

U.S. White Pine Resistance Breeding Program

History, Current and Future Directions

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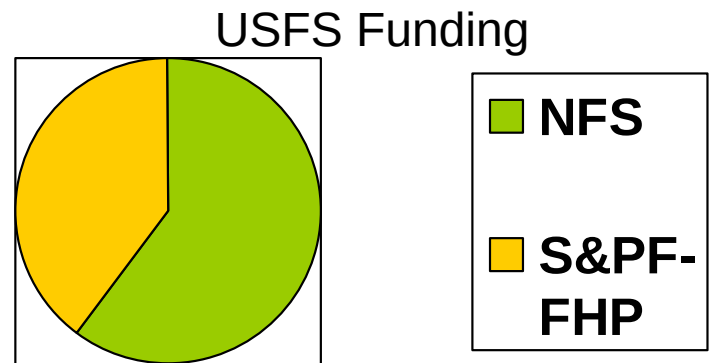
Western white pine species range

- Scope of presentation
ID, MT, eastern WA,
BC
- Rust resistance
program in OR/WA
(Dorena)
- Initial selections NV,
CA (Placerville)



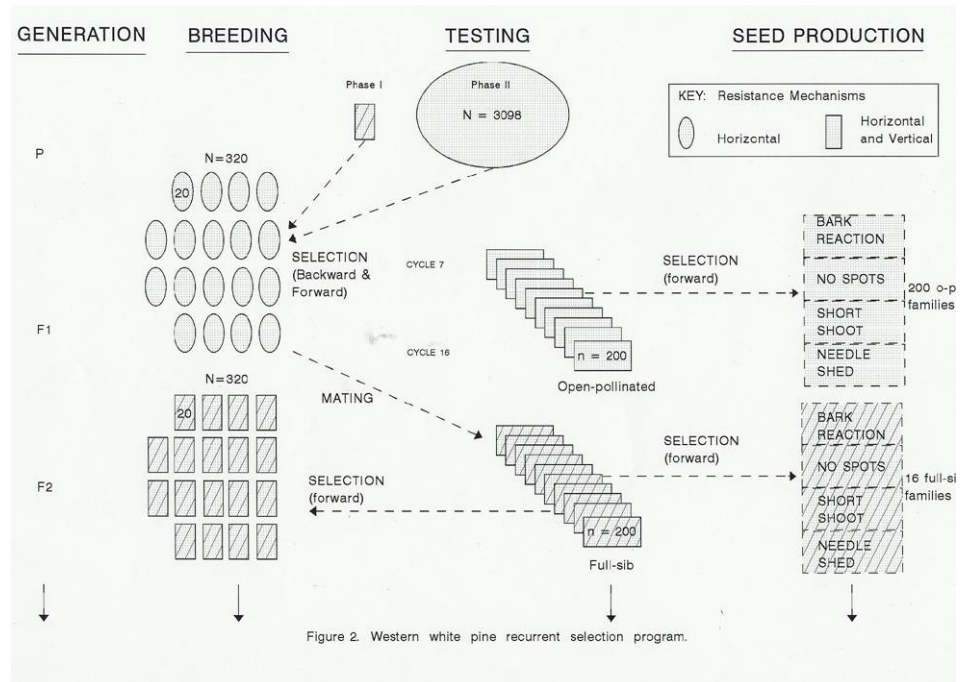
Collaborative Effort

- USFS Research initiated Phase I 1950s
- Program transferred to USFS National Forest Systems 1970s
- Phases II and III joint endeavor of USFS and IETIC



Recurrent Selection Program for General Combining Ability

- Testing program (Phases I-III)
- Breeding program (18 sublimes)
- Production seed orchards
- Gene conservation



Phenotypic Selections

- Phase I (n=400) rust resistance
- Phase II (n=3,098) rust resistance and height
- Phase III (n=304) genetic diversity in previously unsampled areas

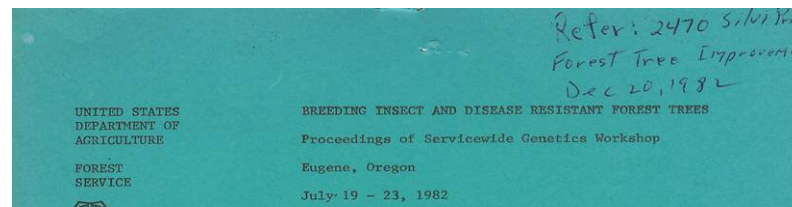


Testing Population (23 Cycles)



- Artificial inoculations to evaluate rust resistance
- Cycle = progeny from ~ 200 plus trees + controls in a rust screening
- 2008 Cycles 20-22 at Coeur d'Alene Nursery (ID)

14 Host Responses w/Genetic Basis



Last Update 7-17-07 MFM

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Mechanisms/Host Response	Host Pathogen	Region-Station Reporting	Hypothesized Inheritance	Citation	Description
Foliage					
1. Resistance in secondary needles that prevents spot formation (INT)	WWP/BR EWP/BR	INT R-1 R-5 R-9	Nondominant gene $h^2 = 0.37$	Hoff, Bingham, McDonald, 80	Seedlings do not have needle spots and no stem symptoms. (INT) Failure to produce spots. (R-5)
a. Needle lesions not formed (R-1)	SP/BR				
b. Reduced needle spot frequency (R-5)					
2. Reduced frequency of secondary needle infections (INT)	WWP/BR EWP/BR	INT R-1 R-6 R-9	Polygenic	Hoff and McDonald 1980	Frequency of needle spots varies with family (INT) Relatively few spots. (R-1). Is a horizontal resistance mechanism Response among families in continuous
a. Low needle lesion frequency (R-1) (spots per meter)			Polygenic $h^2 = 0.23$	Mahalovich 2006 Mahalovich and Eramich 1995	Seedlings with this resistance mechanism have 10 times less needle spots than susceptible seedlings. (R-6)
b. Reduced frequency of lesions (R-6)			Single gene	No citation	
3. Resistance in secondary needles to a yellow-spot forming race	WWP/BR	INT	Recessive gene	McDonald and Hoff 1975	Color of needle spots on seedlings 9 months after inoculation varied. Some were typical lemon-yellow others were bright yellow.
4. Resistance in secondary needles to a red-spot forming race	WWP/BR	INT	Dominant gene	McDonald and Hoff 1975	Color of needle spots on seedlings 9 months after inoculation were red to red-orange.
5. Resistance in secondary needles to a	WWP/BR	INT	Dominant gene	McDonald and	The island effect resulted in green-

Operationally screen for 7 resistance traits

HORIZONTAL RESISTANCE TYPES

Family Selection:

Reduced spot frequency/meter

Phase I

X

Phase II

X

Reduced early stem symptoms

X

Bark reaction

X

Canker alive (tolerance to infection)

X

VERTICAL RESISTANCE TYPES

Individual-tree Selection:

No Spots

X

Needle Shed

X

X

Short Shoot

X

X

HORIZONTAL RESISTANCE TYPES

Individual-tree Selection:

Bark Reaction

X

X

Individual-tree Selection:

Fifth-year total height

X



Gains for family selection

	h^2_F	%Gain
Spots per meter	0.23	-7
Early stem symptoms	0.60	-13
Bark reactions	0.64	6.3
Canker Tolerance	0.55	9.3

Performance Tests

- 34 performance tests
- Monitor resistance under field conditions
- Test for the presence of genotype-by-environment interactions
- Validate breeding zone boundary (phenological vs. rust resistance data)
- Compare family performance based on natural vs. artificial inoculation



Realized Gain Trials



- Determine gain for rust resistance under operational conditions; 4 sites
- Monitor potential impact of nursery cultural practices on family numbers and resistance traits
- Formally evaluate hypothesis of rust virulence at Merry Creek

Testing Population Summary

- 3,802 selections
- 23 nursery rust screenings (Phases II and III); three on-going
- 34 performance tests (includes CC and HM)
- 4 realized gain trials

WP Phase I Orchards

- Seed sources: F1 & F2
- Orchard design: random mating
- Deployment: o-p bulked collection by *orchard*
- Expected resistance gain 30% (F1)
- Expected resistance gain 66% (F2)
- Realized gain 20% (F2)



Nursery Cultural Practices Study

Orchard Lots	Coeur d'Alene	RT Bingham
% Resistant	63	58
% Susceptible	37	42
Trait Ratio NO:NS:SS:BR	22:9:43:26	19:12:39:29
Horizontal Rust Index	20	17
5-yr ht (cm)	73	73

WP Phase II Orchards

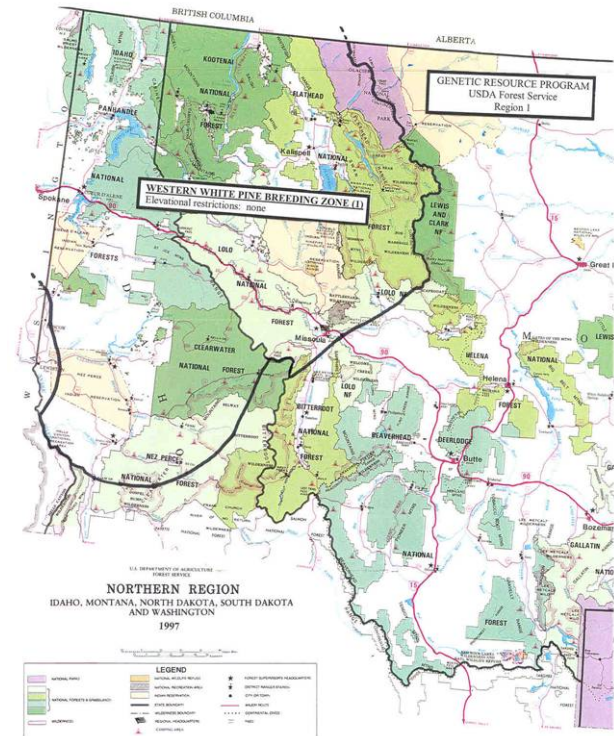
- Seed source: F2
- Orchard design: blocks by NO, NS, SS, BR
- Deployment: o-p bulked collections by *block*. Sow, grow, and lift by *block*. Pack with equal numbers of resistance type.
- Expected resistance gain 100%
- Possible realized gain 65%



All orchards based on forward selections

Breeding Strategy

- One breeding zone
- No detectable MGR in interior white pine
- Resistance traits repeatable
- Some concerns of inbreeding
- Low N_e in Phase I program



Interior and Coastal Comparison

Differences

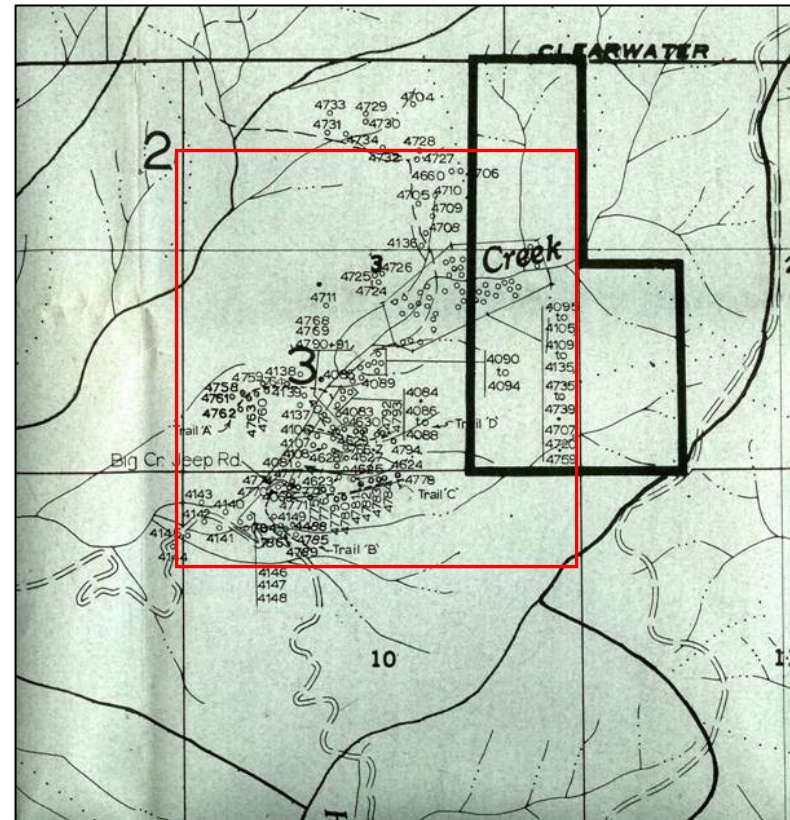
- No MGR in interior
- Terpene (Hunt and Rudloff 1977)
- Early frost hardiness (Rehfeldt *et al.* 1984)
- cp DNA (White 1990)
- Coastal region 20% more cold damage than interior (Thomas and Lester 1992)

Similarities

- No differences in survival and height (Steinhoff 1981)
- No differences in survival and height (age 11) between ID and Vancouver Island bulked seedlot (Bower 1987)

Inbreeding concerns

- Selection criterion—
plus trees separated by
300 feet
- Phase I and II
selections as close as
30 feet from
neighboring selection
- Majority of Phase I from
Emerald Creek



Role of sublines

- Structured breeding groups within a population to manage inbreeding
- Inbreeding tolerated within subline
- Goal to have unrelated entries in seed orchard

Breeding Orchard

- Backwards selection
- Assigned to sublines based on geographic origin
- Outdoor orchard ~2003
- 7 ramets per elite tree

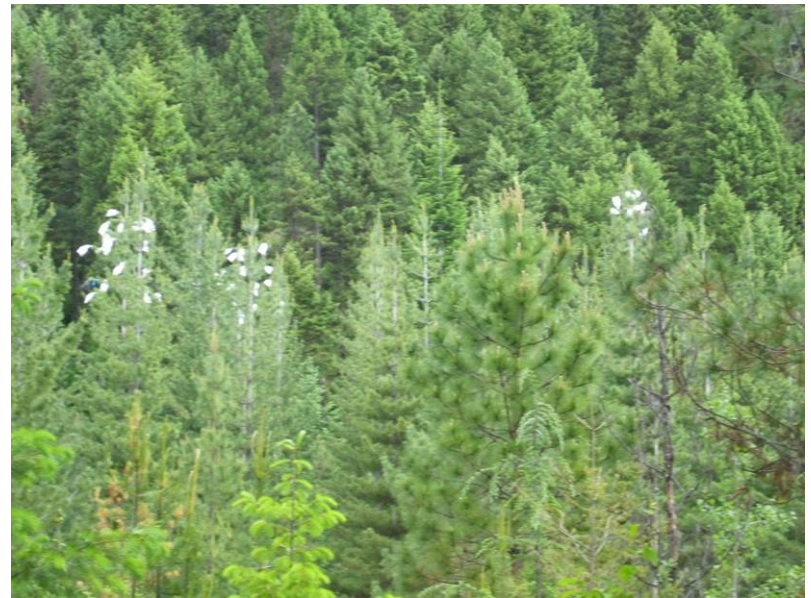


- Circular half-sib
- Elite trees within a subline assigned in rank order
- Positive assortative mating

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Vertical Resistance Study

- Initiated 1993
- Controlled crossing to verify genetic control of needle shed, short shoot, and bark reaction traits
- Accomplishment 66% of 120 crosses completed



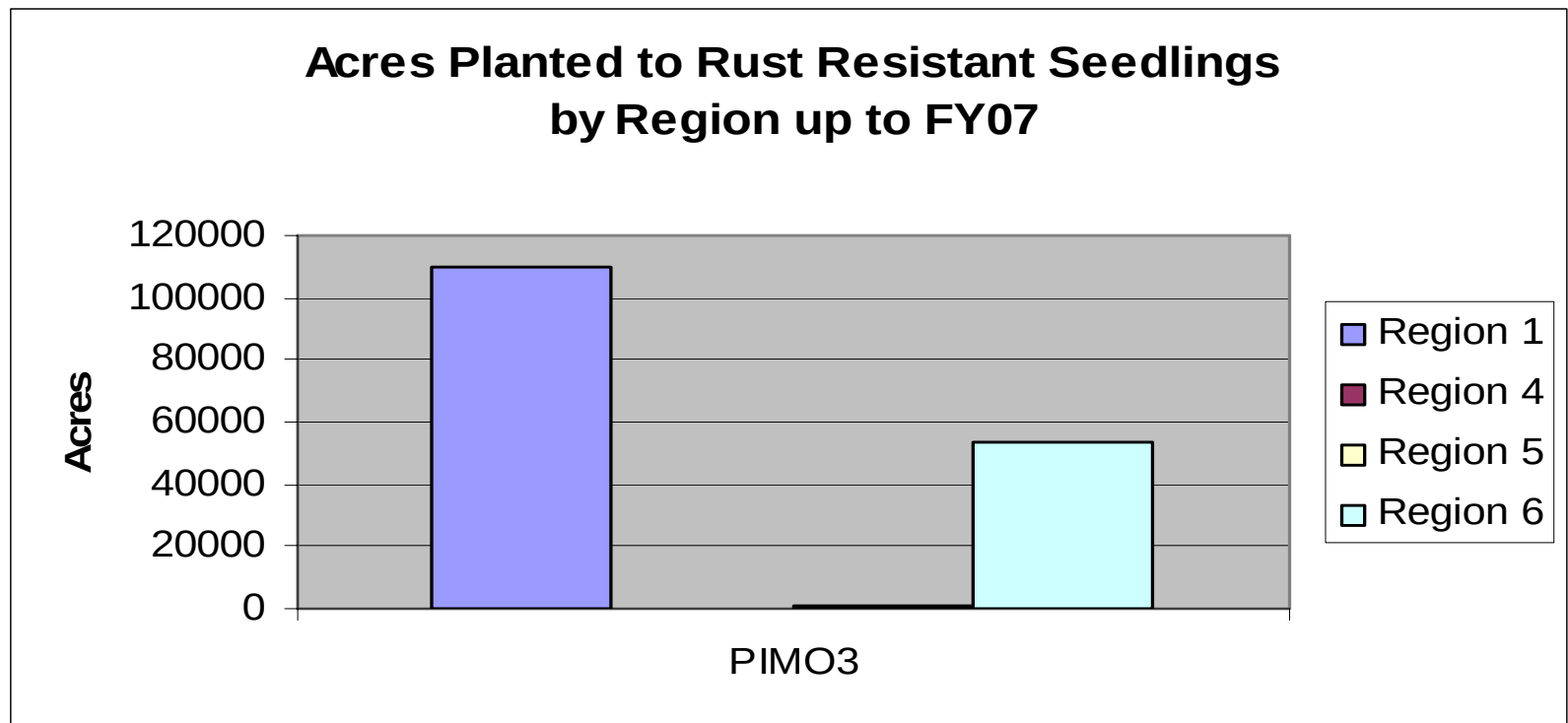
Canyon Creek

Gene conservation

- 4 clone banks
- Network of plus trees across landscape
- 34 genetic tests
- 256 lbs of seed
- 15,770 gm pollen



Payoff



For more information

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