

NORTHWEST TREE IMPROVEMENT COOPERATIVE REPORT

OCTOBER 1 2007 TO JULY 31 2009

SEPTEMBER 2009



Members of the Northwest Tree Improvement Cooperative as of June 30, 2009

Bloedel Timberlands	Quinault Indian Nation
Bureau of Land Management	Rayonier Timberlands Operating Company
Cascade Timber Consulting, Inc.	Rocking C Ranch
Forest Capital Partners	Roseburg Resources Company
Fruit Growers Supply Company	SDS Lumber
Giustina Land and Timber Company	Seneca Jones Timber Company
Giustina Resources	Sierra Pacific Industries
Green Crow Management Services	Silver Butte Timber Co.
Green Diamond Resource Company	South Coast Lumber Company
Hampton Tree Farms, Inc.	Starker Forests, Inc.
Hancock Forest Management	Stimson Lumber Company
Lone Rock Timber Company	The Campbell Group
Longview Timberlands	Timber West Forest, Ltd.
Miami Corporation	Washington Department of Natural Resources
Oregon State Department of Forestry	West Fork Timber
OSU College Forests	Liaison Members
Plum Creek Timberlands L.P.	Pacific Northwest Tree Improvement Cooperative
Pope Resources	USFS-PNW Research Station Genetics team
Port Blakely Tree Farms L.P.	

Front Cover, Progressing third-cycle breeding and testing has been a major focus of NWTIC over the past two years. Several Douglas-fir breeding orchards have been established for third-cycle breeding. Clockwise from top right: South Central Coast, at Plum Creek's Cottage Grove facility; South Central Coast, at Roseburg Forest Products Lebanon Forest Regeneration Center (photo by Sara Lipow); Vernonia/Ryderwood, in the greenhouse; Early stimulation at two years after grafting, of a selection earmarked for 3rd-cycle CASTIC breeding; CASTIC, at Cascade Timber Consulting Mason Orchard.

NORTHWEST TREE IMPROVEMENT COOPERATIVE

Report October 1, 2007 to July 31, 2009

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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

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DIRECTOR'S FOREWORD

It is a pleasure to bring a report to NWTIC members after a gap of nearly two years. There is much to report and document, despite the serious downturn in the economy and the forest products industry: breeding, testing, data collection and analysis have continued, and there have been substantial investments in seed orchard establishment. It is particularly exciting to report, that in both realized genetic gain trials and in second-cycle tests, we have been able to document substantial realized genetic gains for height, dbh and dbh² x height in the full-sib populations over woodsrun (unimproved) controls.

NWTIC has also been fortunate in maintaining stable membership to date with only one member withdrawing in 2008-9; the continued support by members is much appreciated. This shows a clear understanding by members of the long-term nature of tree improvement and their commitment to persevere through difficult times.

COOPERATIVE SECOND-GENERATION BREEDING AND TESTING OF COASTAL DOUGLAS-FIR

The overall progress and status of the various advanced-generation programs is summarized in Table 1. The pace of second-cycle test establishment has decreased, with that phase of the program projected to end by 2011 or 2012..

Table 1. Summary of advanced-generation Douglas-fir trials established in 2008-2009

Pro-gram	Plant-ing Year	Number of				Purpose
		Entries	Loca-tions	Test Trees	Test Trees+ Fillers+ Buffers	
WA Coast	2008	106 families + 2 woods-run controls	5	10,936	15,487	<ul style="list-style-type: none"> •Rank families and parents •Verify breeding zone(s)
Puget Sound Phase II	2009	164 families + 2 woods-run controls	5	16,496	21,365	<ul style="list-style-type: none"> •Make forward selections

Puget Sound

The five Puget Sound metacooperative Phase I tests were measured in fall-winter 2008-9. In addition to the routine height, dbh and stem defect traits, fall cold hardiness was assessed by collecting stem, bud and needle samples from 12 trees at each of two sites.

The cold-hardiness data were generated by the Pacific Northwest Tree Improvement Research Cooperative (PNWTIRC) and Conifer Translational Genome Network (CTGN) personnel in the College of Forestry, OSU. All data were analyzed by NWTIC by March 2009. Forward selections from Phase I tests are to be grafted in breeding and production orchards in early 2010.

Five Phase II tests were outplanted in early 2009 (Table 1), completing test establishment for this cooperative. One of these sites accommodated a replicate of the Seed Source trial (organized by Connie Harrington, Brad St Clair and Peter Gould all of the USFS-PNWRS) within the fenced area; PSMC donated the extra length of fence but other costs were met by the PNWRS researchers.

Three of the four cooperators decided to proceed to a 3rd cycle of breeding and testing with more or less the same emphases of the first two cycles (rapid growth, log quality and adaptability). A list of candidate selections was generated by NWTIC, and the candidate trees were reviewed in the field in July 2009. The Washington DNR opted to pursue a separate path mostly emphasizing wood stiffness in its third cycle.

Washington Coast

The Phase I tests were planted in the winter of 2007-8. Test establishment proceed very much as normal, with the one exception being some mortality likely due to the Root Collar weevil. This insect has not previously

been a problem in 2nd-cycle progeny testing, but was observed in the Grays Harbor Genetic Gain / Type IV trial which was also established on coastal sites. Only one Phase of testing is envisaged for this second-cycle co-operative..

Washington Cascades (WACTIC)

Crossing has been completed for WACTIC; and the Phase IIa tests were sown in March 2009. Spring budburst data were collected from all trees in two Phase I sites (one low-elevation, the other high-elevation) in May 2009.

Vernonia/Ryderwood and NOCTIC

Spring budburst data were collected at one Phase II site in May 2009, to be followed by collection of growth and form data on five sites in fall 2009.

Fifty-five forward selections from the Phase I second-cycle tests were successfully pot-grafted for a 3rd-cycle breeding orchard in spring 2008-9. The field-planted rootstock, growing at the Schroeder seed orchard, will be used to graft selections from the Phase II tests shortly after measurement of those tests in fall 2009.

NOCTIC

Forward selections from the tests were grafted in one production orchard and one 3rd-cycle breeding orchard in spring 2009. In addition to these forward selections, a small number of first-cycle parents (BLM McKenzie, USFS) which had not been used in 2nd-cycle breeding and testing were grafted in the third-cycle breeding orchard. Some stimulation was also done in spring 2009 – a small number of BLM McKenzie parents and two ramets each of 20 selections grafted two years previously in a production orchard. This early stimulation is hopefully the first of many aggressive efforts to move third-cycle breeding forward rapidly.

Many NOCTIC members are strongly interested in improving or maintaining wood stiffness. As a result the first operational assessment of acoustic velocity in the cooperative Douglas-fir programs got underway in 2008, with four sites assessed in each of the Snow Peak Low and Snow Peak High first-generation programs. This was being followed by screening of the Molalla first-generation program in July 2009.

TRASK

Almost all the 21 Trask test sites were visited during this period. In addition to routine site tours, the Trask Coast Phase I sites were evaluated for incidence of Swiss Needle Cast (with help and input from ODF Pathologist Alan Kanaskie), and the decision made to score needle retention on all six sites along with growth and form measurements in fall-winter 2009. Needle retention scoring in late winter 2009-10 would be ideal, but the data would then be collected after selections were made and grafted in production and breeding orchards. It would also require a second visit to all sites and all trees, which would add to the costs.

The majority of TRASK members supported progress to a third cycle of breeding and testing. Rootstock were sown in winter 2007-8 for a 3rd-cycle breeding orchard to be located at Plum Creek's Cottage Grove facility.

South Central Coast

The SCC Phase I tests (Mainline, Needlecast and Family blocks) were measured at age-7 from seed; and Plum Creek's CL98 tests also received their age-10 measurement. The tallest tree in the SCC test series was over 29 feet tall, and the tallest tree in CL98 was 42 feet tall. Recognizing the financial contribution of the Swiss Needlecast cooperative used for needle retention assessment, a separate analysis was conducted and provided to that co-operative.

Over 100 forward selections were made from these two test series, and grafted in production orchards and two 3rd-cycle breeding orchards.

Roseburg-Umpqua (ROSETIC)

The second group of ROSETIC tests (Umpqua Phase II) were sown in March 2009 ; 75 crosses and 2 woodrun controls were sown. These are to be planted in space left at the Phase I sites.

Over 250 crosses have been attempted to date involving parents within the Roseburg zones, BLM McKenzie and Giustina's program. For the same period 245 pollens have been collected (at the orchards mentioned above and at BLM's Provolt orchard) and 1119 ramets stimulated for crossing. These crosses will be sown in the Roseburg Low and Roseburg High tests.

Table 2. Status of / plans for cooperative second-generation Douglas-fir breeding populations as of 2009.

Location	Status	Number of Crosses			Test Establishment			
		Total Population Size	Planted or Sown	Local or Elite Crosses with Sufficient Seed	Target Number	Number Established	Start Planting in Spring Of	Complete Planting in Spring Of
Washington Cascades	Phase I completed (eight sites), seed sown for four Phase IIA sites in winter 2008-9	320	291	300	16	8	2006	2011
Puget Sound	Test establishment completed	276	292	90	10	10	2003	2009
Washington Coast	Test establishment completed	110	106	137	5	5	2008	2012
Vernonia/Ryderwood	Test establishment completed	404	416	325	10	10	2001	2005
North Oregon Cascades	Test establishment completed	414	399	350	11	11	2001	2005
Trask (Coast + Inland)	Test establishment completed	550	500	427	21	21	2004	2007
South Central Coast	Test establishment completed	760	604	604	20	20	1998	2006
ROSETIC- Umpqua	Planted 5 sites in winter 2006-2007, sowed for 5 Phase II sites in winter 2008-9	160	170	250	10	5	2007	2010
ROSETIC-Roseburg Low	Crossing	200	-0-	157	8	-0-	2011?	2011?
ROSETIC-Roseburg High	Crossing	100	-0-	40	4	-0-	2012?	2011?
TOTAL		2,658		≈2,680	115	90		

COOPERATIVE SECOND-GENERATION BREEDING AND TESTING OF WESTERN HEMLOCK

Age-10 data were collected from the Vollmer Creek site, and those data analyzed along with the East Humptulips data which had been obtained the previous year. The remaining Local Diallel and Elite sites are to be measured in fall 2009. A field

tour was held in June 2009 to discuss traits to be measured: in addition to height and diameter, forking, ramicorn branching, sinuosity and branch angle were considered. After further consideration sinuosity and branch angle were omitted.

TECHNICAL UPDATES AND DEVELOPMENTS

Wood Stiffness

A detailed review and synthesis of the place of wood stiffness in the genetic improvement of coastal Douglas-fir in the Pacific Northwest has been completed (authored by NWTIC and other personnel), and will be released this month as a College of Forestry Research Contribution. This has been a lengthy

project pulling together information from a number of sources, and extensively reviewed and edited. A short summary of this document is provided in this report. NWTIC also helped organize (along with the PNWTIRC, the SMC and the WFCA) a workshop on wood quality held in Portland in May 2008.

In order to support members in ranking elite germplasm for wood stiffness, NWTIC also (1) developed a sampling scheme for collecting acoustic velocity data (number of sites and trees/

site) (2) researched stiffness assessment tools and purchased a TreeSonic tool in July 2008. This tool has already been put to use in 12 test sites and two seed orchards.

GENETIC GAIN TRIALS AND DEMONSTRATION PLANTINGS

Four sites of the Molalla Genetic Gain trial and the partial site at Gates were measured in fall-winter 2008-9 (age-15 from seed). These data were analyzed with the age-13 data collected from the Molalla site, and a summary is provided in this report.

Herbicides were applied at NWTIC expense and under NWTIC direction on the six Grays Harbor

Genetic Gain / Type IV trials in April and June 2009. NWTIC personnel visited the Grays Harbor sites on several occasions during the period of this report. Age-5 (from seed) data were collected by the SMC field crew in winter 2009 from the three sites planted in 2005. These results, and the age-3 results on all six sites, are provided in this report.

DATA MANAGEMENT, ANALYSIS AND REPORTS

Work has continued on updating the database. The NWTIC directory now holds 30,043 files. Of the 32,567 parent-tree records expected, the database contained complete data for 31,736 records by June 2009. There were also data on 1,874 cross-tested parents involving 94 programs; a minority of first-generation parents were tested in two (or perhaps three) programs; cross-testing was generally in adjacent breeding zones. By June 2009 3,744,642 progeny test measurement records had been loaded (394,274 for 2nd-generation programs), and 2,620,607 genetic gains loaded. Measurement data include such traits as spring budburst (61,775 records), fall cold hardiness (1,581 records), specific gravity (11,367 records) and acoustic velocity (12,639 records).

Information on full-sib and polymix crosses were updated as information was received. These were mainly crosses made by the advanced-generation Douglas-fir and western hemlock metacooperatives, but also included crosses sown in the first generation tests. By June 30 the database contained records on 6,062 full-sib and polymix crosses (4,787 of which were made for the 2nd-generation testing effort).

A recent development has been the addition of information on seed orchards and clone banks: the database now contains information on 171 such orchards / clone banks and 66,845 ramets. It is hoped

that having such records at NWTIC will increase the security and availability of that information.

NWTIC filled over 170 individual requests for data and analyses. The member-access secure website has been updated and improved. It is now set up to allow viewers to view and download Excel datasets, meeting notes, progeny data files etc. There are currently 35 accounts for NWTIC members to access the data.

In addition to continued work loading progeny measurement files and other data into SQL server, useful datasets are made available through views that could be called up in Microsoft Access or on the member-access website. A view is set up by retrieving relevant columns of data from one or more tables in the database and filtering it for specific sites, programs, seed orchard etc. Permissions are then assigned to each view to allow access to the information for the appropriate set of cooperators. By June 30, 2009 2,663 views (220 of which were 2nd-generation) had been created

NWTIC maintained a very strong emphasis on data analysis, completing genetic gain predictions and reports for 24 first-generation breeding units, 11 analyses involving advanced-generation programs, and five other quantitative analyses addressing technical issues. Some of these are provided in this report.

Table 3. Summary of genetic gain predictions using BLUP, and other analyses, completed October 2007 through June 2009.

FIRST-GENERATION ANALYSES	
Butte Falls 1	D-fir
Butte Falls 2	D-fir
Cowlitz BU-1	D-fir
Cowlitz BU-2	D-fir
Cowlitz BU-3	D-fir
USFS Estacada (202-06015)	D-fir
USFS Estacada (202-06014)	D-fir
Estimate heritability of forks, ramicombs, forks + ramicombs, correlations of these 3 variables with other traits, for the Port Gamble program	D-fir
BLM BU-30	D-fir
BLM BU-31	D-fir
BLM BU-32	D-fir
BLM BU-33	D-fir
Vernonia Sunday Creek (age10 to24)	D-fir
Gold Beach BU-3	D-fir
Forks	Hemlock
Grays Harbor (age-5 to 23)	D-fir
DNR Northwest	D-fir
DNR Southwest	D-fir
DNR Central	D-fir
DNR South Sound	D-fir
DNR Coast	D-fir
DNR Forks	D-fir
Green Diamond - Shelton full-sib data	D-fir
Snow Peak High acoustic velocity data	D-fir
Snow Peak Low acoustic velocity data	D-fir
SECOND-GENERATION ANALYSES	
Comparison of gains predicted from HEMTIC tests with first-generation predicted gains	D-fir
Recalculate NOCTIC Index adding BLM gains and new equation	D-fir
Plum Creek T96 Age-12 data + relevant 1st-gen data	D-fir
South Central Coast Age7 + First-gen Age7 + Budburst + Swiss Needlecast Data	D-fir
Plum Creek CL98 Age-10 data	D-fir
HEMTIC Age-10 (East Humptulips and Vollmer Creek)	Hemlock
Recalculate NOCTIC Selection Index adding BLM 30-33 first-generation gains	D-fir
SCC Phase I Needlecast data	D-fir
Recalculate Vernonia/Ryderwood Selection Index due to (1) changes in protocol, and (2) adding 1st-gen gains for 1st-gen FS.	D-fir
Recalculate NOCTIC Selection Index by adding 1st-gen gains for 1st-gen FS.	D-fir
Puget Sound Age7 data + age6-8 1st-gen data	D-fir
OTHER QUANTITATIVE TASKS	
Summarize (A) 1st-cycle gains, (B) 2nd-cycle full-sib means, and (C) 2nd-cycle mid-parent predicted gains for the top 10 and bottom 10 crosses (selected on 1st-gen gains) per 1st-gen breeding zone	D-fir
Molalla Genetic Gain trial age-15 data	D-fir
Investigate benefit vs cost of a GCA test instead of a full 3rd-cycle program, for the South Central Coast co-operative	D-fir
Grays Harbor gain trial age2 (6 sites)	D-fir
Investigate possible modifications to BZERC 2nd-cycle strategy, for the ROSETIC co-operative	D-fir

GETTING GENETIC GAIN IN OPERATIONAL PLANTATIONS

2009 looks to be a heavy seed producing year for coastal Oregon and Washington with even unstimulated trees in the woods, the Molalla Gain trial and 2nd-cycle tests producing cones. Substantial amounts of seed are coming available for southern Oregon, from the BLM's Tyrell and Provolt orchards, especially after BLM orchard staff earned permission (after years of painstaking Environmental Impact Assessment procedures) to aerially protect the seed crops against cone and seed eating pests. There were some Controlled Mass Pollination (CMP) projects undertaken, both at Schroeder and at CTC's Mason orchard.

For the ROSETIC area, the "Roseburg Low" and "Roseburg Cascades" orchards are progressing well, and the "Elk Creek" block was pot-grafted in early 2009. A co-operative "South Central Coast" orchard was also pot-grafted, and a 2nd-cycle North Oregon Cascades field-grafted in early 2009.

The Bureau of Land Management developed plans to consolidate its Douglas-fir orchards in Oregon onto two locations, and graft new replacement 1.5-generation orchards. The ramets in many of the first-generation BLM orchard blocks are growing to a size where cone collection is difficult. Under the Western Oregon Plan Revision released in late 2008 there were projections of increased timber harvest, requiring more seed, but those plans for increased timber harvest were abandoned in mid 2009 under the new administration.

Roseburg Resources progressed establishment of new 1.5-generation and 2nd-generation orchard blocks at its Lebanon, Elkton and Dillard facilities. There has been considerable establishment of new 1.5-generation orchards, and plans to establish 2nd-cycle orchards, for timberlands in Washington (by the Washington DNR, Green Diamond Resource Co., Pope Resources, Port Blakely Tree Farms, Sierra Pacific Industries and SDS Lumber).

NWTIC personnel helped organize the 2008 and 2009 meetings of the NW Seed Orchard Manager's Association, and posted the proceedings of those meetings (and some previous meetings) on the NWTIC website. The 2008 and 2009 meetings contained a wealth of information on establishment and management of coastal Douglas-fir orchards. With assistance from Jim Smith (Plum Creek) and Mike Crawford (BLM), Keith published an article in Tree Planter's Notes on the same topic ("Establishment and Management of Coastal Douglas-fir Orchards").

NWTIC again attempted to collate the number of coastal Douglas-fir and western hemlock seedlings planted by members, especially since there are no published reports on the number of seedlings derived from orchard seed planted in Oregon and Washington. While data were not provided by non-members (some private companies and non-industrial woodland owners), the figures in Table 4 provide some idea of the impact of the tree improvement programs in the region.

Table 4. Survey response on coastal Douglas-fir and western hemlock seedlings planted by NWTIC members in 2005-2009¹.

Year	coastal Douglas-fir			western hemlock		
	Clonal/ Seedling orchard	Rogued progeny test	Woodsrun	Clonal/ Seedling orchard	Rogued progeny test	Woodsrun
2005	53,737,985	1,469,000	7,292,511	5,342,251	0	1,437,774
2006	56,437,587	1,595,000	6,994,261	4,775,327	0	1,771,017
2007	59,375,026	957,443	9,564,035	3,981,237	0	1,711,605
2008	55,885,602	946,110	5,309,256	3,339,033	11,250	636,290
2009	56,679,472	610,600	3,730,211	4,693,194	2,000	758,230

¹ Responses provided by 29 of the 32 NWTIC members for 2005 and 2006, 35 of 35 in 2007, 32 of 35 for 2008 and 2009. In order to compare across years, this survey also includes Weyerhaeuser Company which withdrew from NWTIC in 2008. For 2008 and 2009, 50% of the 2007 planting was assumed for the three non-respondents to obtain a lower bond of total planting.



*Puget Sound
Phase I: Forward
selection from
Green Diamond's
test site*

*Puget Sound
Phase I: Forward
selection from Pope
Resources' test site*



*WACTIC Phase I:
Hancock Forest
Mangement's
Tong site*



*WA Coast I:
Rayonier Forks
site*

*NOCTIC Phase II:
CTC's Jack32 site in
5th growing season*



*TRASK Coast
Phase I: ODF's
Klines Creek site*



*TRASK Inland
Phase I:
Weyerhaeuser's
Fairchild site*



*SCC Phase I: Lyon's
Ridge site*

*ROSETIC
Phase I:
Roseburg
Resources' 21
Grand Site.*



*CL98: Forward
selection from
Moon Creek site*

BASIC ANALYSIS OF GRAYS HARBOR GENETIC GAIN / TYPE IV TRIAL (3-YR AND 5-YR)

Terrance Ye and Keith Jayawickrama

Introduction

The principal objectives of this trial were (1) to understand the long-term effects on productivity, quality, and diversity of Douglas-fir trees and stands when the latest advances in genetics, seedling culture, and early vegetation management are deployed in combination; (2) to compare the growth of genetically selected trees to unselected woodsrun trees; (3) to compare the predicted genetic gains derived from progeny tests with realized gains in independent block plot trials; (4) to provide data to modify / update growth models for effects caused by genetic selection, intensive weed control and different spacing; and (5) to demonstrate volume gains on an area basis.

The trial was established over two years, with three sites established in 2004-5 and three more in 2005-6. Data were collected at each site after two seasons in the ground (age-3), on a total of 12,845 trees, for the variables height (feet), basal diameter (inches) and dbh (if trees had reached breast height). Data were also collected at three sites after four seasons in the ground (age-5), on a total of 6314 trees, for the variables height (feet), basal diameter (inches) and dbh (if trees had reached breast height). About half of the trees were measured for either basal diameter or dbh but not both; dbh was used for this analysis.

Treatments

1. Genetic levels of seedlots (gen):
 - (1) Base population (random sample of 50 wild trees distributed throughout the Grays Harbor breeding zone).
 - (2) Intermediate population (a mix of pair crosses among 20 parent trees chosen to represent an intermediate level of genetic gain).
 - (3) Elite population (a mix of crosses among clones of the 20 best parent trees in each breeding unit designed to represent a high level of genetic gain).
1. Density treatments (den):
 - (1) Low density – 15 × 15', 200 SPA
 - (2) Intermediate density – 10 × 10', 440 SPA
 - (3) High density – 7 × 7', 889 SPA.
2. Vegetation control levels (veg):
 - (1) Standard
 - (2) Complete
3. Test design:
 - (1) # sites = 6
 - (2) # plots / site = 22
 - (3) # measurement trees / plot = 64, 100, and 250 for den = 1, 2, and 3, respectively
 - (4) Considered as completely random design

Data analyses

1. Single-site plot mean level

An analysis of variance (ANOVA) was conducted for each trait at each site using maximum likelihood analysis in ASReml. In all analyses, all factors were treated as fixed except for the random error. The linear model was:

$$y_{jkl} = \mu + \text{gen}_j + \text{veg}_k + \text{den}_l + (\text{gen} \times \text{veg})_{jk} + (\text{gen} \times \text{den})_{jl} + (\text{veg} \times \text{den})_{kl} + \epsilon_{jkl}$$

where y_{jkl} is the plot mean of height or basal diameter for the j th seedlot, k th vegetation control, and l th density; ϵ_{jkl} is the random error.

The least-square mean for each seedlot (*gen1*, *gen2*, or *gen3*), density (*den1*, *den2*, and *den3*), and vegetation control (*veg1* and *veg2*) was estimated using the prediction statement in ASReml. In the cases where the difference among seedlots was statistically significant, the realized gains for the two genetically improved seedlots were estimated with the formula: $G2 = (gen2 - gen1) \times 100 / gen1$ and $G3 = (gen3 - gen1) \times 100 / gen1$.

2. Multiple-site plot mean level

The following linear model was used for conducting across-site ANOVA for both height and basal diameter:

$$y_{ijkl} = \mu + \text{site}_i + \text{gen}_j + \text{veg}_k + \text{den}_l \\ + (\text{site} \times \text{gen})_{ij} + (\text{site} \times \text{veg})_{jk} + (\text{site} \times \text{den})_{il} + (\text{gen} \times \text{veg})_{jk} + (\text{gen} \times \text{den})_{jl} \\ + (\text{veg} \times \text{gen})_{kj} + (\text{site} \times \text{gen} \times \text{veg})_{ijk} + (\text{site} \times \text{gen} \times \text{den})_{ijl} + (\text{gen} \times \text{veg} \times \text{den})_{ikl} \\ + \epsilon_{ijkl}$$

where y_{ijkl} is the plot mean of height or basal diameter for the *i*th site, *j*th seedlot, *k*th vegetation control, and *l*th density. All model terms were considered as fixed except for the random error (ϵ_{ijkl}). Each site was assumed to have a unique error variance.

The realized gains for the genetically improved seedlots were estimated using the same way as single-site analyses.

3. Multiple-site individual tree level

In order to test the effect of full-sib crosses within gain levels, cross nested within gain level was added to the model above, along with the cross(gain) interactions with site, vegetation control, density, and vegetation control x density. Cross predicted values were obtained and correlated with gains predicted from the first-generation Grays Harbor progeny tests.

Results and Discussion:

Age-3

1. There were large difference among test sites, for both height and basal diameter at age 3.
2. In the within-site plot-mean analysis, 2 of the 6 sites showed significant difference among seedlots for 3-yr height. No significant difference was found between seedlots at any site for basal diameter. Basal diameter may be more variable than height, due the influence of branch clusters, stem swelling, differences in planting depth, lean, etc.
3. In the across-site plot-mean analysis, genetic gain had a statistically significant effect, with elite and intermediate seedlots showing 5.83% and 2.97% realized gains for height over base population, respectively. No meaningful across-site difference among seedlots was expressed for basal diameter at this age.
4. In the within-site plot-mean analysis two sites showed significant difference among vegetation control levels, and one site showed significant difference among spacing levels, for 3-yr height. One site showed significant difference among vegetation control levels, and one site showed significant difference among spacing levels, for 3-yr basal diameter.

5. According to the across-site plot-mean analysis, neither different levels of vegetation control nor stand density had a significant effect on height growth. They, however, did show marginal significances on basal diameter, with complete vegetation control > standard and intermediate density > high or low density.
6. In the across-site individual-tree analysis, genetic gain had a statistically significant effect, with elite and intermediate seedlots showing 9.69% and 8.62% realized gains for height over base population for height, 4.60% and 5.62% realized gains for height over base population for basal diameter. There were significant differences between crosses within gain levels.

Age-5 (three sites)

7. Large differences were found among test sites for both height and dbh as well as for survival at age 5, with site productivity: 601 > 603 > 602.
8. Based on within-site plot-mean analyses, one of the three sites showed significant difference in height (site: 601, $P=0.03$) among seedlots. A marginal significance ($P=0.06$) was also found for dbh at this site. The unimproved population did not outperform either the elite or intermediate population, in height or dbh, at any site. The effect of vegetation control was only significant at site 603 for both height and dbh. Significant density effect was observed only at site 602 for height. The lack of statistical significance for the treatments may be due to the small number of replicates within sites (St. Clair *et al.* 2004, WJAF 19(3): 195-201).
9. According to the across-site plot-mean analysis, the genetically-improved seedlots grew significantly better than the unimproved seedlot for both height and dbh. No significant difference was found between the elite and the intermediate seedlots. Realized gains were higher for dbh (11.2% for the elite, 12.5% for the intermediate) than for height (7.9% for the elite, 6.5% for the intermediate). Survival rate was similar among seedlots at this age. The trees planted at the 7 × 7 ft and the 10 × 10 ft were taller than that from the 15 × 15 ft plots, although such difference was only marginally significant ($P=0.08$). There were significant differences between densities for survival. The different levels of vegetation control had no meaningful effect of tree growth. The lack of significance between the elite and intermediate populations, and in seedlot × density and seedlot × vegetation interactions may have been due to weak inter-tree competition at age 5.
10. The across-site analyses on the basis of individual trees exhibited a similar pattern of among-seedlot differences. The realized gains estimated based on individual trees were close to that based on plot means. Realized gains varied greatly among full-sib families within each improved seedlot. There were significant differences between families within seedlots for both height and dbh.
11. The correlation of estimated realized gains for height between age 3 and 5 was about 0.7, based on the data from the three 2005-installation sites.

DO WE SEE EVIDENCE FOR REALIZED GENETIC GAIN AND CORRESPONDENCE TO FIRST-CYCLE GAINS IN SECOND-CYCLE DOUGLAS-FIR TESTS?

Keith Jayawickrama and Terrance Ye

It is desirable to verify the genetic gains predicted in progeny tests with other experiments. One important source of such information for NWTIC are the realized gain trials, of which two are active (Molalla and Grays Harbor). The age-8 data from the Molalla Gain trial has been collected, analyzed and published, and the age-15 data have similarly been submitted for publication.

A second source of information available to us is the 2nd-cycle tests established by NWTIC members, of which five have been measured. These trials contain full-sib crosses between parents (original parents, or forward selections from those parents) for which gains have already been predicted by NWTIC. We therefore attempted to compare the gains predicted in the first cycle programs with the performance of the full-sib progeny of these entries. In second-cycle programs which included unimproved controls, we compared the mean of the full-sib crosses with the mean of the unimproved controls. The results are shown in Table 5.

Method: We have coded both the 2nd-cycle and 1st-gen programs to maintain confidentiality of the individual programs. We summarized the (A) 1st-gen mid-parent gains¹, (B) 2nd-cycle full-sib means, and (C) 2nd-cycle mid-parent predicted gains for the top 10 and bottom 10 crosses (selected based on 1st-gen gains) per 1st-gen breeding zone; for each of five 2nd-cycle programs for which data have been collected (age-7, age-10 or age-12). The following procedure was used:

- Merge 1st-gen parental gains with 2nd-cycle cross gains;
- Drop all non-local crosses, if any;
- Drop all 1st-gen programs with less than 30 crosses for each trait (with less than 30 crosses the difference between top 10 and bottom 10 would not be meaningful);
- Calculate the 1st-gen mid-parent gains (HT, DBH, VOL) for crosses;
- Sort the gain table by 1st-gen program and 1st-gen mid-parent gain;
- Select the top 10 and bottom 10 crosses, in each 1st-gen program, based on mean mid-parent 1st-gen gain;
- Output a) 1st-gen mid-parent gains, b) 2nd-cycle cross means, and c) 2nd-cycle mid-parent gains for the top 10 and bottom 10 crosses by each 1st-gen program;
- Calculate **1st-gen predicted gain difference (A)** = difference in 1st-gen gain prediction between top 10 crosses and bottom 10 crosses;
- Calculate **2nd-cycle realized gain difference (B)** = 100*(Phenotypic mean of top 10 crosses - phenotypic mean of bottom 10 crosses);
- Calculate **2nd-cycle predicted gain difference (C)** = 2nd-cycle gain prediction of top 10 crosses - 2nd-cycle gain prediction of bottom 10 crosses.

Results are shown in Table 6.

¹ 1st-gen mid-parent gain for a cross = 0.5* (gain predicted for parent1 from 1st-gen tests + gain predicted for parent2 from 1st-gen tests).

Results and Discussion

1. "In 2nd-cycle programs which included unimproved controls, did the full-sib crosses outperform the controls?". The answer is, **YES**.
2. The next question is "Were the 2nd-cycle full-sib group means of the top 10 crosses selected on first-gen gains higher than those of the bottom 10 crosses?" The answer is, reassuringly, "Yes"; the % difference of top 10 – bottom 10 (column I) is positive in 48 of 49 cases², with average differences of 9.7% for dbh, 8.9% for ht, and 29.0% for vol.
3. The next question is "Are the differences between 2nd-cycle full-sib group means similar to the first-gen predicted gains of those groups of parents?" The answer is shown in column L; in 34 cases the difference of 2nd-cycle gains was less than the difference in 1st-gen gains, but in **15 of 49** the difference in 2nd-cycle means was actually greater than was predicted from first-gen gains (A-B was negative).
4. The fourth question is "Are the differences between 2nd-cycle full-sib group means similar to the 2nd-cycle predicted gains of those groups of parents?" The answer is shown in column N; in 48 of 49 cases the difference of 2nd-cycle gains was less than the difference in 2nd-cycle full-sib means (B-C was negative). This is expected due to the shrinkage property of BLUP³.
5. It is noteworthy that in some cases the difference between 1st-gen gains was very high (E-11-HT) while the realized 2nd-cycle gains were smaller; in other cases the difference between 1st-gen gains was moderate (E-8-HT) while the realized 2nd-cycle gains were higher. This seems to underscore one caution we have conveyed to users of 1st-gen predicted gains: they are probably more reliable for comparing parents within a first-generation program than across first-generation programs. For example, it would be unwise to assume that a parent with 20% predicted gain in one program is exactly equivalent to a parent with 20% predicted gain in another program.
6. The average of all A numbers was 19.7% while the average of all B numbers was 15.3% and the average of all C numbers was 9.7%.
7. Note that the first-gen gains were predicted at age-15, while the second-cycle tests were age-7, age-10 or age-12 at the time of measurement. All gains were predicted using the data from its own generation (i.e., not from the across-generation combined analyses).

² Note we do not state the gains are significantly higher; standard statistical tests would not apply for the quantities reported here.

³ The shrinkage effect is considered a desirable property of BLUP. As Hill and Rosenberger (1985) pointed out, "..... intuition tells most breeders to suspect a new entry with an exceptionally large or low mean, and the shrinkage property makes an adjustment consistent with the need for caution."

Table 5. Percent Difference of (Mean of Full-Sib Crosses - Mean of Unimproved Controls) in four 2nd-cycle Douglas-fir Programs

2nd-Cycle Program	Age from seed	HT	DBH	HT* DBH ²
A	10	6.2	8.0	18.0
B	12	9.2	9.9	21.9
C	7	12.0	9.5	33.0
D	7	7.8	9.7	24.0

Table 6: Comparison of the top 10 crosses (based on first-generation gains) and bottom 10 crosses (also based on first-generation gains) in second-cycle Douglas-fir programs.

A: 1st-gen predicted gains of top 10 crosses - 1st gen predicted gain of bottom 10 crosses. B: 100*(Phenotypic mean of top 10 crosses - phenotypic mean of bottom 10 crosses) C: 2nd-cycle gain prediction of top 10 crosses - 2nd-cycle gain prediction of bottom 10 crosses

2nd-cycle program (coded)	Trait	1st-gen gain type	Selection	1st-gen program (coded)	1st-gen mid-parent gain	1stGen Predicted gain difference A:	2nd-cycle cross mean	Realized gain B:	2nd-cycle mid-parent gain	2nd-cycle predicted gain difference C:	A-B	A-C	B-C
B	dbh	gain1	top10	2	8.6	15.8	81.5	12.6%	5.0	8.0	3.2	7.8	4.6
B	dbh	gain1	bot10	2	-7.1		72.4		-3.0				
B	dbh	gain1	top10	3	8.3	7.5	80.2	6.6%	3.8	4.8	0.9	2.7	1.8
B	dbh	gain1	bot10	3	0.8		75.2		-1.0				
C	dbh	gain1	top10	4	9.0	6.7	24.0	3.3%	5.9	2.3	3.4	4.4	1.1
C	dbh	gain1	bot10	4	2.2		23.3		3.6				
C	dbh	gain1	top10	5	15.4	8.8	23.1	6.0%	1.1	2.8	2.8	6.0	3.2
C	dbh	gain1	bot10	5	6.6		21.7		-1.7				
A	dbh	gain1	top10	1	20.5	24.9	120.5	17.8%	6.8	13.3	7.1	11.6	4.4
A	dbh	gain1	bot10	1	-4.4		102.3		-6.5				
D	dbh	gain1	top10	6	6.1	5.5	34.7	11.2%	6.7	7.8	<u>-5.7</u>	-2.4	3.4
D	dbh	gain1	bot10	6	0.6		31.2		-1.1				
B	dbh	gain3	top10	2	8.6	15.7	82.8	15.0%	4.9	8.3	0.7	7.5	6.7
B	dbh	gain3	bot10	2	-7.2		72.1		-3.4				
B	dbh	gain3	top10	3	8.4	7.9	81.0	6.1%	4.3	4.5	1.8	3.4	1.6
B	dbh	gain3	bot10	3	0.5		76.4		-0.2				
C	dbh	gain3	top10	4	16.8	18.6	24.1	5.1%	5.6	4.0	13.5	14.6	1.1
C	dbh	gain3	bot10	4	-1.8		22.9		1.6				
C	dbh	gain3	top10	5	19.8	13.8	22.1	-0.5%	-1.1	-0.7	14.2	14.5	0.3
C	dbh	gain3	bot10	5	6.0		22.2		-0.4				
E	dbh	gain3	top10	10	13.5	8.6	51.1	9.1%	12.7	8.2	<u>-0.5</u>	0.4	0.9
E	dbh	gain3	bot10	10	5.0		46.8		4.5				
E	dbh	gain3	top10	9	17.6	11.5	45.5	4.5%	3.2	-0.1	7.0	11.6	4.6
E	dbh	gain3	bot10	9	6.2		43.6		3.3				
E	dbh	gain3	top10	11	41.2	31.9	48.1	13.8%	7.5	6.0	18.1	25.9	7.8
E	dbh	gain3	bot10	11	9.3		42.3		1.5				
E	dbh	gain3	top10	7	20.7	12.8	44.3	6.7%	1.0	2.9	6.1	9.9	3.8
E	dbh	gain3	bot10	7	7.9		41.6		-1.8				
E	dbh	gain3	top10	8	4.2	3.6	45.3	13.6%	0.9	7.0	<u>-10.0</u>	-3.4	6.6
E	dbh	gain3	bot10	8	0.5		39.9		-6.1				
A	dbh	gain3	top10	1	20.7	25.3	120.5	17.8%	6.8	13.3	7.5	11.9	4.4
A	dbh	gain3	bot10	1	-4.6		102.3		-6.5				
D	dbh	gain3	top10	6	6.2	5.8	34.0	16.0%	5.5	9.0	<u>-10.2</u>	-3.2	7.0
D	dbh	gain3	bot10	6	0.4		29.3		-3.6				
B	ht	gain1	top10	2	10.0	18.7	725.9	16.9%	6.7	11.6	1.8	7.1	5.3
B	ht	gain1	bot10	2	-8.7		621.0		-4.9				
B	ht	gain1	top10	3	6.4	6.9	708.6	7.3%	4.1	5.2	<u>-0.4</u>	1.7	2.1
B	ht	gain1	bot10	3	-0.5		660.2		-1.1				?
C	ht	gain1	top10	4	7.4	4.1	290.6	7.8%	2.6	7.0	<u>-3.8</u>	-2.9	0.9
C	ht	gain1	bot10	4	3.4		269.5						
C	ht	gain1	top10	5	16.5	8.6	287.1	5.5%	1.0	3.4	3.0	5.2	2.2
C	ht	gain1	bot10	5	7.9		272.0		-2.4				
A	ht	gain1	top10	1	15.7	16.5	906.9		7.6	10.4	2.4	6.1	3.7
A	ht	gain1	bot10	1	-0.8		794.9		-2.8				
D	ht	gain1	top10	6	7.0	4.8	337.9	3.0%	2.4	2.1	1.8	2.7	0.9
D	ht	gain1	bot10	6	2.3		328.0		0.3				
B	ht	gain3	top10	2	9.9	18.7	725.9	16.9%	6.5	11.6	1.8	7.1	5.3
B	ht	gain3	bot10	2	-8.8		621.0		-5.1				
B	ht	gain3	top10	3	6.4	6.9	708.6	7.3%	4.2	5.4	<u>-0.4</u>	1.5	1.9
B	ht	gain3	bot10	3	-0.6		660.2		-1.2				

A: 1st-gen predicted gains of top 10 crosses - 1st gen predicted gain of bottom 10 crosses. B: 100*(Phenotypic mean of top 10 crosses - phenotypic mean of bottom 10 crosses) C: 2nd-cycle gain prediction of top 10 crosses - 2nd-cycle gain prediction of bottom 10 crosses

2nd-cycle program (coded)	Trait	1st-gen gain type	Selection	1st-gen program (coded)	1st-gen mid-parent gain	1stGen Predicted gain difference A:	2nd-cycle cross mean	Realized gain B:	2nd-cycle mid-parent gain	2nd-cycle predicted gain difference C:	A-B	A-C	B-C
C	ht	gain3	top10	4	14.5	16.0	291.3	4.8%	3.0	3.9	11.2	12.1	0.9
C	ht	gain3	bot10	4	-1.5		278.1		-0.9				
B	ht	gain3	top10	3	6.4	6.9	708.6	7.3%	4.2	5.4	<u>-0.4</u>	1.5	1.9
B	ht	gain3	bot10	3	-0.6		660.2		-1.2				
C	ht	gain3	top10	4	14.5	16.0	291.3	4.8%	3.0	3.9	11.2	12.1	0.9
C	ht	gain3	bot10	4	-1.5		278.1		-0.9				
C	ht	gain3	top10	5	20.8	12.1	284.4	2.0%	1.0	0.8	10.1	11.2	1.2
C	ht	gain3	bot10	5	8.7		278.8		0.2				
E	ht	gain3	top10	10	14.7	8.9	456.5	6.9%	9.8	5.8	2.0	3.1	1.1
E	ht	gain3	bot10	10	5.8		426.9		4.1				
E	ht	gain3	top10	9	16.9	10.8	414.2	1.8%	0.8	0.6	9.0	10.2	1.2
E	ht	gain3	bot10	9	6.2		406.9		0.2				
E	ht	gain3	top10	11	32.6	25.4	454.3	14.5%	10.3	10.2	10.9	15.2	4.3
E	ht	gain3	bot10	11	7.2		396.7		0.1				
E	ht	gain3	top10	7	15.0	8.0	422.7	9.5%	3.5	7.3	<u>-1.4</u>	0.8	2.2
E	ht	gain3	bot10	7	7.0		386.1		-3.7				
E	ht	gain3	top10	8	5.5	2.7	415.6	10.8%	1.4	6.4	<u>-8.1</u>	-3.7	4.4
E	ht	gain3	bot10	8	2.8		375.2		-5.0				
A	ht	gain3	top10	1	15.3	16.5	902.6	12.8%	7.5	9.8	3.7	6.7	3.1
A	ht	gain3	bot10	1	-1.2		799.9		-2.3				
D	ht	gain3	top10	6	8.0	6.2	348.5	9.7%	4.9	7.7	<u>-3.5</u>	-1.5	2.0
D	ht	gain3	bot10	6	1.8		317.6		-2.8				
B	vol	gain1	top10	2	26.2	46.6	63.2	60.2%	17.0	27.4	<u>-13.7</u>	19.2	32.9
B	vol	gain1	bot10	2	-20.4		39.4		-10.3				
B	vol	gain1	top10	3	23.6	21.9	56.2	19.7%	10.8	13.3	2.1	8.5	6.4
B	vol	gain1	bot10	3	1.8		47.0		-2.5				
C	vol	gain1	top10	4	24.6	16.7	2.8	4.5%	14.3	6.1	12.2	10.6	-1.6
C	vol	gain1	bot10	4	7.9		2.7		8.2				
C	vol	gain1	top10	5	56.1	34.4	2.4	11.0%	-0.8	5.2	23.5	29.2	5.8
C	vol	gain1	bot10	5	21.6		2.2		-6.0				
A	vol	gain1	top10	1	60.3	71.5	138.9	52.1%	20.6	34.8	19.4	36.6	17.2
A	vol	gain1	bot10	1	-11.2		91.3		-14.3				
D	vol	gain1	top10	6	18.2	15.2	5.1	36.6%	12.8	20.9	<u>-21.4</u>	-5.6	15.8
D	vol	gain1	bot10	6	3.0		3.8		-8.1				
B	vol	gain3	top10	2	25.9	46.4	63.2	60.2%	16.7	27.6	<u>-13.8</u>	18.9	32.7
B	vol	gain3	bot10	2	-20.5		39.4		-10.9				
B	vol	gain3	top10	3	23.7	22.4	55.9	15.9%	8.8	10.4	6.5	12.0	5.5
B	vol	gain3	bot10	3	1.3		48.2		-1.7				
C	vol	gain3	top10	4	54.0	57.2	2.9	12.4%	15.3	10.3	44.8	46.9	2.1
C	vol	gain3	bot10	4	-3.2		2.6		5.0				
C	vol	gain3	top10	5	71.9	50.3	2.5	7.5%	1.0	1.5	42.8	48.8	6.0
C	vol	gain3	bot10	5	21.6		2.3		-0.5				
E	vol	gain3	top10	10	46.8	28.1	16.9	21.5%	34.1	19.6	6.6	8.6	1.9
E	vol	gain3	bot10	10	18.7		13.9		14.5				
E	vol	gain3	top10	7	65.4	41.6	12.4	21.9%	3.9	11.1	19.7	30.4	10.8
E	vol	gain3	bot10	7	23.9		10.2		-7.3				
E	vol	gain3	top10	8	14.1	9.7	12.2	21.2%	2.7	16.9	<u>-11.5</u>	-7.2	4.3
E	vol	gain3	bot10	8	4.4		10.0		-14.2				
A	vol	gain3	top10	1	60.6	72.0	138.9	52.1%	20.6	34.9	20.0	37.1	17.2
A	vol	gain3	bot10	1	-11.4		91.3		-14.3				
D	vol	gain3	top10	6	19.2	17.3	5.1	38.2%	14.3	23.9	<u>-20.9</u>	-6.6	14.3
D	vol	gain3	bot10	6	1.8		3.7		-9.7				

INCLUDING WOOD STIFFNESS IN TREE IMPROVEMENT OF COASTAL DOUGLAS-FIR IN THE US PACIFIC NORTHWEST: A LITERATURE REVIEW AND SYNTHESIS¹

Jayawickrama, KJS, TZ Ye, R Gupta, and ML Cherry. 2008.

Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] is the most important timber species in the Pacific Northwest (PNW) of the United States, and high stiffness is important for many of its products. We estimate that about 17% of Douglas-fir harvested in the PNW is used as peeler logs for plywood and 2–5% as machine-stress-rated (MSR) lumber. Stiffness is assumed as being implicit but not measured in some other products, visually graded lumber being the most prominent example. Perhaps 68% of the Douglas-fir harvested in the PNW is used as visually graded lumber. Another 12% of softwood harvest (predominantly Douglas-fir) is for pulpwood, fuel, posts, and such where, again, stiffness is not measured. It is hard to predict whether the current situation—in which 100% of Douglas-fir logs are sold and nearly 80% are processed without reference to stiffness—will continue.

A moderate increase in specific gravity and a much more pronounced decrease in fibril angle is observed from pith to bark in Douglas-fir. This combination results in the juvenile wood (closer to the pith) being less stiff than mature wood. It is therefore likely that current management regimes, especially rotations as short as 35 yr, will reduce average wood stiffness of Douglas-fir products. There are some nongenetic options for adjusting for reductions in average stiffness, maintaining or improving stiffness; log segregation based on acoustic velocity is the most promising and cost-effective of these and has already been adopted.

There have been many studies on the inheritance of specific gravity and stiffness in Douglas-fir and other conifers, with the stiffness studies occurring mostly in the past decade. Stiffness appears to be under stronger genetic control than height or DBH, but this control is weaker than for wood specific gravity (which is another compound trait). Methods and tools for screening stiffness in tree improvement programs are improving rapidly, becoming more reliable and easier to use. Most promising of those are acoustic tools that can be used on standing trees.

It would be feasible to select for and breed for higher wood stiffness for coastal Douglas-fir. Stiffness data could be fed into the tree improvement programs in the short term through collecting open-pollinated seed from select families or producing control mass-pollinated seedlots, and in the medium-term through high-stiffness orchards, high-stiffness third-cycle crosses or elite populations. A preliminary breeding objective of 1.6 million psi average whole-tree stiffness is proposed. The direct cost of a well-designed program would be low when translated to dollars per reforested acre, since it would make use of existing tests and seed orchards. The main cost of such a program is indirect, namely, volume gain foregone. Genetic selection for wood stiffness may be very profitable for some forest growers, and less so for others.

¹ Research Contribution 50, Forest Research Laboratory, Oregon State University, Corvallis

PROPOSED SAMPLING STRATEGY FOR ACOUSTIC VELOCITY:

NUMBER OF SITES AND PROGENY

Terrance Ye

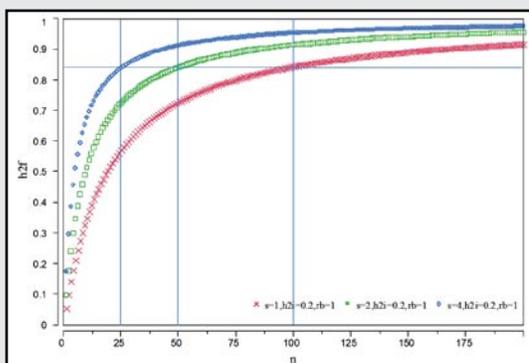
1. Sample size:

(1) Number of sites

When site-to-site correlation is not perfect (generally the case), sampling from more sites is important and helpful. I made some deterministic simulations for the changes of family-mean heritability with different sample sizes as shown below.

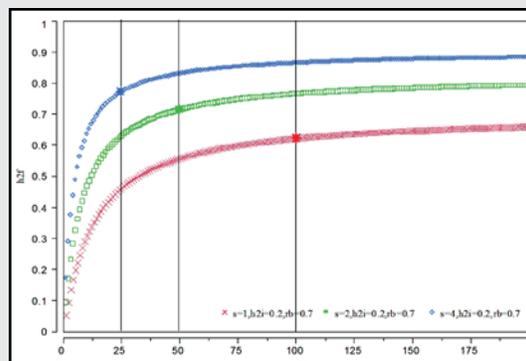
If $r_B = 1.0$ (i.e perfect correlation between sites), the family-mean heritability h_f^2 increases with n (number of trees/family/site), and s (number of sites) does not matter.

Figure 1: Variation in family-mean heritability with number of sites, number of progeny with perfect genetic correlation between sites.



But if $r_B < 1.0$, say $r_B = 0.7$, then s has big impact on h_f^2 . In the following chart I compared the scenarios with $s = 1, 2$, and 4 . When the total number of trees per family keeps constant, $s = 4$ is better than $s = 2$, and much better than $s = 1$. It would be better to sample four sites instead of two, though there is some extra cost for adding more sites. In the similar study on slash pine, they sampled six sites in total (Li et al. 2007).

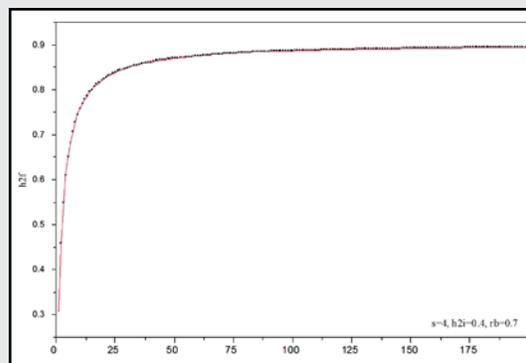
Figure 2: Variation in family-mean heritability with number of sites and number of progeny with a genetic correlation of 0.7 between sites.



(2) Number of trees per family

Family-mean heritability increases with number of trees per family. Thus, we could expect extra genetic gain for both backward and forward selections by increasing the sample size.

Figure 3: Variation in family-mean heritability with number of progeny, with a individual heritability of 0.4 and a genetic correlation of 0.7 between sites. The



decision is made by balancing the gain and the cost. In the above plot I assume $s = 4$, $h_i^2 = 0.4$ and $r_B = 0.7$, then $n = 3$ (i.e., 12 trees/family) leads to $h_f^2 = 0.55$. One more tree measured per family per site will increase h_f^2 quite a lot (i.e., from 0.55 to 0.62).

Li, X, DA Huber, GL Powell, TL White and GF Peter. 2007. Breeding for improved growth and juvenile corewood stiffness in slash pine. *Canadian Journal of Forest Reserach* 37: 1886-1893.

AGE-15 REALIZED GAINS FROM THE MOLALLA GENETIC GAIN VERIFICATION TRIAL

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Executive Summary

Realized gains for coastal Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) were evaluated using data collected from 15-year-old trees from six sites (five complete, one partial) planted in large block plots in the Oregon Cascades. Three populations with different genetic levels (elite - high predicted gain; intermediate - moderate predicted gain; and unimproved – wild seedlot) were compared at two planting spacings (1.8 × 1.8 m or 6 × 6 ft, and 3.6 × 3.6 m or 12 × 12 ft). The main analysis was based on the five complete sites, but the realized gains from the partial site – Gates (which had the elite and the unimproved populations at 3.6 × 3.6 m only) were also calculated in a separate analysis. A total of 16,171 living trees were measured.

The realized gains at age 15 averaged over both the elite and intermediate progeny were 17.2% for stand volume per hectare, 3.5% for mean height, and 4.3% for diameter, compared to predicted genetic gains of 16.0% for volume, 5.4% for height, and 6.4% for diameter. The realized gains for the elite progeny were 22.1% for stand volume per hectare, 4.2% for mean height, and 5.2% for diameter; at the partial site they were 32.5%, 4.2%, and 8.7%. At the Gates sites, where only the elite population was planted and compared with the unimproved population at the wide spacing, 32.5% realized gain for volume (4.2% for height and 8.7% for DBH) were obtained. It should be noted that the realized gains obtained in this study are by no means the upper limit that may be obtained for coastal Douglas-fir in the Molalla breeding zone. While the age-15 predicted individual-volume gain of the elite population was 23.7%, the average predicted gain of the top 20 parents within the Molalla breeding zone was actually much higher at 56.5%. Thus we can assume that higher realized gain might have been achieved if the best crosses had been available and used.

Realized and predicted gains correlated well at family mean level at age 15, with an average correlation coefficient close to 0.8. When the relationship was regressed for each trait, no regression coefficient was statistically significant from 1. This suggests that predicted gains obtained using BLUP gave unbiased predictions of realized gains from the gain trials.

Strong genetic level × planting spacing interaction effects were revealed for age-15 growth traits. Realized gains for stand per-hectare volume and mean growth rate were at least twice as large in the elite population as in the intermediate population in the closely-spaced plots. By contrast, both populations performed similarly at the wide spacing. Such differences highlight the fact that selections made in progeny trials had different responses to the changes of competitive environments, and the realized gain trials should closely mimic the operational plantations in order to provide valid estimates of realized gains.

The improved populations had higher survival rate and lower stem sinuosity than the unimproved population. Realized gains in per-hectare volume varied greatly among test sites. No significant genetic level × site interactions were found for any traits.

COOPERATORS

NWTIC chair for 2007-2009:

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NWTIC representatives for 2007-2009:

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Membership Changes

Weyerhaeuser Company withdrew from NWTIC, and the second-generation cooperatives it was involved in, at the end of 2007.

Change at OSU

The College of Forestry was restructured in 2008, reducing from four departments to three. As of July 2008 NWTIC is now housed in the Department of Forest Ecosystems and Society. With the closure of the former Department of Forest Science, Tom Adams (Professor and Department Head) retired from OSU in April 2009. Tom was a key figure in the relocation of NWTIC to OSU in 1999-2000, helped greatly in the transition, and was a strong supporter and advocate of NWTIC at OSU. Thank you Tom! Dr Brenda McComb took the position of Department Head.



Back Cover, clockwise from top left: Grays Harbor Genetic Gain / Type IV site: Donaldson Creek (Weyerhaeuser); Grays Harbor Genetic Gain / Type IV site: Left Court (Port Blakely); Molalla Genetic Gain trial: Silver Falls site; 2nd-cycle production orchard: Roseburg Resources' South Central Coast block (photo by Sara Lipow); Acoustic velocity data collection at a first-generation Snow Peak test site.