Oregon State University College of Forestry

Northwest Tree Improvement Cooperative Report

July 1, 2009 to September 30, 2012

October 2012

Stimulation in the South Central Coast breeding orchard at Plum Creek Timber Company, Cottage Grove.

Leader damage is being scored in some 2nd-cycle programs, if the incidence is frequent enough. This damage could arise from late spring frosts (see photo below), fall frosts, winter desiccation, or other causes.

The Quinault Nation has offered the use of a limited number of potted hemlock ramets in their greenhouse production orchard block to aid moving 3rd-cycle HEMTIC breeding forward.

Western hemlock ramets in the HEMTIC breeding orchard block at Green Diamond Resource Company's orchard near Shelton.

Cover: Co-operative third- cycle Douglas-fir crossing is underway.

Top row, left: The first cross attempted for CASTIC, at Cascade Timber Consulting's Mason seed orchard;

Top row, middle: Isolations for third-cycle South Central Coast, at Roseburg Forest Products Lebanon Forest Regeneration Center..

Middle row, left: Unexpected unstimulated flower crops: Santiam production orchards and in the third-cycle Vernonia/Ryderwood breeding orcahrd benefitted the CASTIC and VRTIC3 breeding programs respectively.

Bottom row and top row right: Controlled pollination workshop and training program held in March 2012.

Northwest Tree Improvement Cooperative

Report July 1, 2009 to September 30, 2012

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October 2012

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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

Contents

Director's Foreword

Three more years of intense activity by NWTIC and the advanced-generation cooperatives are described here. Members continued to fund progeny test establishment, data collection, breeding orchard establishment and other aspects of cooperative tree improvement, and supported NWTIC by continued membership during this triennium. This was despite a prolonged economic downturn, and a severely depressed domestic house construction and lumber market. Fortunately active log exports from western North America to Asia in 2010 and 2011 helped some NWTIC members, and resulted in intense harvesting and reforestation for them. The production of seed from most of the high-gain 1.5-generation orchards established from the mid-1990s onward had ramped up in time for such opportunities.

The co-op marked 25 years of continuous operation (September 1986-2011); NWTIC's predecessor the IFA-Progressive Tree Improvement program was launched in 1966. In addition to this important milestone, one of the most exciting developments during my tenure at NWTIC has been a sizable third-cycle crossing effort in the spring of 2012.

Advanced-Generation Breeding and Testing

Trials established in 2010 - 2012 are described in Table 1, and the overall progress and status of test establishment is summarized in Table 2. The pace of second-cycle test establishment has decreased, and it is likely that the 12 ROSETIC Roseburg Low and High tests established in early 2012 marked the end of the cooperative 2nd-cycle test establishment phase. However the trees in the large network of 115 test sites are maturing and data are steadily being collected (Table 3).

Puget Sound

Seedlings in the Phase II sites experienced a challenging first year due to an extended summer drought. Cold hardiness data were collected from two sites in fall 2009. Seventy-two forward selections from PSMC Phase I tests + Green Diamond Puget Sound full-sib tests were grafted in breeding and production orchards in early 2010.

Washington Coast

Budburst data were obtained in June 2011. Whether due to the inherent nature of the genetic material, the cool rainy environments of the western part of the Olympic Peninsula, or the specific patterns of that spring, budburst occurred later in the year (early June) than any other second-cycle program scored to date. Second flushing taking place in summer 2010, frost damage in March 2011 and top damage for the 2010 growth season were also scored.

Cold hardiness was scored on two sites in fall 2012. Along with the VRTIC Phase II tests described below, this season was the first in which the lab analysis of tissue

Table 1. Summary of advanced-Generation Douglas-fir trials established in 2010-12. The purpose of all these trials was to rank families, make forward selections, and verify breeding zones.

Program	Planting Year	Number of			
		Entries	Locations	Test Trees	Test Trees + Fillers + Buffers
WA Cascades II A	2010	144 families + 2 woodsrun controls	4	11,840	15,988
ROSETIC Umpqua II	2010	70 families + 2 woodsrun controls	5	7,235	10,263
WA Cascades II B	2011	144 families + 2 woodsrun controls	4	11,840	15,148
ROSETIC Roseburg Low	2012	220 families + 5 woodsrun controls	7	29,533	38,140
ROSETIC Roseburg High	2012	107 families + 5 woodsrun controls	5	10,384	14,890

Table 2. Status of cooperative 2nd-cycle Douglas-fir breeding populations as of 2012. Test establishment is completed for all of these programs.

Location	Number of Crosses Planted	Test Establishment		
		Number Established	Start planting in spring of	Complete planting in spring of
Washington Cascades	291	16	2006	2011
Puget Sound	292	10	2003	2009
Washington Coast	106	5	2008	2008
Vernonia/ Ryderwood	416	10	2001	2005
North Oregon Cascades	377	11	2001	2005
Trask (Coast + Inland)	500	21	2004	2007
South Central Coast + CL98	604	20	1999	2006
ROSETIC- Umpqua	178	10	2007	2010
ROSETIC- Roseburg Low	228	7	2012	2012
ROSETIC-Roseburg High	116	5	2012	2012
TOTAL	2,640	115		

Table 3. Status of measurement of 2nd-cycle Douglas-fir and western hemlock tests. Dates of work done during the period of this report are indicated.

	Budburst Measurement	Fall Cold Hardiness Measurement	Growth and Form - First Measurement	Needle Retention Score	Number of Forward Selections Made	Growth and Form - Second Measurement
CL98			√		49	√
NOCTIC I	√		√		48	2011-12
Vernonia/Ryderwood I	√		√		55	2011-12
HEMTIC			√		125	√
South Central Coast I	√		√	√	97	
Puget Sound I	√	2009	√		60	
Trask Coast I	√		2009-10	2009-10	84	
Vernonia/Ryderwood II	√	2011	2009-10		39	
Trask Inland I	√		2010-11		75	
NOCTIC Phase II	√		2010-11		55	
WACTIC Phase Ia	√	2010	2011-12			
WACTIC Phase Ib						
Trask Coast II	2012					
Trask Inland II	2012					
South Central Coast II	√		2011-12		27	
ROSETIC Umpqua I	2012					
WA Coast	2011	2011				
Puget Sound II						
WACTIC Phase IIa						
ROSETIC Umpqua II						
WACTIC Phase IIb						
ROSETIC Roseburg Low						
ROSETIC Roseburg High						

damage was scored by NWTIC (the work in fall 2008 and 2009 was completed by the PNWTIRC).

Washington Cascades (WACTIC)

Phase IIb tests were planted in March 2010, completing test establishment for this cooperative. Cold hardiness samples and data were collected for two contrasting sites (one low-elevation, one high-elevation) in fall 2010. Leader damage was scored in one of the Phase I sites. Age-7 data were collected on the Phase Ia sites in fall 2011, including second flushing.

Vernonia / Ryderwood

Growth and form data were collected on five Phase II sites in fall 2009, and age-12 data were collected from the Phase I sites in early 2012. These sites were also pruned along the measurement corridors (see NOCTIC below). Fall cold hardiness was scored on two Phase II sites in October – November 2011.

Thirty-nine forward selections from the Phase II second-cycle tests were field-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.

NOCTIC

Forward selections from the Phase II tests were grafted in two production orchards and one 3rd-cycle breeding orchard in spring 2011. NOCTIC also made use of the opportunity provided by the age-15-measurement of the Molalla Genetic Gain verification trial (with up to 600 trees planted per cross, many of which were not represented in NOCTIC) to make additional, unrelated forward selections for the 3rd-cycle breeding orchard.

Three Phase I sites were pruned in anticipation of the age-12 measurement, completed in fall 2011. Every other row was pruned in the direction of measurement, with the objectives of improving access and visibility of the upper stem. NOCTIC also made plans to collect acoustic velocity data in the 2nd-cycle tests in 2012, and the pruning will aid collection of those data as well.

TRASK

Trask Coast Phase I and Inland Phase I test sites received their age-7 measurement. Eighty-four and 75 forward selections were grafted from these two programs respectively, into the 3rd-cycle breeding orchard at Plum Creek Timber Company’s Cottage Grove facility.

South Central Coast

The SCC Phase II tests were measured at age-7 from seed, and 27 forward selections were made and grafted in two production orchards and two 3rd-cycle breeding orchards. The Phase I sites were pruned in anticipation of the age-12 measurement in late summer / early fall 2012; the measurement was awarded to two contractors and we expect a few 50-foot tall trees in this series at age 12. We observed that that SCC breeding zone is very conducive to the growth of Himalayan and other blackberries, which have gained a tenacious hold on many of the progeny trees!

Roseburg-Umpqua (ROSETIC)

Budburst data were collected from ROSETIC Umpqua Phase I sites in spring 2012. ROSETIC crossing was completed in spring 2010, and the seed were sown at Arbutus Grove Nursery in British Columbia in early 2011. The Roseburg Low tests were planted in February 2012 and the High-elevation sites in April of the same year. Thankfully the nursery successfully raised a large crop of healthy, vigorous seedlings, tree planting went well (although one of the roads to a high-elevation test site had to be cleared of snow in mid-April to allow access), and a prolonged wet spring allowed for good establishment on these predominantly Douglas county test sites.

This was followed, however, by a prolonged dry spell, and its impact on survival and growth will be of great interest to its cooperators.

HEMTIC (western hemlock)

Age-10 data were collected in fall 2009 from the western hemlock test sites planted in 2001. In addition to height and DBH, forking, ramicorn branching and stem breakage (presumably caused by ice) were scored. This was such a large project that it took two contractors three months to complete the measurement.

There was good support by HEMTIC to continue to 3rd-cycle breeding, so an additional western hemlock breeding orchard block was established at Green Diamond's orchard complex near Shelton. As on previous occasions, the propagation team at Cowichan Lake Research Station, BC, produced the pot-grafts; even though scion collection took place quite late the grafting was successful.

Third-cycle Breeding and Testing

Third-cycle activitis are gathering momentum at the end of the 2012 crossing/stimulation season:

- 9 breeding orchard blocks have been established
- About 921 selections have been grafted
- Stimulation of selections in 6 breeding or production orchards
- Pollen collected from 134 genotypes
- 92 3rd-cycle crosses attempted

Pros and cons of a single third-cycle co-operative for western Washington was debated.

Technical Updates and Developments

A publication *(Heritabilities, Intertrait Genetic Correlations, G x E Interaction and Predicted Genetic Gains for Acoustic Velocity in Mid-Rotation Coastal Douglas-fir)* based on data collected from four first-generation programs in Oregon was published in Silvae Genetica. A second publication *(Early Selection for Improving Volume Growth in Coastal Douglas-fir Breeding Programs)* was accepted for publication, also in the same journal. A third document *(Third-Cycle Douglas-Fir and Western Hemlock Controlled Crossing Guidelines)* was written to facilitate the crossing programs, and later converted to a manuscript to be submitted for publication.

A fourth paper *(Genetic Selection in Coastal Douglas-fir for Tolerance To Swiss Needle Cast Disease)* presented at an IUFRO meeting in Eugene in July 2011 is being published in a USDA Forest Service General Technical Report.

Mindful of the need to develop a skilled workforce to execute 3rd-cycle crossing, NWTIC coordinated a crossing workshop/field session at the Cascade Timber Consulting office and the Mason seed orchard near Sweet Home. This was well attended by prospective contractors, co-operator representatives, and NWTIC and PNWTIRC personnel. Thanks to the presenters who shared their expertise, and CTC for providing the facilities. We had true controlled pollination weather, with a mixture of rain and sleet on a cold March day!

In anticipation of a continued demand for testing fall cold hardiness, NWTIC helped pay for the repair of the programmable freezer located at OSU.

Acoustic velocity was measured by Oguz Urhan (OSU graduate student) at three second-cycle test sites (the Toledo HEMTIC site, the Roaring River NOCTIC I site, and the Fir Grove Orchard Trask Inland site) for his Master's thesis funded by the Pacific Northwest Tree Improvement Research Co-operative (PNWTIRC) and the Center for Advanced Forestry Systems (CAFS). We look forward to the results to help guide wood stiffness data collection protocols in the 2nd-cycle programs.

Genetic Gain Verification Trials

Data from the age-13/15 measurement of the Molalla Genetic Gain trial were published in Silvae Genetica. (*Realized Gains from Block-Plot Coastal Douglas-fir Trials in the North Oregon Cascades*).

Herbicides were applied at NWTIC expense on the 2006-planted Grays Harbor Genetic Gain / Type IV (GGTIV) trials in 2010; this was the final application on the "Complete Weed Control" plots since the trees had adequately captured the site. Age-5 (from seed) data were collected by the SMC field crew in winter 2009-10 from the three sites planted in 2006, age-7 data were collected by Ron Rhatigan and the NWTIC field crew in March-April 2011 from the three sites planted in 2005 and by a measurement contractor (Williams Forestry) for the remaining three sites a year later. The results of the age-5 and age-7 measurements are presented in this report.

A proposal to measure wood properties in the GGTIV was presented at the June 2011 meeting of the Center for Advanced Forestry Systems in Seattle, WA, and subsequently approved by the CAFS membership. More details of the proposal are provided later in this report.

The NARA Project

Keith was a co-PI on a multi-institution project led by Washington State University (Northwest Advanced Renewables Alliance = NARA) on renewable production of aviation fuel from wood in PNW states, funded in 2011 by the USDA-National

Institute of Food and Agriculture (NIFA). In addition to research on chemical processing, harvesting, transport of wood residues, the proposal includes research on the genetic control of several wood chemistry traits (such as total sugars, lignin, and extractives) and marker-aided selection in Douglas-fir. The first population to be studied is Plum Creek's T96 2nd-cycle program located near Toledo. The intent is to continue to several other 2nd-cycle and even first-generation population. This project should provide exciting opportunities to get additional value from the investments in testing by the applied breeding cooperatives.

Data Management, Analysis and Reports

The status of the database is summarized in Table 4. An important change was storing metadata about variables, units and order of variables found in progeny dataset views. The goal was to eventually have one view of metadata for each view of data that existed in the database. As of June 2012 there were 41 cooperators with user accounts in the member-access secure website. NWTIC also filled over 200 individual requests for data files, analyses and other information.

NWTIC maintained a strong emphasis on data analysis, completing genetic gain predictions and reports for 28 first-generation breeding units, 15 analyses involving advanced-generation programs, and 11 other quantitative analyses. Summaries of some of those quantitative analyses are included in the report.

Membership and an Important Milestone

There have been no membership changes during this period. In September 2011 NWTIC completed a major milestone: 25 years of continuous operation. Of the current members 13 were members in 1986; two of the representatives present at the 1986 meeting (Jim Carr and Jim Hargrove) were present in 2011. This 25 years follows another 20 years of operation by the IFA-Progressive Tree Improvement program led by Roy Silen and Joe Wheat.

At the end of June 2012 Jeff Madsen retired from Port Blakely Tree Farms. Jeff had many years of involvement in cooperative tree improvement, starting with the first-generation Cowlitz tree improvement program with Champion International, various terms as Chair of the NWTIC Steering Committee, and continuing to Puget Sound and WACTIC with Port Blakely. Two long-term BLM representatives to various tree improvement cooperatives (Rich Kelly BLM-Eugene, Bob Ohrn BLM-Salem) also retired during the duration of this report. We wish Bob, Jeff, and Rich all the best in retirement!

Table 4. Highlights of information in core NWTIC Database tables.

Table	Total Number of Records	Number of 1st -generationRecords	Number of 2nd-cycle Records
Acoustic velocities (AV)	39,307	39,307	
Address Phone	447		
Advanced Generation Seed Usage	1,607		1,607
AV Wood Quality Measurements	11,266	11,266	
Budburst Measurements	101,819	45,407	56,412
Clone Bank Seed Orchard Inventories	66,928	66,388	540
Clone Banks and Seed Orchards	171		
Fall Cold Hardiness	3,308		3,308
Contacts	3,003		
Co-ops	38	31	7
Cross Tested Parents	1,895	1,876	19
Crosses (includes fillers)	7,020	1,288	5,732
Diallels	661		661
Gain Trial Measurements	41,716		
Gain Trial Sites	12		
Gen2_Progeny_Measurements	432,891		432,891
Gen2_Progeny_Trees	582,019		582,019
Gen2_Selected_Progeny_Individuals	818		818
Generational Gains	9,439	3,879	5,560
Genetic Gains	2,620,607	2,579,730	40,877
Later Genetic Gains	199,789	198,874	915
Later Progeny Measurements	253,691	252,606	1,085
Metadata Variables	2,225		

Table	Total Number of Records	Number of 1st -generationRecords	Number of 2nd-cycle Records
NWTIC Dataset TOC	2,928	2,484	355
Orchard Stimulation	1,993		
Owners	66		
Parent Tree Coordinates	31,718	31,627	81
Polymixes	149	122	27
Progeny Measurements	3,352,248	3,352,248	
Progeny Trees	3,352,305	3,352,305	
Program Images	38		38
Program Layouts	148	130	17
Program Views	147	130	17
Programs	154	135	19
Seed	5,857	981	4,872
Selected First Generation Parents	2,355	2,355	
Selected Progeny Individuals	2,735	2,735	
Sets for Multiple Site Plantations	105	105	
Site Thinning Archiving	976	976	
Sites	1,152	1,013	133
Sowing Schedules	1,342	1,198	138
Specific Gravity	14,509	13,829	680
Swiss Needle Cast Monitoring	32,764	32,764	
Tree Identifiers	41,499		
View Metadata	62,265	52,604	8,837
Z Scores	19,111	19,111	

Table 5. Summary of genetic gain predictions using BLUP, reports and other quantitative tasks, completed July 2009 through September 2012. Analyses are coastal Douglas-fir unless western hemlock indicated with a[1].

First-Generation Analyses	Trait
Snow Peak Low	Specific gravity
Snow Peak High	Specific gravity
Molalla	Specific gravity
BLM BU-30	Specific gravity
BLM BU-33	Specific gravity
Molalla	TreeSonic acoustic velocity
Umpqua Noti	Age-10 to age15 (HT, DBH, and VOL), and age15 to age30 (DBH) increments
Snow Peak Wiley Creek	Age-10 HT
Port Gamble	ST300 + HM200 acoustic velocity data
BLM BU- 33	TreeSonic acoustic velocity
Jacksonville BU-2	Age-15 data
South Umpqua BU-1	Age-10 to age-15 HT increment
South Umpqua BU-2	Age-10 to age-15 HT increment
South Umpqua BU-3	Age-10 to age-15 HT increment
South Umpqua BU-4	Age-10 to age-15 HT increment
South Umpqua BU-5	Age-10 to age-15 HT increment
Riddle BU-1	Age-10 to age-15 HT increment
Riddle BU-2	Age-10 to age-15 HT increment
Riddle BU-3	Age-10 to age-15 HT increment
Riddle BU-4	Age-10 to age-15 HT increment
Nehalem	(1) Have there been notable changes of ranks for dbh over the years on Needlecast affected sites? (2) How much diameter growth is occurring on the top families? (3) What is the predicted gain for total dbh and dbh increment of the top families? (4) What is the correlated gain for dbh at age 25.5 from selection for height / dbh / volume index / crown traits at age-11?

Burnt Woods I	Specific gravity
Burnt Woods II	Specific gravity
Dallas Low	Specific gravity
Dallas High	Specific gravity
Vernonia Sunday Creek	Specific gravity
BLM BU-11	Specific gravity
BLM BU-12	Specific gravity
BLM BU-13	Specific gravity
BLM BU-14	Specific gravity
Forks	Forks, sinuosity
Grays Harbor	Forks + ramicorns, straightness

Second-Generation Analyses
Puget Sound Age-7 HT data: Heritabilities on data not subject to spatial analysis (unadjusted data) Compare adjusted and unadjusted data
Vernonia-Ryderwood Phase I and II age-7 growth, stem form, budbreak data
[1]HEMTIC Age-10 data from all sites (western hemlock)
WACTIC Phase I age-4 budbreak data
WACTIC Phase I and PSMC Phase I fall cold hardiness data
[1]HEMTIC Age-5 basal forking data (western hemlock)
Plum Creek CL98 Age-5 to age-10 HT increment
Trask Inland I + Coast Phase I +VRTIC I and II combined age7 data (growth, form, needle retention, budburst). Generate BLUP gain predictions, correlations, genetic parameters. Investigate: Are rankings in Trask Coast, Trask Inland and V/R sufficiently different to justify 3 breeding zones, or do age-7 data indicate these could be combined to one or two zones?
NOCTIC Phase I and II age-7 growth, stem form, budbreak data
Puget Sound, WACTIC and WA Coast bud break data
NOCTIC Phase II age-12 growth and stem form data

VRTIC Phase II fall cold hardiness data
WA Coast second flushing and leader damage data
SCC Phase I and II, CL98 age-7 growth, stem form, budbreak data
Puget Sound Phase I, WACTIC Phase Ia growth, form, leader damage data. Generate BLUP gain predictions, correlations, genetic parameters. Investigate: Are rankings in PSMC, WACTIC medium-elevation and WACTIC high-elevations sufficiently different to justify 3 breeding zones, or do age-7 data indicate these could be combined to one or two zones?
Other Quantitative Tasks
Journal publication on Molalla Genetic Gain trial age-15 data
Grays Harbor Genetic Gain trial age-5 data (3 sites)
Journal publication on inheritance of acoustic velocity in D-fir (Snow Peak Low and High, Molalla, BU-33)
Using a resampling technique on Trask Coast Phase I data, investigate how many individuals are required to adequately estimate genetic parameters (e.g., h2), estimate breeding value, maximize genetic gain, evaluate genotype x environment interaction. Test the statement "we need 20 progeny/site for each site to stand alone".
Oregon Coast Range first-generation programs investigate 1) if there is evidence for trends in growth gains and survival based on elevation of test site 2) if there is reason to break breeding and deployment zones based on elevation 3) where such breaks should take place if needed.
Grays Harbor Genetic Gain trial age-5 data (6 sites)
Molalla Genetic Gain trial age-15 data - predicted gains of individual trees
Analyze 1) Vernonia Original age-25 HT-DBH-VOL, 2) Burnt Woods Phase I (age-38/40) HT-DBH-VOL, 3) Sunday Creek age 24 HT-DBH-VOL, 4) Vernonia original age-30 DBH 5) Umpqua Swisshome age-30 DBH 6) Umpqua Noti age-30 DBH 7) Nehalem age-26 (DBH) 8) BW Phase II age-25 HT-DBH-VOL 9) BLM Lorane age-20 10) BLM McKenzie age-20. Compare and contrast selection on total height vs. selection on growth increments. Critique current strategy of first measurement of 2nd-cycle tests at age-7 and second measurement at age-12. Estimate selection efficiencies at various ages. Verify if Johnson et al. 1997 selection-age conclusions remain valid.
Grays Harbor Genetic Gain trial age-7 data (3 sites)
Journal publication on optimum selection age in Douglas-fir
Grays Harbor Genetic Gain trial age-7 data (6 sites)

SURVEY ON USE OF GENETICALLY IMPROVED SEED

NWTIC again attempted to collate the number of coastal Douglas-fir and western hemlock seedlings planted by members in western Oregon and Washington, since there are no other published reports on the number of seedlings derived from orchard seed planted in these two states. While data were not provided by a few members, or by non-members (some private companies and non-industrial woodland owners), the figures in Table 6 provide some idea of the impact of the tree improvement programs in the region. Despite the recession, there was thankfully no dramatic reduction observed in the planting of Douglas-fir and western hemlock seedlings. It is also encouraging to see the reduced percentage of woodsrun seedlings, for Douglas-fir, from 11.7% in 2005 to 5.6% in 2012.

Table 6. Survey response on coastal Douglas-fir and western hemlock seedlings planted by NWTIC members in 2005-2012[1].

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
2010	45,194,219	3,604,367	3,371,082	2,847,701	311,000	790,629
2011	41,758,451	4,321,562	3,233,478	2,642,519	1,493,485	807,444
2012	45,750,187	5,694,744	3,062,788	3,696,812	1,224,510	1,095,879

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, and 31 of 34 for 2010-2012. This survey also includes Weyerhaeuser Company, the largest owner of private timberland in OR and WA, which withdrew from NWTIC in 2008 but provided data through 2012.

Analysis of Grays Harbor Genetic Gain / Type IV Trial (5-yr and 7-yr)

Terrance Ye, Keith Jayawickrama, Eric Turnblom and Brad St Clair

Introduction

Background on the objectives, experimental design of this trial, and linear model for data analyses were presented in the 2007-9 NWTIC report. Very briefly the trial has the following notable features:

Treatments:

- Three levels of genetic gain: Unimproved, Intermediate Gain and Elite.
- Three Density treatments: Low density (15 × 15′), Intermediate density (10 x 10′), High density (7 × 7′)
- Two Vegetation control levels: Standard, Complete

Test design:

- 6 sites
- 22 plots per site
- 64, 100, and 250 measurement trees / plot for den = 1, 2, and 3, respectively,
- Considered as a completely random design

Results and Discussion:

Age-5, 6 sites

1. 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 or 604 > 605 > 606 > 602.

2. Based on within-site plot-mean analyses, two sites showed significant difference in height (site: 601, P=0.03; site: 604, P=0.01) among seedlots. A significant difference (P=0.01) was also found for dbh at site 604. The effect of vegetation control was significant at sites 603 and 605 for both height and dbh, and the density effect was significant at site 602 for height. Lack of statistical significance may be partially due to the small number of replicates within site (St. Clair *et al.* 2004, WJAF 19(3): 195-201).

3. **According to the across-site plot-mean analysis, the genetically-improved seedlots grew significantly better than the unimproved seedlot for both height and dbh (P<0.001).** However, no significant difference was found between the elite and the intermediate seedlots. Realized gains were much higher for dbh **(15.5% for the elite, 13.2% for the intermediate)** than for height **(9.6% for the elite, 7.6%**

for the intermediate). Survival rate was similar among seedlots at this age. The trees planted at the 7 x 7 ft. and the 10 × 10 ft. were bigger (in both height and dbh) than those from the 15 x 15 ft. plots, although such differences was only marginally significant (P=0.052). The two levels of vegetation control had no meaningful effect of tree growth. The lacks of significance in seedlot x density and seedlot x vegetation may have implied that inter-tree competition at age 5 is weak.

4. The across-site analyses on the basis of individual trees showed a similar pattern of among-seedlot differences. Realized gain estimates based on individual trees were very 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.

5. The correlation of estimated realized gains for height between age 3 and 5 was 0.73 (Figure 1).

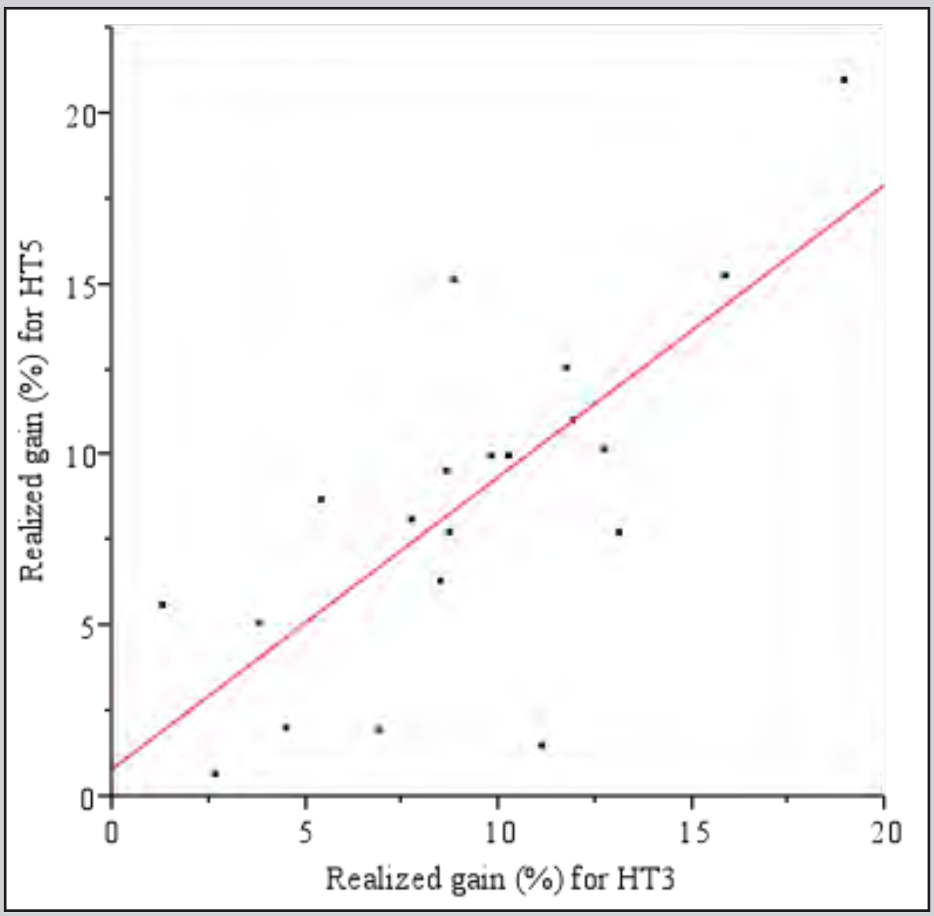

Figure 1: Relationship between age-3 and age-5 realized gains for height across six sites of the Grays Harbor Genetic Gain – Type IV trial.

Age-7, 6 sites

1. At the time of the age-7 measurement, there were 12,289 surviving trees. Survival (surv7) varied from 72 to 90% within sites. The number of incidents of forking and ramicorn branching, and stem sinuosity, were subject to the square root transformation before the mixed model analysisHighly significant differences were found among test sites for all the traits measured at age 7. Site productivity based on ht7 was in the following order: 601 $>$ 604 $>$ 603 $>$ 605 $>$ 602 $>$ 606.

2. Based on within-site plot-mean analyses, five sites had significant differences in ht7 ($P<0.05$) among seedlots,whileonesignificantdifference ($P=0.05$) was found for dbh7 and vol7. Differences among levels of spacing or vegetation control for growth traits were statistically significant for 2/18 and 1/18 combinations. Similarly, all interaction effects were undetectable statistically at this age.

3. Analyzed across all six sites, the genetically-improved seedlots had significantly greater height and diameter (dbh7) than the unimproved seedlot ($P<0.001$), with larger crown base height (cbh7, $P=0.01$) and fewer incidences of ramicorn branching ($P=0.001$). While differences between gain levels for forking were non-significant, least-square means for forking were marginally lower in the intermediate and elite lots than in the unimproved lot. Realized genetic gains were slightly higher for diameter (12.5% for the intermediate, 12.2% for the elite) than for height (10.0% for the intermediate, 10.7% for the elite). For tree volume, realized gains were 27.6% for the intermediate and 29.5% for the elite.

4. No significant difference was found between the elite and the intermediate seedlots in terms of growth rate. The reason for the elite seedlot not outperforming the intermediate seedlot in growth is not straightforward. However, competition effect and its interaction with seedlots might have played a non-trivial role. The elite and intermediate were selected and classified based on their performance in the Grays Harbor first-generation progeny test. Due to the tight spacing (6′ x 6′) used in the progeny test, we would expect crown closure and strong inter-tree competition at the time of final measurement (age-10). Hence, the elite seedlot may be a collection of families characterized with high competition ability, with highest gains at narrow spacing. Its superiority over the intermediate seedlot might not be evident prior to onset of strong inter-tree competition such as the current condition in the GGTIV. The lack of significance in seedlot ´ spacing and spacing ´ survival may imply that inter-tree competition at age 7 is still weak.

5. The trees planted at the narrow spacings (7′ and 10′) were on average taller (~5%) and had greater diameter (~4%) than those from the plots of

wide spacing (15′). Spacing did not, however, have significant impact on tree survival (P=0.25), implying that among-tree competition was not strong enough to cause density-dependent mortality at the close spacing by this age. Differences between the two levels of vegetation control were insignificant for most traits except for dbh7 (P=0.05), cbh7 (P=0.02), and surv7 (P=0.05), with the complete control having slightly better diameter growth, smaller crown base height, and higher survival. The Grays Harbor area receives rainfall through most of the year, so periods of summer drought are shorter than in some parts of the Douglas-fir region. We would expect larger gains from complete weed control in areas subject to more severe summer droughts.

6. Realized gains varied greatly among full-sib families within each improved seedlot for all the traits studied, and within-seedlot variation was much larger than among-seedlot variation. The highest realized gains for age-7 height, diameter, and volume for a full-sib cross were 23.6%, 27.3% and 73.8% respectively; these were based on about 480 surviving trees for that cross.

7. Comparing the age-7 realized gains from this study with the age-10 predicted gains from the Grays Harbor first-generation, the correlation between the two types of gains was very low (r = 0.02~0.20). This is different from three previous publications from Douglas-fir genetic gain trials. This may have been contributed by many factors such as the small number of tested families (a truncated population), strong site × family interaction, different measurement ages, and existence of seedlot × silvicultural treatment.

Acknowledgements

Rayonier Forest Resources (RFR) and Quinault Indian Nation (QIN) developed the Grays Harbor breeding population on which this trial was based. Mike Bordelon and Jess Daniels were early supporters of establishing realized gain trials in the PNW. The full-sib crosses were made by RFR (coordinated by Jessica Josephs), while the QIN (coordinated by Jim Hargrove) helped collect the unimproved seed. These trials were established through the collaboration of the SMC, NWTIC and the US Forest Service PNW Research Station. Green Diamond Resource Company, Port Blakely Tree Farms, QIN, RFR, WA Department of Natural Resources and Weyerhaeuser Company provided the test sites. Ron Rhatigan and his field crew (OSU) measured three sites while Williams Forestry measured the remaining three. Bob Gonyea and Bert Hesselberg (SMC) helped audit measurements on three sites, and monitored the sites from the time of establishment and provided maintenance as needed. Data management was done by Randy Collier (SMC) and Denise Cooper and Lauren Magalska (NWTIC).

Impact of Genetic Gain, Spacing, and Weed Control on Wood Stiffness, Density and Knot Index in a Large-plot trial of Coastal Douglas-fir: Measurements in the Joint SMC Type IV / NWTIC Grays Harbor Genetic Gain Trials (Center for Advanced Forestry Systems CAFS 11.35)

Turnblom, E.C.; Briggs, D.B.; Jayawickrama, K.J.S.; Ye, T.; Lowell, E.C.; Huang, C.L.

Introduction

Wood stiffness, density, and knot size have substantial impacts on log and wood quality and product yield in Douglas-fir, and can be limiting in intensively-managed short-rotation plantations. The impact of both genetic selection for growth rate and intensive early weed control, on wood stiffness and knot size in operational plantations of coastal Douglas-fir in western Washington and Oregon is imperfectly understood. The information we have on genetic effects is obtained from single-tree-plot progeny tests; there is evidence that wood stiffness and density are strongly inherited at the family level, with a modest adverse correlation with diameter growth rate. There is better information on the effect of spacing: wide spacing and growth acceleration from weed control can also be expected to have some impact on wood stiffness, density, and knot size. but there is no previous information in the public domain on the interactions of spacing, genetic gain, and weed control intensity on these traits.t it would be extremely valuable for members to know the exact extent of that reduction (singly and together) in operational plantations. This will allow them to modify their silvicultural treatments as needed. Another benefit to members would be the incorporation of wood quality traits into selection criteria.

Acoustic velocity, an indicator of stem stiffness; resistance, an indicator of wood density; and diameter of the largest branch in the BH region, which is correlated with a log knot index commonly used in product recovery studies, knot index will be assessed in the BH region on a sample of trees in the joint Genetic Gains / SMC trials. After a brief outline of the experimental material in sections A through C, desired measurements and sampling strategies are outlined in sections D & E, with section F alluding to field testing time and place.

Objectives

- To obtain acoustic velocity, wood density, and knot index of Douglas-fir at three genetic gain levels (elite and intermediate gain, woodsrun), three spacings (7’, 10’ and 15’), and two weed control levels (5 years control vs. 1 year control)
- To assess impacts of genetic gain level, spacing, and weed control on the obtained metrics of wood quality (acoustic velocity, wood density, and knot index)

- To establish an early baseline from which a monitoring program can be launched that will track changes in these wood quality metrics over time that may provide forest managers information so that appropriate silvicultural choices can be made to maintain or improve quality to meet future customer needs under now more common shorter rotations within the forest industry

Experimental Material

A. Installations

- Six (6) research sites (installations) in Grays Harbor, WA area, three planted in 2005 and three in 2006.

B. Plots

- Twenty two (22), mostly 100-tree plots available at each installation
  - ¤ 19 plots under **complete** weed control are common to all installations (except 606, which is missing the 7x7′ elite gain):
    - Two (2) at 7x7′ spacing, one woods-run, one elite
    - Five (5) replicate plots respectively of woods-run, intermediate gain and elite gain stock at 10x10′ spacing
    - Two (2) at 15x15′ spacing, one woods-run, one elite
  - ¤ Three (3) plots under **standard** weed control vary from site to site following an Incomplete Block Design (except 606, which has four):

C. Families

- Seedlings were tagged with coded family numbers at the time of planting, linked to tree number in the SMC database
- Each gain level is represented by the following number of trees/plot for each of ten (10) families: 7′ spacing – at least 22 trees; 10′ spacing – 10 trees; 15′ spacing – at six (6) trees.

Measurements

The three sites planted in 2005 will be measured at the end of the 2012 growing season when the trees will be nine seasons from seed with an anticipated average height of 18-20 feet. **Diameter of largest branch** in the breast height region is measured on every sample tree, along with number of live and dead branches, following SMC branch measurement protocols developed for Douglas-fir, which also calls for these measurements on the trees with the smallest and largest DBH. Knot indexes will be derived from these. **Resistance** will be measured with a Resistograph F400S 2.5 cm above breast height in line with the vertical axis defined by placement of the two piezo sensors. Increment core extracted from every other sample tree 2.5 cm below breast height along the axis formed by the vertical placement of SD02/60 sensors and saved for subsequent **density** analysis for calibration of velocity and resistance readings.

The budget (in-kind SMC contribution) allows for four (4) weeks of field measurements per year during the measurement season, which should allow for sampling 30-40% of the trees within each family, i.e., 30-40 trees per plot. Three to four sample trees will be randomly chosen from each of the ten families on each plot before going to the field using family codes to identify associated tree numbers in the SMC database. Cores from the two trees closest to the median DBH of sampled trees in each family on each plot will be extracted with an increment borer. The total number of trees measured per season is estimated at between 2,000 to 2,600.

The field measurements will be repeated at the end of the 2013 growing season on the three sites planted in 2006. This project sets the stage for future re-measurement of these characteristics and assessment of the ability of early measurement of these properties to predict values at later ages.

Expected Outcomes

- AFTER ONE YEAR: By the end of 2012, data will be collected on three sites, providing age-9 acoustic velocity, resistance, and knot index on Douglas-fir trees of three genetic gain levels, planted at three spacings, and treated with two weed control levels. Analyses will provide information on the relationship between these variables and key growth and stem form variables (height, dbh, volume index, forking, ramicorn branching and stem sinuosity) that are routinely measured on these trials.
- LONG TERM: These and other measurements will greatly improve our understanding of the effects of genetic gain, spacing, and weed control on tree, log, and wood quality over time in Douglas-fir plantations.
- TIMELINE: Data collection: Autumn 2012 and 2013

  Analysis and reporting: Spring 2012 and 2013

  Completion of Master’s Thesis and submission of journal article: 2014

Optimal Numbers Of Offspring Per Family Per Site in NWTIC 2nd-Cycle Programs Using A Re-sampling Technique on TRASK Coast Phase I 2nd-cycle Progeny Trial (Age-7 data)

Terrance Ye and Keith Jayawickrama

Introduction

Robertson (1957), with particular reference to animal breeding, proposed that the optimum number of half-sib individuals per family for estimating heritability is approximately:

$$N = 4 / h^2 \quad \text{(e.g., } N = 20 \text{ when } h^2=0.2\text{)}$$

Magnussen and Yanchuk (1993) determined selection ages for height growth in coastal Douglas-fir on four sites (23-year-old, 14~18 families/site) on Vancouver Island by stochastic simulation. Their criteria were the age-age correlation and gain ratio. They concluded that early family selection (age < 15) required at least 20 trees per family per test site, but very early family selection (age < 10) required at least 40 trees per family per site.

In Randy Johnson's General Technical Report (1998) on breeding and testing coastal Douglas-fir it is stated that *"The NWTIC progeny tests serve not only to rank families but also to provide information for delineating breeding zones. Each site, therefore, must provide reliable estimates of family means on each site; …… Progeny tests, therefore, should have a minimum of 20 trees per family per site."* No backing numbers from quantitative genetics were provided.

The following changes have taken place in NWTIC progeny trials over time:

	FROM	TO
Experimental Design:	Reps-in-sets or Sets-in-reps	Alpha or RCB
Mating Design:	Open-pollinated families	Full-sib families
Analysis Method:	NOVA and INDEX	BLUP and Spatial Analysis

Now that age-7 to age-10 results from seven 2nd-cycle test series have been collected, it is time to re-visit the question: what is the optimal number of tree/family/site for our advanced-generation progeny tests?

Objective

Determine how many individuals are required to adequately (1) estimate genetic parameters (e.g., h2) (2) estimate breeding values (3) maximize genetic gain and (4) evaluate genotype x environment interaction in a 2nd-cycle breeding program.

Materials

TRASK Coast Phase I 2nd-cycle progeny test series was used, with 212 crosses, 18.2 trees living / family / site at age 7, 6 sites with ~20 reps/ site, established according to an alpha design. The traits were HT7, HT7a (spatially de-trended), DBH7, and DBH7a (spatially de-trended).

Analysis Methods

We used a re-sampling technique, choosing random samples with replacement from a data set and analyzing each sample in the same way to establish the uncertainty of the quantity we are estimating.

Details

Randomly drop 1 to 17 reps from each site, re-sample 500~800 times each scenario, conduct mixed model analysis for each sample and record the estimated genetic parameters, summarize the results and identify patterns.

Results

1. **The accuracy of PBV** = the correlation between the true and predicted genetic values. The larger the r_{gg}, the more precisely the breeding values and genetic gains are predicted.

$$r_{gg} = \sqrt{1 - \frac{PEV}{\sigma_A^2}}$$

The accuracy of PBV (r_{gg}) increased with number of trees (Figure 2). After 10~11 trees/family/site, the additional gain from adding additional trees is minimal. Traits after spatial adjustments gave a slightly better r_{gg}, and reach the asymptote earlier. Backward selections had higher prediction accuracy than forward selections.

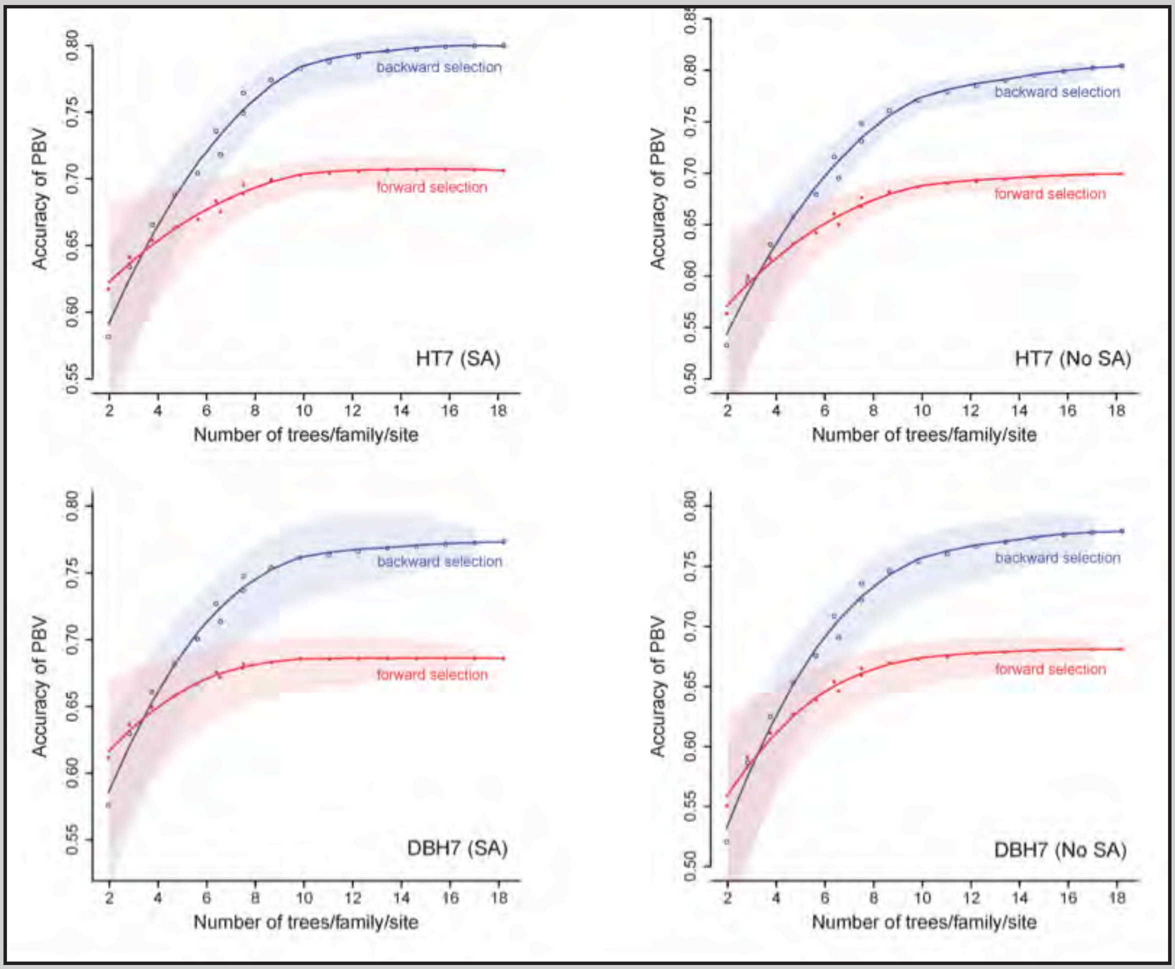

Figure 2: Variation in accuracy of predicted breeding value with number of trees per family per site (HT7 = age-7 height, DBH7= age-7 diameter at breast height, SA = spatial adjustment).

2. The precision of heritability estimate.

$$\frac{\sigma_{h^2}}{h^2}\times 100\%$$

The smaller the value, the more precisely the heritability is estimated.

The precision of heritability estimates increased with number of trees (Figure 3). After 9~10 trees/family/site, the additional gain from adding additional trees is minimal. However, the estimate is generally associated with large confidence interval. Spatial analysis provided better heritability estimates, especially when the number of trees per family is small.

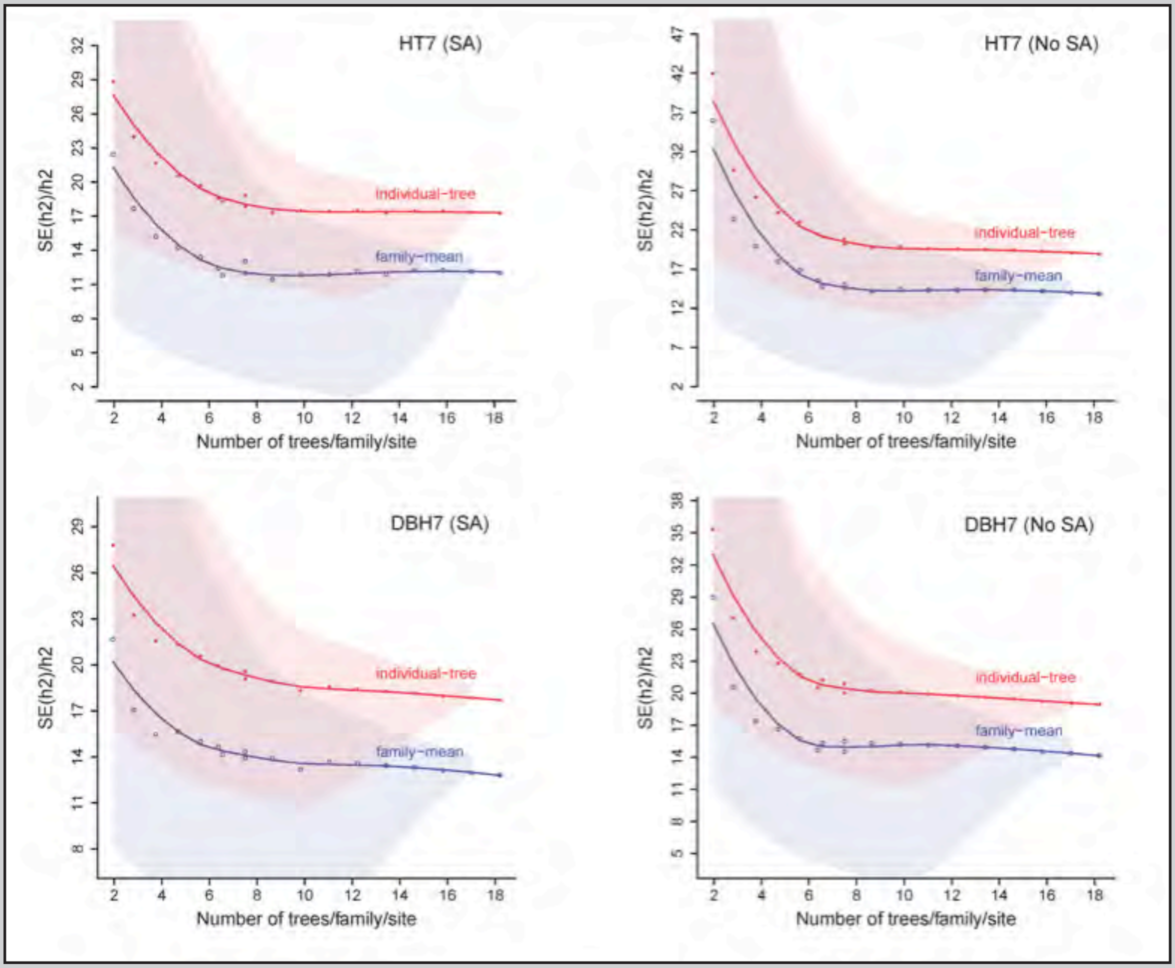

Figure 3: Variation in precision of heritability estimates with number of trees per family per site (HT7 = age-7 height, DBH7= age-7 diameter at breast height, SA = spatial adjustment).

3. **The level of family-mean heritability (h^2f**

where $k_5 \approx$ mean number of trees per family across sites. Family-mean heritability estimate is an important component in predicting genetic gains. It generally increases with number of trees per family.

$$h_f^2 = \frac{\sigma^2_{female} + \sigma^2_{male}}{\sigma^2_{female} + \sigma^2_{male} + \sigma^2_{cross} + \frac{\sigma^2_{female\times site}}{k_2} + \frac{\sigma^2_{male\times site}}{k_3} + \frac{\sigma^2_{cross\times site}}{k_4} + \frac{\sigma^2_e}{k_5}}$$

The family-mean heritability did increase with the number of trees, but after 10~11 trees / family / site, the additional gain from adding additional trees was minimal. Traits after spatial adjustments gave a slightly higher family-mean heritability estimates.

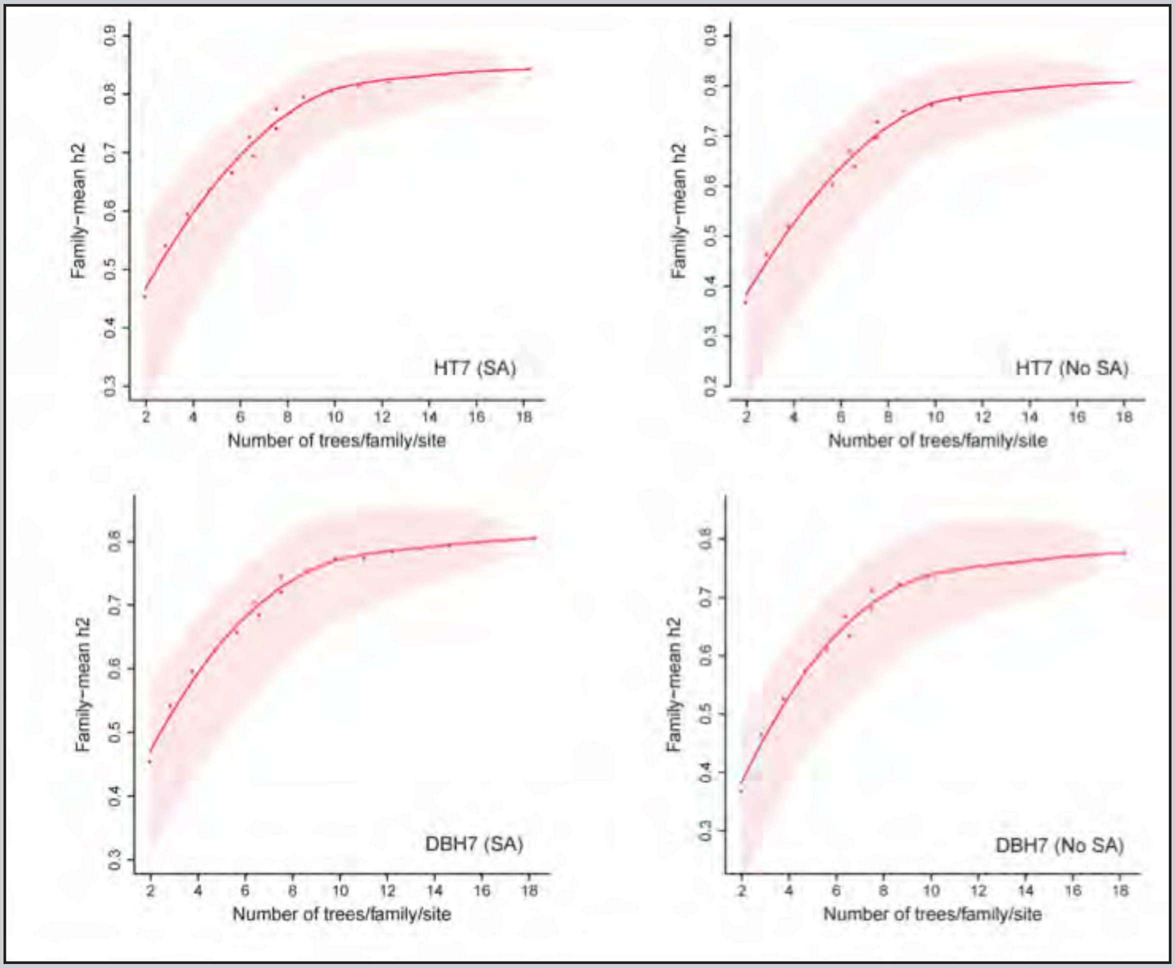

Figure 4: Variation in the level of family-mean heritability estimates with number of trees per family per site (HT7 = age-7 height, DBH7= age-7 diameter at breast height, SA = spatial adjustment).

4. **The level of predicted genetic gains.**

$$\Delta G(\%) = \left(\frac{i_f \cdot h_f \cdot \frac{\sigma_A}{\sqrt{2}}}{\mu} + \frac{i_w \cdot h_w \cdot \frac{\sigma_A}{\sqrt{2}}}{\mu} \right) \times 100$$

Predicted gains depend on selection intensity (i), heritability (h2), additive genetic variance (2A), and population mean (μ). Again, for both backward and forward selections, the predicted genetic gains increased with number of trees, and became relatively stable after 10~11 trees / family / site.

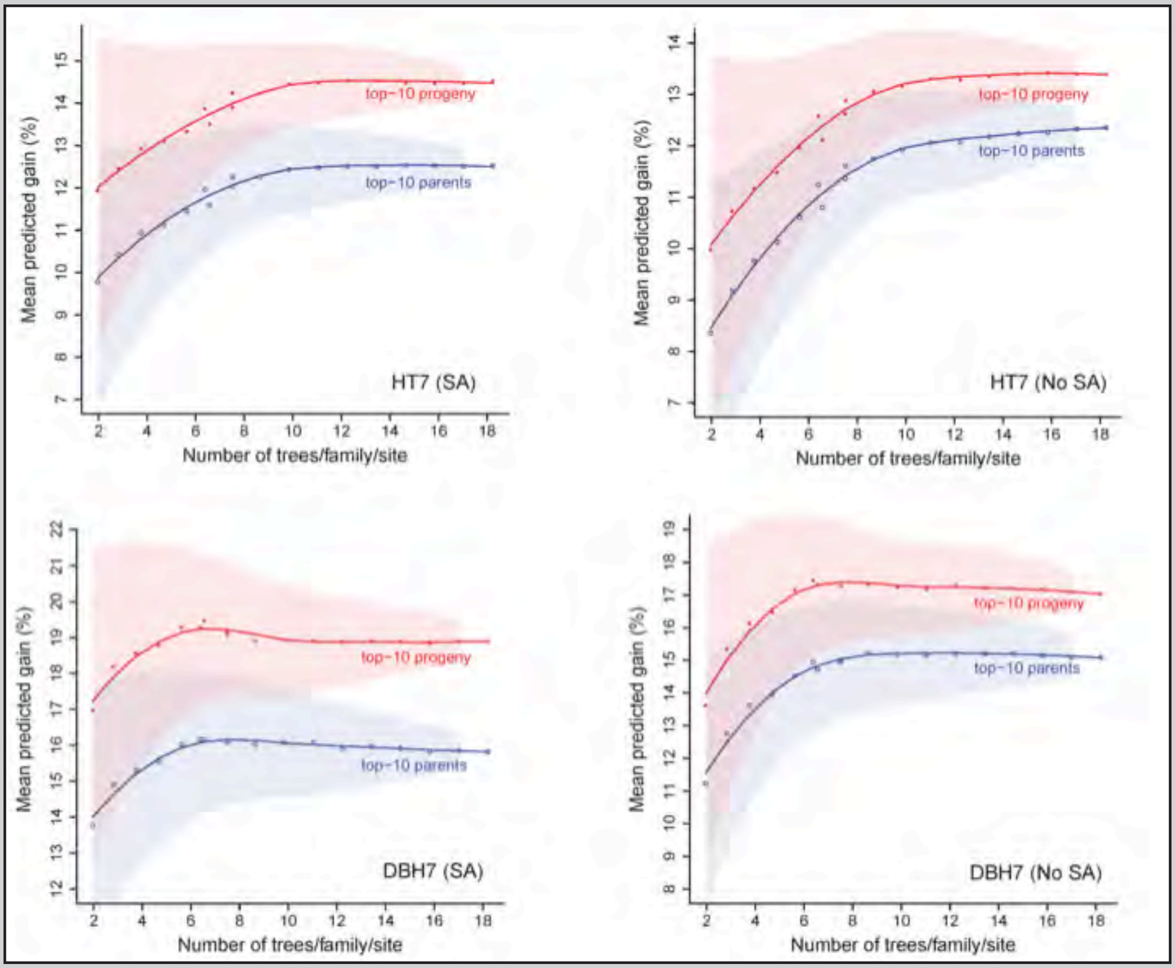

Figure 5: Variation in the mean predicted gain estimates with number of trees per family per site (HT7 = age-7 height, DBH7= age-7 diameter at breast height, SA = spatial adjustment).

5. **The precision of the type-B genetic correlation r_B estimate:**

$$\frac{\sigma_{r_B}}{r_B} \times 100\%$$

The type-B genetic correlation (r_B) is a measure of family x site interaction. Precisely estimating r_B is helpful for selecting the most stable families as well as for delineating breeding zones. The smaller the value, the more precisely the r_B is estimated.

Unlike previous parameters which were stable or nearly stable after 10~11 trees / family / site, the precision of r_B tended to keep increasing by adding additional trees. After 13 trees / family / site, however, the changes were no more than 2%. The confidence interval decreased dramatically after 10~11 trees / family / site.

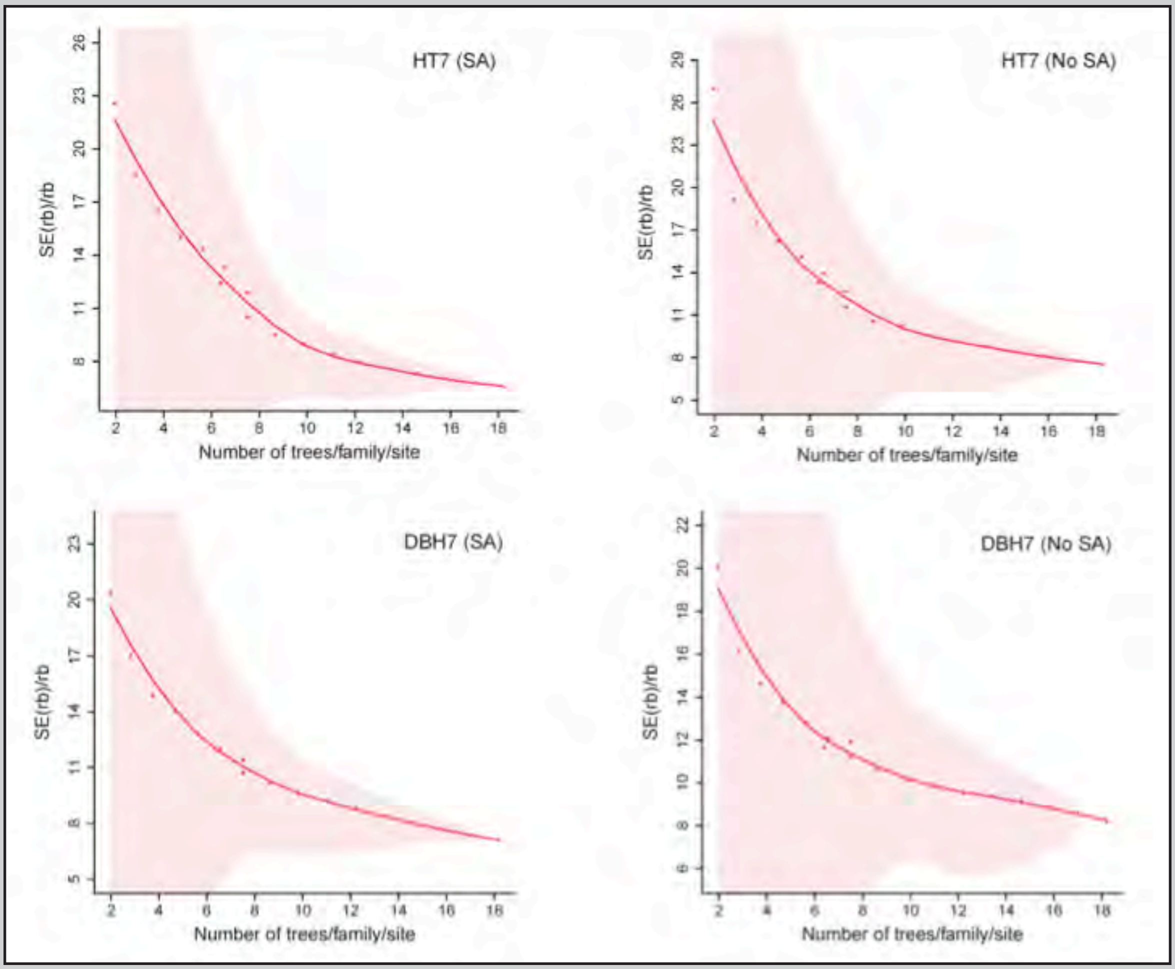

Figure 6: Variation in the precision of the type-B genetic correlation.

Conclusions

Progeny trials generally serve multiple purposes in tree breeding. For the purposes of predicting breeding values and genetic gains for making selections, 10~11 living trees/family/site and 6 sites in a typical NWTIC 2nd-cycle testing program seemed to be optimal at age-7 for height and diameter. Adding 15~20% potential mortality, 12~13 trees/family/site seems to be sufficient in most cases at this age.

The number of trees would need to be higher if (1) heritabilities are lower, either because tests are less precise or genetic variation is lower (2) mortality is higher and (3) there is interest in thinning and maintaining the trials long-term.

For the purposes of exploring the G x E pattern, a few more trees per family (and perhaps more sites) would be beneficial. Spatial analysis helps in achieving better accuracy or precision of genetic predictions, especially when the number of trees/family/site is small.

The optimal number of trees/family/site may vary among testing programs, traits of interest, and measurement ages. While TRASK Coast Phase I is a fairly typical 2nd-cycle program, more tests will be needed in order to draw general conclusions. Reducing number of tree/family/site could make space for other testing extra unrelated families, which would otherwise be excluded due to limited resources and spaces in the tests.

Heritabilities, Inter-trait Genetic Correlations, G x E Interaction and Predicted Genetic Gains for Acoustic Velocity in Mid-Rotation Coastal Douglas-fir

KJS Jayawickrama, TZ Ye and GT Howe. 2011. Silvae Genetica 60(1): 8-18

Abstract

Acoustic velocity (AV) data from 7,423 coastal Douglas-fir trees drawn from 347 wind-pollinated families on 14 sites, from four first-generation testing programs in the north Oregon Cascades, were analyzed. Families were measured on two or four sites at ages 23 to 41 years from seed using the Fakopp TreeSonic standing-tree tool. Height (HT) and DBH data collected at ages 15 and 16 from seed, from all trees in the four programs (95,795 trees, 955 families), were used to calculate volume index ($VOL=HT*DBH^2$) and stem taper (TAP=DBH/HT). All traits were analyzed using multivariate mixed model analyses.

Across-site individual narrow-sense heritabilities for AV^2 ranged from 0.24 to 0.40 among first-generation programs, compared to 0.12 to 0.23 for HT, 0.10 to 0.16 for DBH, 0.11 to 0.20 for VOL and 0.14 to 0.17 for TAP.

Across-site type B correlations for AV^2 ranged from 0.85 to 0.95, compared to 0.62 to 0.83 for HT, 0.60 to 0.74 for DBH, 0.67 to 0.78 for VOL and 0.66 to 0.79 for TAP. AV^2 was negatively correlated with HT in three programs (r_A =0.17 to -0.28), and negatively correlated with DBH (-0.12 to -0.46), VOL (-0.05 to -0.44) and TAP (-0.09 to -0.40) in all four programs.

Selecting the top 10% of the families sampled based on AV^2 gave predicted gains of 4.4% to 9.6% for AV^2 and -9.3% to 10.6% for VOL. The adverse genetic correlations between AV^2 and growth, and the losses in gain in AV^2 from selection based on growth, may be overestimated by suppression of slower-growing families in these older tests.

Genetic Selection in Coastal Douglas-fir for Tolerance to Swiss Needle Cast Disease

Keith Jayawickrama and Terrance Ye, Dept. of Forest Ecosystems and Society, Oregon State University,
David Shaw and Robin Mulvey, Dept. of Forest Engineering, Resources, and Management, OSU

Abstract Presented at: "Disease and Insect Resistance in Forest Trees". Fourth International Workshop on the Genetics of Host-Parasite Interactions in Forestry. July 31 - August 5, 2011, Valley River Inn, Eugene, Oregon, USA. (Presented as a Paper). Subsequently accepted for publication in a USFS General Technical Report for the Workshop.

Swiss needle cast (SNC) of Douglas-fir, caused by the ascomycete fungus Phaeocryptopus gaeumannii, is associated with significant volume growth losses (20-50%) along the Oregon Coast. Although the pathogen is endemic, disease symptoms have intensified in coastal forests of Oregon and Washington since the early 1990s, and reached a peak of 393,923 symptomatic acres detected in the 2010 aerial survey of western Oregon. Climatic conditions near the Oregon coast are often conducive to SNC disease development. Coastal Douglas-fir is an enormously important timber species for Oregon; consequently, there has been considerable interest and investment in developing seed sources suitable for this zone.

Early research on genetic tolerance versus resistance confirmed that there are no known resistance mechanisms, as all foliage and all trees are susceptible given the right climatic conditions during spore dispersal and colonization. Fungal infection and needle colonization occur passively, through needle stomata and the needle apoplast, respectively, and neither process requires physical or enzymatic penetration of host tissue that might trigger a host defense response. Nonetheless, tolerance to the disease was documented, with some families continuing to grow well in the presence of SNC, and family-mean narrow-sense heritabilities of 0.6 to 0.8 for traits such as needle retention, crown density and foliage color. Several studies have centered on the Nehalem progeny trial series of 400 first-generation families established on ten sites in 1986 and subject to moderate to heavy SNC disease pressure. This series was re-measured in summer 2010, and age-26 diameter growth results from 200 families on five sites will be presented. Selections have also been made from other first-generation programs near the coast.

The Trask and South Central Coast Douglas-fir breeding co-operatives, operating within the Northwest Tree Improvement Cooperative, have established 26 new progeny test sites along the Oregon Coast between 2002 and 2006 to obtain 2nd-cycle selections. Ability to maintain height and diameter growth, and needle retention scores, will be the primary selection criteria. The goal is to develop seed sources capable of acceptable growth rates on sites averaging ≥ 2 years of needle retention. In areas with higher disease pressure and foliage retention ≤ 2 years, it may be prudent to use alternate timber species, such as western hemlock, red alder, western white pine and Sitka spruce (some forest owners have been making this switch during the past 10-15 years). The Swiss Needle Cast Cooperative has collaborated with PNW tree improvement researchers and funded several tree improvement projects over the past 12 years, and recently developed an Integrated Pest Management strategy that depends on tree improvement efforts to aid in the long-term management of the disease.

Early Selection for Improving Volume Growth in Coastal Douglas-fir Breeding Programs

Terrance Z. Ye and Keith J. S. Jayawickrama. Silvae Genetica (in press)

Abstract

Measurements on growth traits up to 41 years of age from 68 progeny sites in eight first-generation breeding zones of coastal Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco var. menziesii) in the US Pacific Northwest were used to investigate age trends of genetic parameters and to determine optimum age of selection. Heritabilities and age-age genetic correlations were estimated using univariate or bivariate mixed model analyses.

Heritability estimates tended to increase with age for both total growth and growth increment traits. HT heritabilities were higher than DBH and VOL at all ages investigated. The estimates showed different age trends among breeding zones, but the differences were generally small. Age-age genetic correlations for total growth traits fitted Lambeth's model surprisingly well, despite the data being collected from multiple breeding zones. The genetic correlations between early height or diameter growth and age-50 stem volume (VOL50) were strong, and well fitted by Lambeth's equation (R^2 = 0.63 for HT, and 0.94 for DBH). At young ages (≤ 22 years), HT was genetically better correlated with VOL50 than DBH (or VOL) with VOL50, but the reverse was true beyond age 25.

Using rotation-age (i.e., 50yr) volume as the selection criterion, the greatest correlated gains per year were achieved by making family selection at juvenile ages (i.e., 9 for height, 13 for diameter, and 11 for volume). Similar results were obtained for within-family selection except that the optimum ages of selection were 2~4 years later than that from family selection, i.e., 11 for height, 15 for diameter and volume. Early selection on total height was always more efficient and had earlier optimum ages than on other total growth traits. Using an interest rate d = 6%, the shapes of curves of discounted efficiency (Q′) with age were similar to that of gain per year efficiency (Q), and also had a broad range of selection ages that gave close to optimal relative efficiency. The maximum Q's for VOL50 when selecting on various traits before age 13 were in the following order: HT > VOL > DBH > HT_INC or DBH_INC > VOL_INC. Through family selection, Q′ for VOL50 when selecting on HT was maximized at 10 years, and that based on DBH or VOL selection was maximized at 12 or 11 years.

The optimum ages of early family selection on total growth were 4~11 years earlier than on the corresponding growth increment traits. It was also evident that the optimum ages of selection occurred later for slow-growth trials than for fast-growing trials; the optimum selection age was 1~4 years earlier when the slowest-growing third of trials per breeding zone were dropped from the dataset.

Key words: Douglas-fir, growth, growth increment, early selection, selection efficiency, optimum age, heritability, age-age genetic correlation.

Effect of Data Transformation on Magnitude of Predicted Gains in Douglas-fir Programs

Terrance Ye and Keith Jayawickrama

Introduction

The predicted gains for tree volume for the top Douglas-fir parents in the NWTIC programs can be very large, especially at younger ages, raising the question if they are realistic. Unlike height and diameter, volume is a derived trait rather than a direct measurement; in the calculation equation, diameter receives much more weight than height. When trees are young, a small difference in diameter would result in large difference in volume.

Most parametrical statistical analyses, including BLUP analysis, requires that all random effects (including residuals) have normal distributions (e.g., Henderson 1984). The quality of BLUP when the normality assumption on random effects is violated has been well investigated in the longitudinal data analysis literature; e.g., Verbeke and Lesaffre (1996), Li et al. (2004, 2007). What we learn from this literature implies that the non-normality in random effects could cause the quality of BLUP or its refined version to deteriorate, that mild violation such as mild skewness or slightly longer tails could cause some mild biases for the regression parameters at the level of 2–8%, and that the multi-modal scenario such as mixture of normals could lead to more severe biases (28–45%; Table 2 of Li et al. 2007).

We therefore took the Grays Harbor Douglas-fir age-10 volume (**vol10** = ht10 x dbh10 2) data as an example, and examined the effect of data transformation [**vol10x** = square-root(vol10+0.5)] on the fit of normality assumption and the prediction of genetic gain.

Results

We commonly see a long tail on the right side in the histograms of volume data. In this data set the pattern was seen; in Figure 7, for example, the volume of the largest tree was about 5 times bigger than the average. Such skewness was greatly reduced after conducting a square-root data transformation (Figure 8). Before transformation, the distribution of residual was apparently skewed to the left, similar to the distribution of raw data (Figure 9). After transformation, the data showed more symmetric and less skewness than before (Figure 10).

The predicted parental gains were compared before and after the square-root transformation. The two sets of gain prediction were correlated very well, with both simple and rank correlations being 0.99, indicating that data transformation had little effect on parental ranking. The absolute gain values, however, changed a lot. For example, the average predicted gain for the top 10 parents dropped from 68% before transformation to 35% after transformation.

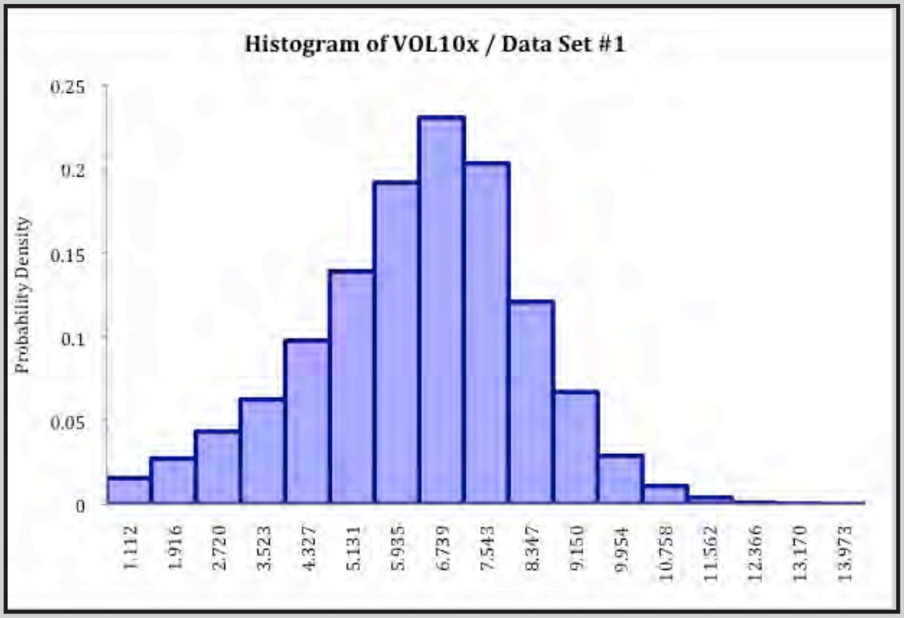

Figure 7. Histogram of Raw Data - VOL10.

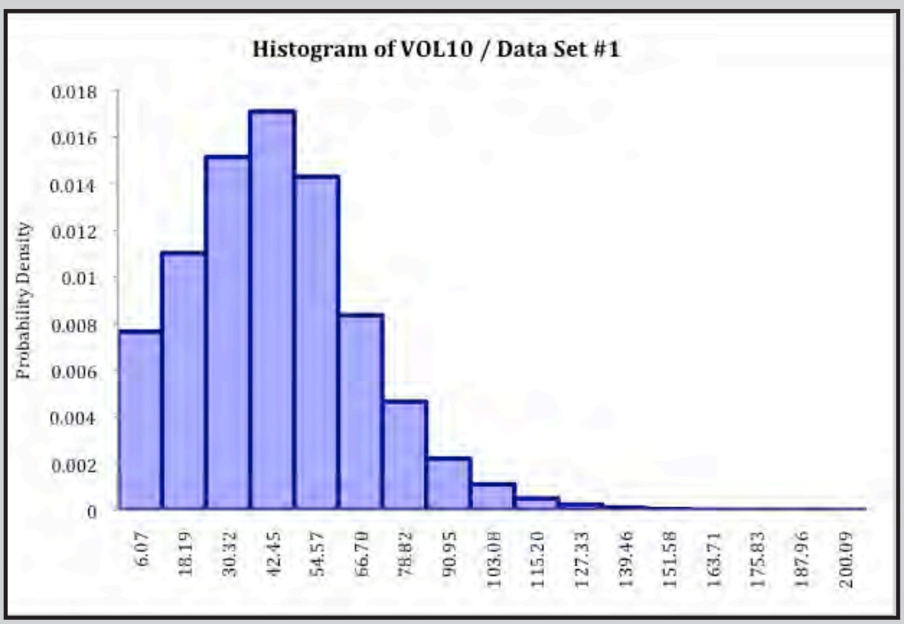

Figure 8. Histogram of Square-Root Transformed Data - VOL10x.

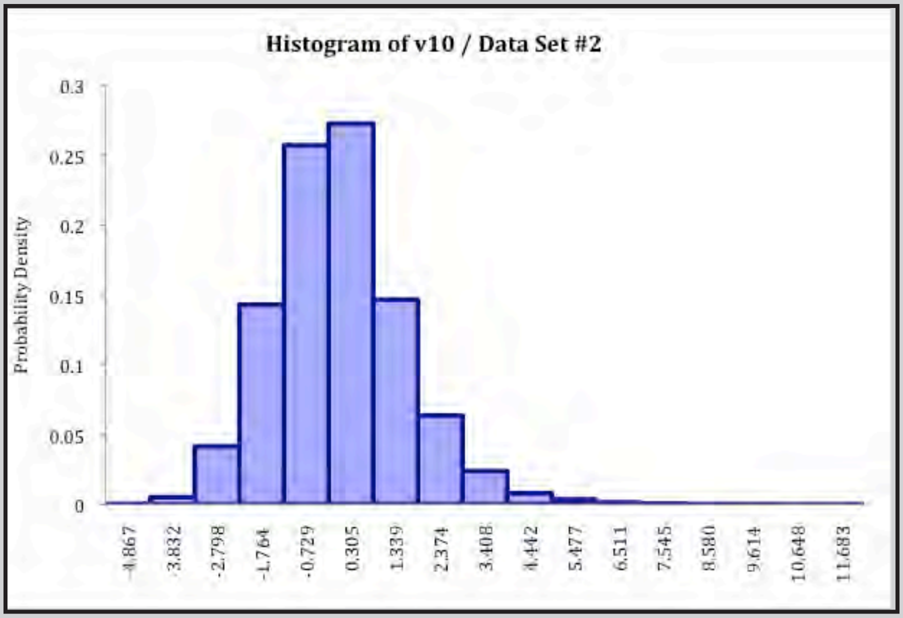

Figure 9. Histogram of Residual for Raw Data - VOL10.

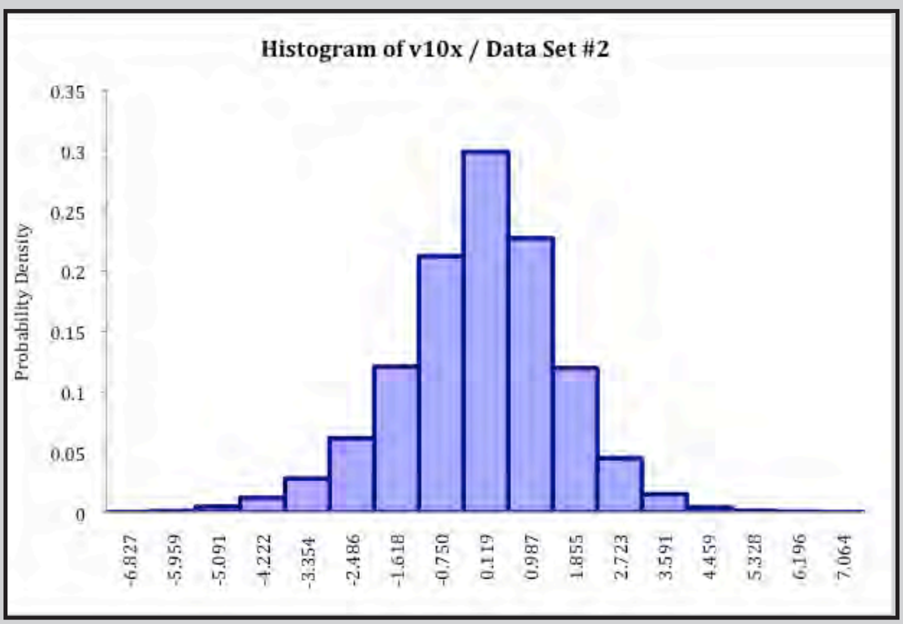

Figure 10. Histogram of Residual for Square-Root Transformed Data - VOL10x.

Discussion

This analysis indicates that transformation may improve the statistical properties of volume, without affecting the ranking of parents and progeny or influencing selections. However transformation will result in other changes. While the long-tailed skewness of the un-transformed volume data may have contributed on the extremely high predicted gain values for the top trees / parents, the predicted gains are also directly related to the scale and the unit of the trait. For example, we can't simply say that 20% gain in trait A is better than 10% gain in trait B without considering their economic weighs to the final products. Tree volume is well understood and economically meaningful to cooperators but the square root of the tree volume may not be. Thus, although the square root of volume may have better statistical properties and also show more realistic gain levels, it is hard to answer questions like "what is the economic value of having 20% of gain in square-root of tree volume". These are the main reasons that NWTIC has chosen to run the analyses on untransformed volumes.

References.

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Cooperators and Representatives

Beth Fitch **(Hampton)** was NWTIC chair for 2009-2011, followed by Mike Warjone **(Port Blakely)** for 2011-2012. NWTIC representatives for 2009-2012, and the members they represented, were:

Bloedel Timberlands: Roy Bever

Bureau of Land Management: Bob Ohrn / Michael Crawford

Cascade Timber Consulting: Bill Marshall

Forest Capital Partners: Jerry Anderson / Rudy Frazzini

Fruit Growers Supply: Rod Burns

Giustina Land and Timber: Mike Tucker

Giustina Resources: Paul Wagner

Green Crow Management Services: Harry Bell

Green Diamond Resource Company: Randall Greggs

Hampton Tree Farms: Beth Fitch

Hancock Forest Management: Dean Stuck

Lone Rock Timber: Bryan Nelson

Longview Timberlands: Rick Brooker / Dan Cress

Menasha Corp/ The Campbell Group: Jim Carr

Miami Corp: Joe Steere

Oregon Department of Forestry: Larry Miller

OSU College Forests: David Lysne / Brent Klumph

Plum Creek Timberlands: Jim Smith

Pope Resources: Dan Cress

Port Blakely Tree Farms: Jeff Madsen / Mike Warjone

Quinault Indian Nation: Jim Hargrove

Rayonier Timberlands: Candace Cahill / Josh Sherrill

Rocking C Ranch: Paul Zolezzi

Roseburg Resources: Dave Walters / Sara Lipow

SDS Lumber: Aric Lemmon

Sierra Pacific Industries: Keith Greenwood

Silver Butte Timber Company: Lew Howe

South Coast Lumber: Marc Halley

Starker Forests: Fred Pfund

Stimson Lumber Company: Margaret Banks

The Campbell Group: Dave Rumker

Timber West Forest: Tim Crowder

Washington Department of Natural Resources: Jeff DeBell

West Fork Timber: Gene McCaul

Liaison Members

Pacific Northwest Tree Improvement Cooperative: Glenn Howe

USFS-PNW Research Station Genetics team: Brad St Clair

Staff

NWTIC Personnel

Director: Keith Jayawickrama

Quantitative Geneticist: Terrance Ye

Information Management Specialist: Denise Cooper / Lauren Magalska

Test Coordinator: Ron Rhatigan

After 11 years as Data Manager, Denise Cooper left for other employment in 2011, and the Test Coordinator position ended in June 2012 subsequent to completing establishment of co-operative2nd-cycle tests in Oregon. Denise built the SQL database with Microsoft Access views which have served so well. Ron measured several Oregon test series, five sites of the Molalla Gain trial, three sites of the Grays Harbor Genetic Gain/Type IV trial, and implemented acoustic velocity data collection in four first-generation progeny test series. We thank Denise and Ron for their years of service, and wish them the best in future endeavors.

Lauren Magalska took over the Data Management duties in January 2012, after finishing a Master's degree at OSU emphasizing Forest Tree Improvement. Lauren had previous exposure to NWTIC, using first-generation progeny test data for her thesis. Welcome aboard, Lauren!

Obtaining wood cores from Plum Creek Timber Company's T96 2nd-cycle test series, for the USDA-funded NARA project.

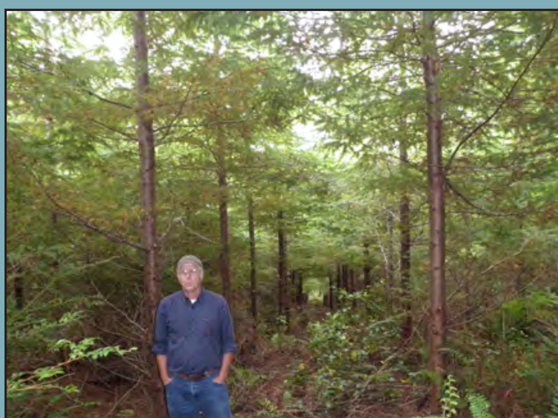
NWTIC staff scored bud, stem and needle damage on samples collected at four sites in October-November 2011 and plans to provide this service in subsequent seasons.

Left:Fine-tuning plans for the CAFS wood quality study in the Grays Harbor Genetic Gain / Type IV trial. Branch index, wood density/resistance, and acoustic velocity are to be measured. This is a joint project between NWTIC, SMC and the PNW Research Station.

Right: Oguz Urhan, PNWTIRC graduate student, collected acoustic velocity data in the Toledo Local Diallel HEMTIC site and two Douglas-fir sites for his Master's thesis project.

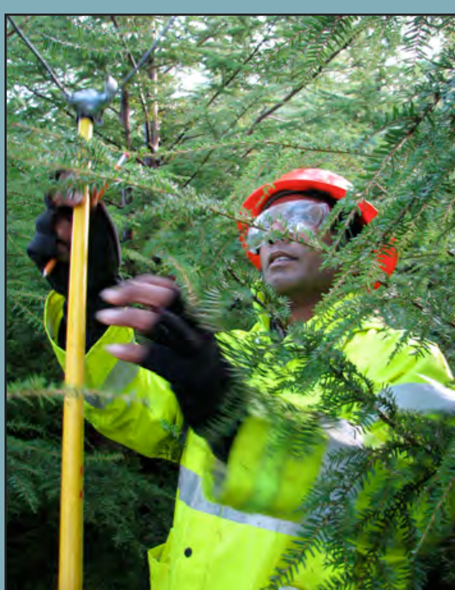
Three long-term representatives to cooperative tree improvement programs retired during this period, (left to right): Rich Kelly BLM-Eugene; Bob Ohrn, BLM-Salem; Jeff Madsen, Port Blakely/The Campbell Group/Champion International.

At 3,600 feet, the Simpson Creek test site (ROSETIC Roseburg High) planted in April 2012 on Seneca Jones land is the second highest elevation site in the 2nd-cycle programs serviced by NWTIC.

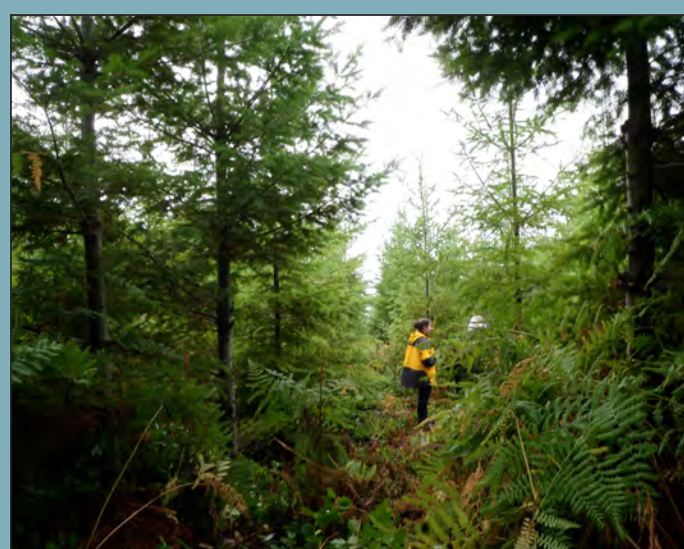


Exceptional tree growth continues in SCC's Phase I site at Lyon Ridge, seen here in the middle of its twelfth growing season.

Terrance Ye with one of the ten forward selections made in the Molalla Genetic Gain trial for use in CASTIC.



Auditing age-10 growth and stem form data in the HEMTIC trials.



The NOCTIC Phase I trial was pruned in preparation for the age-12 measurement.