4	4	2	2	
WA Coast	NWTIC: Grays Harbor	Douglas-fir	< 500'	506	**80**	15	8	15	15	8	8	
WA Coast	DNR	Coast	0-1,400	120	**15**	12	2	4	4	2	2	
WA-Coast	DNR	Southwest	400-1,800	120	**12**	12	2	4	4	2	2	
WA-Puget Sound	Shelton	Simpson	< 500'	306	3	**15**	3	3	3	3		
WA-Puget Sound	NWTIC: Port Gamble	Pope Resources	< 1,000'	130	4	**12**	4	4	2	2		2
WA-Puget Sound	DNR	South Sound	0-1,900	120	4	**12**	12	4	2	2		2
WA-Puget Sound	DNR	Central	0-2,000	120	4	**12**	12	4	2	2		2
WA-Puget Sound	Elite Semilocal			18	27	**27**	27	27		27		10
WA-Cascades	NWTIC: Cowlitz	BU-1	< 1,500'	265	5	9	**28**	5				9
WA-Cascades	NWTIC: Cowlitz	BU-2	1,500 - 2,500'	360	3	6	**36**	6				12
WA-Cascades	NWTIC: Cowlitz	BU-3	1,500 - 2,500'	240	2	4	**24**	4				8
WA-Cascades	NWTIC: Cowlitz	BU-4	2,500 - 3,500'	300		4	**36**	4				12
WA-Cascades	NWTIC: Cowlitz	BU-5	2,500 - 3,500'	200		3	**28**	3				9
WA-Cascades	NWTIC: Snoqualmie	BU-1	500 - 1,700'	238		8	**23**	4				8
WA-Cascades	NWTIC: Snoqualmie	BU-2	> 2,000'	330		12	**35**	3				12
WA-Cascades	DNR	Northwest	200-2,300	120		5	**12**					2
WA-Cascades	NWTIC: Skagit - Low	Douglas-fir	300 - 1,300'	150		4	**20**					4
WA-Cascades	NWTIC: Skagit - High	Douglas-fir	1,300 - 2,700'	150		4	**20**					4
Trask-Coastal	OR Dept. Forestry	NWA	< 2,000'	150								
Trask-Coastal	NWTIC: Nehalem	Co-op Program	< 2,500'	380	12	6		6	**60**	**25**	12	
Trask-Coastal	USFS	Hebo Series 1&2	350-2,160	281	9			5	**30**	**15**	9	
Trask-Coastal	USFS	Alsea/Waldport										
		Low Series 1&2	250-1,500	284	9			5	**31**	**10**	9	

*Originating from this zone

Table 5 continued

Second Generation Meta-cooperative	First Generation Program		Elevation	Tested Parents*	Second Generation Meta-coops							
					WA Coastal	Puget Sound	WA Cascades	Veronia Ryderwood	TRASK Coast	TRASK Inland	South Central Coast	NOCTIC
Trask-Coastal	USFS	Alsea/Waldport High	1,000-2,000	151				2	**13**	**5**	2	
Trask-Coastal	GP	Toledo (Roadside Trees)	200 - 2,250'	250	7			3	**15**		7	
Trask-Coastal	GP	Toledo (Plus Trees)	250 - 2,000'	100				3	**20**		3	
Trask-Both	BLM	BU-11: Nestucca	900 - 2,900'	260		4		4	**22**	**22**	4	4
Trask-Both	BLM	BU-13: Alsea	1,000 - 2,700'	205				3	**20**	**20**	3	3
Trask-Both	BLM	BU-12: Yamhill	900 - 2,900'	213		2		2	**15**	**15**	2	2
Trask-Both	NWTIC: Burnt Woods	Phase I	500 - 2,000'	162	3			3	**22**	**15**	3	3
Trask-Both	NWTIC: Burnt Woods	Phase II	200 - 2,700'	312	5			5	**41**	**25**	5	5
Trask-Inland	NWTIC: Dallas	Valley Side	400 -2,100	228	4	4		8		**37**	4	4
Trask-Inland	NWTIC: Dallas	Valley-Addition	360 - 1,500	70						**23**		
Trask-Inland	NWTIC: Dallas	High	860 - 3,100	203	3	3		7		**35**	3	3
Trask-Inland	NWTIC: Vernonia	Sunday Creek	800 - 2,700'	84		3		3		**25**	3	
South Central Coast	NWTIC: Mapleton	Low-Elev. (BU-1)	< 1,000'	256	4				8	4	**44**	4
South Central Coast	NWTIC: Mapleton	High-Elev. (BU-2)	1,000 - 2,500'	240	2				4	2	**31**	4
South Central Coast	NWTIC: Umpqua	Coast	500 - 1,600'	600	8				20	10	**50**	10
South Central Coast	NWTIC: Umpqua	Swisshome	400 - 2,500'	270	4				9	9	**66**	4
South Central Coast	NWTIC: Reedsport	Coastal Test	750 - 1,600'	254	4				9	4	**50**	
South Central Coast	NWTIC: Coquille	Coastal (BU-16)	50 - 1,500'	376	6				13	6	**37**	
South Central Coast-Inland	NWTIC: Umpqua	Elkton	400 - 2,300'	297								
South Central Coast-Inland	NWTIC: Umpqua	Noti	500 - 1,800'	331								
South Central Coast-Inland	NWTIC: Umpqua	Wells Creek	500 - 2,000'	216								
South Central Coast-Inland	BLM	BU-34: Lorane	500 - 1,800'	240								
South Central Coast-Inland	NWTIC: Coquille	Inland (BU-17)	240 - 2,480'	280								
Vernonia / Ryderwood	I.P. / Hampton	Ryderwood	300-2,000	298	5	10	5	**50**		10	5	
Vernonia / Ryderwood	NWTIC: Vernonia	Original	200 - 2,000'	905	15	20	15	**298**		20	15	

*Originating from this zone

Table 5 continued

Second Generation Meta-cooperative	First Generation Program		Elevation	Tested Parents*	Second Generation Meta-coops							
					WA Coastal	Puget Sound	WA Cascades	Veronia Ryderwood	TRASK Coast	TRASK Inland	South Central Coast	NOCTIC
Vernonia / Ryderwood	NWTIC: Vernonia	Southeast / BLM 10	300 - 1,500'	169		6	3	**31**		6	3	
NOCTIC	USFS	Estacada 202-06013	2,000 - 3,000'	360			12	6		6		**15**
NOCTIC	USFS	Estacada 202-06014	3,000 - 4,000'	300			5	3		3		**3**
NOCTIC	USFS	Estacada 202-06015	4,000 - 5,000'	100			2					**2**
NOCTIC	NWTIC: Molalla	Original	1,000 - 2,500'	375		6	12	6		6		**74**
NOCTIC	BLM	BU-30: Molalla	1,000 - 2,700'	168		4	8	4		4		**44**
NOCTIC	BLM	BU-31: Molalla	2,700 - 3,800'	134			6	2		2		**0**
NOCTIC	BLM	BU-32: Snow Peak	2,700 - 3,800'	124			6	2		2		**38**
NOCTIC	BLM	BU-33: Snow Peak	1,000 - 2,700'	190		5	9	3		5		**15**
NOCTIC	NWTIC: Snow Peak	Low	< 1,800'	198		2	4	2		2		**53**
NOCTIC	NWTIC: Snow Peak	High	1,800 - 3,000'	215			6	3		3		**66**
NOCTIC	NWTIC: Snow Peak	Wiley Creek	< 1,800'	96			3	2		2		**10**
NOCTIC	USFS	Detroit/Sweet Home Mid	2,000-3,000	210								**?**
NOCTIC	USFS	Detroit/Sweet Home High	3,000-4,000	210			7	3		3		**25**
NOCTIC	USFS	Oakridge Ridgon Lowell Mid Series 2	2,000 - 3,000'	185			9	4		4		**14**
NOCTIC	BLM	BLM McKenzie	800 - 4,100'	513			10	5		5		**25**
ELITE					50	27	50		50		45	36
TOTAL Breeding Population Size				**15,573**	342	287	509	586	443	443	432	545
Local x Local					140	51	210	379	289	272	283	367
(Local x Local) + Elite					190	78	260	379	339	272	323	403
Non-Local					152	209	249	207	104	171	109	142

*Originating from this zone

Table 6. First-generation breeding units not currently planned to continue into second-generation breeding zones.

Cooperative	Breeding Unit		Elevation	Tested Parents
Powers	BU-1	Low	500 - 1,500'	206
	BU-2	Mid	1,500' - 2,500'	194
Gold Beach	Zone 1	North	0 - 1,500'	270
	Zone 2	South	0 - 1,500'	342
	Zone 2 Extension		0 - 1,500'	145
	Zone 3		1,500 - 2,500'	314
McKenzie/Oakridge	USFS-Oakridge/Rigon/Lowell	18011	1,000 - 2,000'	159
	USFS - Oakridge/Rigon/Lowell	18012 (Series 1)	2,000 - 3,000'	90
	USFS - Oakridge/Rigon/Lowell	18013	3,000 - 4,000'	180
	USFS - Blue River/McKenzie	18022	2,000 - 3,000'	204
	USFS - Blue River/McKenzie	18023	3,000 - 4,000'	183
Roseburg	North Umpqua	BU-1&2	500' - 2,000'	390
	North Umpqua	BU-2	2,000' - 2,500'	180
	North Umpqua	BU-3	2,500' - 3,000'	390
	North Umpqua	BU-4	3,000' - 3,500'	400
	North Umpqua	BU-5	3,500' - 4,500'	330
	Riddle	BU-1	1,000' - 1,500'	180
	Riddle	BU-2	1,500' - 2,000'	360
	Riddle	BU-3	2,000' - 2,500'	295
	Riddle	BU-4	2,500' - 3,500'	180
	South Umpqua	BU-1	1,000' - 2,000'	360
	South Umpqua	BU-2	2,000' - 2,500'	360
	South Umpqua	BU-3	2,500' - 3,000'	360
	South Umpqua	BU-4&5	3,000' - 4,500'	353
	Tyee	BU-1	< 1,500'	360
	Tyee	BU-2	1,500' - 2,500'	210
Medford	Butte Falls	Butte Falls BU-1	2,500' - 3,500'	210
	Butte Falls	Butte Falls BU-2	3,500' - 4,500'	200
	Cave Junction	Cave Junction BU-1	1,500' - 2,500'	317
	Cave Junction	Cave Junction BU-2	2,500' - 3,500'	231
	Cave Junction	Cave Junction BU-3	3,500' - 4,500'	220
	Evans-Elk	Evans-Elk BU-1	2,000' - 3,000'	200
	Evans-Elk	Evans-Elk BU-2	3,000' - 4,000'	200
	Grants Pass	BU-2	2,000' - 3,000'	210
	Jacksonville	BU-1	1,500' - 2,500'	210
	Jacksonville	BU-2	2,500' - 3,500'	200

Table 6 continued.

Cooperative	Breeding Unit		Elevation	Tested Parents
	Jacksonville	BU-3	3,500' - 4,500'	204
	Jacksonville	BU-4	4,500' - 5,500'	200
	Marial	BU-1	1,500' - 3,000'	300
	Marial	BU-2	3,000' - 4,000'	210
	Prospect	BU-1	2,500' - 3,500'	197
	Prospect	BU-2	3,500' - 4,500'	200
TOTAL Number of parents				10,504

fluencing the general adaptational character or status of resident populations. While there is genetic variation among populations within an eco-region, the range of variation is expected to be much narrower within than between eco-regions. For example, the coastal areas of Oregon and Washington might be considered as one eco-region, while the Oregon/Washington Cascades could be defined as two additional eco-regions.

Elite population - A subset of the breeding population which is comprised of the very best selections. Elite populations are generally used to accelerate breeding efforts by putting more resources into breeding the elite population relative to the larger breeding population (sometimes referred to as the main population). The increased effort can come as a result of increased crossing efforts (i.e., more crosses per parent), faster turnover of generations, and/or increased testing (e.g., more sites or testing of additional traits). The elite population can also be structured into breeding groups if desired. Normally an elite population gives increased attention to a trait or group of traits. This can result in more than one elite population in a program. For example, there could be two elite populations for the coastal area: one emphasizing Swiss needlecast resistance, and another emphasizing growth and form (for low SNC-hazard areas).

Gene resource population - All of the extant individuals of a species which might potentially be selected for inclusion in various breeding populations for a given eco-region.

Production population - A group of selections used to produce improved operational reforestation stock (e.g., seed orchard clones and/or clonal donor stock). Only clones which have been tested (either by their progeny or sibs) in a deployment unit will be utilized for that unit. For example, a parent which originates from a different breeding unit can be used in the breeding population, yet it would not be considered for use in a production population if it has not been previously tested in the deployment unit which the orchard is to serve.

Testing zone - The land area represented by the group of sites (i.e., environments) chosen for testing selections for a given second-generation co-op program (e.g., a combined Molalla/Snow

Peak/BLM Salem program that might be called the "Northern Oregon Cascades TI Co-op").

Recent Reports and Publications of Interest to Members, and Publications Derived from Cooperative Datasets.

Adams, W.T., Aitken, S.N. Joyce, D.G., Howe, G.T. and Vargas-Hernandez, J. 2002. Evaluating efficiency of early testing for stem growth in coastal Douglas-fir. Silvae Genetica (in press).

Anekonda, T.S., and W.T. Adams. 2000. Cold hardiness testing for Douglas-fir tree improvement programs: guidelines for a simple, robust and inexpensive screening method. Western Journal of Applied Forestry 15(3): 129-136.

Anekonda, T.S., Adams. W.T., Aitken, S.N., Neale, D.B., Jermstad, K.D. and Wheeler, N.C. 2000. Genetics of cold hardiness in a cloned full-sib family of coastal Douglas-fir . Canadian Journal of Forest Research 30: 837-840.

Jayawickrama, K. 2001. Getting Genetic Gain in Operational Plantations. Proceedings of NWTIC Workshop, OSU Capital Center, Beaverton, OR, November 14, 2001.

Jayawickrama, K. and Cress, D. 2001. Guidelines for cooperative second-generation testing of coastal Douglas-fir and western hemlock. Update to NWTIC Tree Improvement Handbook.

Jermstad, K.D., Bassoni, D.L., Wheeler, N.C., Anekonda, T.S., Aitken, S.N., Adams, W.T. and Neale, D.B. 2001. Mapping of quantitative trait loci controlling adaptive traits in coastal Douglas-fir: II. Spring and fall cold hardiness. Theoretical and Applied Genetics 102: 1152-1158.

Johnson, G.R. 2000. Financial feasibility of marker-aided selection in Douglas-fir. Canadian Journal of Forest Research 30: 1942-1952.

Johnson, G.R. 2002. Genetic Variation in Tolerance of Douglas-fir to Swiss Needle Cast as Assessed by Symptom Expression. Silvae Genetica (in press).

O'Neill, G.A., Adams, W.T. and Aitken, S.N. 2001. Quantitative genetics of spring and fall cold hardiness in seedlings from two Oregon populations of coastal Douglas-fir. Forest Ecology and Management 149: 305-318.

O'Neill, G.A., Adams, W.T. and Aitken, S.N. 2000. Genetic selection for cold hardiness in coastal Douglas-fir seedlings and saplings. Canadian Journal of Forest Research 30: 1799-1807.

Temel, F., and W.T. Adams. 2000. Persistence and age-age genetic correlations of stem defects in coastal Douglas-fir (Pseudotsuga menziesii var menziesii[Mirb]Franco). Forest Genetics 7: 145-153.

Webber, J.E. 2000. Western hemlock: a manual for tree improvement seed production. Working Paper 44/2000. Research Branch, BC Ministry of Forests, Victoria, British Columbia, Canada. Working Paper 44/2000.

Woods, J., and K. Jayawickrama. 2000. Notes on a tour of forest tree improvement in the southeastern USA. Western Forestry and Conservation Association, Portland, OR.

Mission of the Northwest Tree Improvement Cooperative

- Oversee cooperative breeding of Douglas-fir, western hemlock and other species of the coastal forests of the Pacific Northwest
- Guide technical aspects of implementing these tree improvement programs
- Analyze and interpret genetic test data
- Store test data and breeding records
- Provide expertise and training in tree breeding