Cooperative Tree Improvement Efforts To Develop Swiss Needle cast Tolerant Sources Of Douglas-fir

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Workshop on "*Operational Management of Swiss Needle Cast in Douglas-fir*", Nov 17 2010, Woodburn, Oregon

Overview

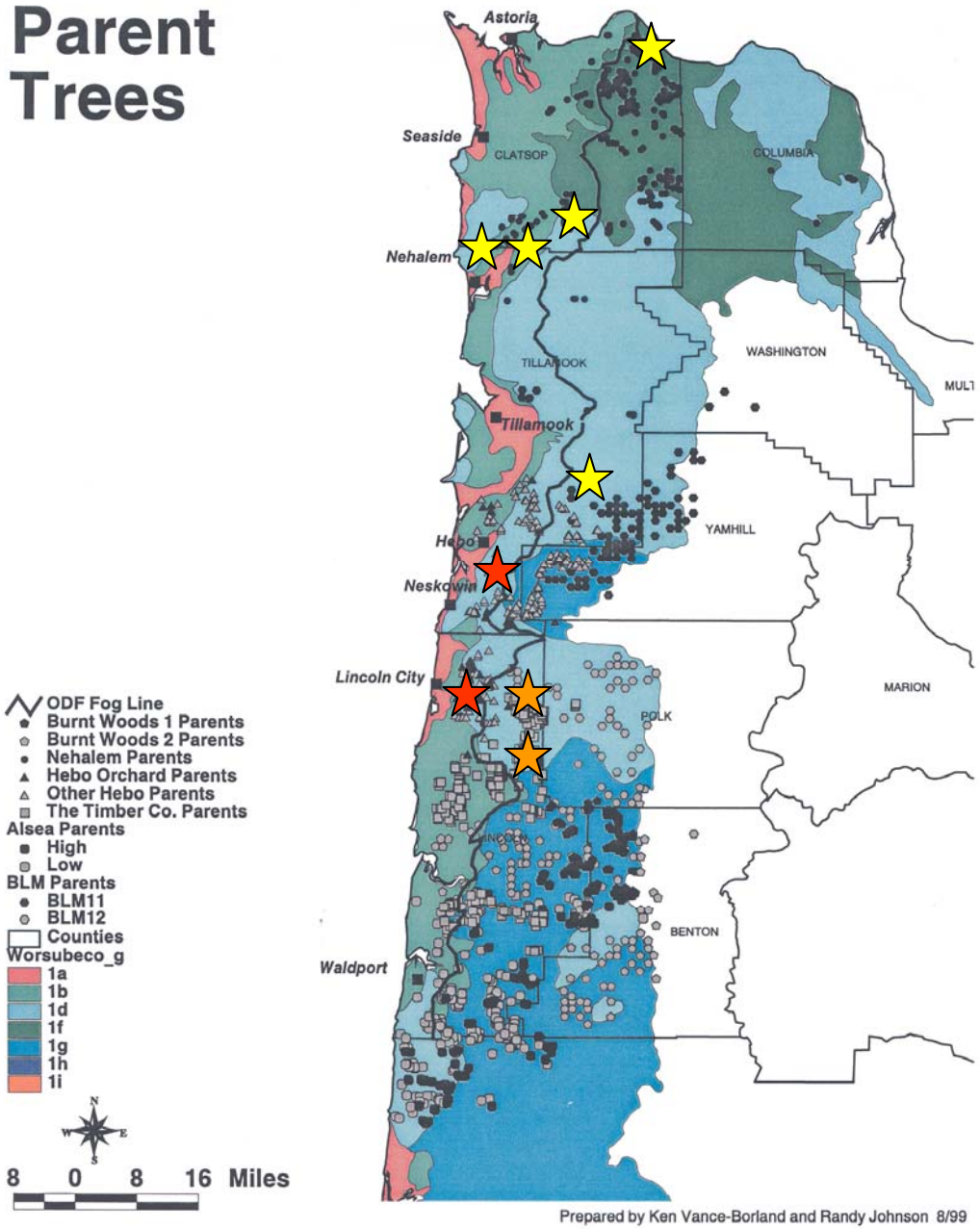
- Work in first generation testing programs
  - Genetic control of traits affected by Needle cast
  - Joint work with SNCC
  - Potential genetic gains
  - Early selection work (Fatih Temel)
- Needlecast-Tolerant Seed orchard
- Second-cycle testing programs
  - South Central Coast (jointly with SNCC)
  - Trask

Work in First Generation Programs

First-Generation Programs

- Tree improvers look for the following with regards to an economically important trait:
  - Evidence for (1) variation between families and (2) correlations of that trait with other economically important traits
  - Estimates of the strength of genetic control
- As SNC effects became apparent in the 1990s, Randy Johnson (USFS PNWRS) and others focused on Douglas-fir tree improvement programs located on the North Oregon coast where the impact was most severe
  - Nehalem cooperative program
  - US Forest Service Hebo programs

Coastal Parent Trees



Progeny Test Sites Used

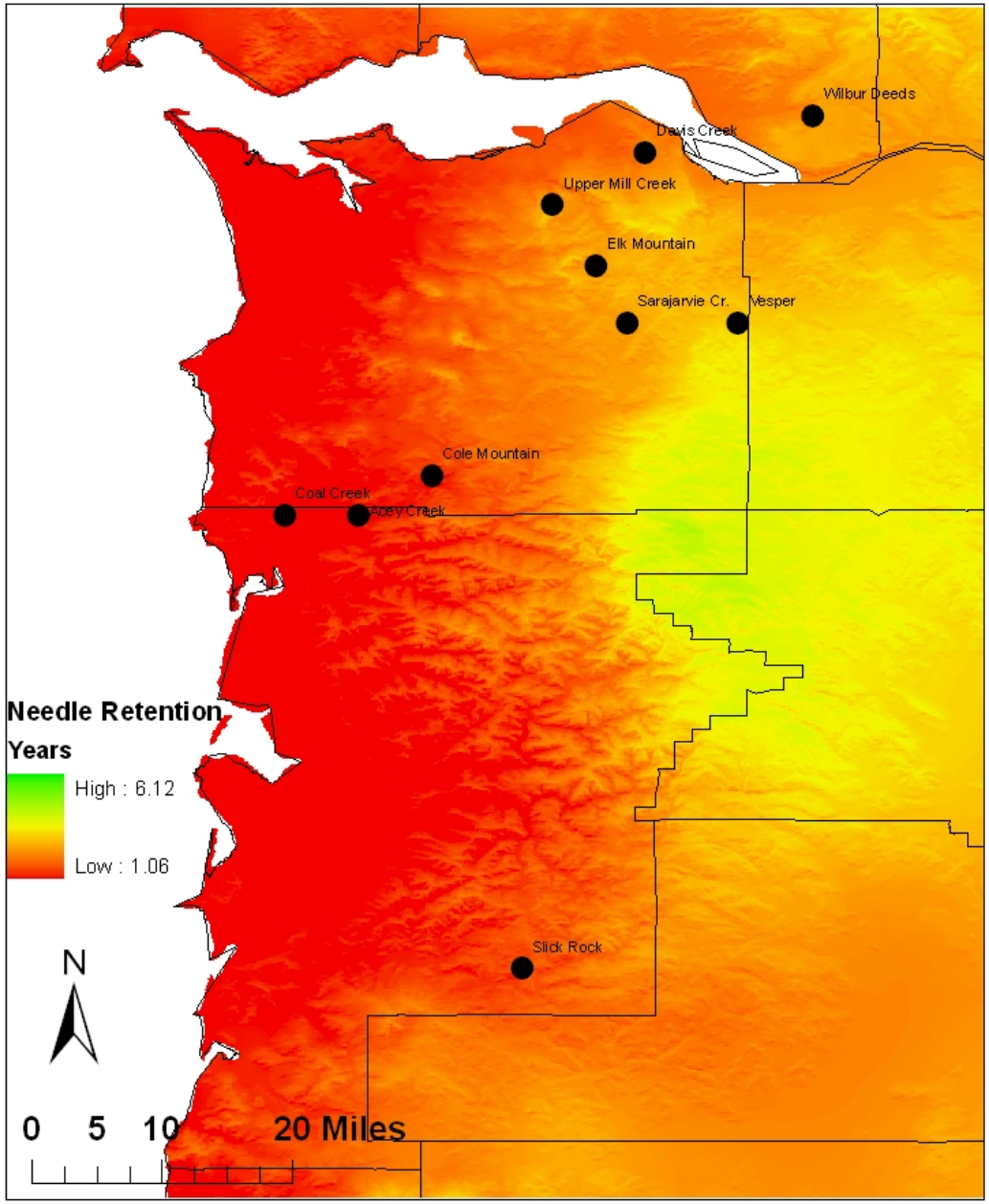
Nehalem
5 Progeny Test Sites

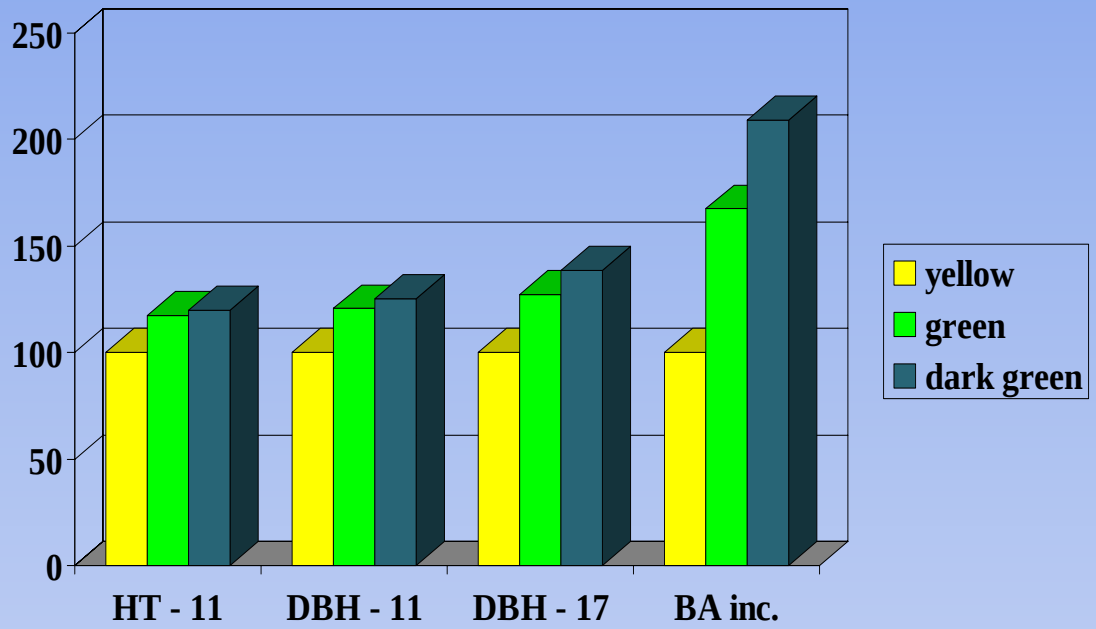
USFS
2 Progeny Test Sites

BLM 12
2 Progeny Test Sites

Slide by: Randy Johnson

Nehalem Test Sites overlaid on Swiss Needle Cast Map



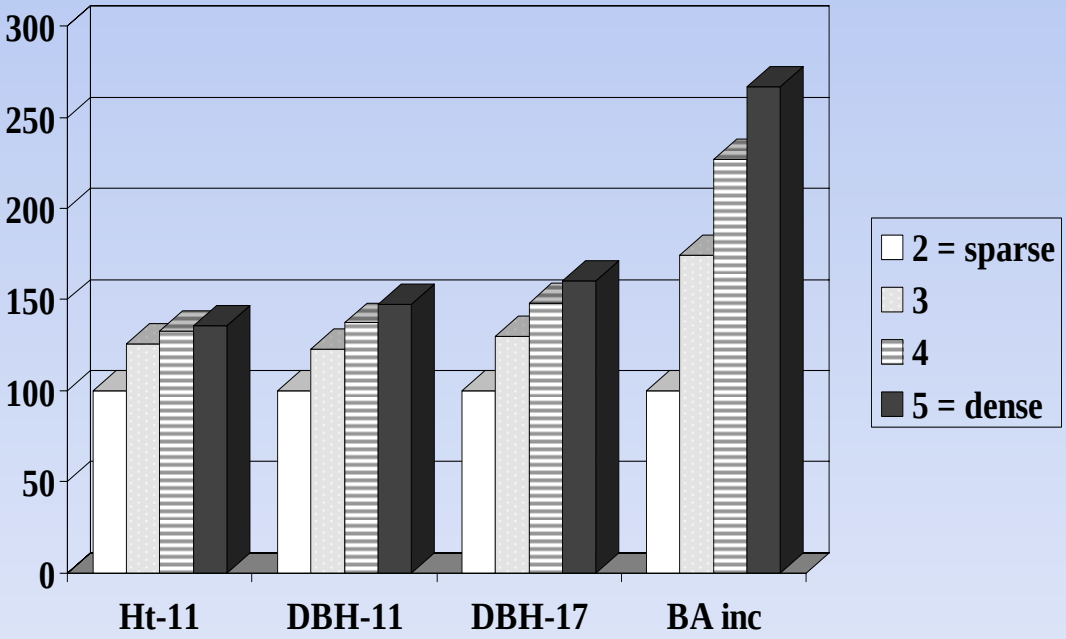


Growth by Color Categories for Nehalem Foliage color

(1=yellow to 3=dark green)

Growth by Crown Density Categories for Nehalem

(1=very sparse to 6=very dense)



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Narrow-sense heritabilities from 1st cycle Nehalem tests (NWTIC analyses)

Trait	Across sites	
	Individual	Family-Mean
Height 11	**0.30**	**0.81**
Volume Index 11	**0.29**	**0.80**
Dbh 11	**0.27**	**0.79**
Dbh 17/18	**0.35**	**0.82**
Dbh_Increment (age-11 to 17/18)	**0.32**	**0.80**
Needle Retention: 1994 primary laterals	**0.12**	**0.62**
Needle Retention: 1994 secondary laterals	**0.10**	**0.57**
Needle Retention: 1993 secondary laterals	**0.23**	**0.77**
Crown Density	**0.18**	**0.71**
Foliage Color	**0.11**	**0.59**

*Needle retention: 0 = <10% to 9 = >90%

Genetic correlations between traits from 1st cycle Nehalem test series (NWTIC analyses)

Traits: age-11 **height** (=HT11) and **DBH** (=DBH11); age-17/18 DBH (=DBH17/18), **needle retention** on 1994 primary laterals (=NR94p), on 1994 second laterals (=NR94s), and on 1993 second laterals (=NR93s)

Across sites					
Trait	NR94p	NR94s	NR93s	crown density	foliage color
HT 11	-0.06	-0.02	0.07	0.13	0.27
VOL 11	0.02	0.07	0.05	0.39	0.43
DBH 11	0.08	0.10	0.04	0.47	0.49
DBH 17/18	0.22	0.24	0.20	0.54	0.61
DBH_Increment (age-11 to 17/18)	0.33	0.34	0.32	0.55	0.66
NR94p		0.97	0.91	0.25	0.58
NR94s			0.90	0.28	0.63
NR93s				0.14	0.50
crown density					0.51

Potential Genetic Gains (NWTIC analyses)

- Nehalem: When the top 30 parents were selected for a given trait, the average predicted gain (ΔG) for age-17/18 DBH was:
  - age-17/18 DBH → ΔG = **20.2%**
  - age-11 DBH → ΔG = **18.4%**
  - DBH increment → ΔG = **21.1%**
  - NR on 1993 secondary laterals → ΔG = **3.2%**
  - Age-11 Crown Density → ΔG = **10.0%**
  - Age-11 Foliage Color → ΔG = **7.3%**

Conclusions from 1st-gen programs

- Foliage traits are heritable, but less heritable than growth traits
  - Could be a result of being subjectively scored
  - **Crown density** seen as a better indicator than **NR** (Johnson 2002)
- Growth after age-11 was more strongly associated with age-11 tree size than with foliage traits
- In areas with ≥ 2 years of foliage, gains from selection for tolerance should be adequate to offset volume growth losses from SNC, and keep Douglas-fir as a viable plantation species

2010 Remeasurement of Nehalem jointly funded by SNCC and Trask 2nd-cycle cooperative

- Following 8-9 more years with severe to moderate SNC on the coast, members of SNCC and of Trask approved in **2010** another study of the growth of families in this series, by means of a 4th measurement (the 3rd for DBH) on **5 sites**.
- The sites (Slick Rock, Acey Creek, Coal Creek, Cole Mountain and Davis Creek) were all owned by ODF and had (1) DBH data from 2001-2 and (2) estimated NR of 1 - 1.5 years based on the Adams / Latta model.
- All sites except Davis creek had been pruned to 7' above ground line. Cole Mountain, Davis Creek and Set 10 had been pre-commercially thinned about 5 years ago and the remaining 9 sets on 3 sites in early 2010. All sites were thinned by removing alternate diagonals.
- We had planned to measure all 10 sets, but the recent thinning of 3 sites left a deep accumulation of logging slash, hindering the work of the field crew. To stay within budget, we only measured **5** sets (including set 10) with over **200** families and **5,962** surviving trees.

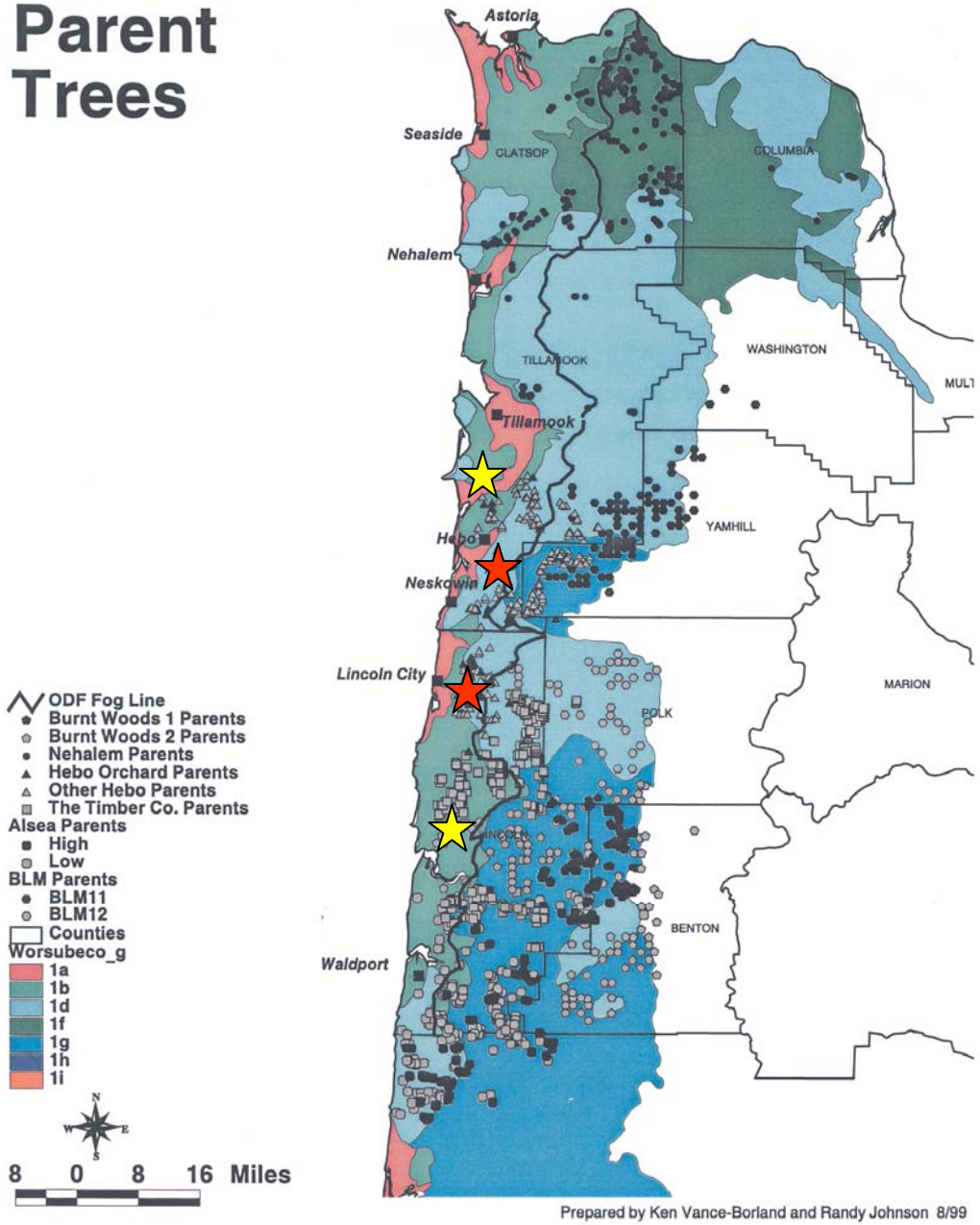
- The incidence of ramicorn branches and forks was recorded as it added little to measurement time. The work was done between July 22 - August 18, 2010 (age 25.5 from seed).
- That # of families, sites and trees should be adequate to draw conclusions on questions as:
  - (1) have there been notable changes of ranks for dbh over the years?
  - (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?
- **These questions will be addressed during the next year.**

Early Selection – Will it help our breeding programs?

Fatih Temel's Ph.D. Thesis

Slide by: Randy Johnson

Coastal Parent Trees



2-yr-old tests

USFS 10-yr-old Progeny Test Sites

Slide by: Randy Johnson

Field Traits Measured in 2-yr-old Trials

- Foliage Color (whole plant)
- Needle Color (selected branch)
- Retention
- Crown density

Foliage assessed in the lab for:

P. gaeumanni infection	Symptoms
Amount of fungal DNA / needle % stomata occluded with pseudothesia	Needle color Needle retention Needle wt Needle specific area Needle length

Slide by: Randy Johnson

- Better h^2 in the field than in the lab, so will focus only on field traits symptoms
- Heritabilities were similar at both ages for the field traits

  All moderately low, 0.11 to 0.37

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Genetic correlations among very juvenile (age-2) and semi-juvenile (age-10) traits

		Age-2 traits			
		Needle color	Needle retention	Crown density	Foliage color
Age-10	Needle retention	**0.75**	**0.75**	**0.63**	**0.83**
	Crown density	0.19	0.25	0.30	0.29
	Foliage color	**0.53**	**0.42**	**0.57**	**0.50**

Slide by: Randy Johnson

Genetic correlations among very juvenile (age-2) and semi-juvenile (age-10 or -13) traits

		Age-2			
		Needle color	Needle retention	Crown density	Foliage color
Age 10 or 13	Ht 10	-0.05	-0.13	-0.02	-0.14
	DBH 13	0.15	0.01	0.13	0.04

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Is it resistance or tolerance - *Why do we see variation?*

The Relationship between SNC symptom severity and level of *Phaeocryptopus gaeumannii* Colonization

More of Fatih Temel's Ph.D. Thesis

Trial #1 – The early selection study
2-year-old progeny tests – Lab results

Trait	Family-mean heritabilities
Needle color	0.26
Needle retention	0.57
Dry weight	0.40
Needle length	0.45
Fungal DNA	**Non Significant**
Pseudothecia counts	0.43
Needle specific area	0.41

No family differences in amount of fungal DNA in needles

Slide by: Randy Johnson

Trial #2

- 2 Nehalem progeny test sites
- 6 families
  - 2 poor, 2 average, 2 good
- Total of 108 trees
- Sampled branch from 4th whorl down
- Looked at relationships between symptom severity and level of *Phaeocryptopus gaeumannii* colonization

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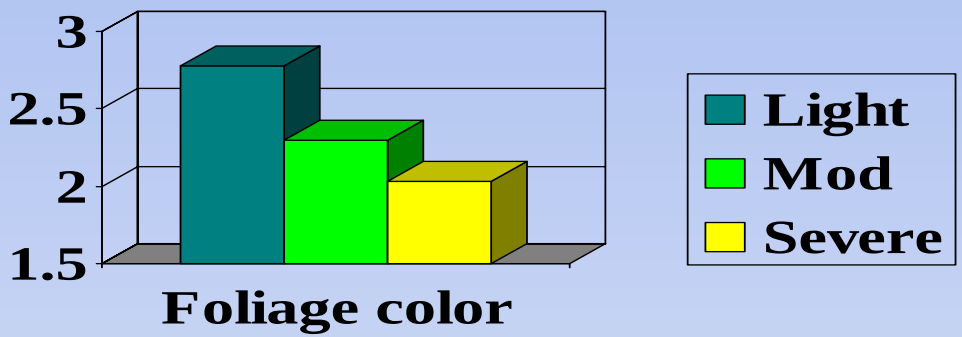
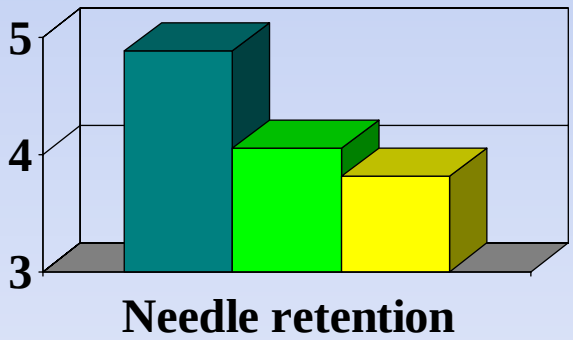
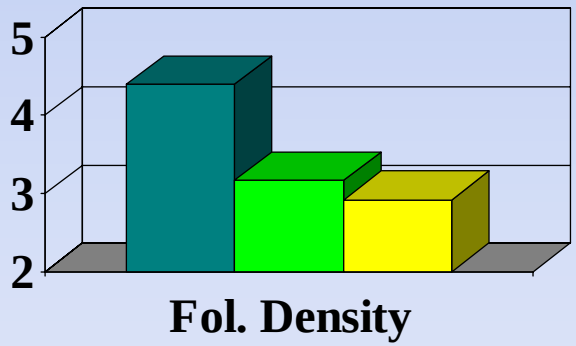
Symptoms differed between the 3 disease severity groups

(no surprise, since they were selected for differences in growth and foliage symptoms)







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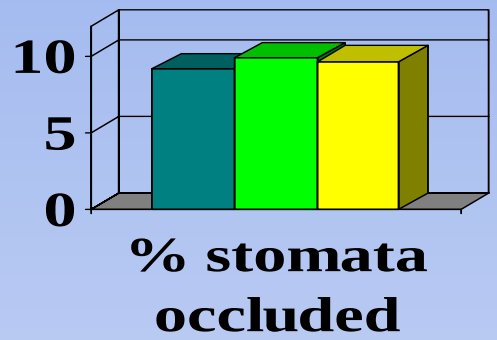
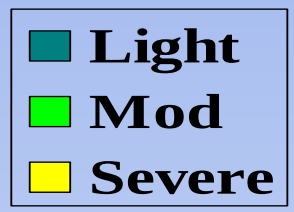
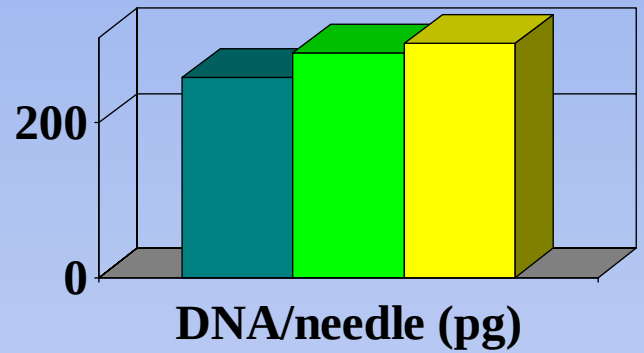
Infection did NOT show statistical differences between the 3 disease severity groups







No true resistance per se.

Two separate studies showed no differences in the amount of fungus in needles of different families

So this must be tolerance

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Possible mechanisms *(Fatih)*

(1) early needle shed, trees drop the needles before they become a photosynthetic sink.

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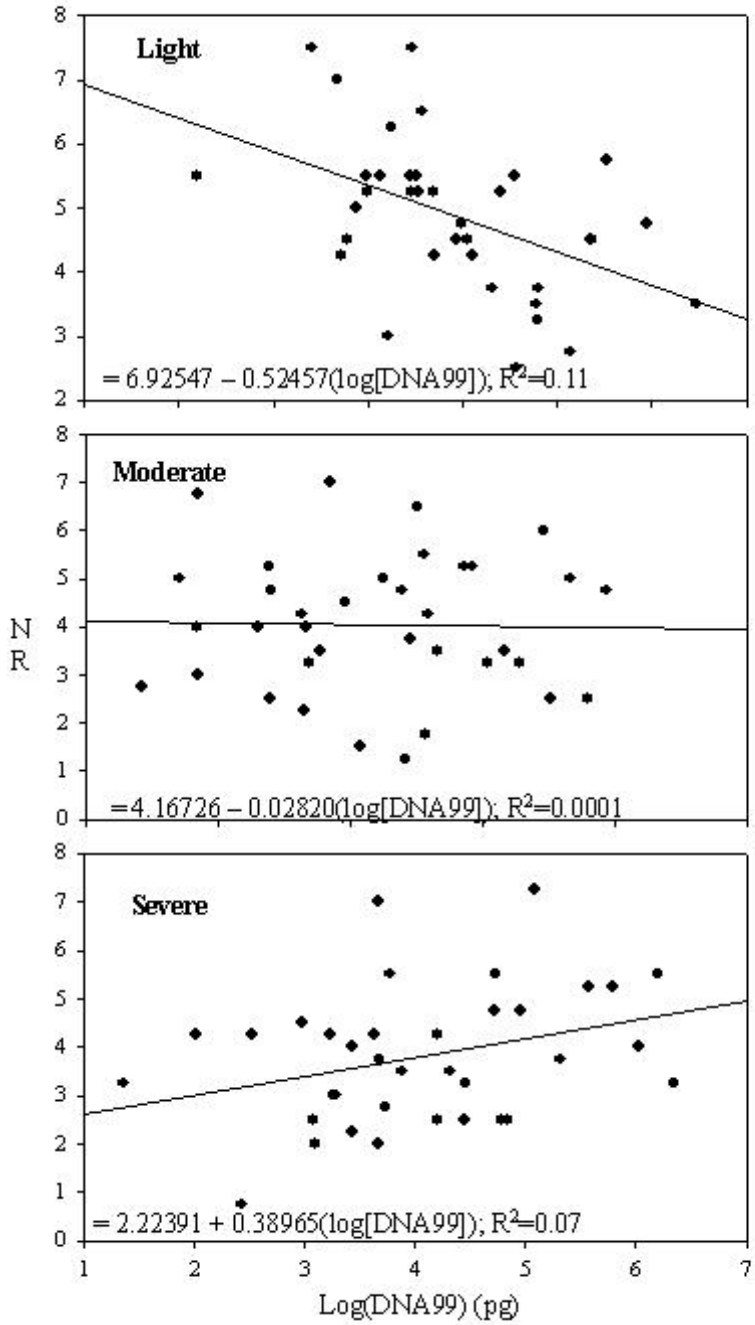


Randy's Conclusions From Temel Work

- Early selection could improve the efficiency (gain/yr) of selection for foliage traits
- But we didn't see any gains in growth traits at age-10 resulting from age-2 selection for foliage traits
- We can breed for tolerance to SNC
- The best trait to select upon is growth in the presence of the disease
- Foliage traits (at age-11) can help a little
- Deploy tolerant stock in areas of moderate SNC impact

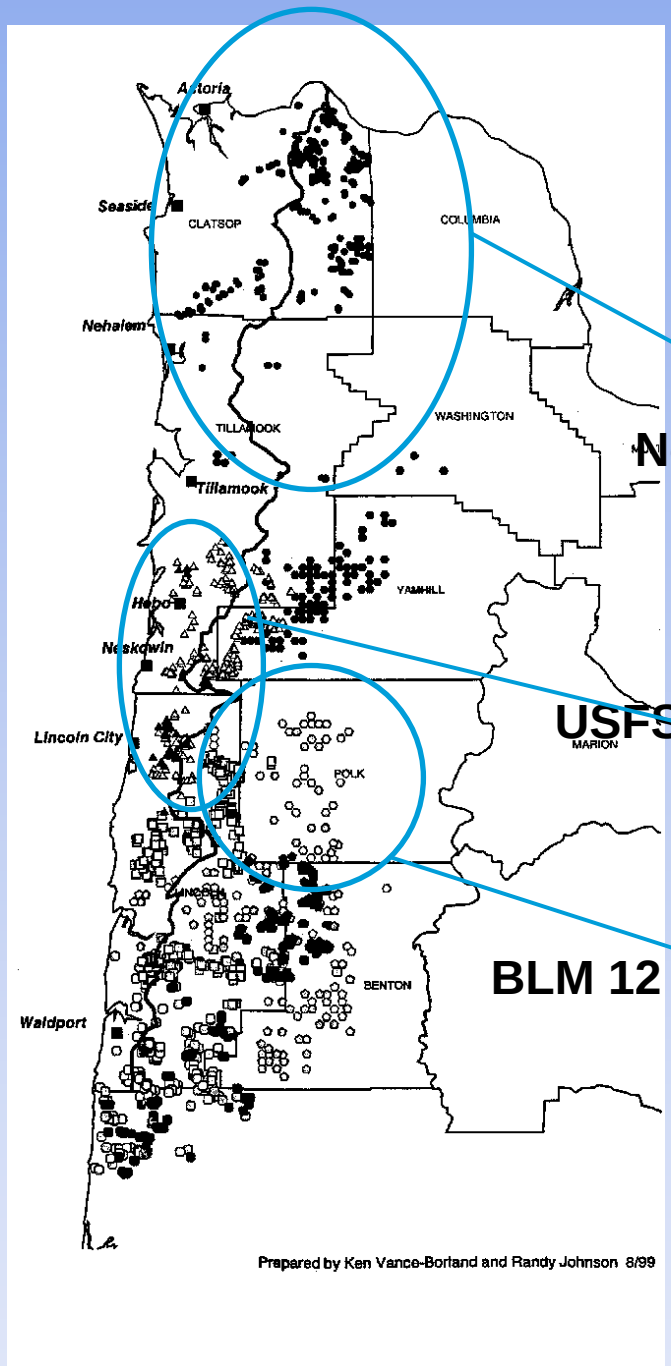
Slide by: Randy Johnson

Needlecast Tolerant Seed Orchard

Needlecast Tolerant Seed Orchard

- ODF Tillamook and Astoria Districts had a strong commitment to growing a proportion of D-fir on the coast, plus large acreages
- Saw tree improvement as a viable tool to counteract SNC
- Re-measured DBH in several Nehalem tests, and took the lead in developing an orchard around 2002
  - Associated with the Nehalem orchard, in place since the mid 1990s at the Schroeder orchard complex near St Paul Oregon
  - Incorporated selections from Nehalem, Hebo, BLM Breeding unit 12
  - 6 acres in extent
  - Other cooperators have subsequently joined

SNC tolerant block at Schroeder in 2002-2003



Nehalem

Nehalem selections

USFS Hebo

USFS Hebo selections

BLM 12

BLM 12 selections

Implementation of Testing for Needle Cast Tolerance in 2nd Generation Programs

2nd-Cycle Programs

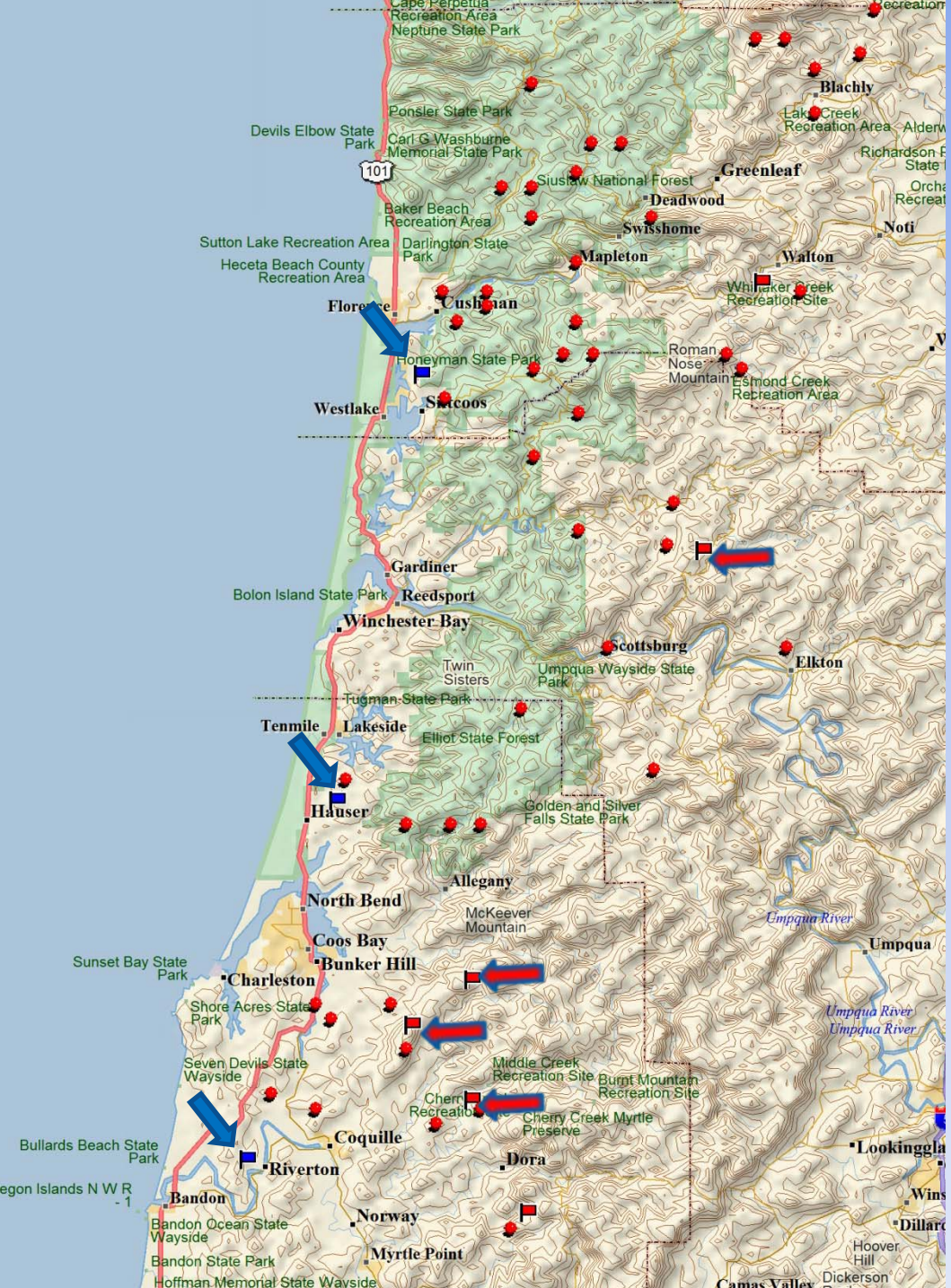
- With insights from 1st-gen data and previous experience, the following steps were taken:
  - Established 2nd-cycle programs on the Oregon Coast
    - *South Central Coast* in the South, with the mainline in the core Douglas-fir area, and a smaller satellite program in the zone most affected by SNC
    - *Trask* in the North, with a *Coast* program (moderately affected by SNC), and an *Inland* program (little affected by SNC)
  - Established 2nd-cycle program on the Washington Coast
    - 5 test sites

2nd-Cycle Programs

- We have selected, and will continue to select, parents and trees with a track record of growing well in areas subject to SNC
  - 1st-gen selections used for crossing
  - Selections from 2nd-cycle tests
- Needle retention is being assessed in SCC and Trask Coast, at age-7 and age-12
  - One age-6 assessment in SCC was funded by SNCC
- DBH is being assessed at age-7 and ag-12, so that an age-7 to age-12 DBH increment can be calculated
  - Possibly additional (later) DBH assessments to confirm continued growth in DBH

2nd Cycle South Central Coast

- 3 sites established along the southern Oregon coast in the SNC zone, in areas specifically selected for obvious needle cast symptoms. Each trial had 50 full-sib families selected for high 1st-cycle gains in growth,
- Another 6 mainline test sites using 284 full-sib families (including the 50 in the SNC sites).
- 4 checklots in each of the 9 sites, including 2 woodsrun lots from the north and south ends of the SCC testing zone
- 20 trees planted per family per site
- Sown in 2001 as 615A container seedlings and planted in February 2002.
- Planted at a 9 × 9 ft initial spacing.



Geographic locations of testing sites in SCC

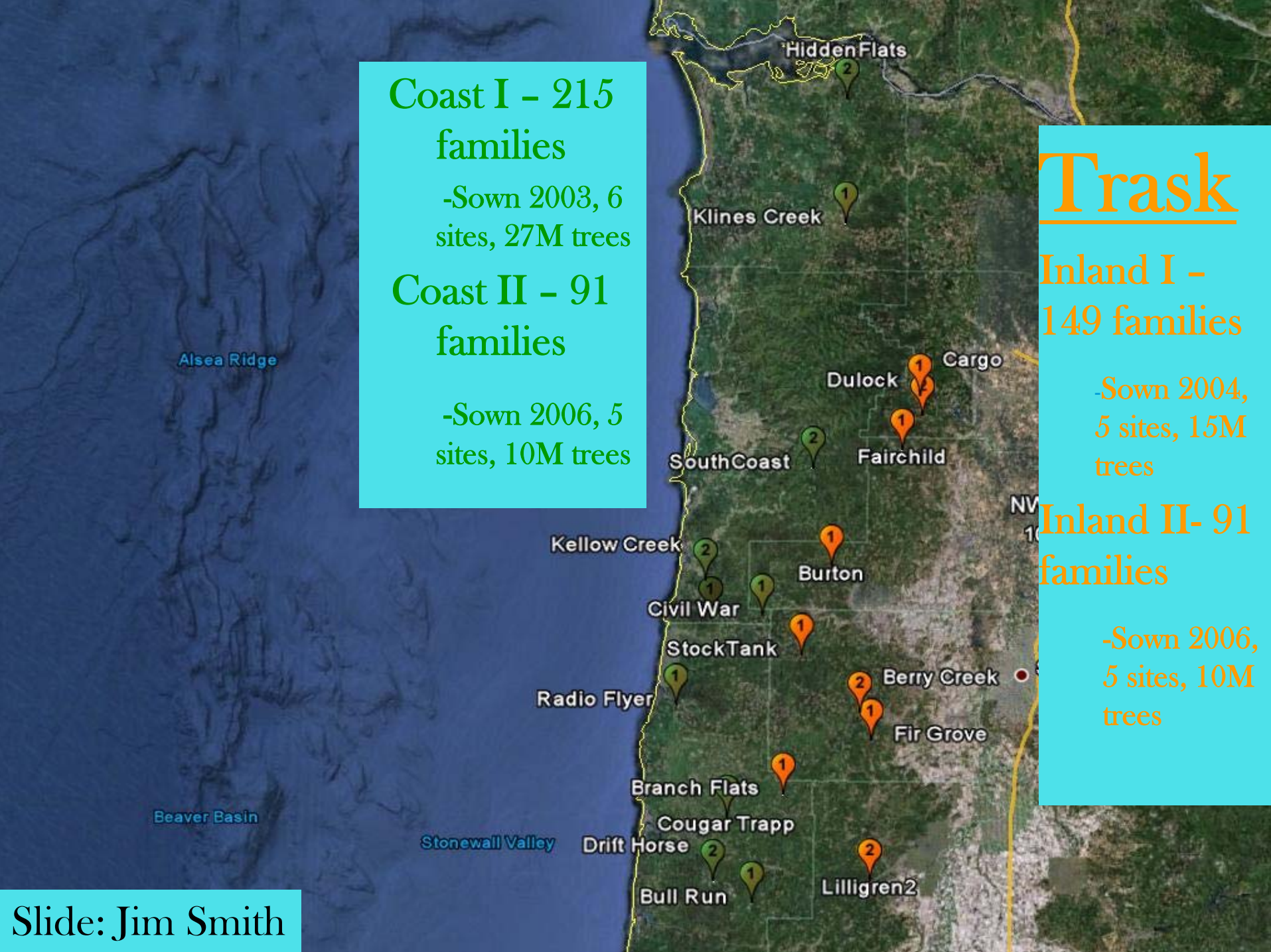
red flags – 2nd-cycle mainline sites;

blue flags – 2nd-cycle SNC sites;

red dots – 1st-cycle sites

Miller Flyway (Roseburg Resources – between Reedsport & Florence)

Transit Hill (Menasha – near Hauser)


Coast I – 215 families
-Sown 2003, 6 sites, 27M trees
Coast II – 91 families
-Sown 2006, 5 sites, 10M trees
Trask
Inland I – 149 families
-Sown 2004, 5 sites, 15M trees
Inland II- 91 families
-Sown 2006, 5 sites, 10M trees
HiddenFlats
Klines Creek
Alsea Ridge
Cargo
Dulock
Fairchild
SouthCoast
Kellow Creek
Burton
Civil War
StockTank
Radio Flyer
Berry Creek
Fir Grove
Branch Flats
Cougar Trapp
Beaver Basin
Stonewall Valley
Drift Horse
Bull Run
Lilligren2
Slide: Jim Smith

Neskowin (Simpson/ Green Diamond/ Hancock – near Neskowin)

Radio Flyer (Boise Cascade /Forest Capital – north of Newport)

Hidden Flats – Hampton Affiliates - Coast Phase II

Slide: Jim Smith

Narrow-sense heritabilities from 2nd cycle tests (age-7)

	Trait	Individual-tree	Family-mean
SCC: Mainline sites	HT	**0.348**	**0.844**
	DBH	**0.224**	**0.746**
	VOL	**0.276**	**0.811**
	Needle Retention	**0.121**	**0.604**
SCC: SNC sites	HT	**0.477**	**0.875**
	DBH	**0.364**	**0.808**
	VOL	**0.402**	**0.796**
	Needle Retention	**0.269**	**0.817**
Trask Coast Phase I	HT	**0.216**	**0.844**
	DBH	**0.184**	**0.806**
	VOL	**0.204**	**0.812**
	Needle Retention	**0.121**	**0.558**

Genetic correlations between traits from 2nd cycle tests (age-7)

		HT7	DBH7	VOL7
SCC Mainline	**NR**	0.44	0.76	0.69
SCC Needlecast sites	**NR**	-0.09	-0.05	-0.04
Trask Coast I	**NR7**	0.20	0.25	0.27

- **SCC**:
- Type B genetic correlations for NR between the SNC sites (0.65~0.90) were much higher than between the mainline sites (0.21~0.39).
- Gains for growth on mainline sites and SNC sites were strongly correlated (0.91 at the family level for Vol7)

Other Findings From 2nd-Cycle Programs

- **SCC**: the **mainline** group had higher NR (1.72) than the **SNC** group (1.45) on average
- **Trask**: NR varied from 1.4 to 2.1 with an average of 1.81
- **SCC**: tested families had high growth gains over woodsrun (39.9% age-7 Volume index on SNC sites) and slightly higher NR (2.8% gain over woodsrun).
- **TRASK**: Top 50 families had high growth gains over woodsrun (48.2% age-7 Volume index) and slightly higher NR (5.7% gain over woodsrun)

Summary for 2nd-cycle programs

- A strong resource of 26 test sites have been established in areas of the Oregon coast with strong to moderate SNC incidence
- 5 test sites established on the WA Coast
- Needle retention is being scored operationally in these tests
- Strength of genetic control (heritability) for NR is similar to those seen in 1st-gen tests
- Tested families showed high genetic gains over woodsrun controls for growth traits, and small genetic gains for NR