



Resistance: What is it?

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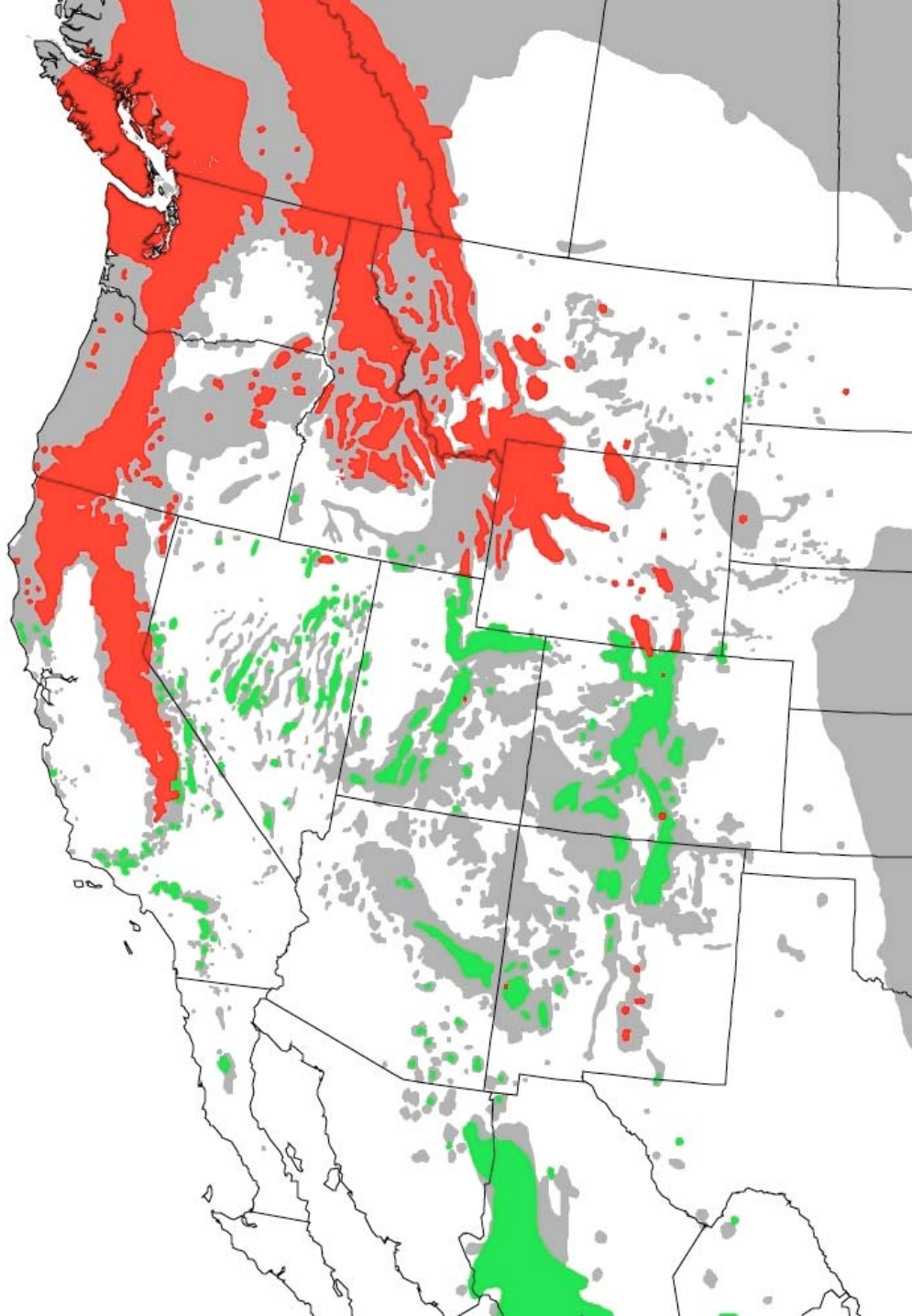
Placerville, CA

Distribution of WPBR in the western U.S.

White pines within *Pinus*

- Genus *Pinus*
 - Subgenus *Pinus* (hard pines)
 - Subgenus *Strobus* (soft pines)
 - Section *Parrya*
 - Subsection *Balfourianae*
 - » RM bristlecone, GB bristlecone, and foxtail
 - Section *Strobus*
 - Subsection *Strobi*
 - » Western white, eastern white, SW white, sugar & limber
 - Subsection *Cembrae*
 - » Whitebark

Based on R.A. Price, A. Liston, and S.H. Strauss, 1998, *Phylogeny and systematics of Pinus*, pp. 64-65 in D.M. Richardson, Ed., *Ecology and Biogeography of Pinus*, Cambridge University Press, 527 pp..



Distribution of
white pine blister rust
in western North America

“resistance”

- The use of this term tends to confuse more than clarify
- It is commonly used to describe several ways that plants cope with disease:
 - Escape
 - Tolerance
 - Resistance

Escape

- The pathogen and host never encounter each other; they are separated in space and time
- Is not strictly a mechanism, since it is highly chancy, not very efficient
- Pollen and seed may be said to “escape” by dissemination

Tolerance

- The ability of a plant to withstand damage from a pathogen (a little sick but not too sick)
- Assumes that the plant is susceptible; otherwise how would you know it was tolerant?
- Tolerance is an alternative to resistance

Resistance

- The ability of a plant to either partially or wholly prevent invasion by and establishment of a pathogen
- Can be controlled by one or several genes
- Can occur quickly (days or weeks) or may take several years to express

Common usages

- The French resistance (*la Résistance*)
- “I felt some resistance in you”
- “Resistant to all my arguments”
- “All resistance is futile!”
- And then there’s the dictionary definition...

Webster's New Collegiate

- **resist:** “to *withstand* the force or effect of, to *exert force* in opposition”
- **resistance:** “the *inherent* capacity of a living being to resist untoward circumstances (as disease or toxic agents)”

Interpretation

- **resist:** *withstand* suggests a **passive** mechanism, while *exert* implies an **active** mechanism
- **resistance:** *inherent* implies that the capacity to resist is **innate**, that it's in the genes

Terms used about resistance

- Active & passive
- Qualitative & quantitative
- Specific & non-specific
- Mode & mechanism

Active & passive

- Active mechanisms
 - Host responds to a specific stimulus
 - Phenomena cannot be observed without the stimulus
- Passive mechanisms
 - Constitutive traits that are already in place
 - No differential response to stimuli

Quantitative & qualitative

- Not truly opposites: actually different ways of observing the actions of genes
 - Quantitative: describe R traits using numeric, continuous variables
 - Qualitative: categorize R traits using discrete character states
- Traits may be simple or complex, genes few or many

Specific & non-specific

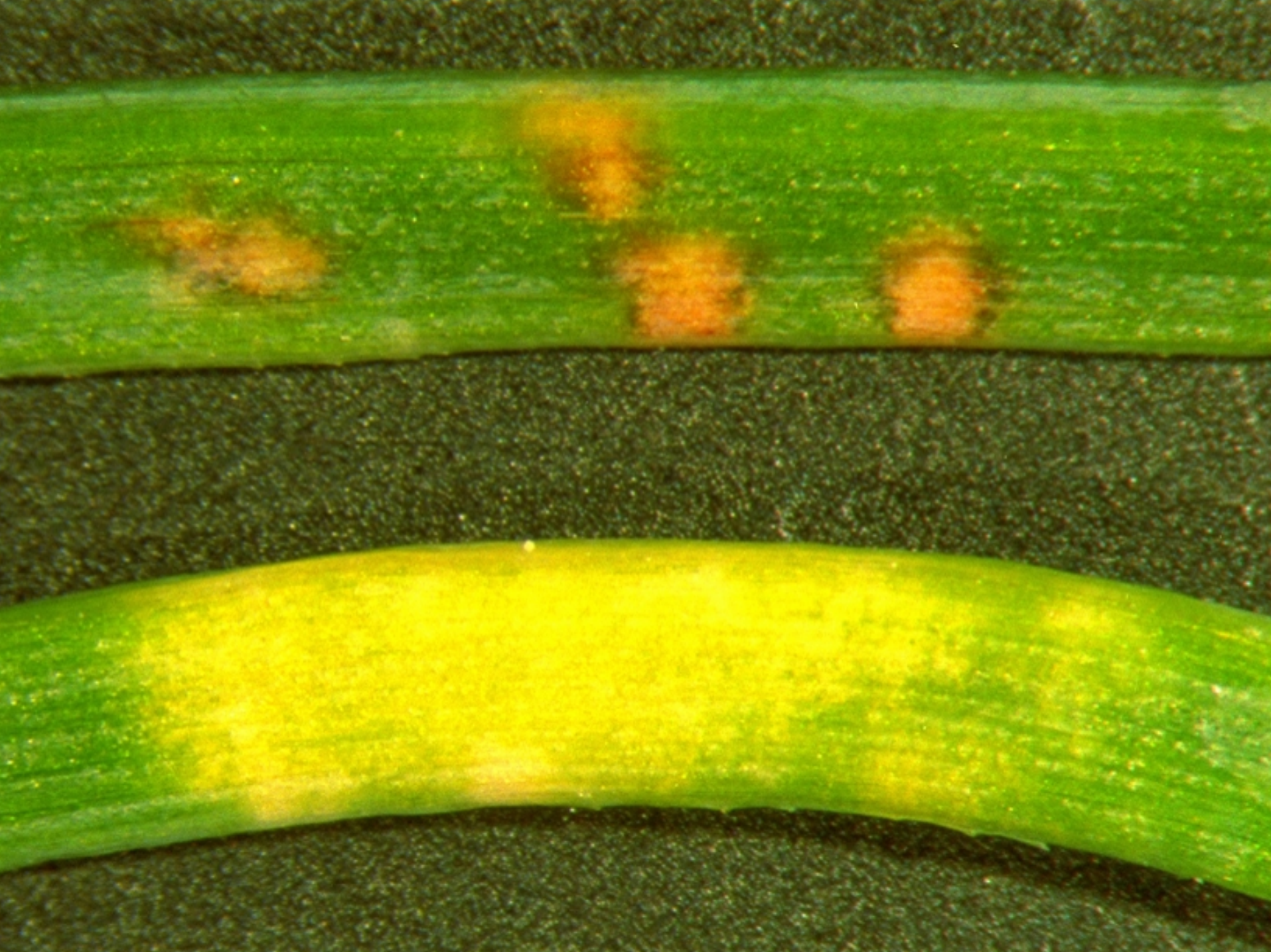
- Specific mechanisms
 - Particular host genotypes react in a specific manner to each rust pathotype
 - Differential interactions
- Non-specific mechanisms
 - All host genotypes react identically to all rust pathotypes
 - No host-pathogen interactions

Modes & mechanisms

- Modes of resistance
 - How resistance is inherited in a host:
 - Simply: one or a few genes
 - Complexly: a few or many genes
- Mechanisms of resistance
 - Mechanisms by which a plant prevents or retards inoculation, infection, and establishment by a parasite or pathogen
- Sometimes these are confused

MGR in SP, WWP, SWWP, LP

- Major gene resistance (MGR) is a somewhat unfortunate term
 - Actually, it's both a mechanism and a mode:
 - complete or immune resistance
 - inherited in a simple manner
- Characterized by hypersensitive needle spot reaction that prevents development of the fungus beyond the needle, a trait inherited in a Mendelian fashion (a single dominant gene)











Major gene resistant (MGR) sugar pine challenged with mixed inoculum, showing both **resistant** (brown circles on left front leaf) and **susceptible** reactions (diffuse yellow spots on left-side leaves) on the same plant.

MGR in North American White Pines

Pine host	MGR?	Virulence?
Sugar pine	Y	Y
Western white pine	Y	Y
SW white pine	Y	(N)
Limber pine	Y	(?)
Eastern white pine	(Y)	(?)
Whitebark pine	(N)	(?)
Foxtail pine	(N)	(?)
RM bristlecone pine	(N)	(?)
GB bristlecone pine	(N)	(?)

Complementarity

Host R genes	Pathogen virulence genes			
	<i>vcr1</i>	<i>vcr2</i>	<i>vcr3?</i>	<i>vcr4?</i>
Sugar pine (CR1)	+	—	—	—
Western white pine (CR2)	—	+	—	—
SW white pine (CR3)	—	—	(+)	—
Limber pine (CR4)	—	—	—	(+)

Slow-rusting in sugar pine

- Actually a misnomer
 - More appropriately, partial resistance that is inherited in a complex manner
- Three traits or mechanisms identified
 - Limited frequency of infection
 - Bark reaction
 - Blight reaction





Bark reaction:
Late, incomplete,
and destructive



Bark reaction:

Timely,
somewhat
destructive



Bark reaction:
Early and relatively
non-destructive

Blight reaction
(twigs, branches)









WWP: blight reaction

- Normal infection, susceptible spots
- Needles turn straw-colored, drop off
- Infection effectively eliminated







Reactions in other species

- Southwestern white pine
 - Characteristic “MGR” type mode and mechanism observed
 - Tree becomes stem-infected, but infection subsequently fails, leaving host rust-free
 - Appears to be simply inherited
 - Poorly understood; just now being studied

SWWP



Reactions in other species

- Bristlecone pines (*Pinus aristata* and *P. longaeva*)
 - No evidence to date for hypersensitive needle spot type resistance (no “MGR”)
 - Susceptibility develops normally
 - Multi-color needle spots, stem discoloration, stem swelling, spermatia, aecia
 - Occasionally, in some families, in a fairly simple mode, infection gets past the base of the needle but is arrested at a stem lesion









Passive, non-specific traits

- Example from Woo, Fins, & McDonald of assay for putative traits that may associate with passive resistance
 - 14 needle traits identified, including
 - Needle length & width, no. of stomatal rows
 - No. of stomata per row, total stomata per needle
 - Stomatal occlusion
 - Epistomatal wax degradation
 - Contact angle of water droplets
 - Etc.

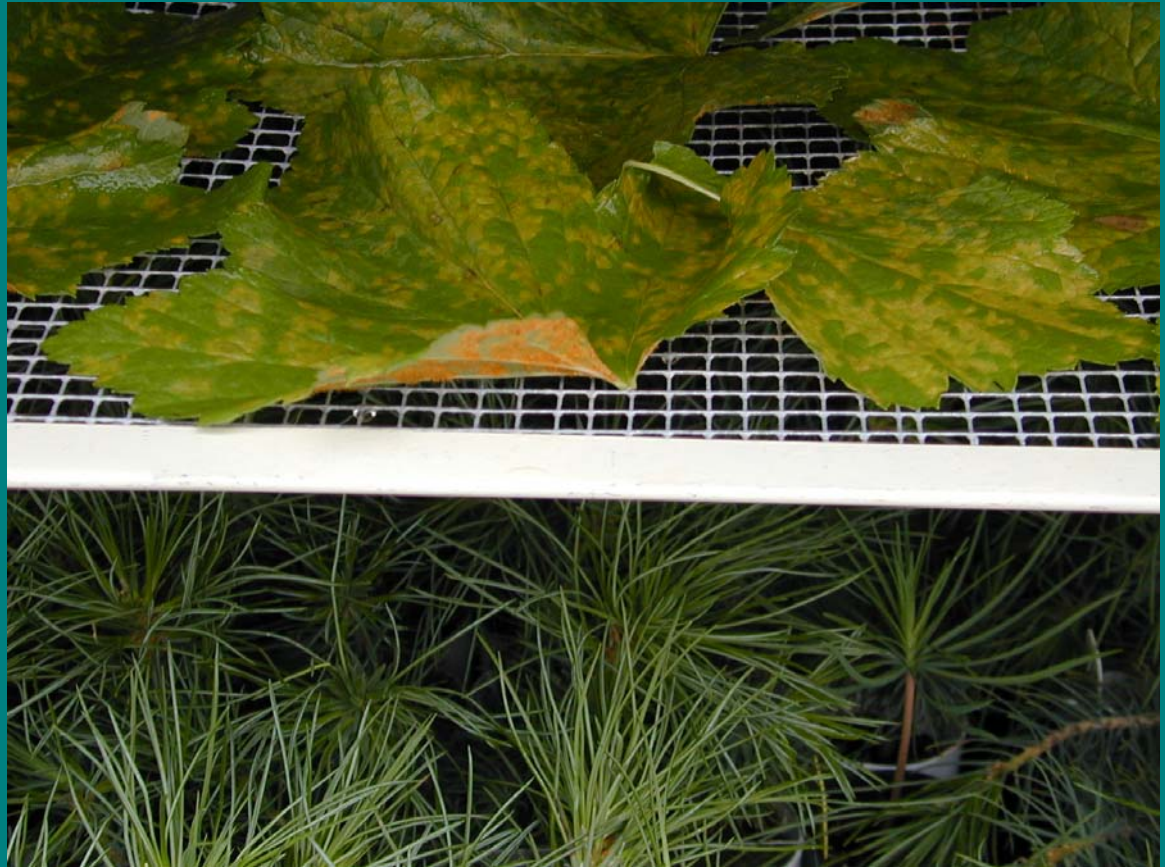




Inoculations in
controlled environment
dew chambers



Dew chamber inoculation at IFG



Sometimes, however, science
is not enough . . .



Thank you ...



Foxtail



