GENETIC RESISTANCE TO WHITE PINE BLISTER RUST IN 5-NEEDLE PINES

A First Look at Resistance in Canadian Limber and Whitebark Pine and Implications for Management

Richard A. Sniezko
USDA Forest Service
Dorena Genetic Resource Center
Cottage Grove, Oregon

SY2014 whitebark pine

Sy2016 Alberta Limber pine Sept 2017 at Dorena GRC

Solution: GENETIC RESISTANCE

- **'Green', natural solution to a disease problem**
- Is there genetic resistance?
  - Is there 'tolerance'?
  - Resistance vs. tolerance
- What types and levels of resistance are available?
- What level is needed?
- What level is achievable?
- Correlations with other adaptive traits?
- Impacts of climate change on resistance?
- **Is it durable resistance?**
- Tree Improvement – producing seed

For discussion, see Sniezko & Koch 2017)

USDA Forest Service
-- Dorena Genetic Resource Center

Example: USFS Dorena Genetic Resource Center

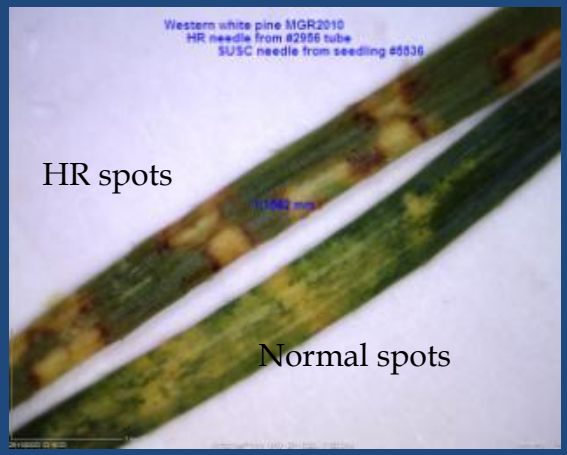
- Lead role in development of **applied resistance**
- USDA Forest Service & Cooperators
- **50 year history and continuity (50th in 2016)**
- Interface between Research and Restoration/Reforestation
- Works closely with Forest Health Protection & partners
- Examines all types of resistance simultaneously
- **Facilitates the development of resistance in useable form**

9 U.S. White Pine Species*

- **Western white pine** **(MGR+)**
- **Sugar pine** **(MGR+)**
- **Whitebark pine**
- **Limber pine** **(MGR+)**
- **Southwestern white pine** **(MGR+)**
- **Rocky Mountain bristlecone pine**
- Great Basin bristlecone pine
- Foxtail pine
- **Eastern white pine**

- *Many Cooperators

Genetic Resistance



- **Complete Resistance**
  - Single dominant gene (**MGR – major gene resistance**)
  - Hypersensitive Response (HR) or HR-like?
  - No stem symptoms (cankerfree)
  - Not durable? Virulence develops?

- **Partial Resistance**
  - 'slow rusting'
  - Quantitative >1 gene
  - Different phenotypes
  - Durable resistance?

Strategy

- **Simultaneously evaluate both MGR and Partial Resistance**
  - Aim for long-term effectiveness- ‘durability’
  - More difficult and longer term seedling trials needed
  - Unknown at onset what types of resistance exist
    - And may vary by breeding zone
  - **Field validation needed**
  - **Parent trees as sentinels** (with progeny screening info)
  - Incorporate both types into orchard production population
  - Breed to increase level and mix of resistances
- **Maintain Genetic Variability**
- **Maintain Adaptability**

Canadian Limber & Whitebark Pine in Dorena GRC Rust Resistance Testing

- **Whitebark Pine** **(18 families)**
  - SY2007 (5 seedlots)
  - SY2012 (10 seedlots) - sister trial in BC
  - SY2013 (3 seedlots)
  - Provenance field trial near Dorena (w/ Charlie Cartwright)

- **Limber Pine** **(120 families)**
  - MGR2014* & SY2014 (5 BC, 5 Alberta)
  - MGR2016 (10 Alberta, + PB2)
  - SY2016 (60 Alberta - includes the 10 in MGR2016)
  - SY2017 (50 Alberta)

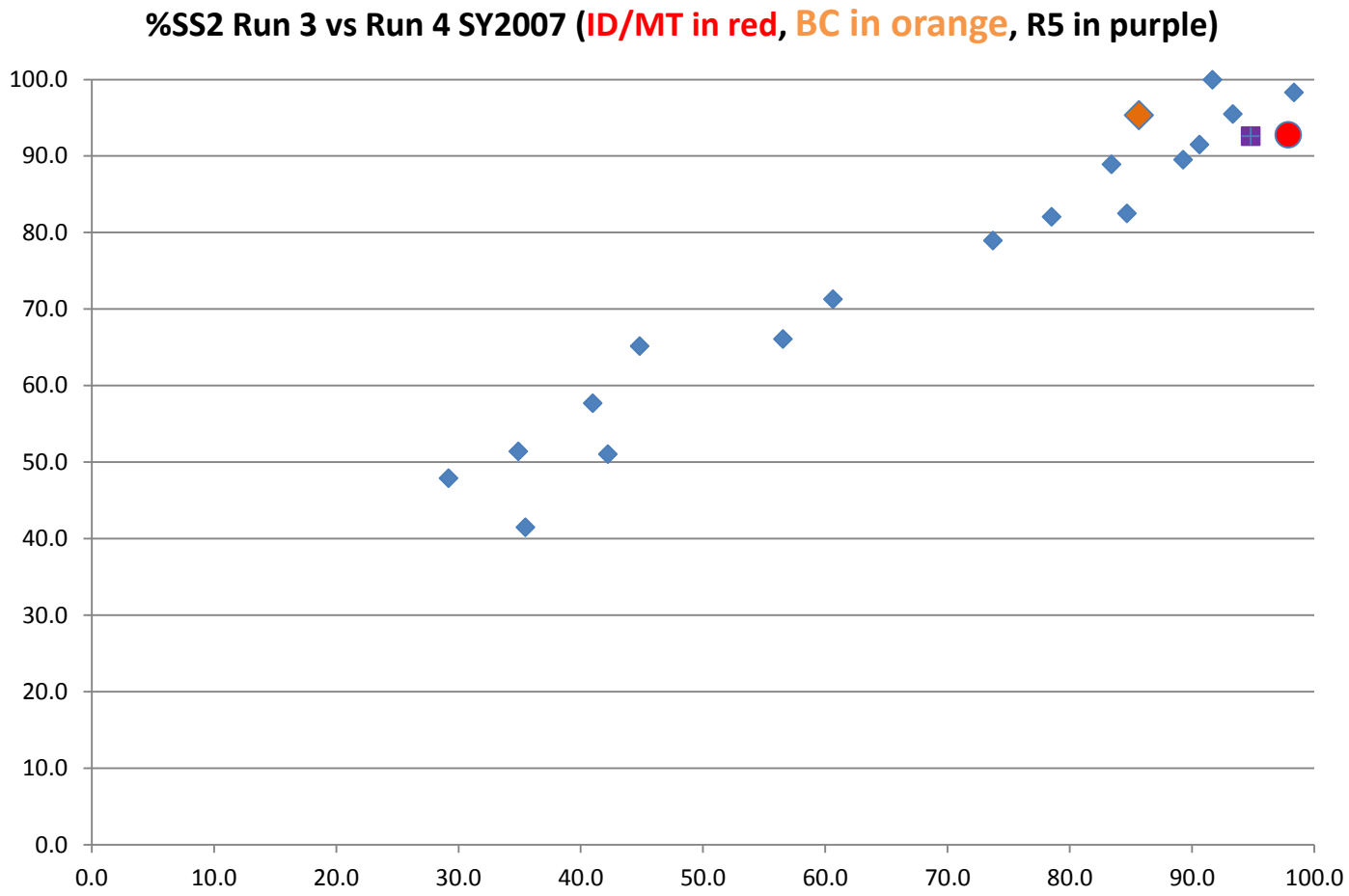
*Sniezko et al (2016) CJFR

SY2007 Whitebark Pine

225 families tested (5 BC families)
2 sources of rust

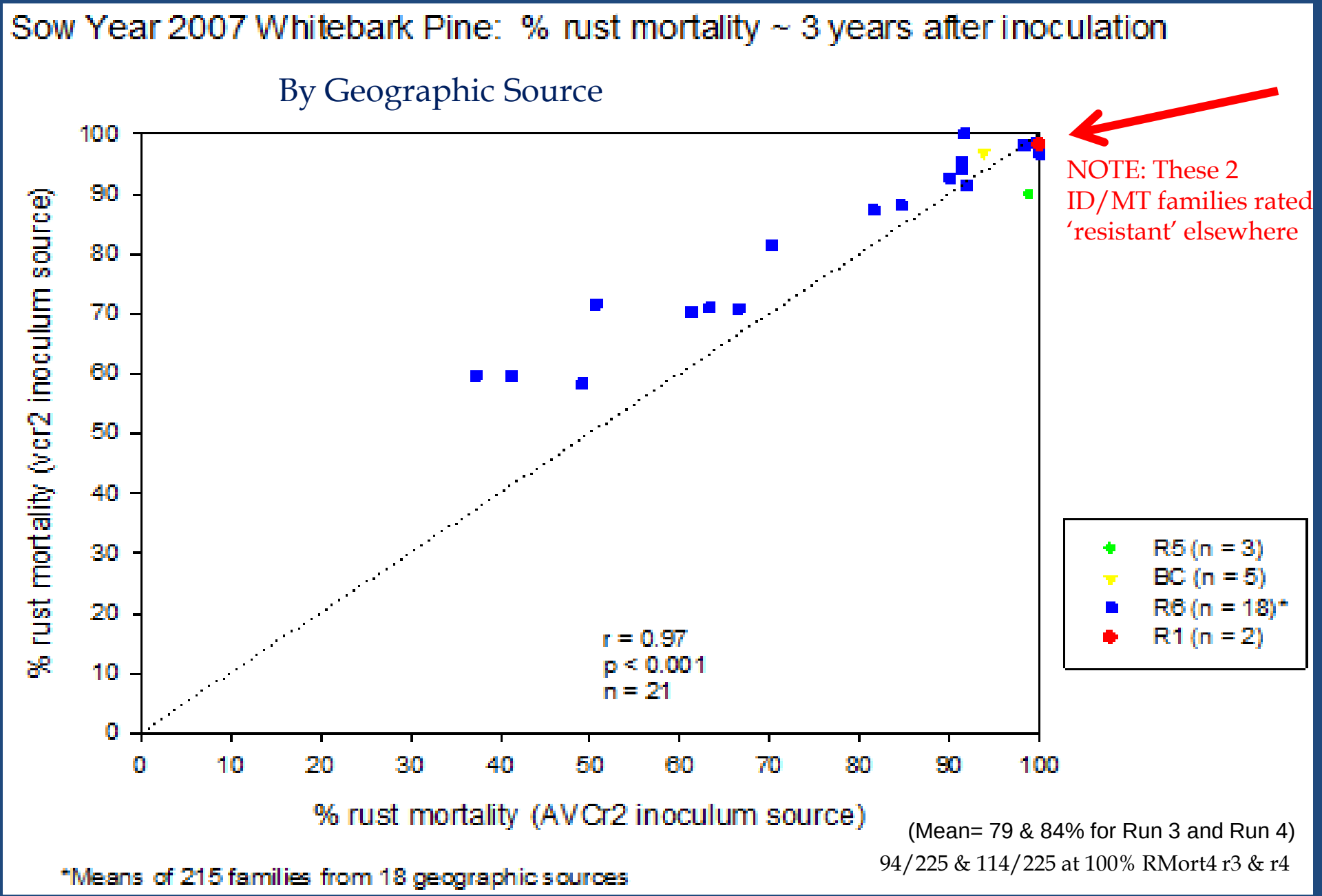
SEED SOURCE VARIATION IN RUST RESISTANCE

Early Stem Infection% of Seedlings (~15 months post-inoculation) – with [a] 2 geographic sources of rust [b] families from different geographic areas



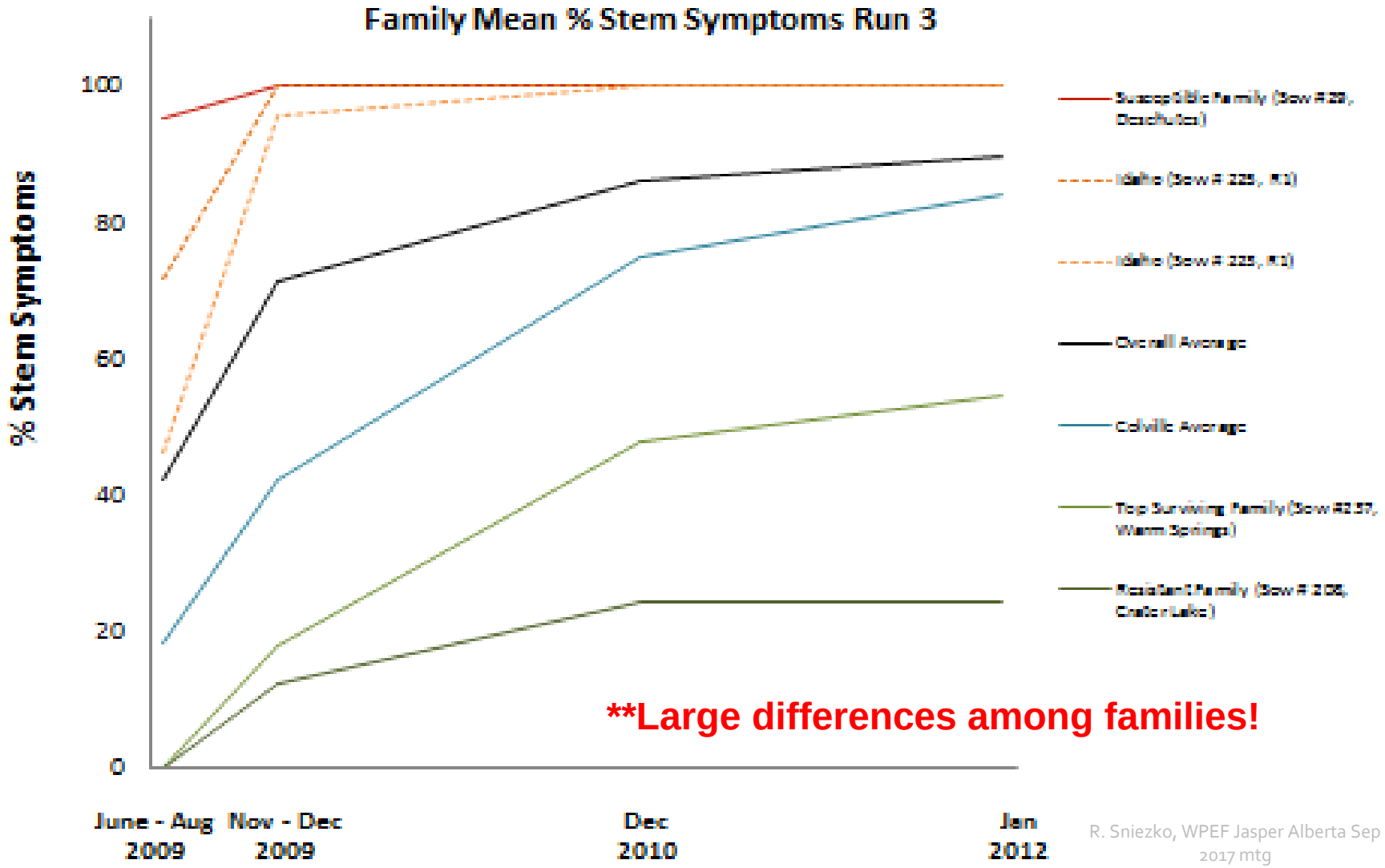
families per source varies, e.g. R1=2 families, BC=5 families; most sources from OR & WA
36/225 & 45/225 families at 100% SS2 for R3 & R4
Trial followed for 4 additional years (Sy2007 whitebark pine – 225 families)

VERY LARGE DIFFERENCES IN RUST MORTALITY – SEED SOURCE

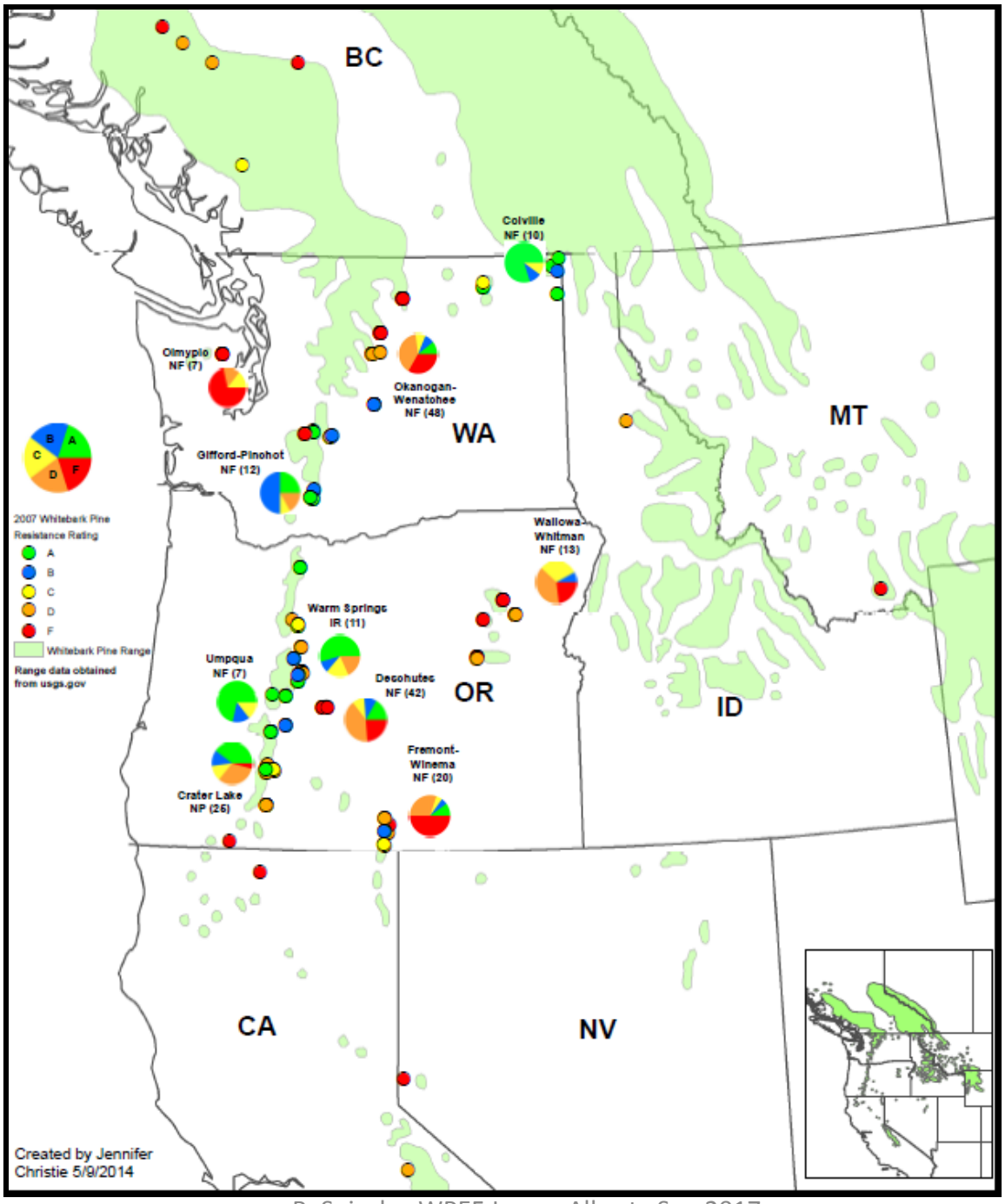


What level of blister rust resistance is there?

%Cankering – Whitebark pine families in SY2007 Run#3 – early data



R. Sniezko, WPEF Jasper Alberta Sep 2017 mtg



Geographic variation in genetic resistance to white pine blister rust in whitebark pine*

*Results shown are from SY2007 trial at USFS R6 Dorena Genetic Resource Center v1.0 Draft - Many more trials underway or completed
Contact Richard Sniezko, rsniezko@fs.fed.us, for more information.

Using 225 families from SY2007

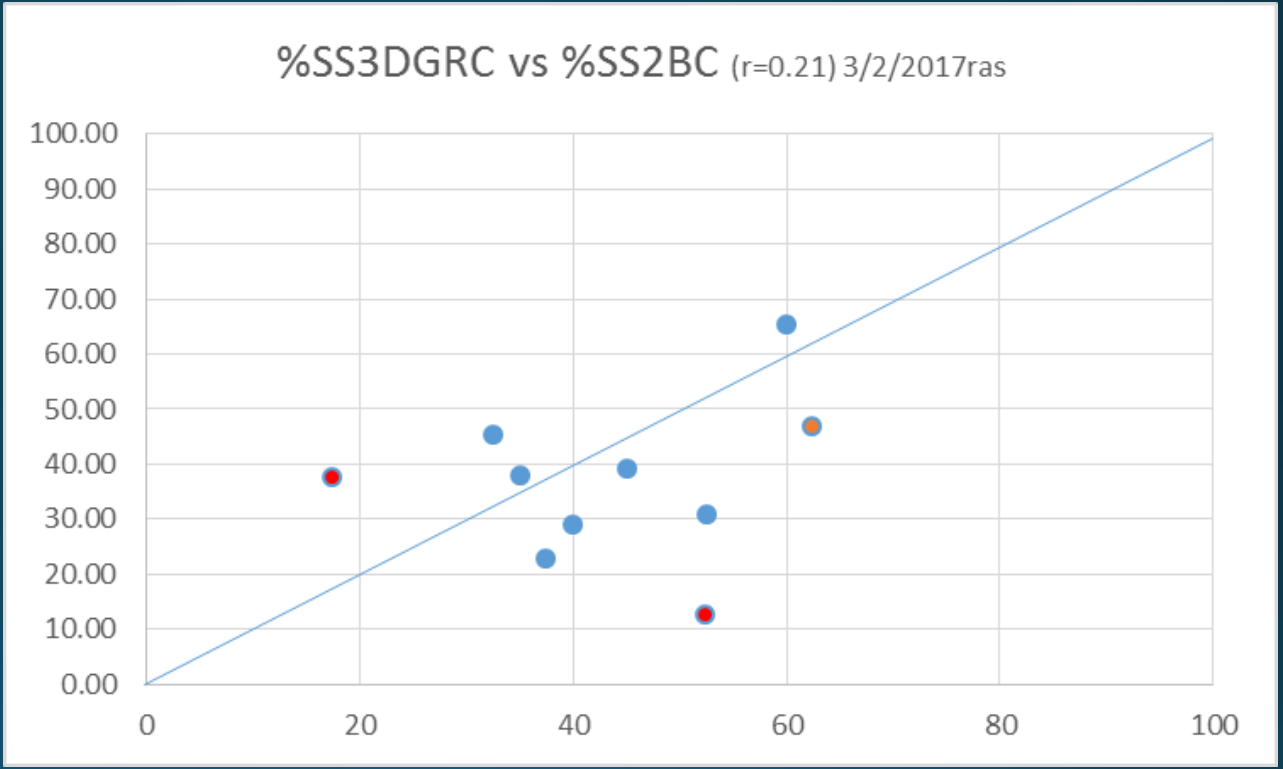
SY2012 Whitebark Pine trial (May 2015) (5878.jpg)

125 famiilies (10 from BC)

R. Sniezko, WPEF Jasper Alberta Sep 2017 mtg

WHITEBARK PINE SY2012
Results for 10 BC seedlots in BC (x) test vs. DGRC (y) test

BrCol	%SS3
Stagleap 2	30.83
Tree 601	45.46
Tree 606	29.07
Tree 610	39.07
Tree 611	37.50
Tree 613	65.28
Tree 617	46.67
Tree 618	37.92
Tree 619	23.02
Tree 622	12.50
	36.50%



BC seedlots show good resistance in both tests

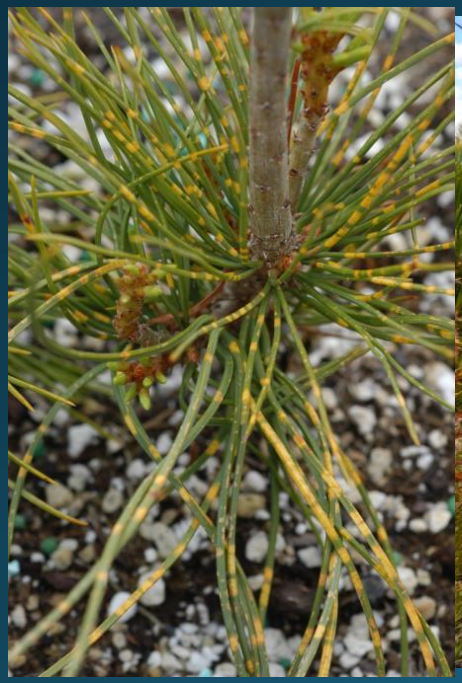
DGRC Test: 75.3% infection over all families vs. 36.5% for 10 BC families

DGRC: 13/125 families at 100% SS2; 25/125 with >=95% SS2

Very few seedlings for 3 BC families at DGRC (8 to 15 available for 3 of the 10 families, noted in red in graph) - at DGRC used in Runs #1 and 2

SY2013 Whitebark pine at Dorena GRC

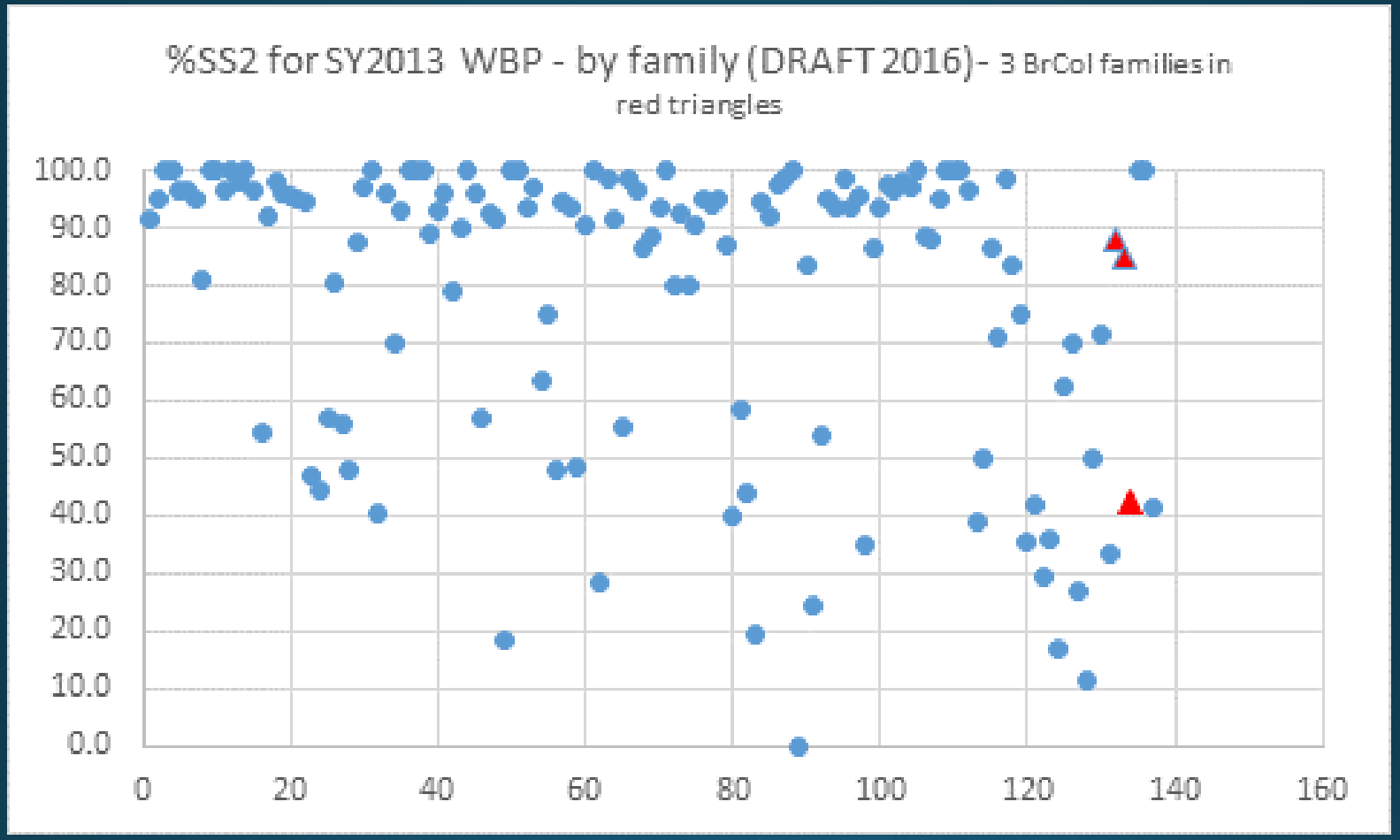
– 137 families includes 3 BC families



Sy2013 Whitebark Pine blister rust resistance trial (summer 2016)

Note the high overall mortality, but the survival of some families (each family is in 10-tree row plots)

22/137 families with 100% SS2; 51/137 w/ >=95% SS2



Sow #	SOURCE	Accession #	Whole Tree #	# reps	# sdlgs	%SS2
142	BC		LAIB1	6	58	88.0
143	BC		LAIB3	3	14	85.0
144	BC		O.Hill	6	57	42.4
145	Susceptible Control	011050	101-01038-007	6	21	100.0
146	Susceptible Control	049011	04014-140	6	47	100.0
147	Resistant Control	066011	06017-003	6	50	41.2
				all families in trial, Mean		79.20%

MGR2014 LIMBER PINE - inoculated Sept 2014

***** 1 of 13 seedlots MGR (1 of 10 Canadian families) ******

- First limber pine resistance noted in Canada for limber pine – and first MGR

(Sniezko et al. 2016 CJFR)

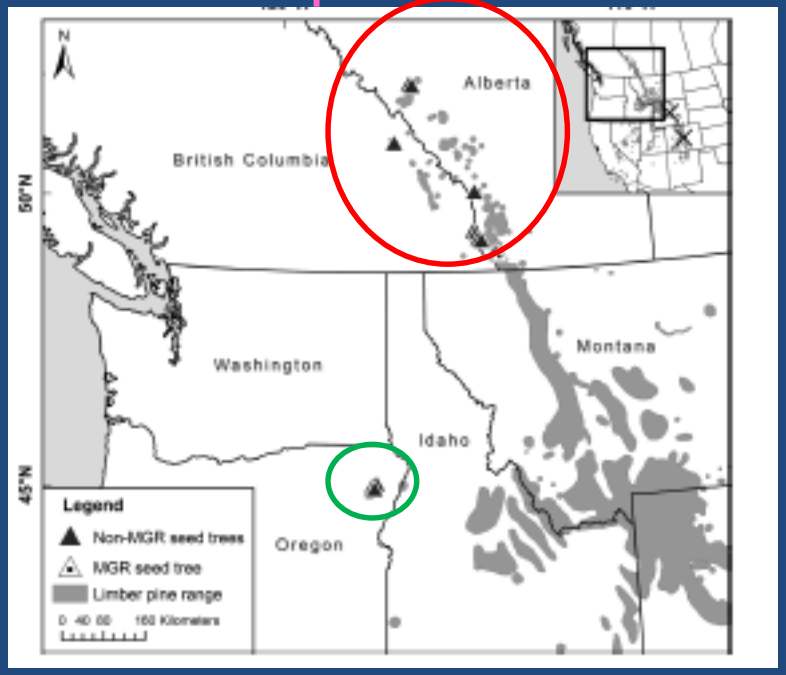
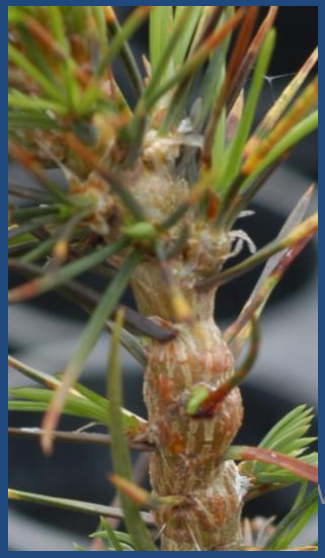


Table 1. White pine blister rust infection (needle and stem) and mortality for 13 limber pine families.

Population and tree number	No. of seedlings	No. with susceptible needle spots	No. dead (non-rust)[a]	No. cankered	Mean no. of cankers[b]
Kicking Horse #1	21	21	0	21	4.0
Andy Good Creek #123	22	22	0	22	2.5
Andy Good Creek #151	17	17	0	17	2.1
Crowsnest Pass #49	21	21	1[c]	20	2.8
Crowsnest Pass #51	21	21	0	21	3.5
Prairie Bluff #2	21	7	2[c], 1[d]	7	0.7 ß (2.0[e])
Prairie Bluff #3	21	21	3[d]	18	2.1
Kananaskis #9	21	21	0	21	2.8
Abraham Lake #1	21	21	0	21	3.5
Abraham Lake #8	21	21	0	21	4.3
Hurricane #1	21	21	0	21	5.0
Hurricane #3	21	21	0	21	3.5
Hurricane #6	21	21	0	21	5.6



SY2014 Limber pine

Most of same families as MGR2014 + a few additional Oregon ones (**Alberta, BC & Oregon** seedlots) - Inoculated Sept 2015

Prairie Bluff#2 is MGR

Very low level of Partial resistance?

MGR2016 LIMBER PINE

Family	**Tree#**	%standInfected	Parent tree infected
6468	**PF480**	87	yes
6470	**Pf482**	87	no
6476	**Pf489**	isolated tree	no
6665	**Pf483**	95	no
6669	**Pf499**	isolated tree	no
6673	**Pf503**	95	yes*
6674	**Pf504**	95	yes
6677	**Pf506**	83	yes
7026	**Pf496**	isolated tree	yes
7027	**Pf508**	83	no
PB # 2		94%	no

11 Families:
10 Waterton Lakes NP families + Prairie Bluff#2

Inoculated Sept 2016

SY2016 Limber Pine Alberta (60 families)

In Search of Partial Resistance

R. Sniezko, WPEF Jasper Alberta Sep 2017 mtg

SY2016 Limber Pine Alberta

(60 families) - Stay tuned - Infected Ribes leaves from E. OR used for Inoculation Run#3 at DGRC 2017

R. Sniezko, WPEF Jasper Alberta Sep 2017 mtg

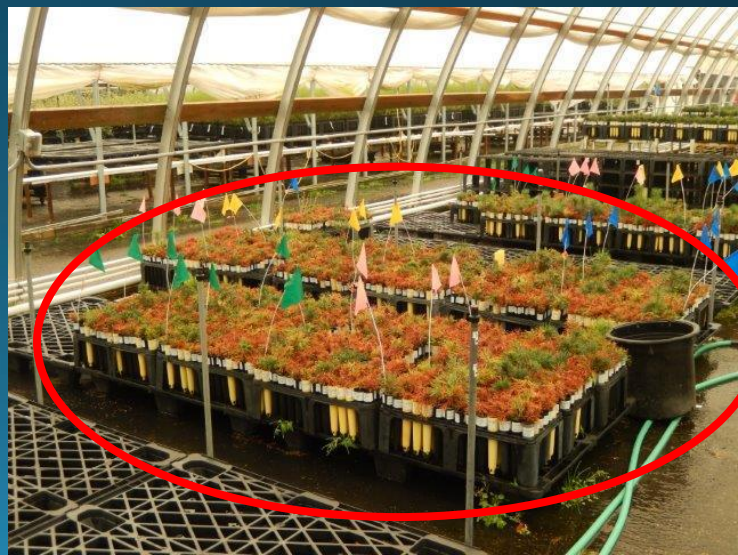
SY2016 - Dorena GRC 2017 – Inoculation #3

R. Sniezko, WPEF Jasper Alberta Sep 2017 mtg

R. Sniezko, WPEF Jasper Alberta Sep 2017 mtg

RESULTS: Limber Pine (Alberta)

- **Major Gene Resistance (MGR)**
  - **5 parents with MGR identified so far** (100 more in testing)
  - Range-wide test of limber pine (for MGR) underway*
- **Partial Resistance**
  - Very little partial resistance identified so far in any limber pine (including ~20 lots from Canada – Alberta and BC)
    - But extensive testing starting (110 families from Alberta)
  - Lots from Oregon, Colorado, Wyoming, Montana also tested



*Co-PI: Anna Schoettle

Next Steps

- Collect seed from resistant parents
- Protect resistant parents (from MPB, fire, etc)
- Use all tested parents as sentinels
- Establish trials to confirm field resistance and durability of resistance
- Test progeny of more parent trees
- Began restoration using resistant seedlots
- Monitor sentinel parent trees

WHITEBARK PINE

July 2011 – status under

Endangered Species Act

U.S. Fish & Wildlife Service agreed that the whitebark pine, a wide-ranging tree species found on mountain tops in much of western North America, faces an "imminent" risk of extinction. **The species was found warranted for protection but currently precluded due to limited budgets.** Development of genetic resistance at Dorena Genetic Resource Center and elsewhere is a key step to successfully restoring the species in many areas.

GENETICS IN ACTION

Whitebark pine restoration at Crater Lake National Park

PROBLEM

SUCCESS

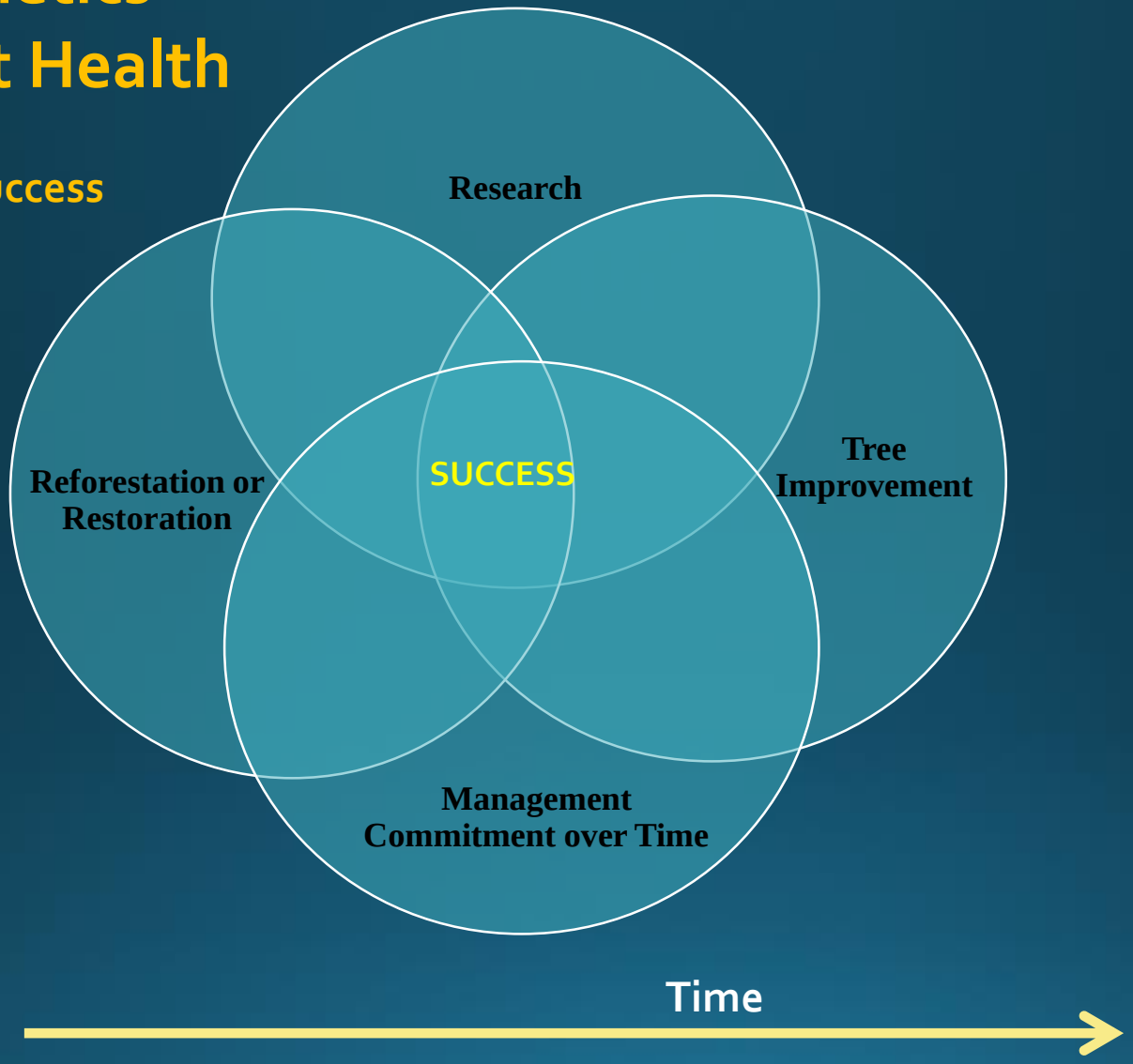
SOLUTION

Develop resistant populations
Maintain genetic diversity
Maintain genetic adaptability
Plant seedlings

R. Sniezko, West Jasper, Alberta Sept. 2017

Using Genetics for Forest Health

- The road to success



Successful program takes several components – all must be present
Partnerships, public support and 'time' also essential
Continuity essential – long-term commitments can be vital

R. Sniezko, WPEF Jasper Alberta Sep 2017 mtg

Literature

- Sniezko, Richard A; Danchok, Robert; Savin, Douglas P.; Liu, Jun-Jun; Kegley, Angelia. 2016. **Genetic resistance to white pine blister rust in limber pine (*Pinus flexilis*): major gene resistance in a northern population**. Can. J. Forest Research. 46 (9):1173-1178 doi:10.1139/cjfr-2016-0128.

- Sniezko, R.A. & Koch, J. 2017. **Breeding trees resistant to insects and diseases: putting theory into application** Biol Invasions . doi:10.1007/s10530-017-1482-5

- Jun-Jun Liu, Holly Williams, Xiao Rui Li, Anna W. Schoettle, Richard A. Sniezko, Michael Murrya, Arezoo Zamany, Gary Roke, Hao Chen… (August 2017) **Profiling methyl jasmonate-responsive transcriptome for understanding induced systemic resistance in whitebark pine (*Pinus albicaulis*)** Plant Molecular Biology pp 1–16 DOI 10.1007/s11103-017-0655-z

- Sniezko, R.A., Kegley, A. & Savin, D.P. New Forests (2017). **Ex situ genetic conservation potential of seeds of two high elevation white pines** . New Forests 48:245-261. doi:10.1007/s11056-017-9579-3

- Liu J-J, Sniezko RA, Murray M, Wang N, Chen H, Zamany A, Sturrock RN, Savin D, Kegley A. (2016) **Genetic Diversity and Population Structure of Whitebark Pine (*Pinus albicaulis* Engelm.) in Western North America.** PLoS ONE 11(12): e0167986. doi:10.1371/journal.pone.0167986

- Sniezko, R.A.; Smith, J.; Liu, J-J.; Hamelin, R.C. 2014. **Genetic Resistance to Fusiform Rust in Southern Pines and White Pine Blister Rust in White Pines—A Contrasting Tale of Two Rust Pathosystems—Current Status and Future Prospects**. *Forests* 2014, *5*(9), 2050-2083; doi:10.3390/f5092050

- Schoettle, AW.; Sniezko, RA.; Kegley, A.; Burns, K S. 2014. **White pine blister rust resistance in limber pine: evidence for a major gene.** *Phytopathology* 104(2):163-173.

Acknowledgments

- Funding from U.S. Forest Service Region 6 Forest Health Protection and Genetic Resources Programs
- All Cooperators, partners & colleagues - including Jodie Krakowski, Robert Sissons, Michael Murray, Charlie Cartwright, Jun-Jun Liu, Don Pigott, Dave Kolotelo ….and many others
- Co-workers at Dorena GRC
- Photos: Molly Oppliger, Richard Sniezko
- Jeremy Johnson, Doug Savin, and

Brianna McTeague for

data summaries/maps