

Root Rot Rudiments

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What is killing these trees?



2000 Root Rot Survey



Root rots on Noble fir trees in 2000

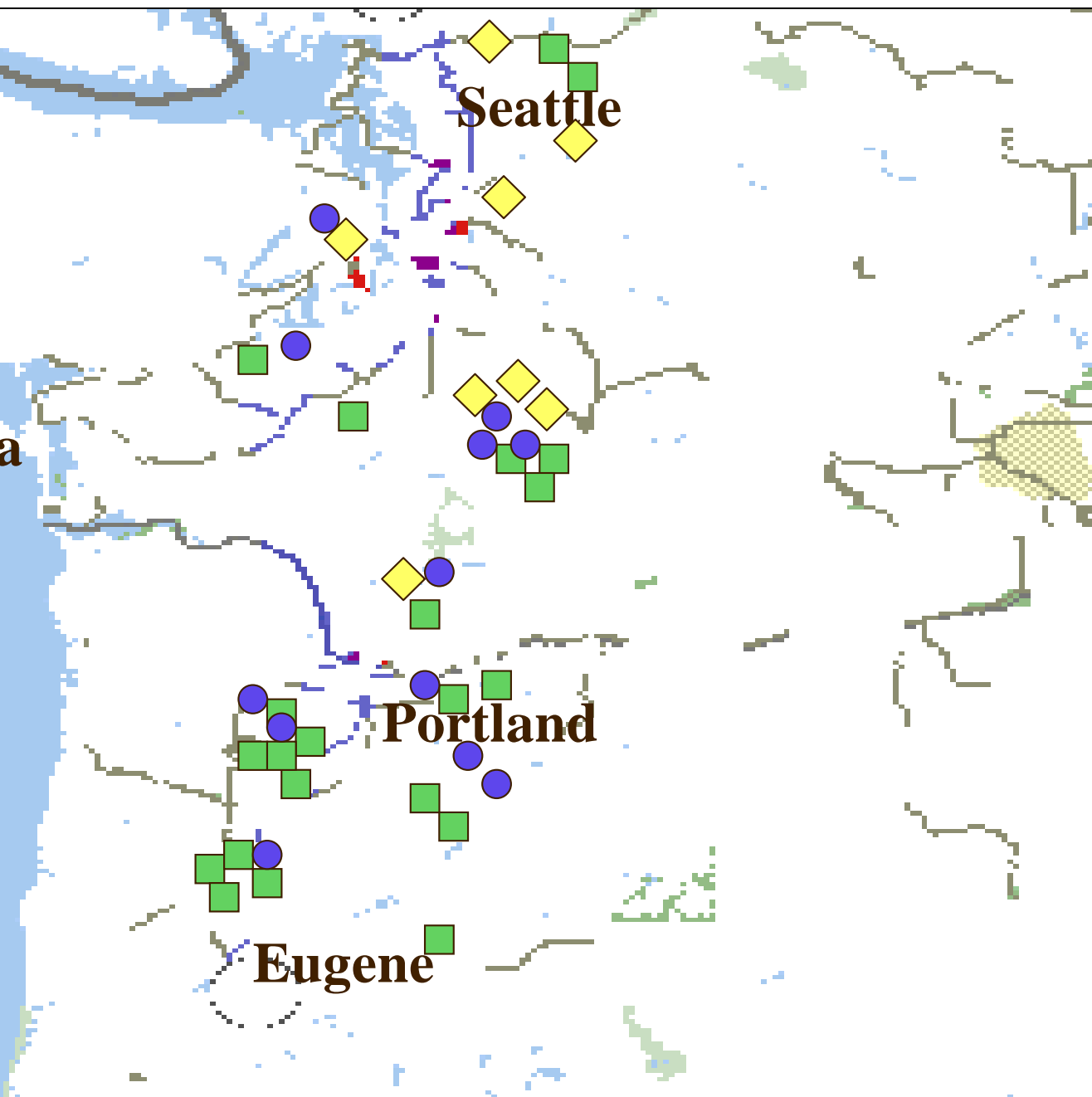
Of the 67 plantations surveyed, trees with suspected root rot problems were present in 57 plantations

Phytophthora, Annosus and Armillaria root rot accounted for about 83% of the dead and dying trees in these plantations

Root disease incidence ranged from <1 to 30%

Distribution of Root Rot Diseases in 2000 Noble fir Survey

- ◆ Armillaria
- Phytophthora
- Annosus



Root Rot Summary

- **The most common root rots on true firs in the PNW are Phytophthora, Annosus, and Armillaria root rot**
- **Annosus and Armillaria root rot have increased during the past 20 years**
- **Growers need to utilize an integrated approach to manage these diseases if they are going to sustain the production of true fir Christmas trees**

Disease Diagnosis and Management

Root Rots and Stem Cankers

Phytophthora root rot and canker

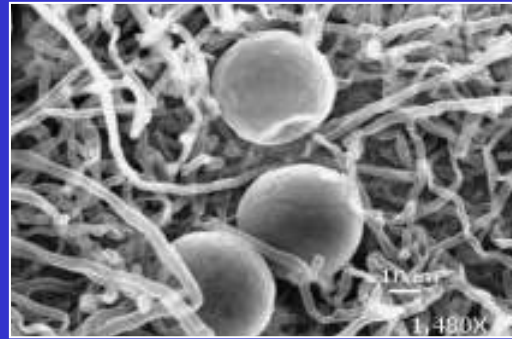
Armillaria root rot

Annosus root rot

Phytophthora Root Rot & Stem Canker



Typical *Phytophthora* Life Cycle



Survives as thick walled **chlamydospores**

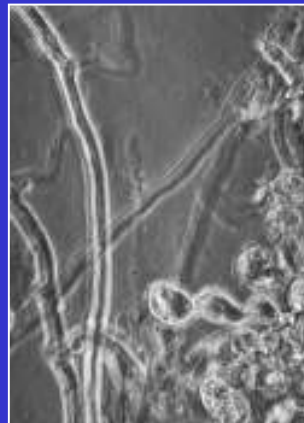
Sporangia produce swimming **zoospores** which infects hosts



Thick walled sexual **oospores**



Symptoms result from **mycelial** growth in host tissue



Identification of Phytophthora root rot



Stem canker



Root rot

***Phytophthora* occurs in areas with poor soil drainage and can infect seedlings in the nurseries and transplant beds**



Eight *Phytophthora* spp. have been associated with diseased trees in the Pacific Northwest

P. cactorum

P. cryptogea

P. cambivora

P. ganopodyides

P. citricola

P. megasperma

P. cinnamomi

P. pseudotsugae

Identification of Phytophthora root rot



Overhead irrigation of trees with contaminated water can result in direct infection of branches by *Phytophthora*



Phytophthora spp. on noble fir Christmas trees¹

Species	% of plantations	% of trees
<i>P. cambivora</i>	27.6	22
<i>P. megasperma</i>	17.2	24
<i>P. ganopodyides</i>	13.8	10
<i>P. cryptogea</i>	10.3	8
<i>P. citricola</i>	6.8	8
<i>P. cactorum</i>	6.8	8
<i>P. cinamomi</i>	6.8	4
Unknown	17.2	20

¹ Includes multiple infections. Chastagner et al. 1995. Plant Disease 79:290-293.

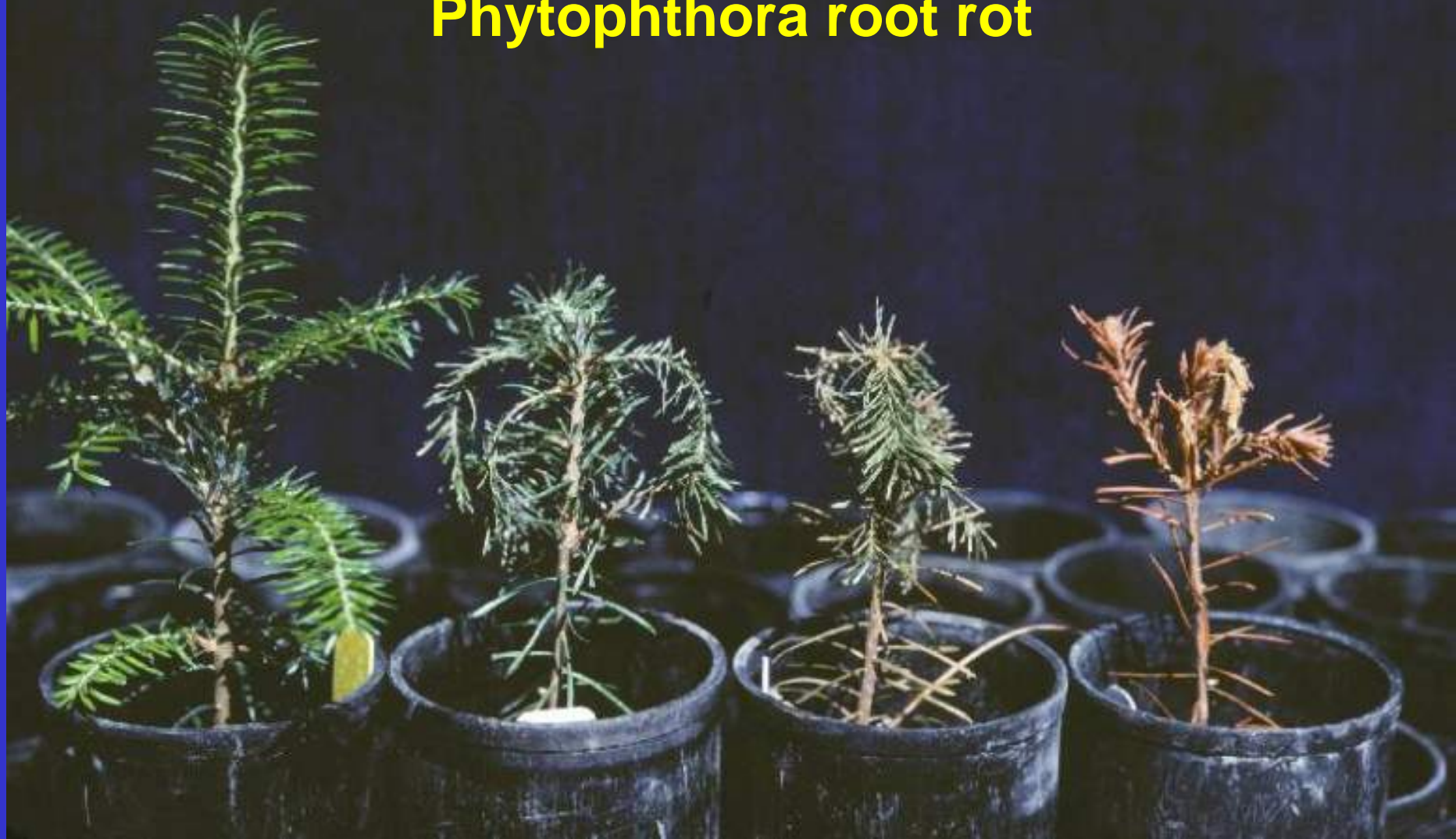
Overall pathogenicity of *Phytophthora* spp. on 13 true firs.

Species	Disease rating ¹	
	1-0 seedlings	2-0 seedlings
<i>P. cryptogea</i>	4.0 a	2.6 b
<i>P. cinnamomi</i>	3.5 b	2.9 a
<i>P. cambivora</i>	1.8 cd	0.8 c
<i>P. cactorum</i>	2.0 c	0.6 cd
<i>P. gonapodyides</i>	1.6 cd	0.4 d
<i>P. pseudotsugae</i>	1.6 cd	0.3 de
<i>P. megasperma</i>	1.5 cd	0.2 e
Check	1.3 d	0.1 e

¹ Disease rated on a scale of 0-5, where 0=0-20%, 1=11-25%, 2=26-50%, 3=51.75%, 4=>75% rotted roots after 10 weeks, and 5=dead by 7 weeks.



**Most true firs are very susceptible to
Phytophthora root rot**



Overall susceptibility of true firs to *Phytophthora* spp. found on noble fir.

True fir	Mortality (%) ¹	
	1-0 seedlings	2-0 seedlings
Noble	43.8 a	25.0 a
Balsam	37.5 ab	7.5 cd
Grand	34.4 abc	17.5 ab
California Red	31.3 abc	-
Shasta	34.4 abc	-
Korean	27.5 abc	5.0 cd
Nikko	20.8 cd	11.3 bc
Fraser	18.8 cde	17.5 ab
White	18.8 cde	18.8 ab
Turkish	9.4 def	7.5 cd
E. silver	3.1 ef	3.8 cd
Veitch	3.1 ef	1.3 d
Nordmann	0.0 f	-

¹ After 10 weeks.

Susceptibility of six true firs to *Phytophthora cinnamomi* (Benson et al, 1998. Biological and Cultural Tests 13:57).

Host	Foliage rating ¹	
	Exp. I	Exp. II
Fraser fir	4.0 a	4.0 a
Canaan fir	4.0 a	3.9 a
Korean fir	3.6 a	2.7 b
Nordmann fir	3.1 b	2.7 b
Turkish fir	1.4 c	1.7 c
Momi fir	1.4 c	1.2 d

¹ Rating: 1="healthy", 2=chlorotic, 3=necrotic, and 4=dead.

Susceptibility of Fraser, Momi, and Siberian fir to *Phytophthora cinnamomi* (Hinesley et al. 2000 HortScience 35(1):87-88)

Host	Top rating ¹		Root rating ²	
	Inoculated	Check	Inoculated	Check
Fraser	4.0 a	1.1 a	5.0 a	2.5 a
Siberian	4.0 a	1.0 a	5.0 a	1.2 a
Momi	1.2 b	1.2 a	2.6 b	1.2 a

¹ Rating: 1=healthy, 2=sl. chlorotic, 3=severely necrotic, and 4=dead after 12 weeks.

² Rating: 1=healthy, 2=1-10%, 3=11-25%, 4=26-50%, and 4=>50% root rot.



Spread of *Phytophthora* root rot

- Infected seedlings
- Contaminated soil
- Water



Irrigation of Transplant Beds





Management of Phytophthora root rot

Fungicides

Nurseries – Reduce disease development and the number of new infections, and increase the number of healthy roots.

Plantations – Effects of fungicides are highly variable. Limited benefit in most studies.

Management of Phytophthora Root Rot

- Plant healthy seedlings
- Plant resistant species or use resistant species as rootstock
- Improve drainage
 - Site selection
 - Drain tile
 - Raised beds



Management of Phytophthora Root Rot

Plant resistant species or use resistant species as rootstock?



Some true firs are very susceptible to
Phytophthora root rot

C-102 Phytophthora Root Rot Susceptibility

- Established in 2002 at WSU Puyallup
- Seven species
 - Balsam fir
 - Grand fir
 - Fraser fir
 - Noble fir
 - Nordmann fir
 - Shasta fir
 - Turkish fir



C-102 Phytophthora Root Rot Susceptibility



**Nordmann
fir**

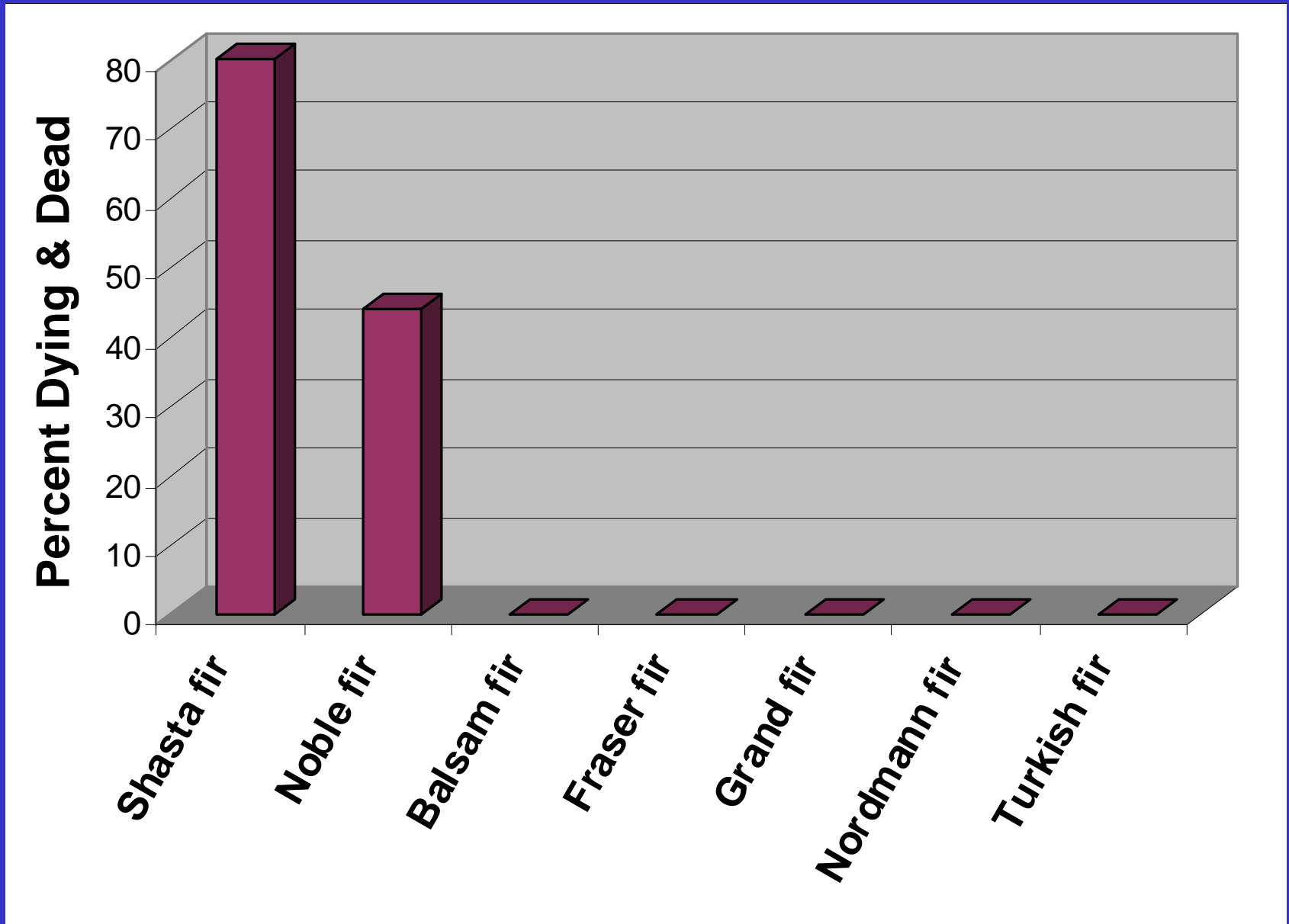
Noble fir



Shasta fir



C-102 Phytophthora Root Rot Susceptibility



PH-306 Phytophthora Root Rot Susceptibility

- Established in 2006 at WSU Puyallup
- Four species
 - Fraser fir
 - King Boris fir
 - Noble fir
 - Nordmann fir
 - Borshomi (3 elevations)
 - Thuji (3 elevations)

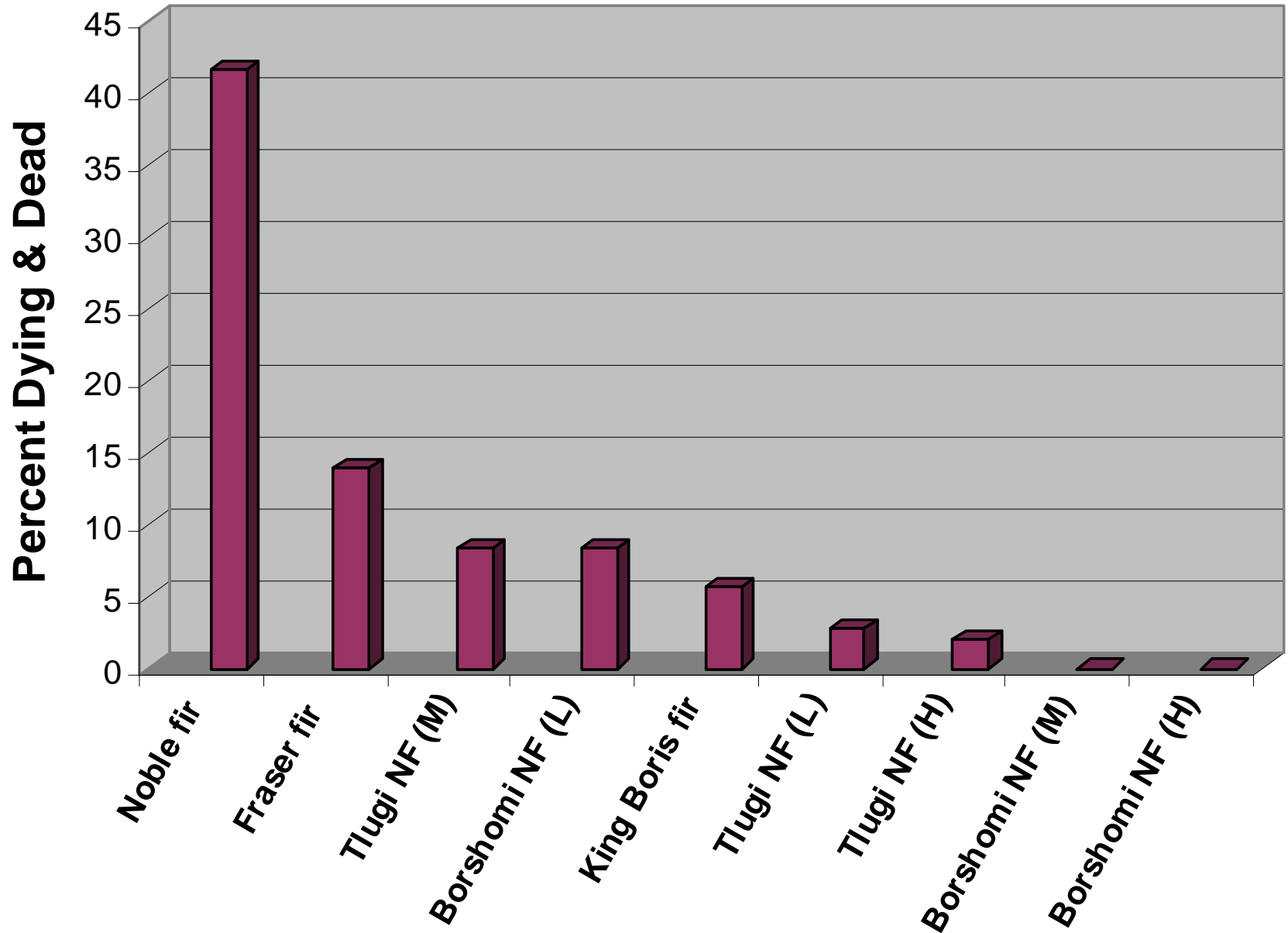


PH-306 Phytophthora Root Rot Susceptibility



Noble fir

PH-306 Phytophthora Root Rot Susceptibility



PH-104 Variation in susceptibility of various true firs to *Phytophthora* root rot



PH-104 Variation in susceptibility of various true firs to *Phytophthora* root rot

- 41 of families included in the 2004 OSU noble fir progeny test plantings
- 25 of Nordmann and Turkish firs included in the 2004 OSU/WSU Nordmann and Turkish fir progeny and provenance and the 2006 OSU Silvaseed provenance test plantings
- Single source of balsam, King Boris, Canaan, European silver, Fraser, grand, Korean, Momi, Nikko, Shasta, Veitch, and white fir.
- Inoculated with *Phytophthora cinnimomi*, *P. cactorum*, *P. cryptogea*, and *P. cambivora* in 2006 and 2007.

Flood Irrigation to Promote Root Rot



Armillaria Root Rot

Mostly *Armillaria ostoyae*



Identification of Armillaria root rot

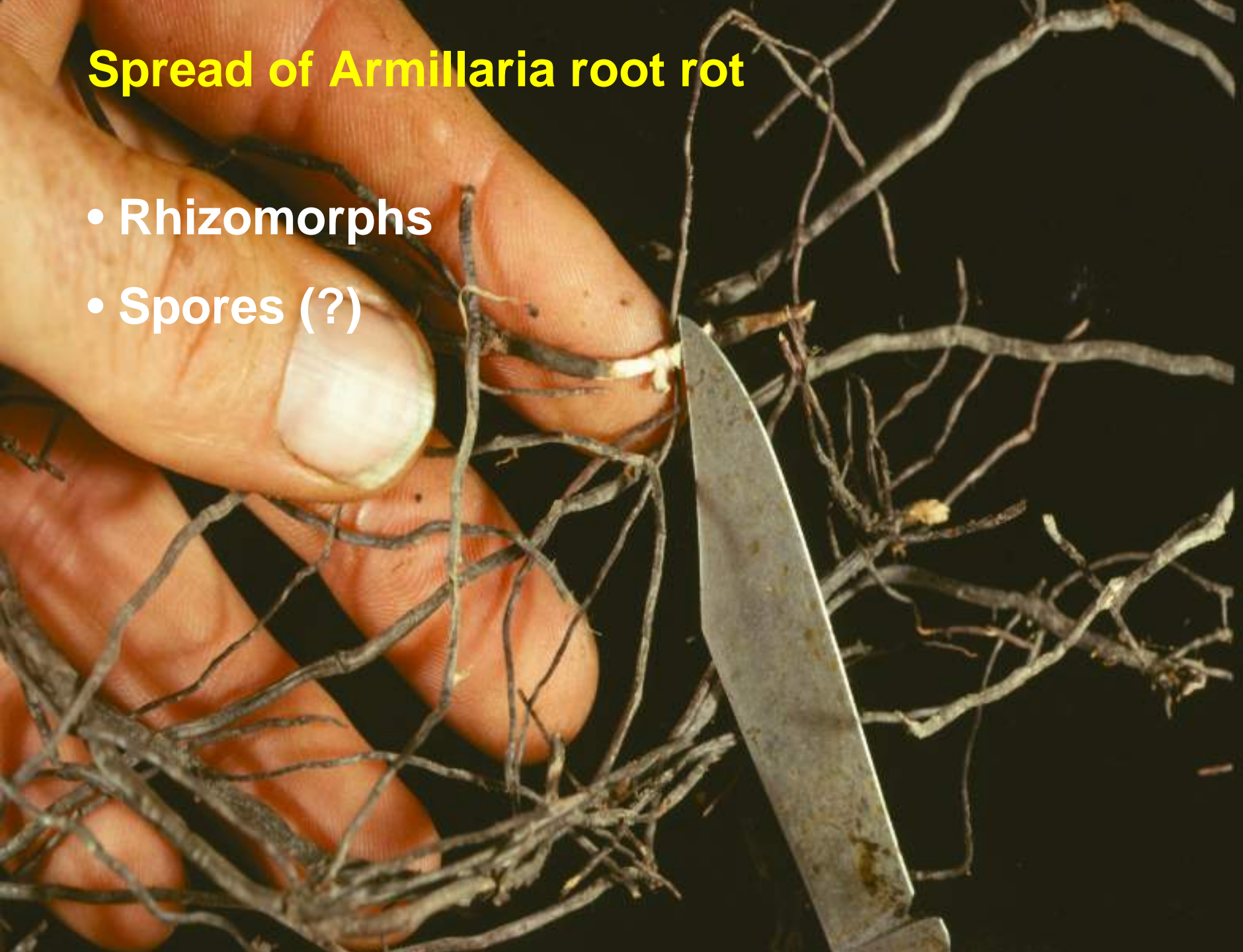


**Root like rhizomorphs
are diagnostic for the
presence of Armillaria
root rot**



Spread of Armillaria root rot

- Rhizomorphs
- Spores (?)



Management of Armillaria Root Rot

- Avoid planting in areas with a history of disease
- Avoid stress (moisture, nutrients, etc.)
- Use local seed sources
- Remove and destroy stumps and roots of diseased trees
- Use trenches to isolated infected trees



Annosus Root Rot

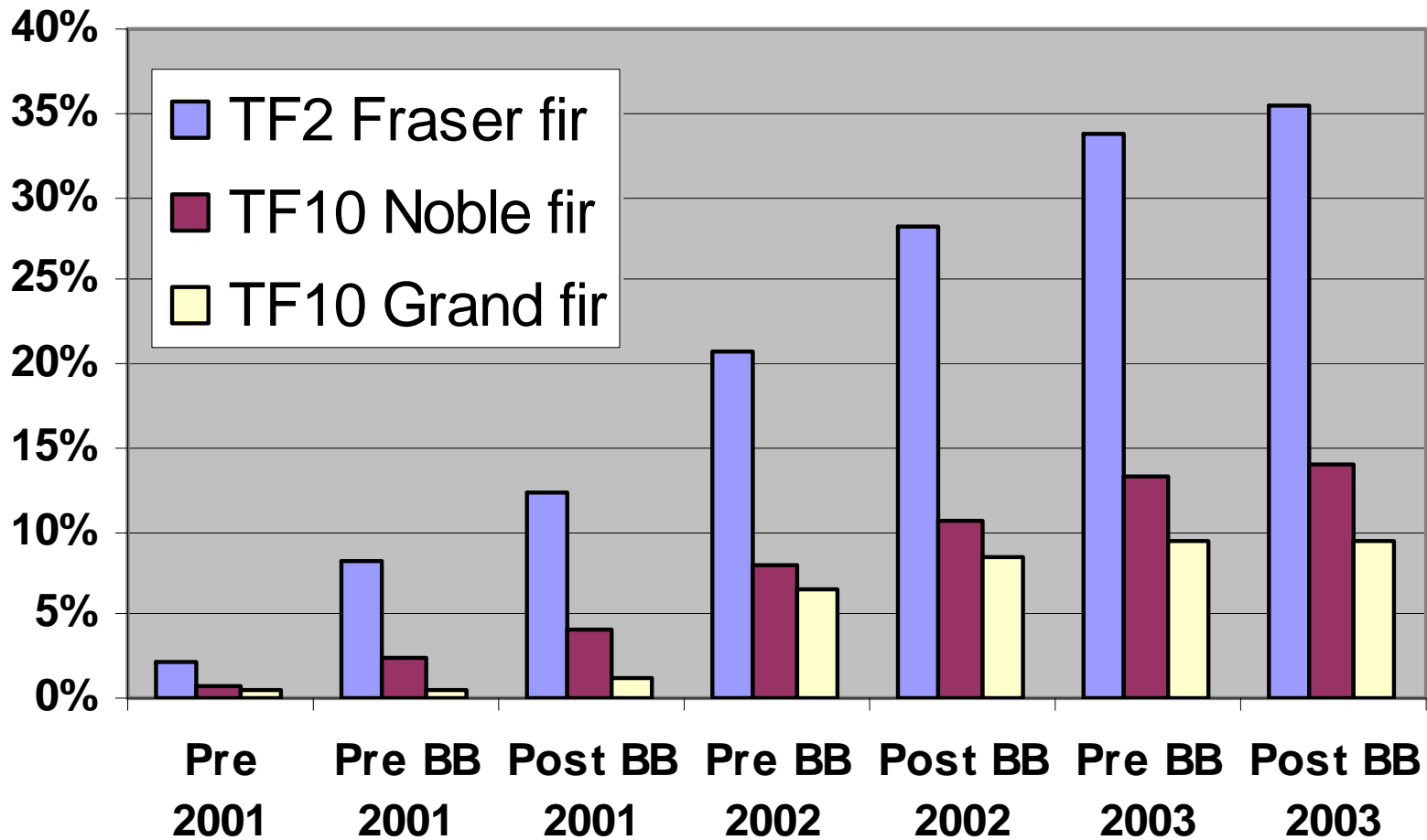
Heterobasidion annosum







Increase in mortality of Fraser, noble, and grand fir Christmas trees during 3 years



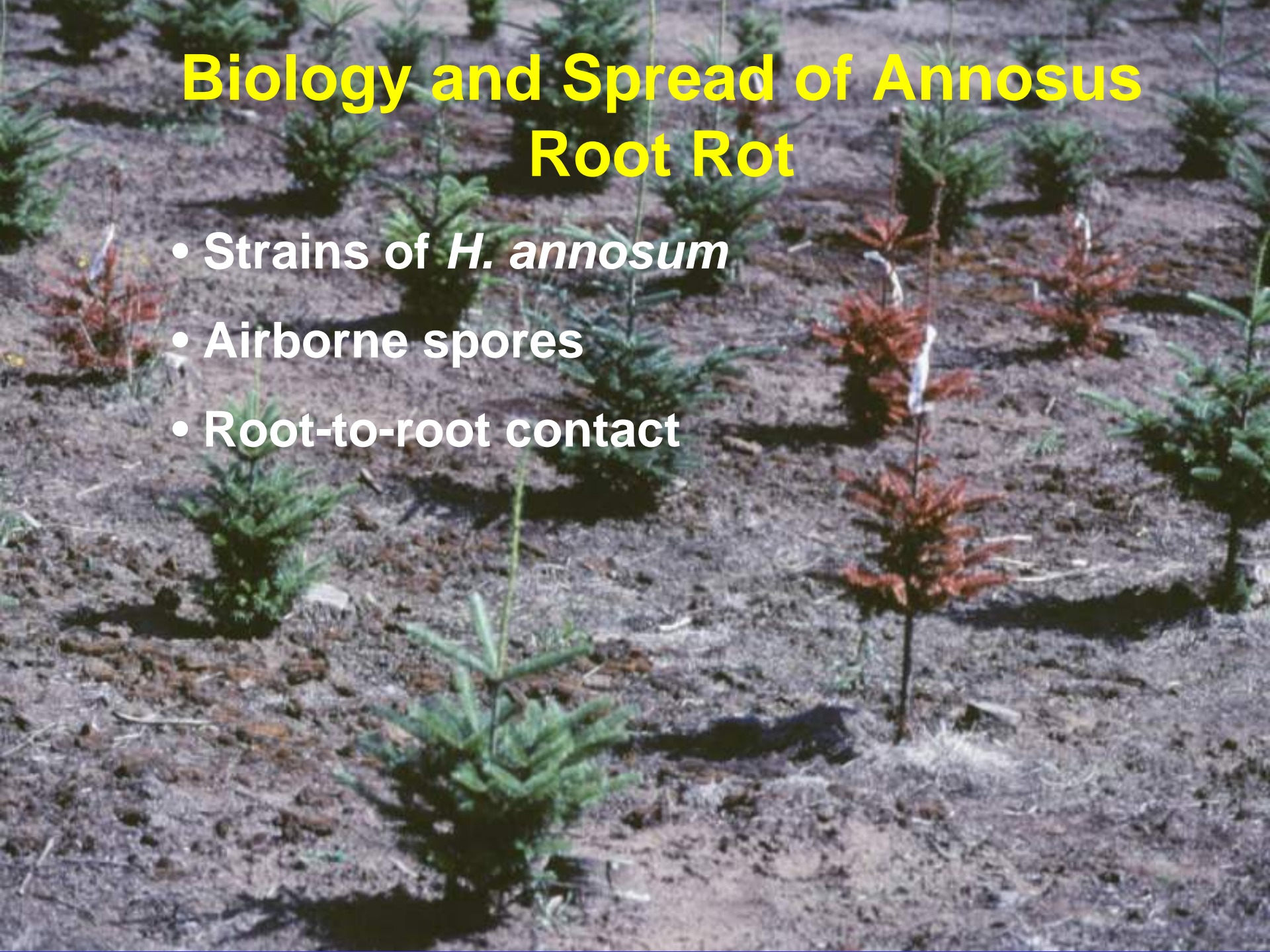


Extent of Staining on Harvested Trees



Biology and Spread of Annosus Root Rot

- Strains of *H. annosum*
- Airborne spores
- Root-to-root contact



Spread of Annosus Root Rot by Spores During Harvest





Numbers of *Heterobasidium annosum* spores trapped in one hour during harvest.

No. of spores per m²

Site	Nov 21	Nov 26	Dec 5	Dec 13	Dec 19	Dec 26
1 (OR)	560.2	-	-	-	-	-
2 (WA)	5,513.0	827.6	3,972.4	776.7	611.1	509.3
3 (WA)	10,058.3	1,922.5	4,660.0	1,107.7	674.8	751.2
4 (WA)	3,233.9	3,246.7	1,438.7	738.5	649.3	598.4
5 (WA)	1,871.6	1,069.5	1,171.3	3,017.5	980.4	700.3

Average based on 10 plates per site on each sample date.



Effectiveness of stump treatments to protect stumps from infection by spores



Potential Stump Treatments



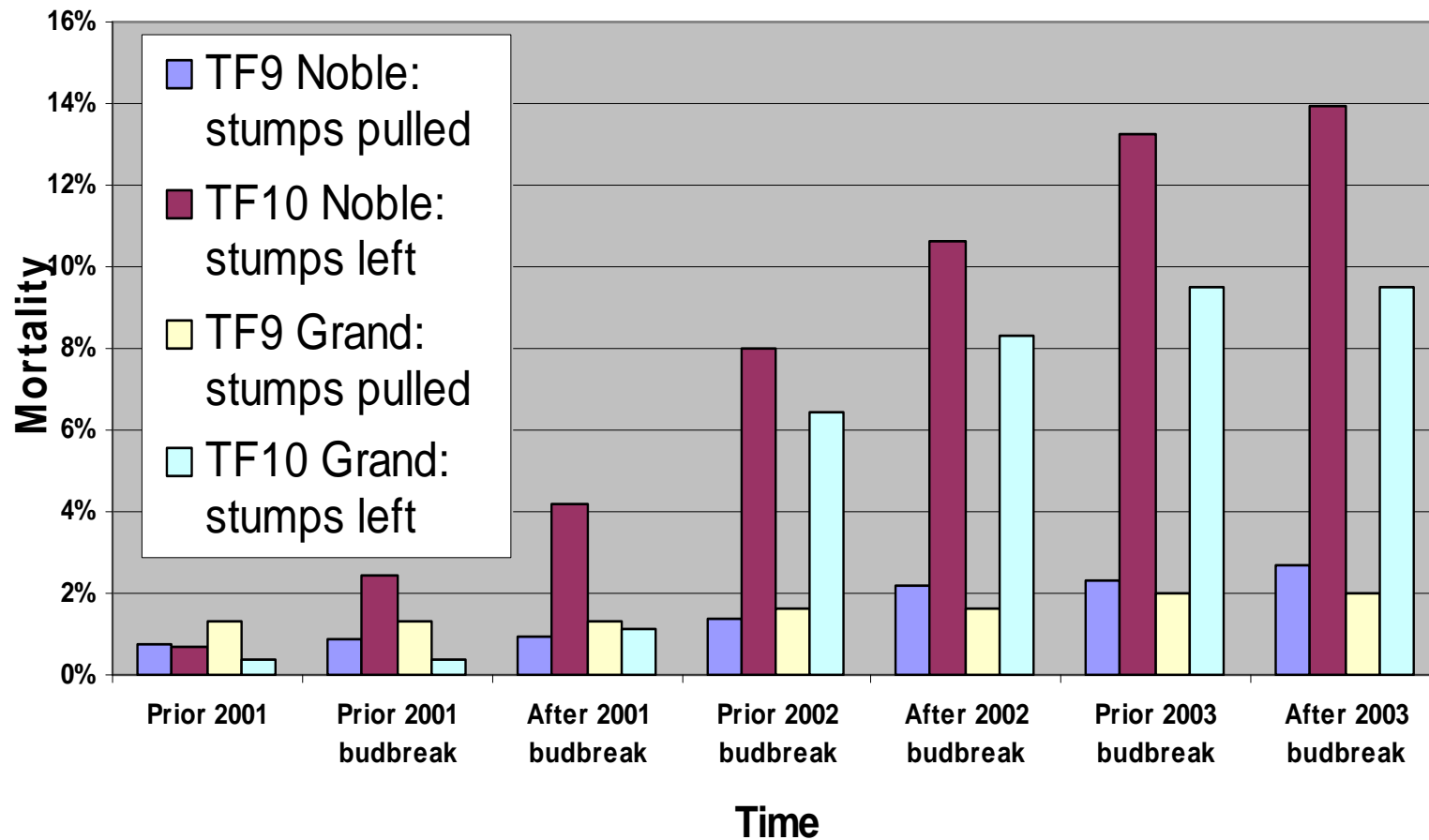
- Sporax
- Urea spray (20%)
- Soil



Effectiveness of Stump Removal in Limiting Disease Development



Effect of stump removal prior to replanting on the accumulative mortality of PNW Christmas trees due to annosus root rot



Estimated increase in the numbers of healthy trees per acre associated with stump removal

Species	2001-2003 period	Total since planting
Noble fir	146 ¹	228
Fraser fir	87	227
Grand fir	98	103

¹ Assumes planting density of 1,300 trees per acre



Estimated increases in the numbers of healthy trees per acre associated with stump removal.

Species	2001-2003 period	Total losses(%)
Noble fir	146¹	228
Fraser fir	87	227
Grand fir	98	103

¹Assumes planting density of 1,300 trees per acre

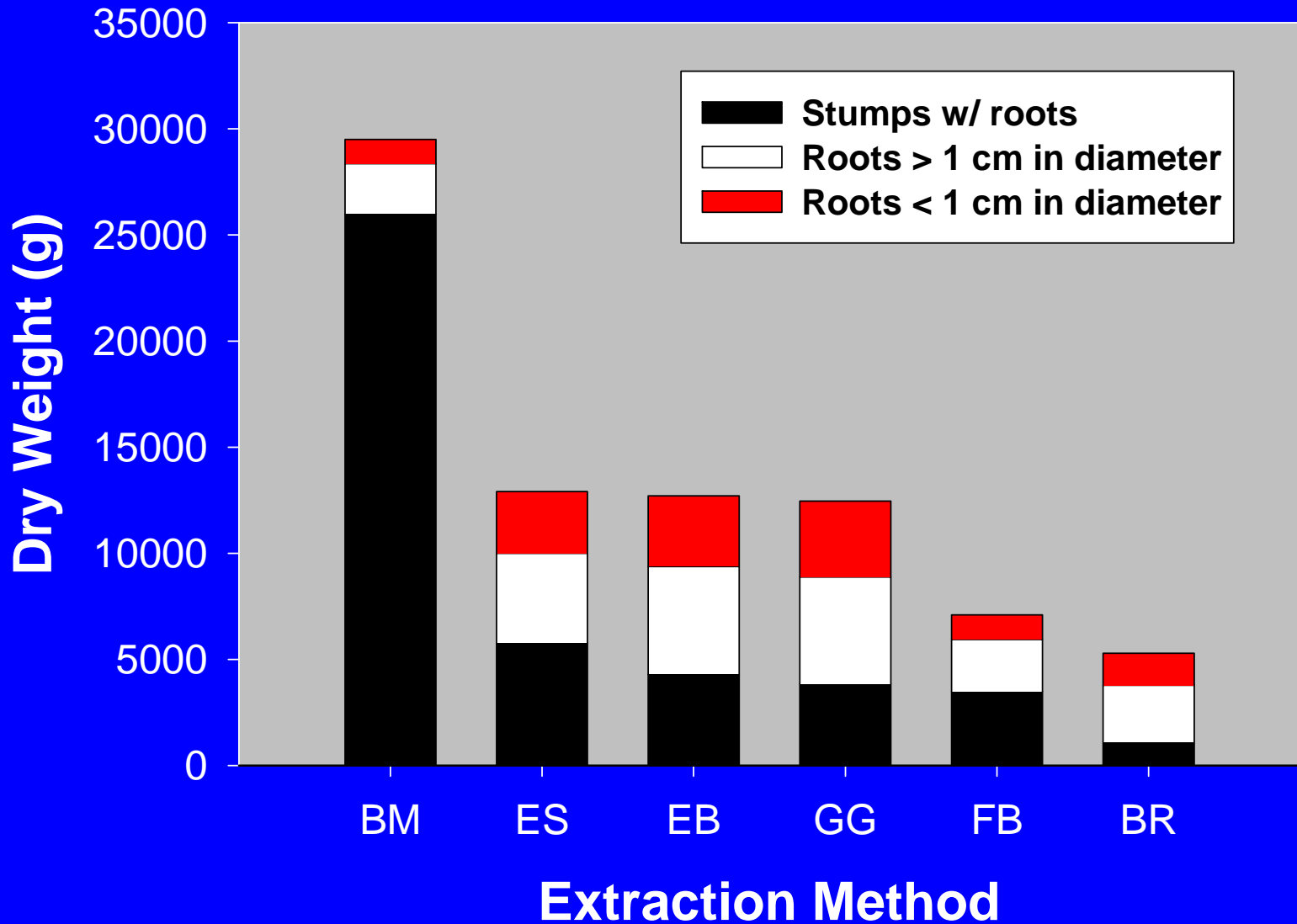






Track hoe with a “brush rake”

Effect of Extration Method on The Amount of Stumps and Roots Left In The Soil



Are some species resistant to Annosus root rot?



Nordmann fir (?)



Management of Annosus root rot

- Plant resistant trees
- Monitor for disease at harvest
- Treat freshly cut stumps to prevent spore infection
- Prevent root-to-root spread of disease
 - Removal of stumps and roots

Thank You

Note: Always check the label prior to application of any pesticide to make sure you are using properly registered products in your disease management program.

Questions?

