Sudden Oak Death, Madrone Canker, and Systemic Acquired Resistance

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Sudden Oak Death

- First seen in early 1990s
- Two types of symptoms
  - Canker
  - Foliar blight
- Caused by *Phytophthora ramorum* (Oomycetes)
- Over 70 plant hosts
- Most of the outbreak in central coastal CA

Dead tanoak in Muir Woods NP, CA

Foliar symptoms on Rhododendron

How *P. ramorum* spreads

- Water - Wind-driven rain, irrigation, runoff
- Humans – soil on hiker's boots and bicycle tires, nursery plants
- Wildlife

Stream monitoring

Rhododendron leaves used as bait

Baits set out in stream for 2 weeks

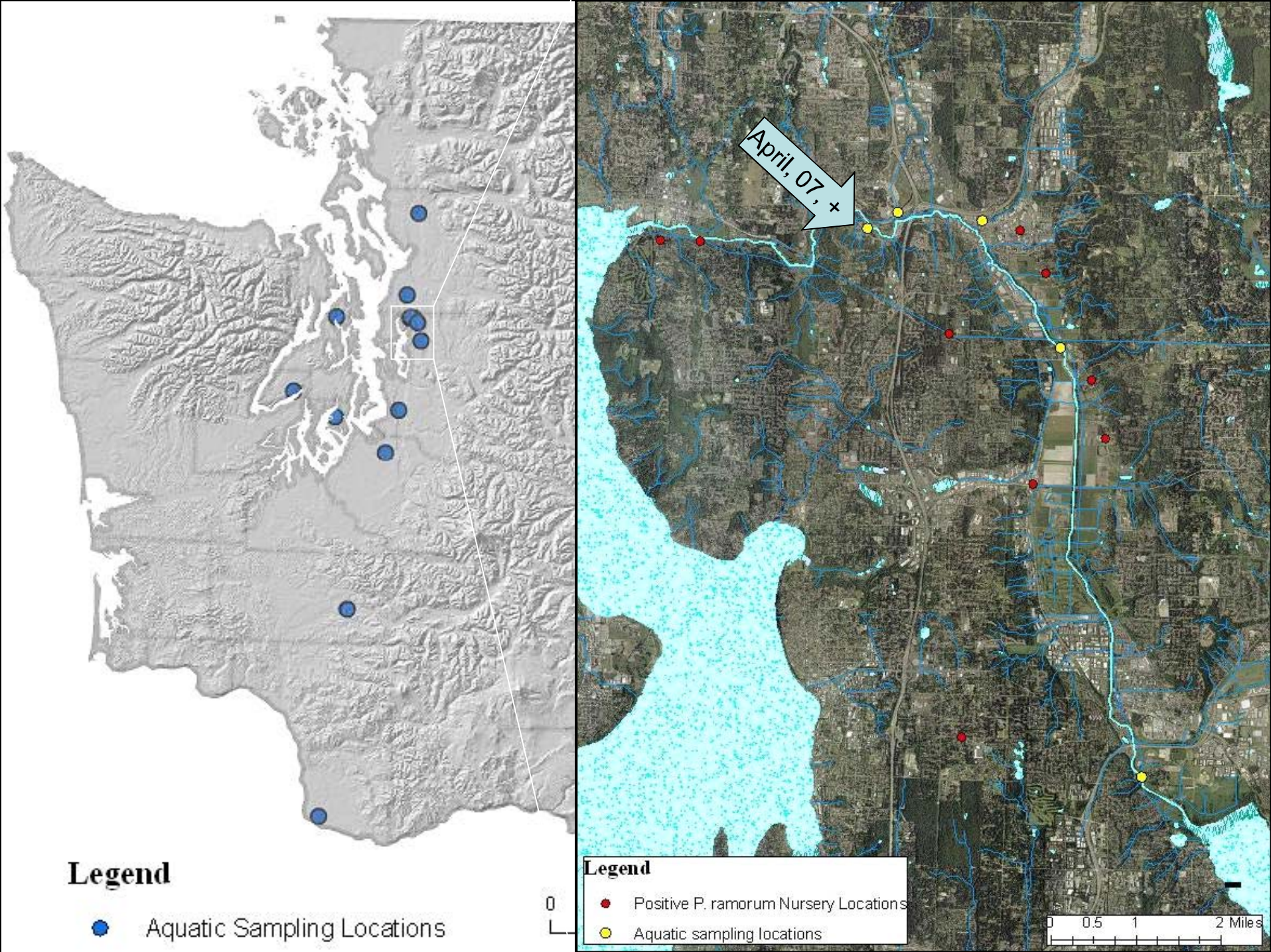
Baits cultured on *Phytophthora* selective medium (CARP)

Phytophthora species identified

Riparian alders dying from *P. alni.* Only found in Europe and Alaska

Stream monitoring is an effective tool for early detection of invasive *Phytophthora* spp. and discovery of new endemic *Phytophthora* spp.

P. kernoviae is more aggressive than *P. ramorum*. Only in UK at present.


April, 07 , +
Legend
Aquatic Sampling Locations
0
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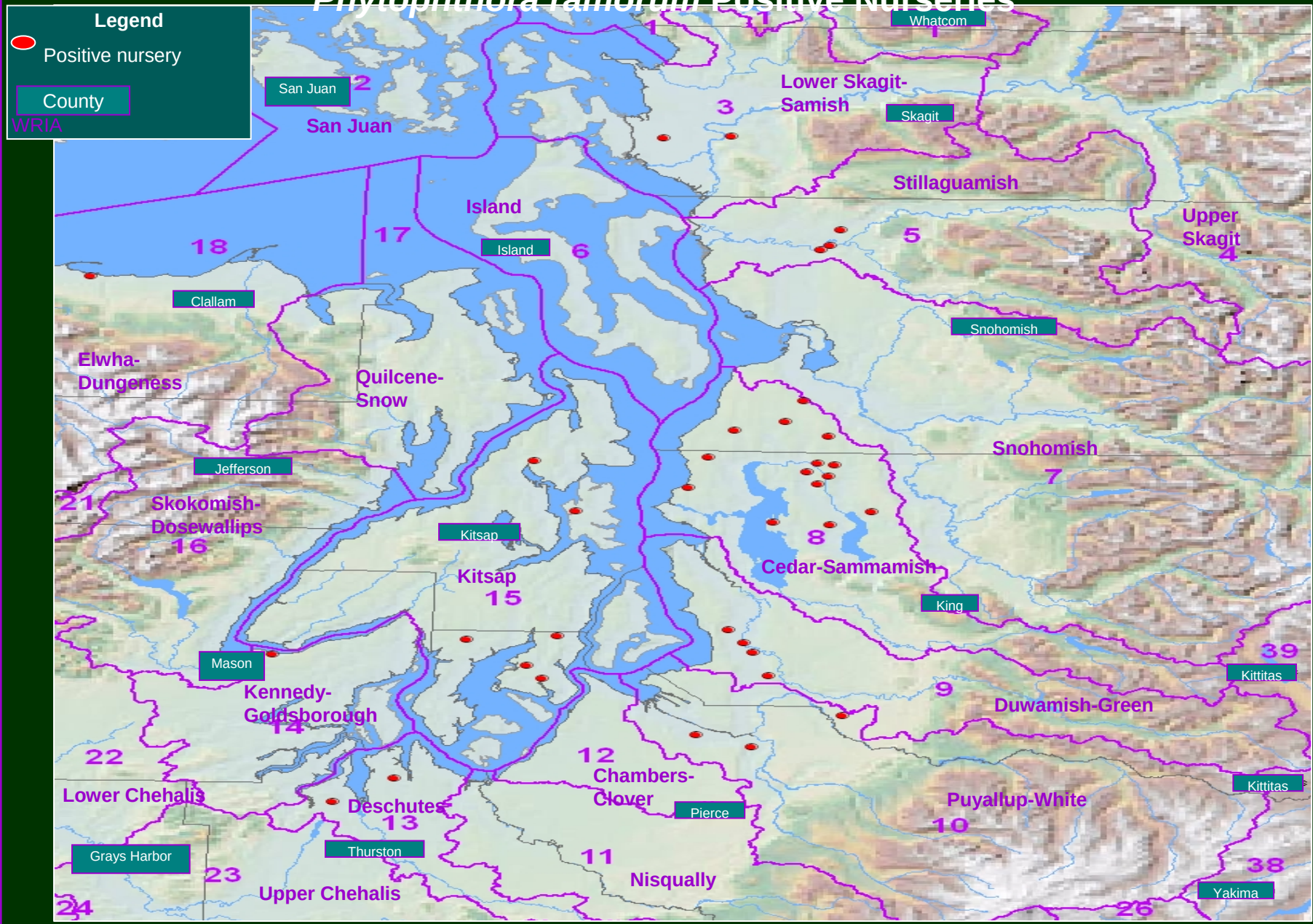
Positive P. ramorum Nursery Locations
Aquatic sampling locations
0 0.5 1 2 Miles

Puget Sound Water Resource Inventory Areas with *Phytophthora ramorum* Positive Nurseries



Four stream sites associated with nurseries

	Years with positive Pr detection	
	Nursery	Stream
Clark County	2008-2009	2008-2009
Rosedale	2004-2005	2006-2009
Gig Harbor	2004, 2009	2009
Sammamish River	2005-2009	2007-2009

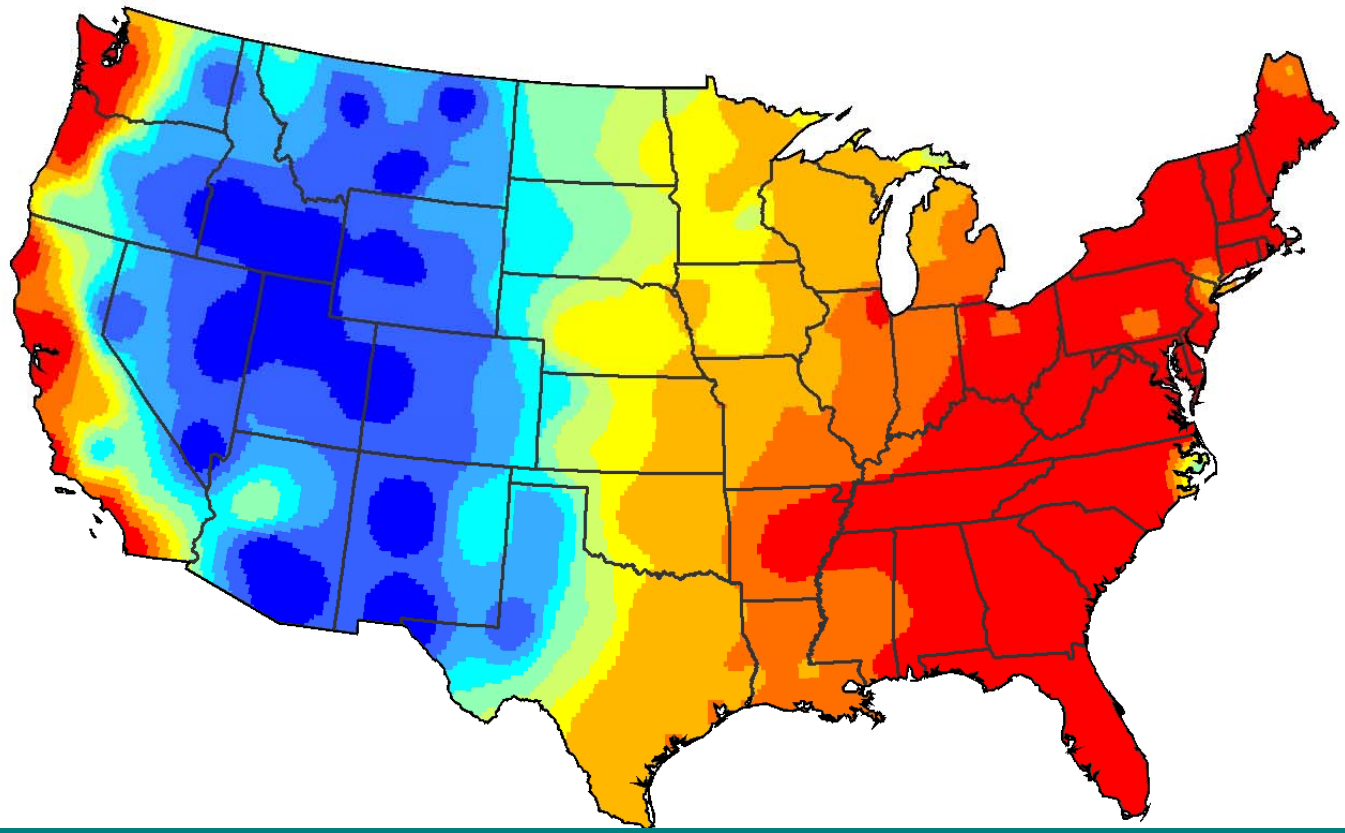
First case of Pr moving from nursery to landscape via stream in WA

P. ramorum in North American forests

- SOD currently found in 14 CA counties and 1 OR county
- These counties are under quarantine
- SOD not known to be established anywhere else in N.A. forests

Map from www.suddenoakdeath.org
Kelly, UC-Berkeley

Risk of sudden oak death based on *P. ramorum* climate matching and hardwood forest density in the USA



Legend

Climate match (frequency)

1
2
Risk Group III

3
4
5
6
Risk Group II

7
8
9
10
Risk Group I
(High)

Fowler, G., Magarey, R., Colunga, M. 2006. Climate-host mapping of *Phytophthora ramorum*, causal agent of sudden oak death In: Frankel, Susan J.; Shea, Patrick J.; and Haverty, Michael I., tech. coords. Proceedings of the sudden oak death second science symposium: the state of our knowledge. Gen. Tech. Rep. PSW-GTR-196. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture: 329-332

Nursery detections of *P. ramorum* in the US

Year	# nurseries	# states	Notes
2000	0		No reported nursery detections before 2001
2001	1	CA	In infested area
2002	0		
2003	20	3 – CA, OR, WA	
2004	176	21	125 linked to one CA nursery's shipments
2005	99	7	
2006	62	11	
2007	23	6	
2008	28	8 – CA, OR, WA, TX, FL, MS, NC, SC	

Costs of SOD to PNW nursery industry

Oregon

- Second largest in US in sales
- $966 million sold in 2006
- OR ships 75% of its production to other states or countries
- Total losses estimated range from $77.9 million to $204 million per year

Washington Nurseries

- 7th largest commodity in state
- 14th in US total gross sales
- Most nursery stock is imported and is sold within the state
- Estimated loss ~$12,000 per nursery (direct costs)

GAIP

Grower Assisted Inspection Program

http://www.oregon.gov/ODA/PLANT/NURSERY/gaip.shtml

P. ramorum in Western US nurseries 2004-2008

Washington *P. ramorum* surveys

Nursery

- 2002 0
- 2003 1
- 2004 25
- 2005 16
- 2006 12
- 2007 7
- 2008 5
- 2009 4

Forest and stream

- 2002 ---
- 2003 ---
- 2004 ---
- 2005 0
- 2006 2
- 2007 2
- 2008 3
- 2009 4

P. ramorum in European forests

Beech: *Fagus sylvatica*

Rhododendron ponticum

Red Oak: *Quercus rubra*

These species used as ornamentals in WA

Slide from the USDA PRED Training Module

Photo: DEFRA

Protecting high-value, high-risk trees

"dead end hosts" – no sporulation

Stem canker hosts of SOD

- Oaks
  - Live oaks
  - Red oaks, Black oaks
- Beeches (*Fagus sylvatica*)
- Tanoak (*Lithocarpus densiflorus*)
- Horse chestnut (*Aesculus hippocastananum*)
- Planetree maple (*Acer pseudoplatanus*)

Bleeding on tanoak

Foliar hosts of SOD

Leaf spots, shoot dieback, defoliation,
sometimes heavy spore production

- California bay laurel (*Umbellularia californica*)
- Pacific madrone (*Arbutus menziesii*)
- Douglas-fir (*Pseudotsuga menziesii*)
- Bigleaf maple (*Acer macrophyllum*)
- Maples (*Acer* spp.)
- Coast redwood (*Sequoia sempervirens*)
- True firs (*Abies* spp.)
- Many others

Look-alikes

Bacterial gummosis on Russian olive caused by *Pseudomonas syringae*

Bacterial wetwood on white oak (*Q. alba*)

Phytophthora root and crown rot cause by *P. cambivora* on beech

Management techniques

Prevention is the most effective method for managing SOD

- Cultural
  - Inoculum removal
- Chemical
  - Agri-fos
  - Insecticides
  - Azomite and limewash

Agri-fos

- Potassium phosphite
- Preventative – use when SOD is in area (within 3 miles of infested plants)
- Requires 4-6 weeks to become assimilated
- Deciduous species – treat when leaves are present
- Healthy trees have a better chance of success

Photo: Phytosphere Research

Pacific Madrone Decline

- First noticed in WA and BC in 1976 after a serious drought
- Found in both urban and natural areas
- Most severe symptoms on exposed sites
- Several fungal diseases

Fungal pathogens

Cankers

- *Fusicoccum arbuti*
- *F. aesculi*

Root rots

- *Armillaria*
- *Heterobasidion annosum*
- *Phytophthora*

Foliar diseases

Leaf blight caused by *Phacidiopycnis washingtonensis*, also a post harvest disease of apples

Symptoms

Madrone canker caused by *Fusicoccum arbuti*

- Cankers
- Branch dieback
- Shoot blight

Conditions for fungal infection and sporulation

- Fungal biology is influenced by climate – temperature and moisture conditions affect sporulation and germination
- *Botryosphaeria* sporulation and germination conditions: 20 – 33 °C and wet
- Infection courts created through heat or freezing damage
- Climate affects host stress: drought → symptom expression → sporulation on recently dead material

Cankered wood

Fruit mummies

Shoot blight

Important sources of inoculum

A

1996

B

2004

Management

- Cultural methods – sanitation (inoculum reduction), improve tree vigor, prevent stress and wounding
- Chemical methods – fungicides (spray, soil drench, injected), plant activators

Injected treatments for management of Madrone canker in urban landscapes

In-vitro test

- Fungal growth on media with 200 ppm active ingredient measured
- 18 chemicals tested, 7 used in field tests
- Benzimidazole and triazole fungicides most effective in vitro
- No inhibition by plant activators, including Phosphorous acid

Chemicals used in field tests

Fungicide	Active ingredient	Manufacturer
Tebuject	Tebuconazole	J. J. Mauget Co.
Fungisol	Debacarb, Carabendazim	J. J. Mauget Co.
Arbotect	Thiabendizole	Syngenta
Alamo	Propiconazole	Syngenta
Phyton 27	Copper sulphate pentahydrate	Source Technology Biologicals
Cambistat	Paclobutrazole	Rainbow Treecare Scientific Advancements
Bio-serum	Phosphorous acid	Bioscape, Inc.

Field tests

- Lopez Island, WA
- 128 trees, 7 treatments + 1 control, 16 trees/group

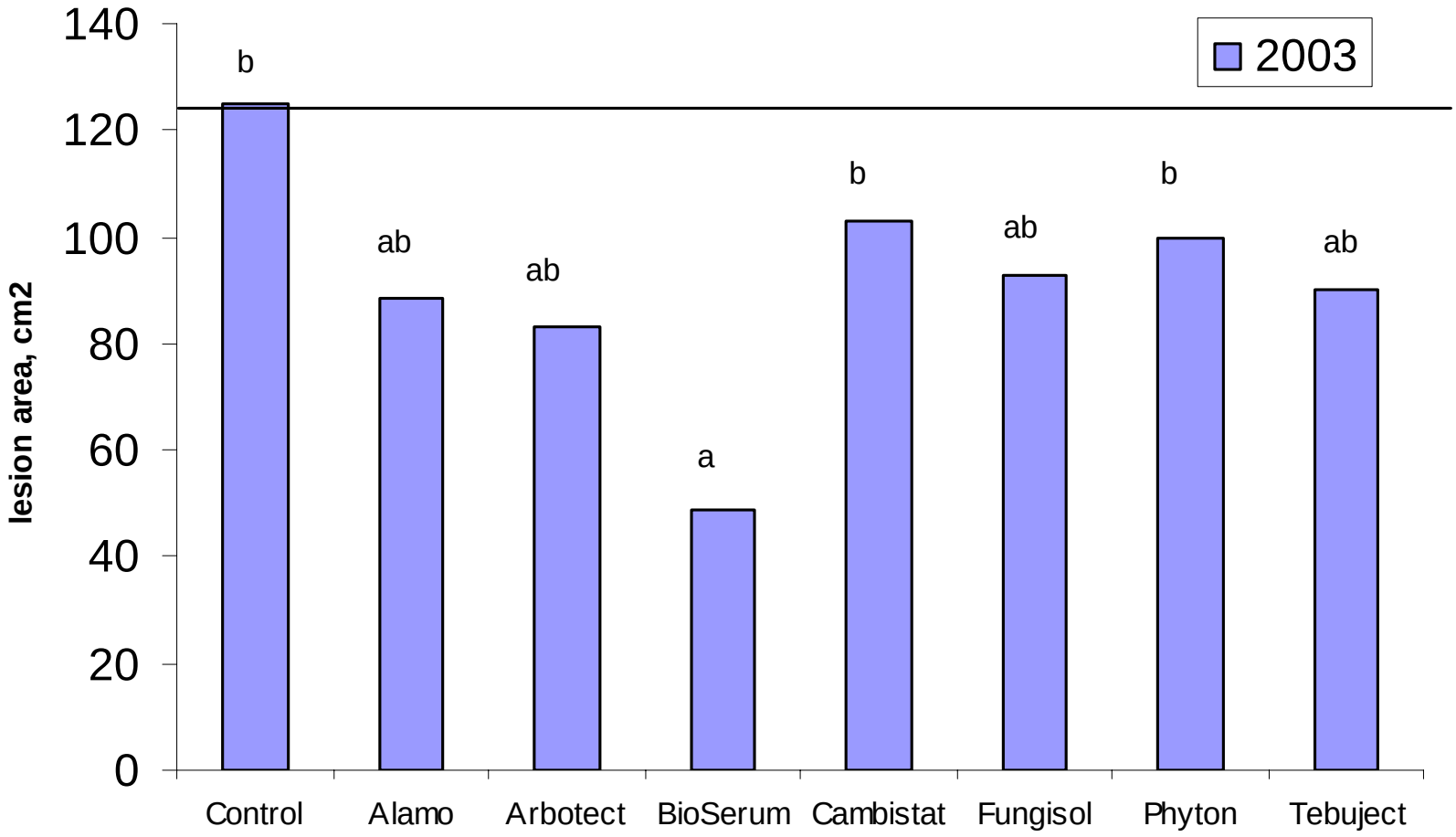
Field tests

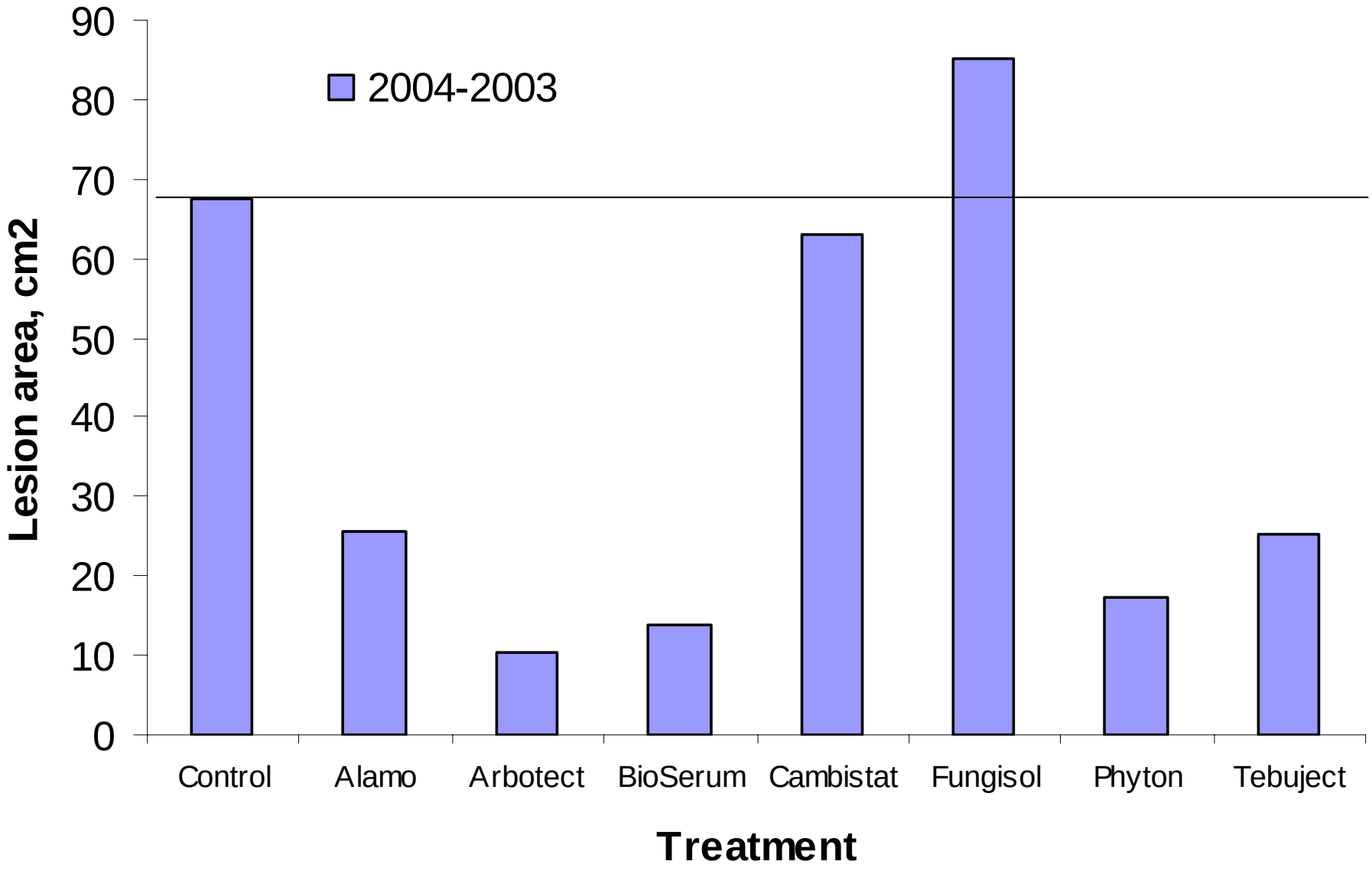
Injection treatments in July 2002

Inoculation with *F. arbuti* September 2002

Cankers measured in July 2003 and July 2004

Results


2003
lesion area, cm2
140
120
100
80
60
40
20
0
b
ab
ab
a
b
ab
b
ab
Control
Alamo
Arbotect
BioSerum
Cambistat
Fungisol
Phyton
Tebuject


90
80
70
60
50
40
30
20
10
0
2004-2003
Lesion area, cm2
Control
Alamo
Arbotect
BioSerum
Cambistat
Fungisol
Phyton
Tebuject
Treatment

Systemic Acquired Resistance

A ‘whole plant’ resistance response to infection by a pathogen – analogous to the immune system in animals.

Long-lasting, broad spectrum disease control based on multiple defense mechanisms

SAR has 3 stages

- Hypersensitive response
- Physical barriers – cell wall thickening to prevent further colonization
- PR proteins – chitinase, peroxidase, glucanase

The hypersensitive response

Chemical activators of SAR

- Salicylic acid
- Jasmonic acid
- Benzothiadiazole (BTH)
- Volatile organic compounds
- Phosphorous compounds
  - Phosphate, phosphorous acid

Biological activators of SAR

- Plant extracts
  - Knotweed (*Polygonum sachalinense*)
  - Neem (*Azadirachta indica*)
  - Ivy (*Hedera helix*)
- Fungi
  - *Trichoderma* spp.
  - *Verticillium dahliae* (DutchTrig®)
- Bacteria
  - *Bacillus subtilis*
  - *Pseudomonas fluorescens*

Giant knotweed

Photo: Thurston Co. Noxious Weed Control Agency

Summary

- SOD is starting to spread from nurseries to landscapes in the PNW, but early detection and eradication will keep it at low levels
- Diseases like SOD and madrone canker can be treated with “plant activators” inducing SAR
- This will reduce chemical fungicide applications and protect trees from a range of pathogens

Visit our website

WSU Puyallup Ornamental Plant Pathology

http://www.puyallup.wsu.edu/ppo/

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