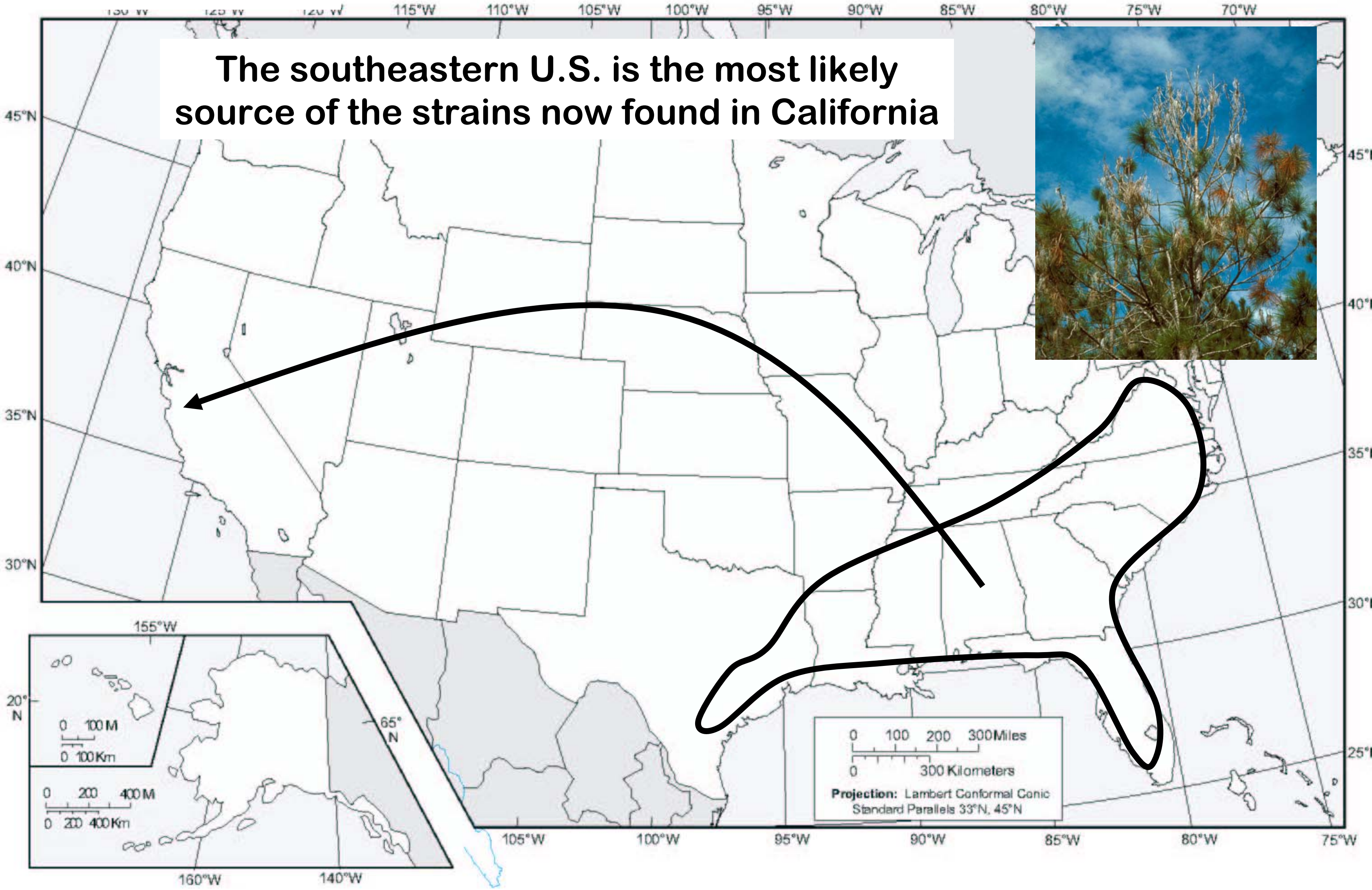
Some of the things we have learned about pitch canker in California

Proximate origin of the infestation

Means by which the pathogen was introduced and disseminated

Nature of the risk to coniferous forests in California



Hepting, G.H. and Roth, E.R. 1946. Pitch canker, a new disease of some southern pines. J. For. 44:742-744.

California and Florida isolates share the same multi-locus haplotype

Isolate	Location	Haplotype
FSP 74	California	AAABAAAA
FL 1	Florida	AAABAAAA
FSP 132	California	BAABAAAA
FL 52	Florida	BAABAAAA

Wikler, K. and Gordon, T.R. 2000. An initial assessment of genetic relationships among populations of *Fusarium circinatum* in different parts of the world. Canadian Journal of Botany 78:709-717.

An initial assessment of genetic relationships among populations of *Fusarium circinatum* in different parts of the world

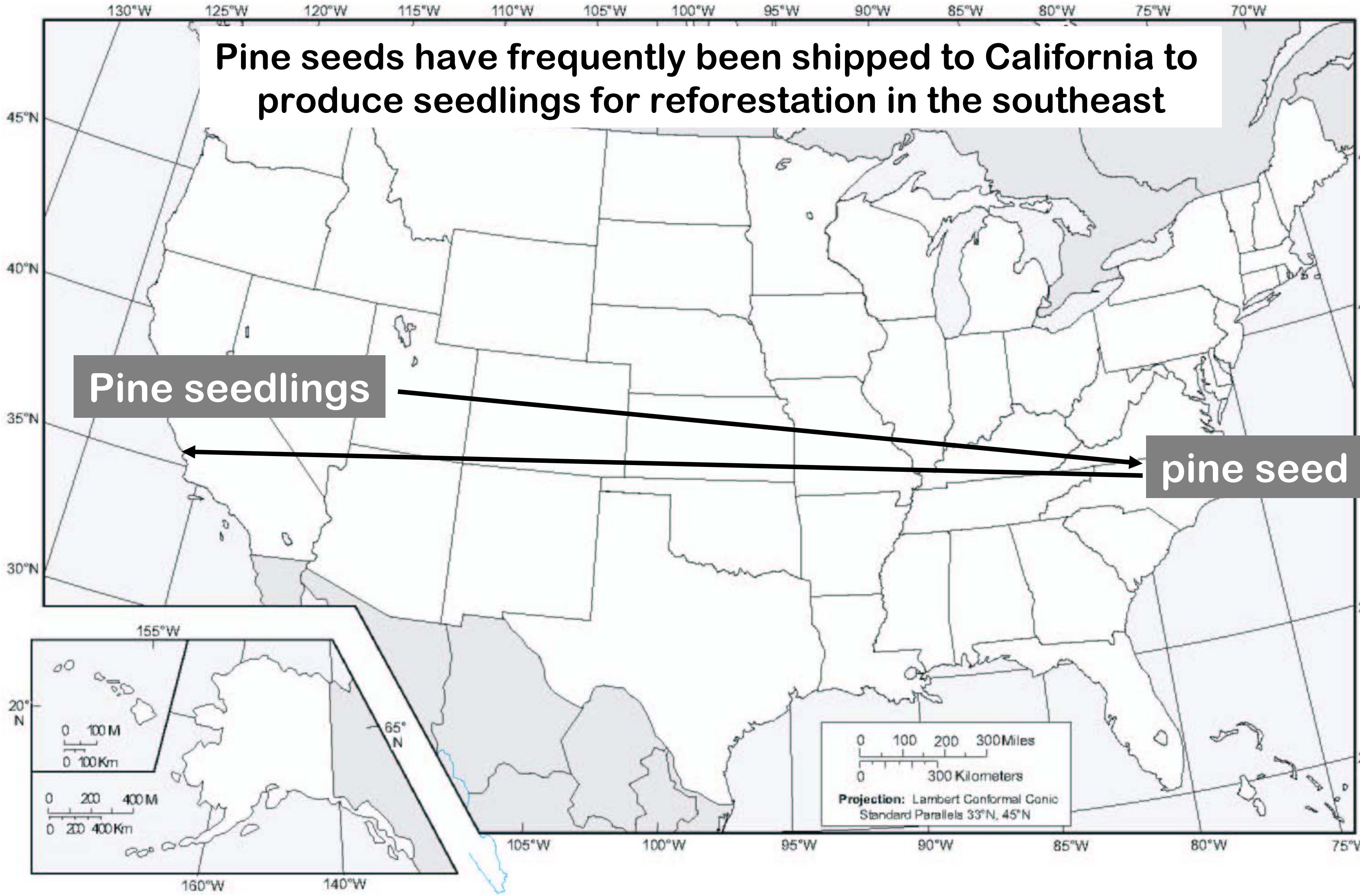
Karen Wikler and Thomas R. Gordon

Abstract: *Fusarium circinatum* Nirenberg & O'Donnell, the fungus responsible for pitch canker disease, is a destructive pathogen of *Pinus* spp. Pitch canker was first described in 1946 in the southeastern United States, and since 1987 has been reported in numerous other locations including California, Mexico, Japan, and South Africa. To make a preliminary assessment of relationships between populations of *F. circinatum* in these different locations, we compared allele and genotype frequencies based on eight polymorphic regions of DNA from 76 isolates of the fungus. Patterns of relatedness indicate that the California and Japanese populations of the fungus share lineages with the southeastern U.S.A. population. Genetic diversity is highest in Mexico, implicating it as the center of origin for the fungus. The association of multiple vegetative compatibility groups with a common multilocus genotype suggests that vegetative compatible group diversity may be generated by mutation, rather than through recombination resulting from sexual reproduction.

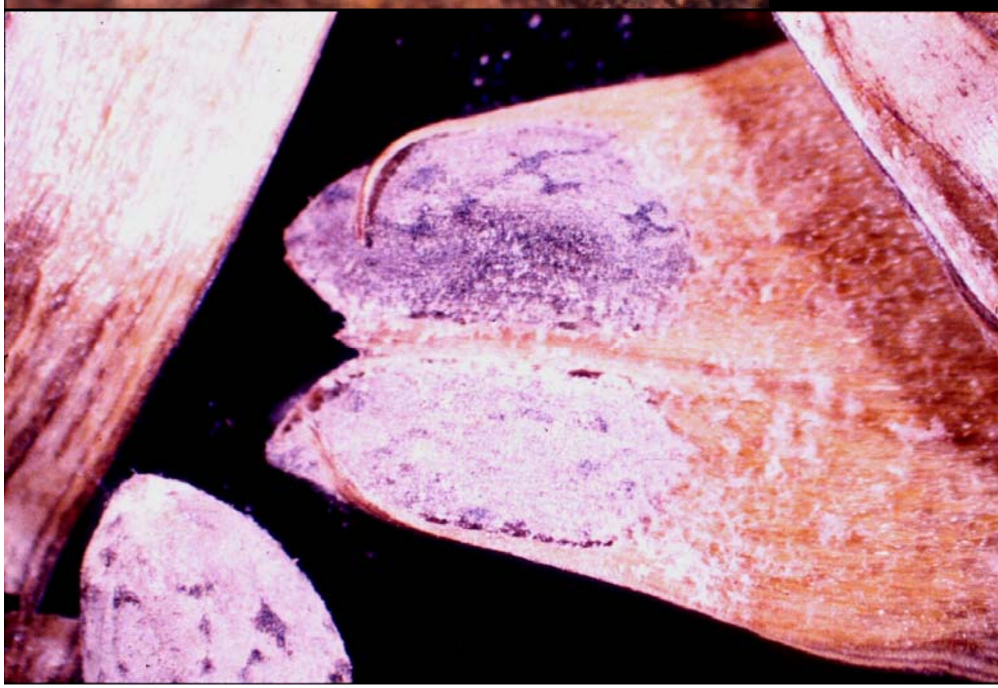
A similar study conducted in South Africa reached the same conclusions

The most likely vehicle for transport of the pathogen is seed

The pathogen is seedborne in southern pines

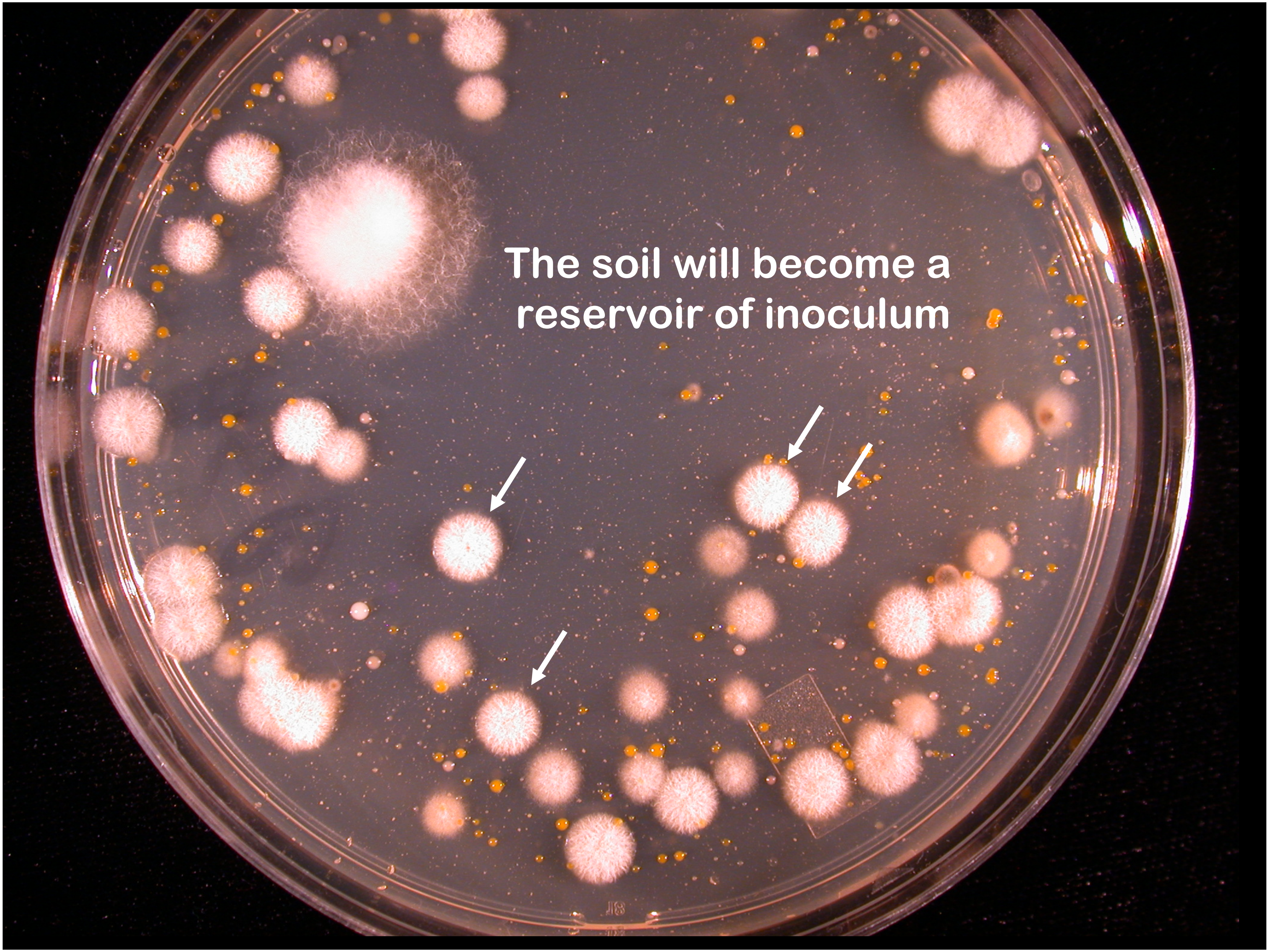


Pine seeds have frequently been shipped to California to produce seedlings for reforestation in the southeast
Pine seedlings
pine seed
0 100 200 300 Miles
0 300 Kilometers
Projection: Lambert Conformal Conic
Standard Parallels 33°N, 45°N



Where infested seed is sown, some seedling mortality will occur

The pathogen will produce spores on infected seedlings

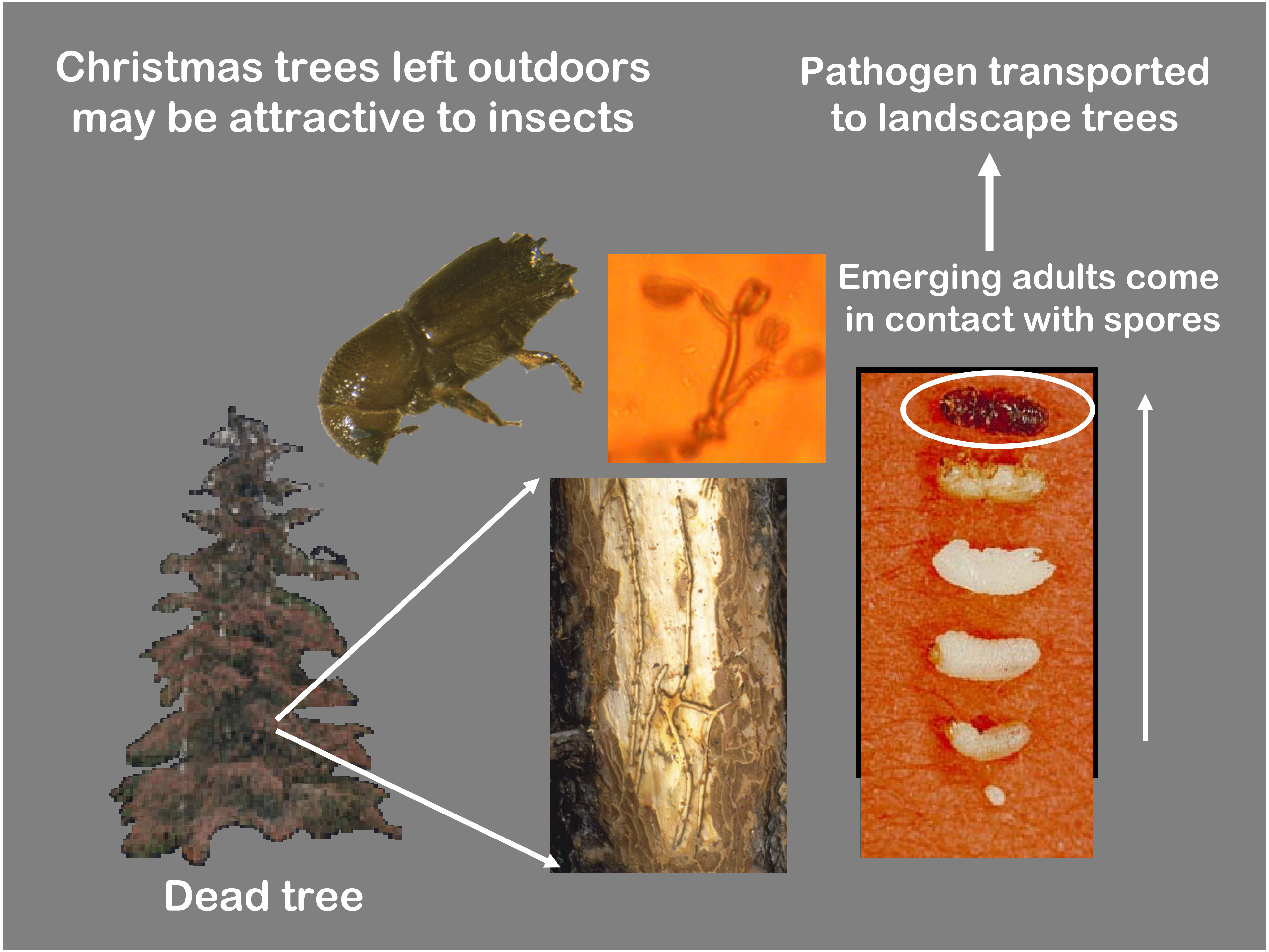

The soil will become a
reservoir of inoculum

If Monterey pines are grown in infested soil, some seedlings will become infected but remain symptomless

Movement of infected but symptomless trees


Establishment at Christmas tree farms

Pre-symptomatic trees allowed the pathogen to be distributed over a wide area


Christmas trees left outdoors may be attractive to insects
Pathogen transported to landscape trees
Emerging adults come in contact with spores
Dead tree

Emergent twig beetles can go directly to declining branches to breed but cannot identify such branches prior to landing. Consequently, they may land on healthy branches and wound them in the process of ‘tasting’ to assess the suitability of the substrate. If the beetle is carrying spores of the pitch canker pathogen, it can serve as a vector

Healthy branches

Breed in weakened branches

Incidence of the pitch canker pathogen and associated insects in intact and chipped Monterey pine branches

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The Canadian Entomologist **134**: 47 – 58 (2002)

This study documents that a high percentage of twig beetles emerging from infected branches will carry the pathogen

The role of olfactory stimuli in the location of weakened hosts by twig-infesting *Pityophthorus* spp.

PIERLUIGI BONELLO,[1] WILLIAM R. MCNEE,[2]
ANDREW J. STORER,[2] DAVID L. WOOD[2] and
THOMAS R. GORDON[1] [1]Department of Plant Pathology, University of California, Davis and [2]Department of Environmental Science, Policy and Management, Division of Insect Biology, University of California, Berkeley, U.S.A.

This study documents that twig beetles cannot locate declining branches prior to landing

The role of *Pityophthorus* spp. as vectors of pitch canker affecting *Pinus radiata*

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This study documents that twig beetles can create wounds that will serve as infection courts

Twig beetles, *Pityophthorus* spp. (Coleoptera: Scolytidae), as vectors of the pitch canker pathogen in California

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This study documents that using pheromones to attract twig beetles will result in a higher incidence of infection

Logs moved by campers contributed to spread of the disease

Mycol Res. **100** (7): 850–854 (1996) *Printed in Great Britain*

Population structure of the pitch canker pathogen, *Fusarium subglutinans* f. sp. *pini*, in California

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Department of Environmental Science, Policy and Management, University of California, Berkeley, CA 94720, U.S.A.

This study showed that the population structure of the pathogen in California was consistent with the aforementioned means of dispersal

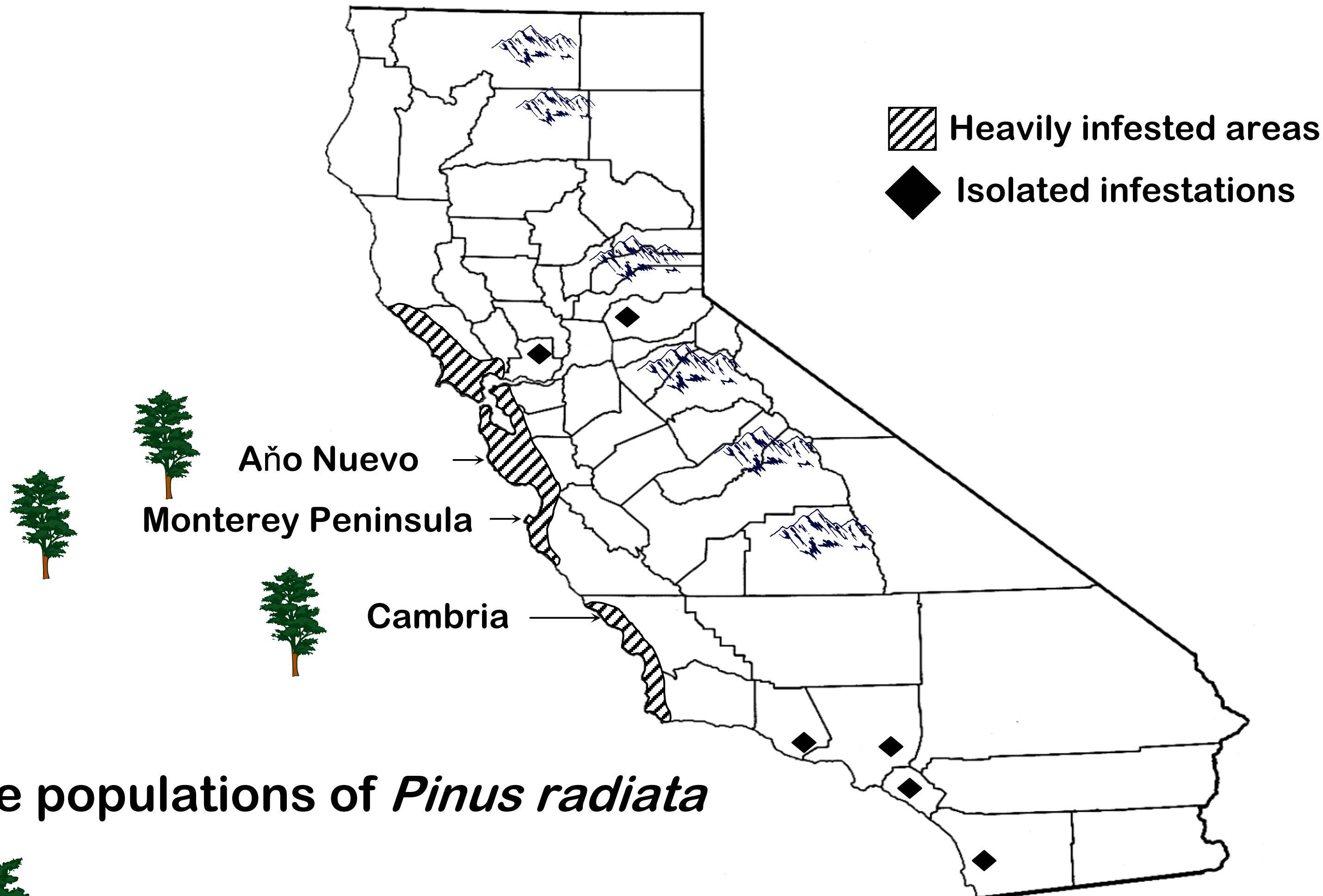
Pitch canker in California

Origin

Dissemination

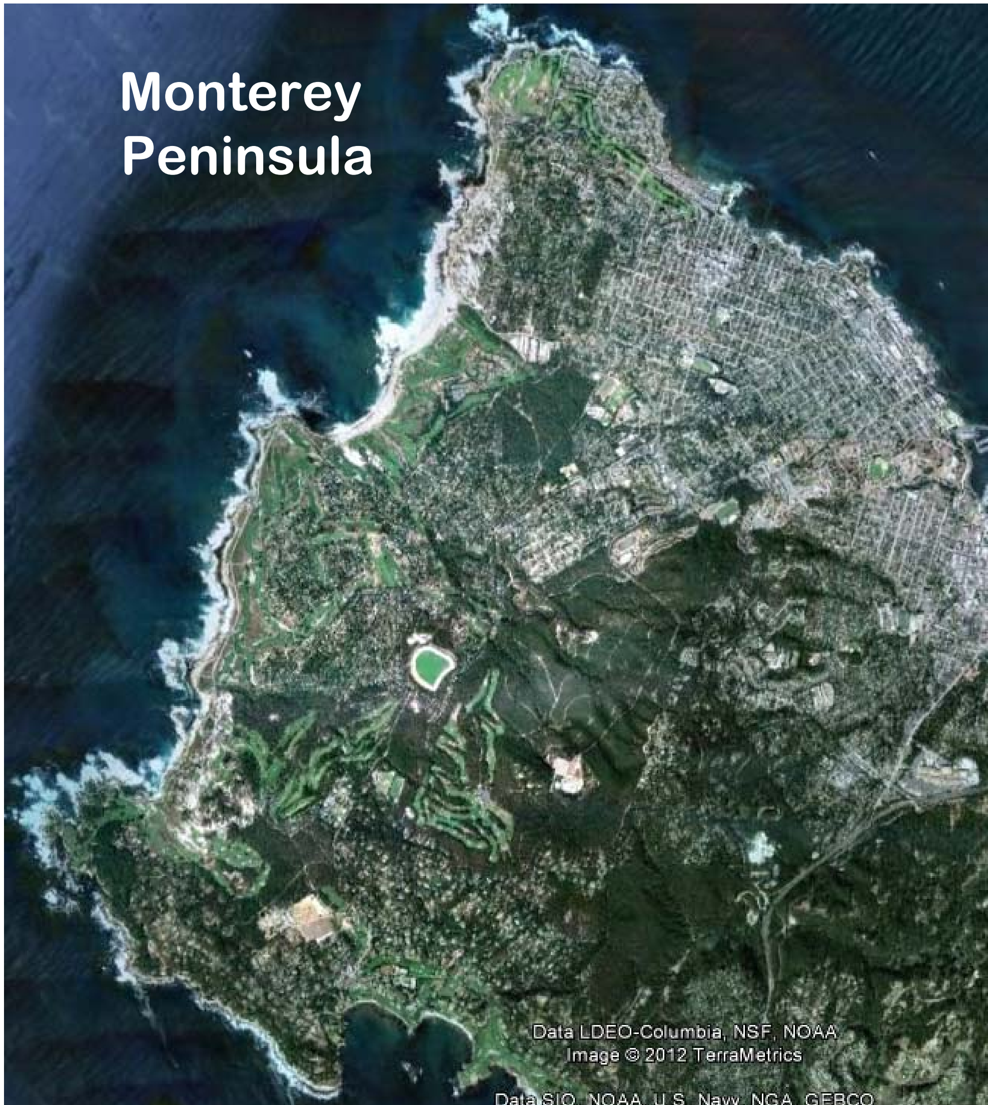
Risk assessment

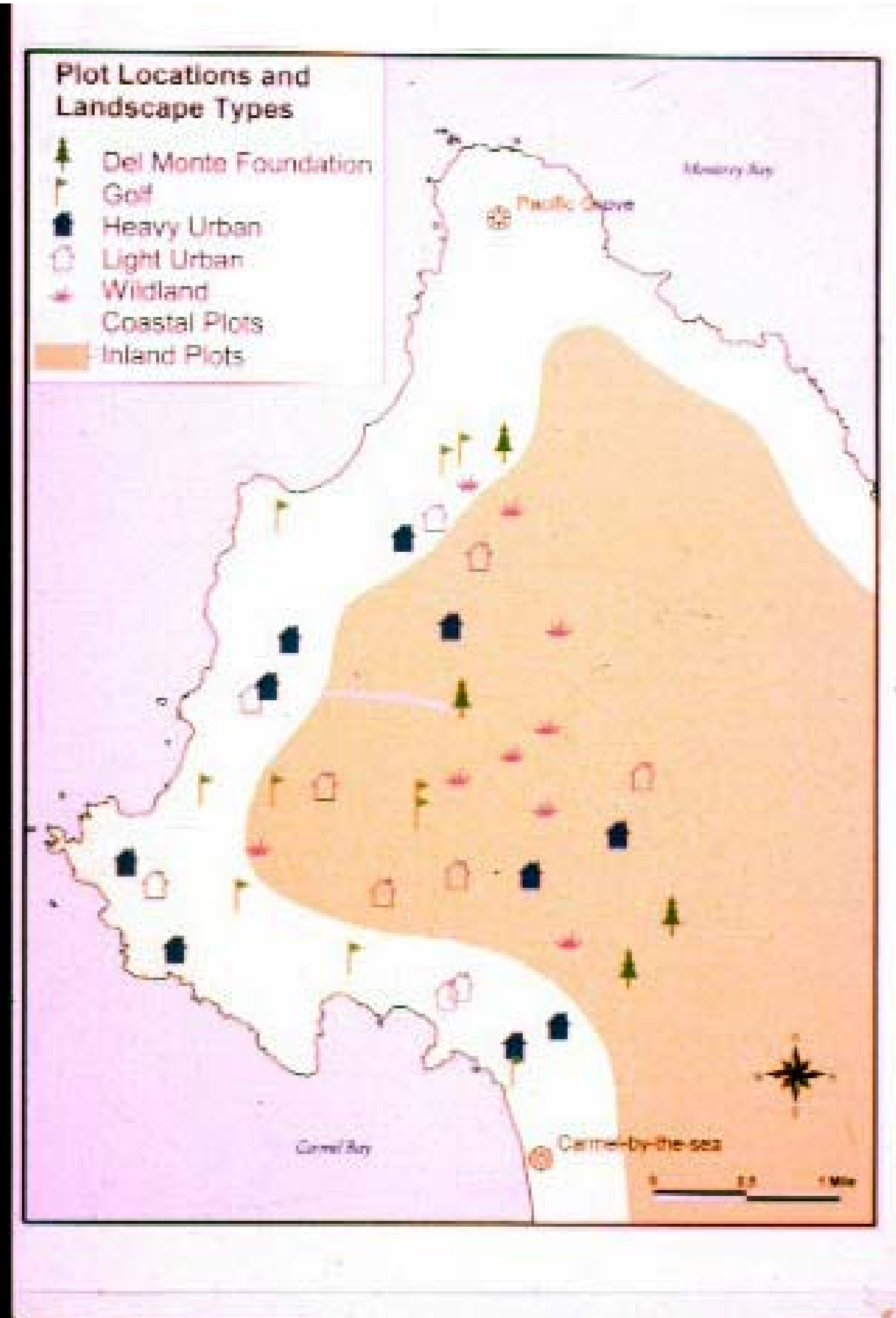
Geographic range of the pathogen



Native populations of *Pinus radiata*

Why is pitch canker restricted to the coast?





Monitoring plots were established in 1996

The dynamics of an introduced pathogen in a native Monterey pine (*Pinus radiata*) forest

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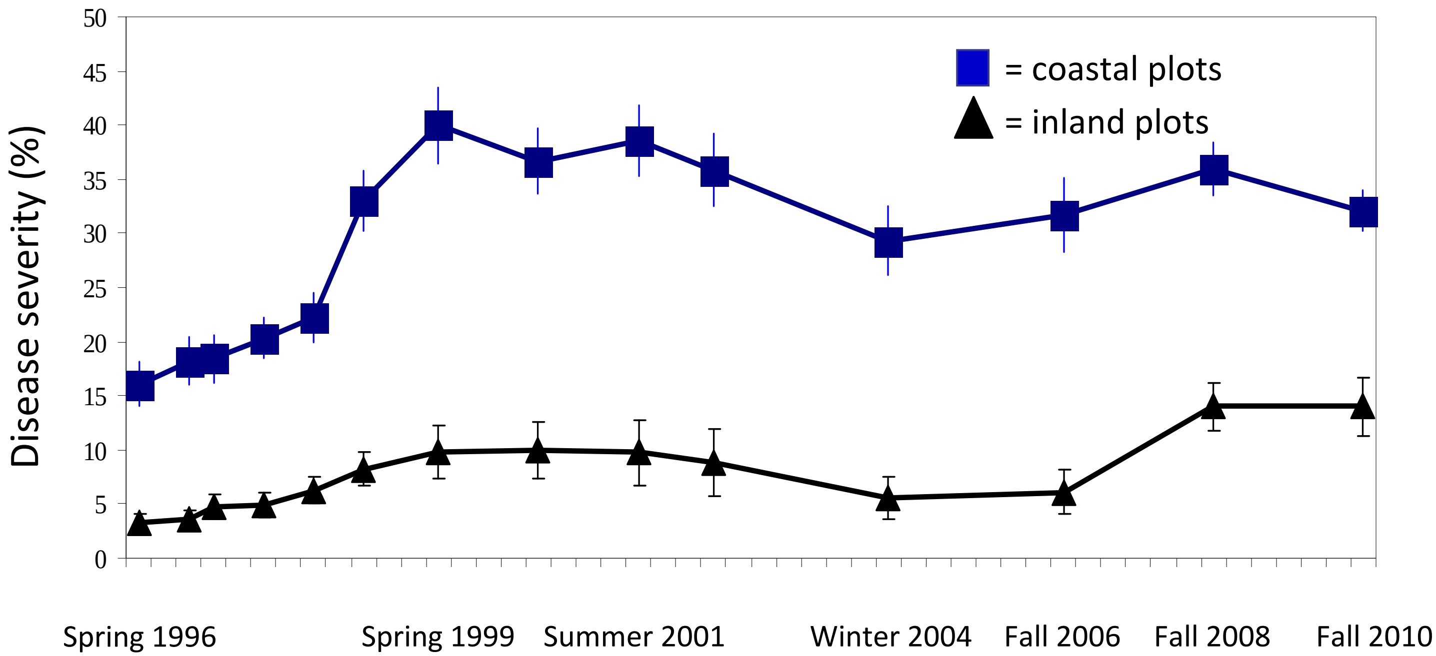
Received 7 July 2002; accepted 28 September 2002



Disease has continued to be more severe near the coast

Limiting Effects of Low Temperature on Growth and Spore Germination in *Gibberella circinata*, the Cause of Pitch Canker in Pine Species

A. R. Inman, S. C. Kirkpatrick, and **T. R. Gordon,** Department of Plant Pathology, and **D. V. Shaw,** Department of Plant Sciences, University of California, Davis 95616

ABSTRACT

Inman, A. R., Kirkpatrick, S. C., Gordon, T. R., and Shaw, D. V. 2008. Limiting effects of low temperature on growth and spore germination in *Gibberella circinata*, the cause of pitch canker in pine species. Plant Dis. 92:542-545.

Pitch canker, caused by *Gibberella circinata* (anamorph = *Fusarium circinatum*), causes canopy dieback and mortality in susceptible pine species in many parts of the world. Pitch canker is most problematic in areas with a relatively warm climate, suggesting a possible limitation on disease development imposed by low temperatures. To test this hypothesis, the effect of temperature on radial growth was examined in isolates of *G. circinata* of diverse geographic origin. All isolates grew most rapidly at 25°C and progressively more slowly at 20, 15, and 10°C. Spore germination occurred most rapidly at 20°C and was slowest at 10°C. To determine if the time required for spore germination might influence the likelihood of infection, the duration of wound susceptibility was examined by inoculating branches of susceptible Monterey pines (*Pinus radiata*). In each of six field trials, branches were wounded and then inoculated immediately or at 2, 6, or 9 days after wounding. The results indicated that wounds inoculated immediately became infected at a significantly higher rate than those inoculated 2 days later. Thus, if low temperatures extend the time required for germination beyond this period, a reduced infection frequency would be expected. Such a limiting effect of temperature could help to explain the current distribution of pitch canker.

Additional keywords: forest pathology, tree disease

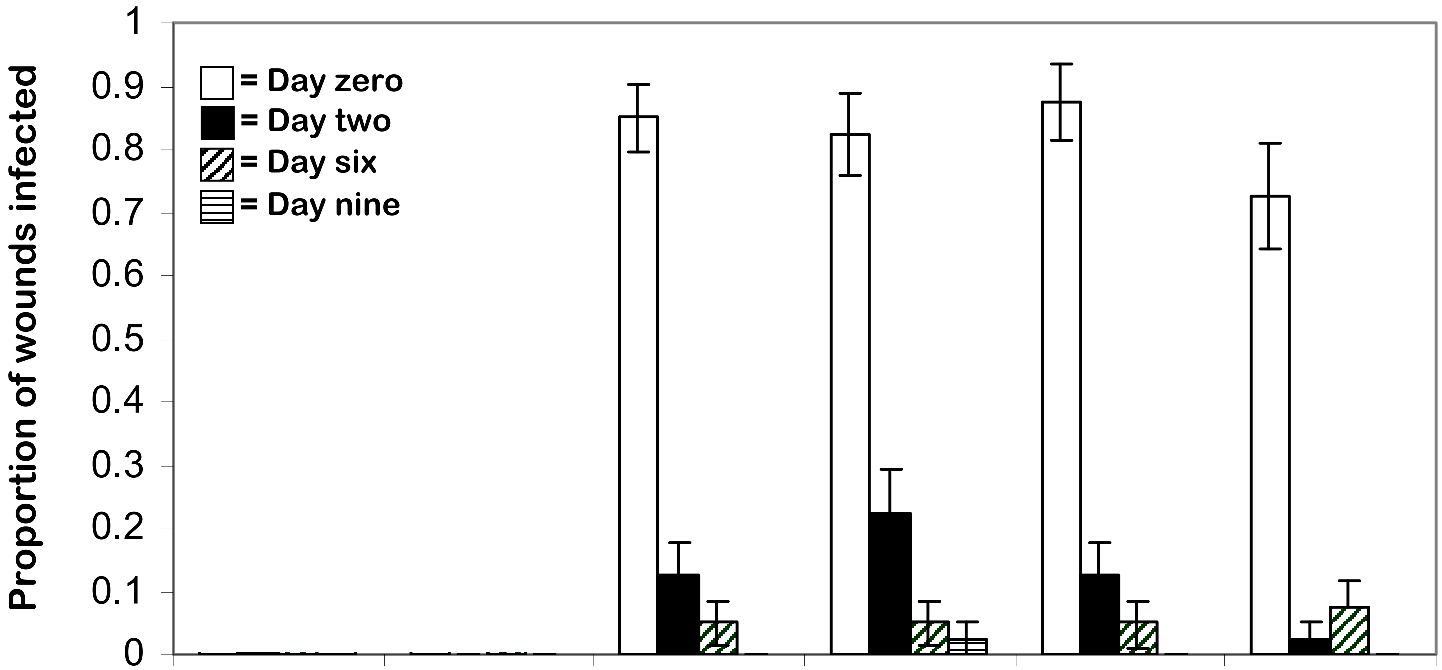
gests that cooler temperatures associated with northerly and montane environments may impose such a limitation.

G. circinata requires a wound to establish an infection. Wounds may be caused by insects or injuries associated with weather or silvicultural practices (8,9). If germination and growth of the fungus proceed more slowly at cooler temperatures, wounded tissue may cease to be susceptible before the pathogen can establish an infection.

The principal goal of this study was to characterize the limiting effects of low temperature on growth and spore germination in *G. circinata* in vitro. To determine if these effects of temperature could influence the pathogen's ability to establish an infection under field conditions, an experiment was conducted to determine how long wounded tissue remains susceptible.

MATERIALS AND METHODS

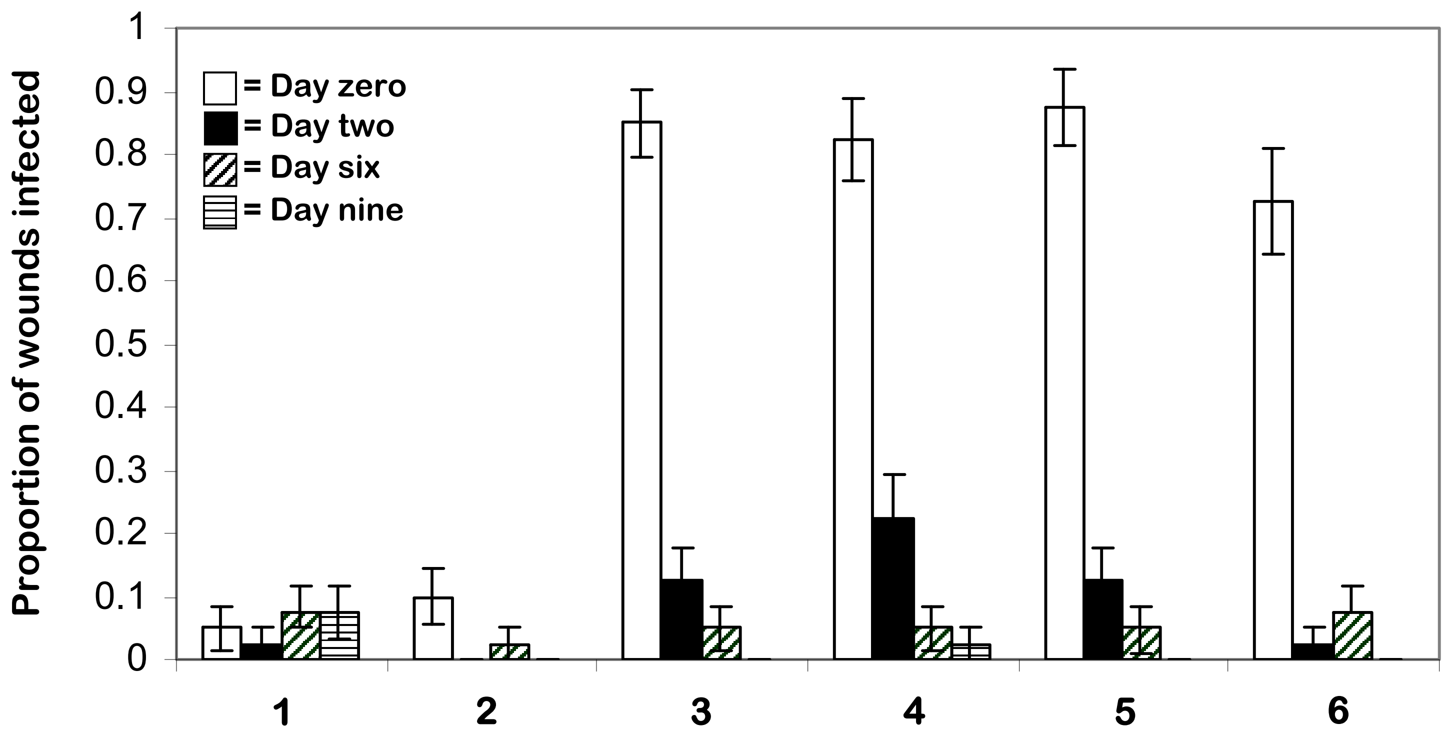
Wounds inoculated immediately have a high rate of infection



Wounds inoculated two days later are infected at a much lower rate

Fig. 3, Inman et al./ *Plant Disease*

A high rate of infection requires that temperatures are high enough to allow for germination and sufficient growth within the 48 hour window of wound susceptibility

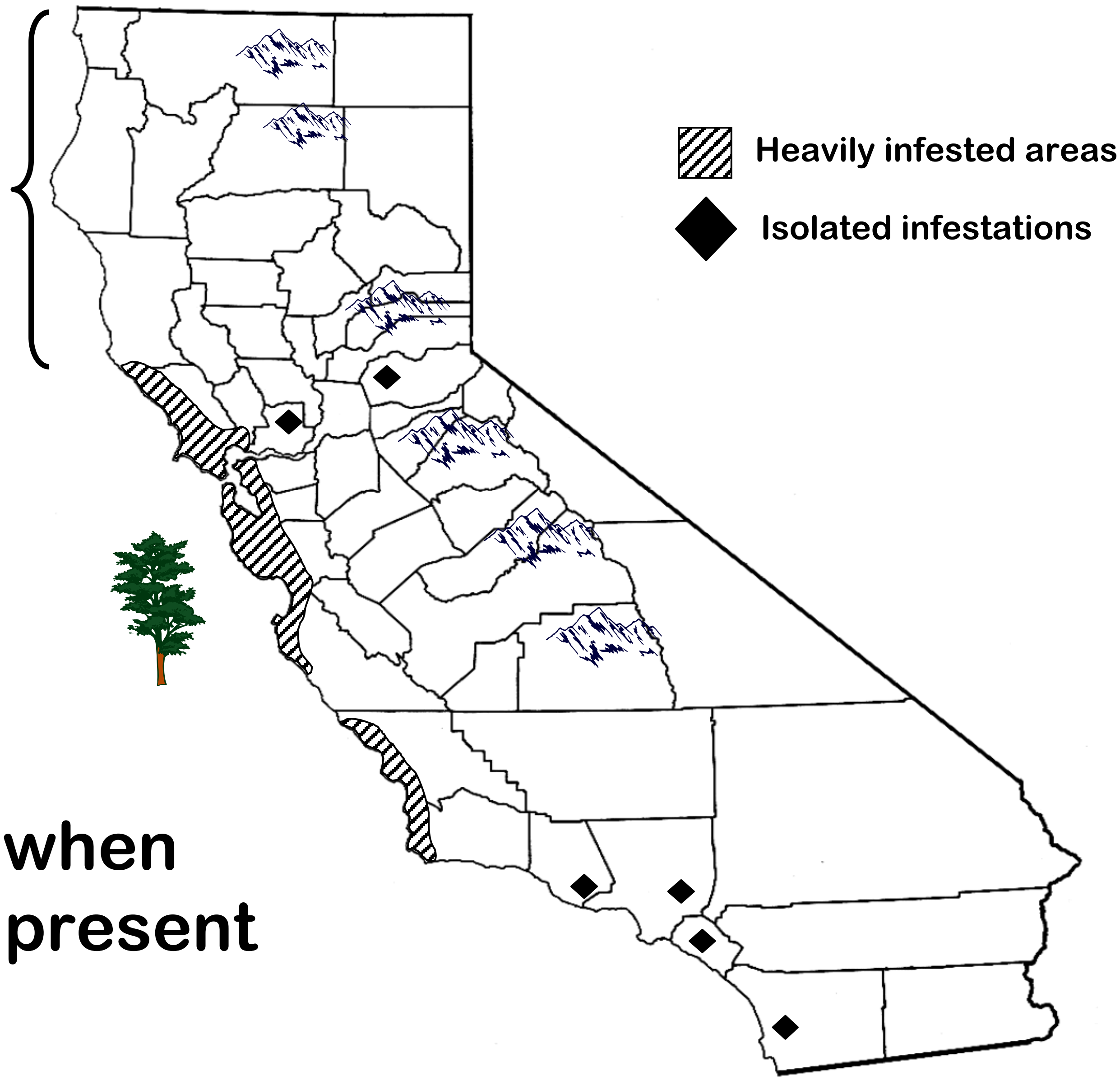


This explains the low infection rate in trials one and two, which were conducted during winter

Current distribution reflects climate limitations

Susceptible trees but no disease

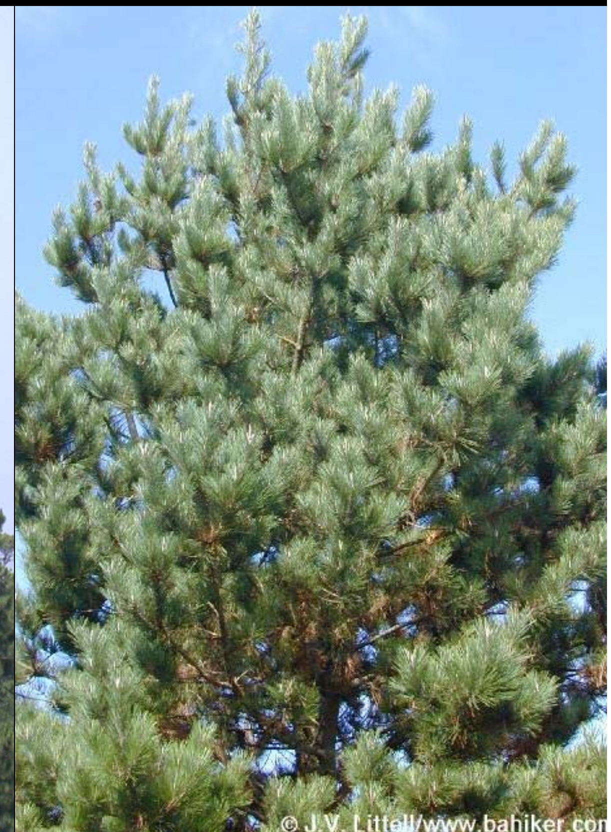
Too cold when moisture is present



Monterey, knobcone and bishop pines are highly susceptible

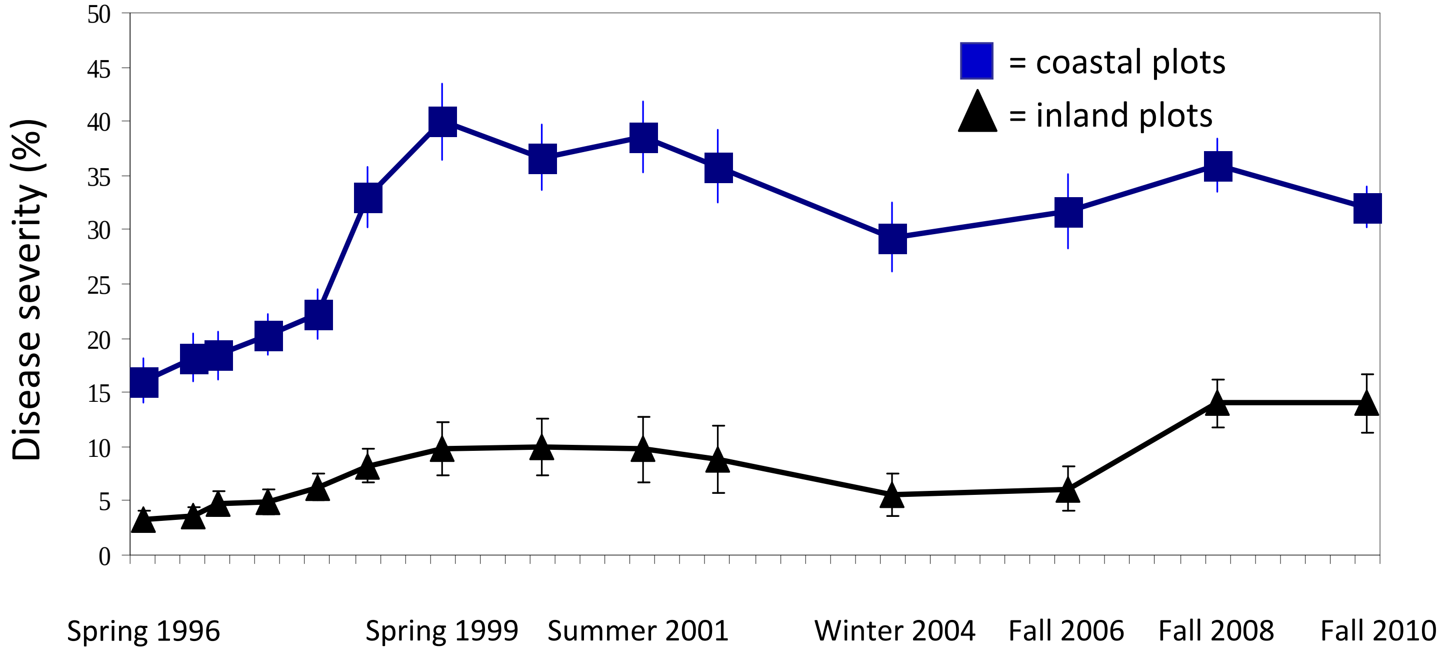
Pinus attenuata

Pinus radiata

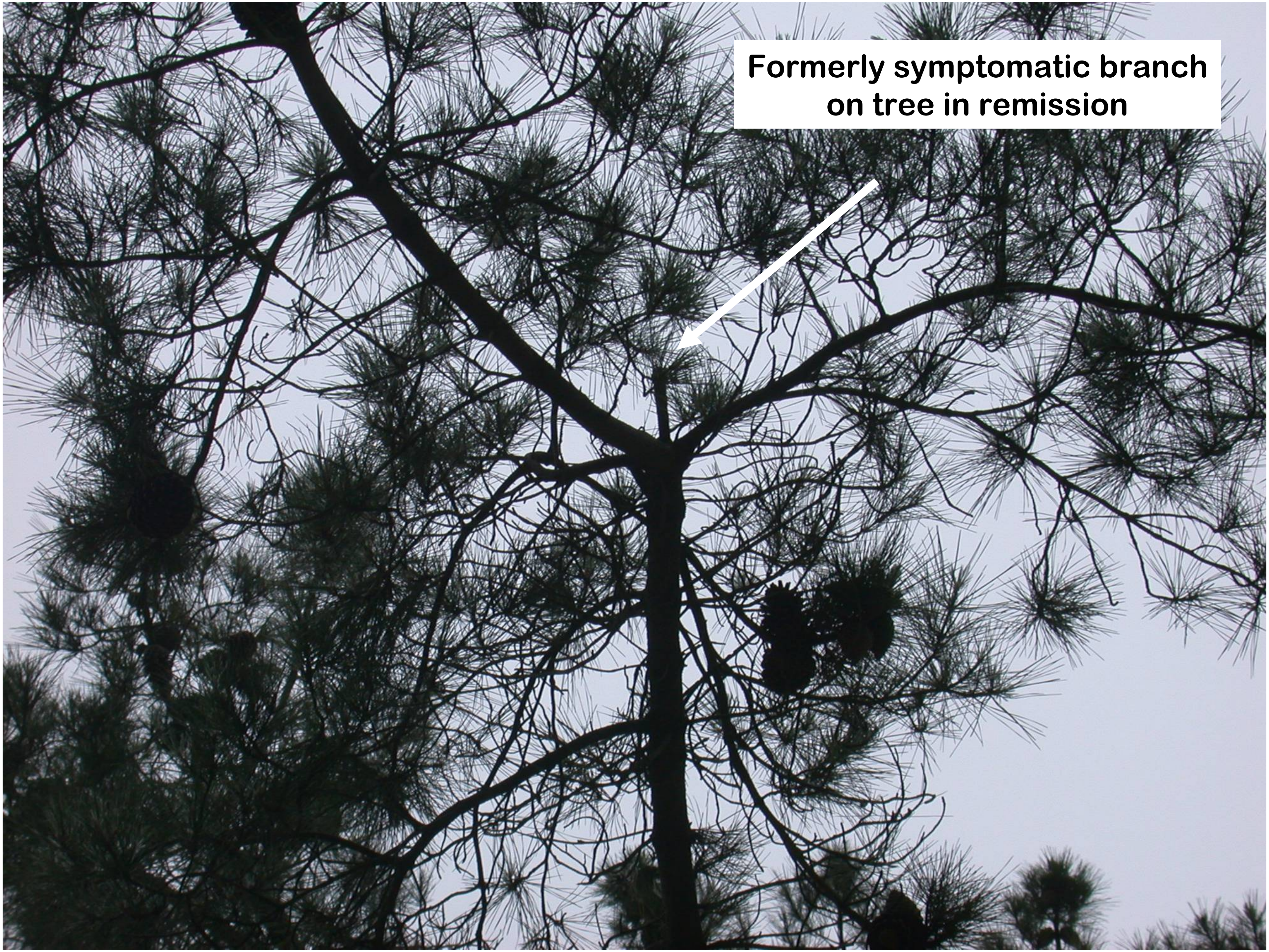


Pinus muricata

Severity has stabilized where the disease is of long residence



At least temporarily

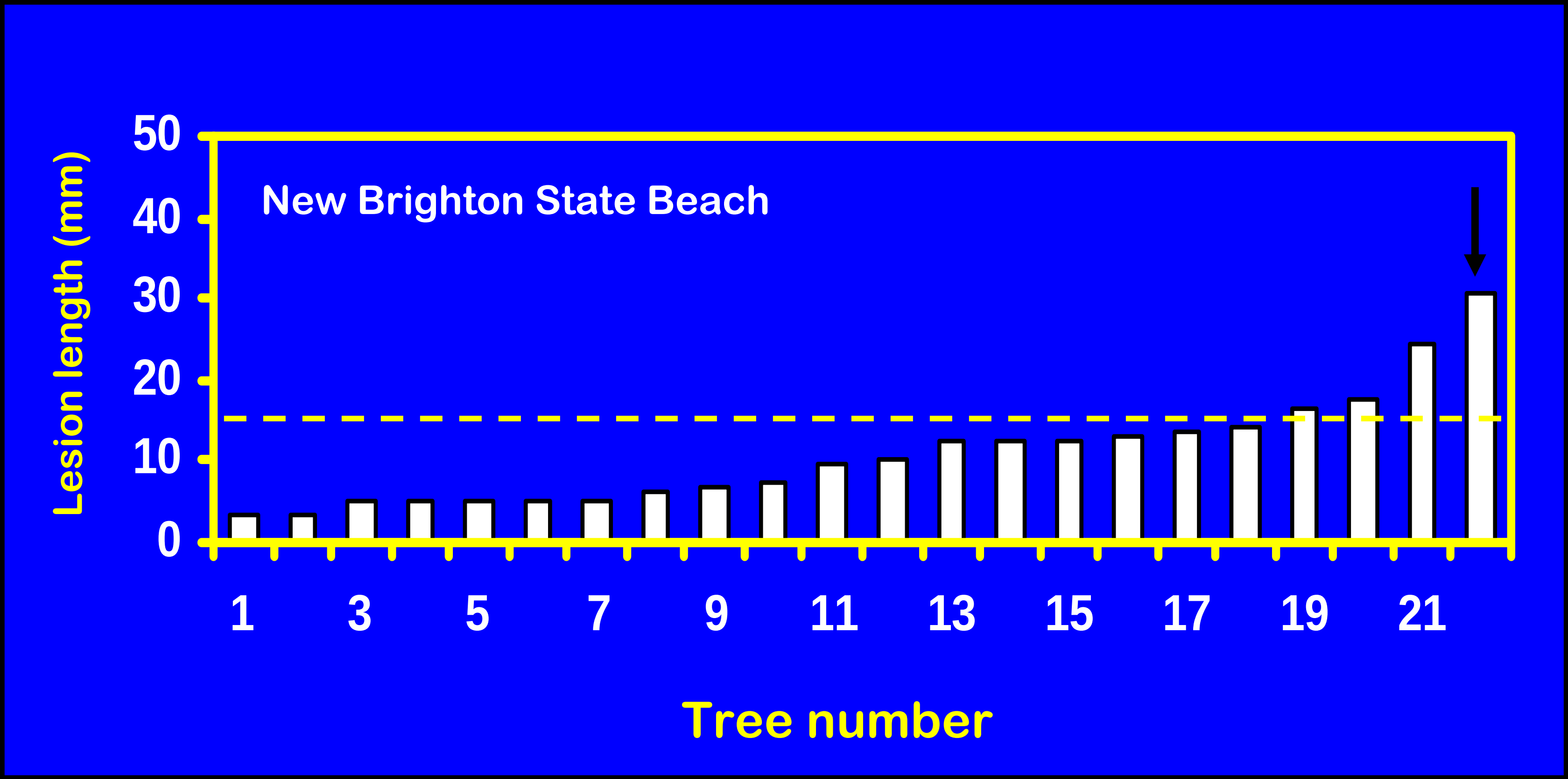

Formerly symptomatic branch
on tree in remission


This tree was severely diseased six years before this picture was taken

Disease remission requires that no new infections occur

This suggests that trees in remission are manifesting systemic induced resistance

Inoculations confirmed that trees that were once severely diseased had become resistant



Trees with lesion lengths below this line are considered resistant

Systemic induced resistance

Susceptibility to pitch canker is influenced by the duration of exposure to the pathogen

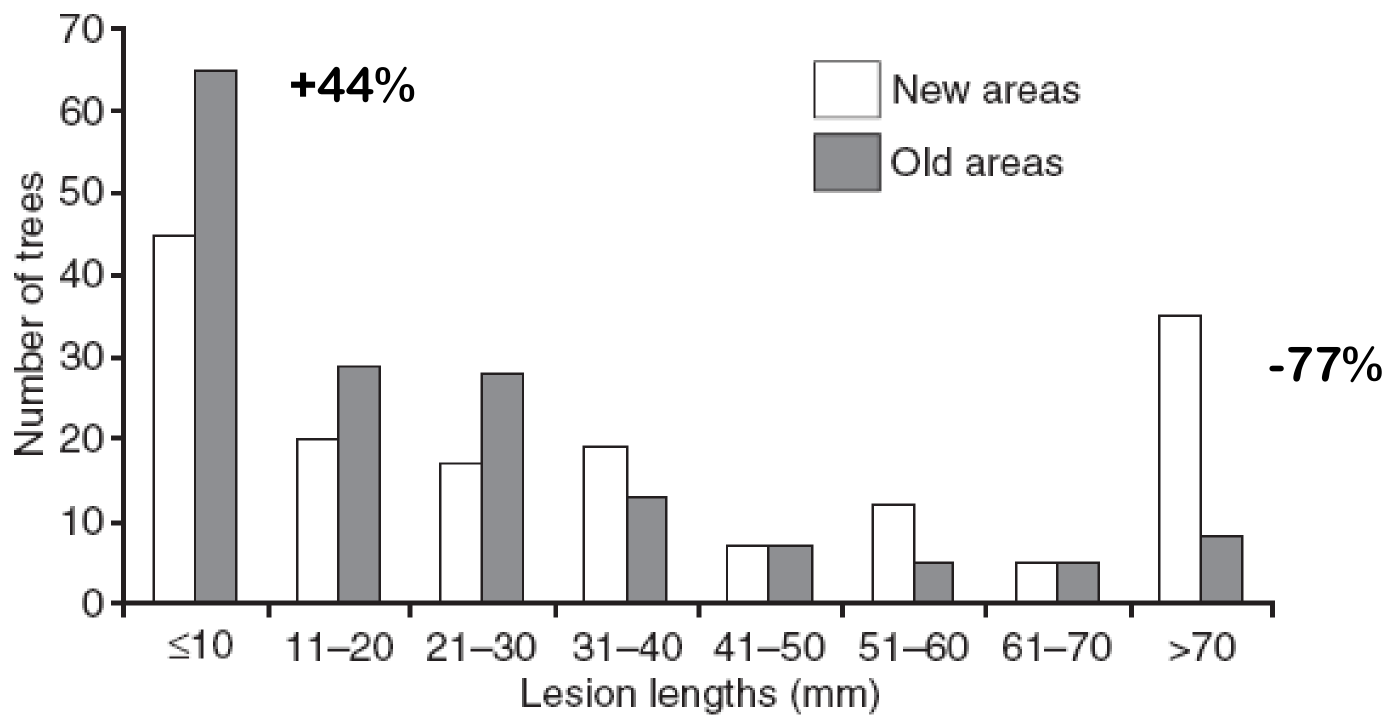
> ten years	≤ two years
160 trees	160 trees
13.6 mm	27.4 mm

Mean lesion length

Forest Pathology

For. Path. doi: 10.1111/j.1439-0329.2010.00678.x

T. R. Gordon, S. C. Kirkpatrick, B. J. Aegerter et al.



Stands in areas where the disease is well established have a greater proportion of resistant trees

Forest Pathology WILEY-BLACKWELL

For. Path. 41 (2011) 227–232
doi: 10.1111/j.1439-0329.2010.00678.x

Evidence for the occurrence of induced resistance to pitch canker, caused by *Gibberella circinata* (anamorph *Fusarium circinatum*), in populations of *Pinus radiata*

By T. R. Gordon[1,4], S. C. Kirkpatrick[1], B. J. Aegerter[1], A. J. Fisher[1], A. J. Storer[2] and D. L. Wood[3]

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This report constitutes the first documentation that systemic induced resistance occurs in nature

Induced resistance in seedlings

Induced resistance in seedlings

Many infected seedling die

But some remain symptomless

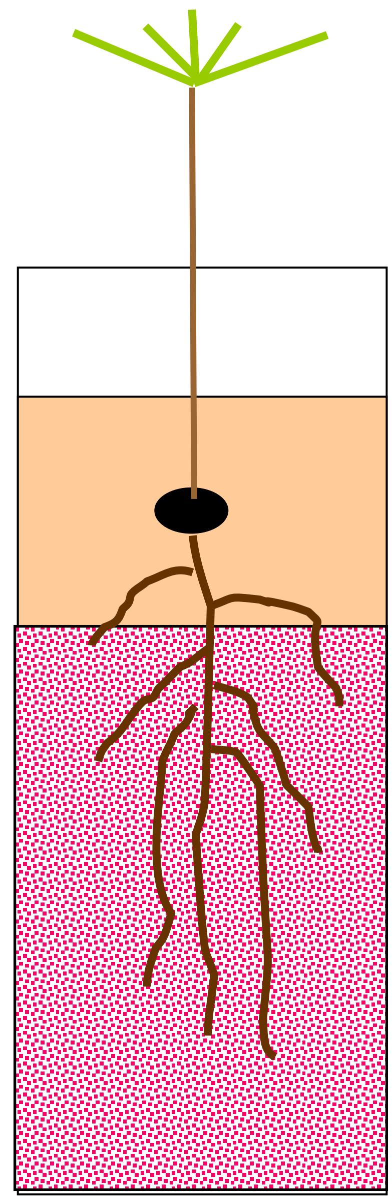


Are they less susceptible to pitch canker?

Exposure to soilborne inoculum

Steam-sterilized sand

Inoculated sand



Seed germinates in absence of the pathogen

Roots become infected as plant develops

Stem challenge inoculation method

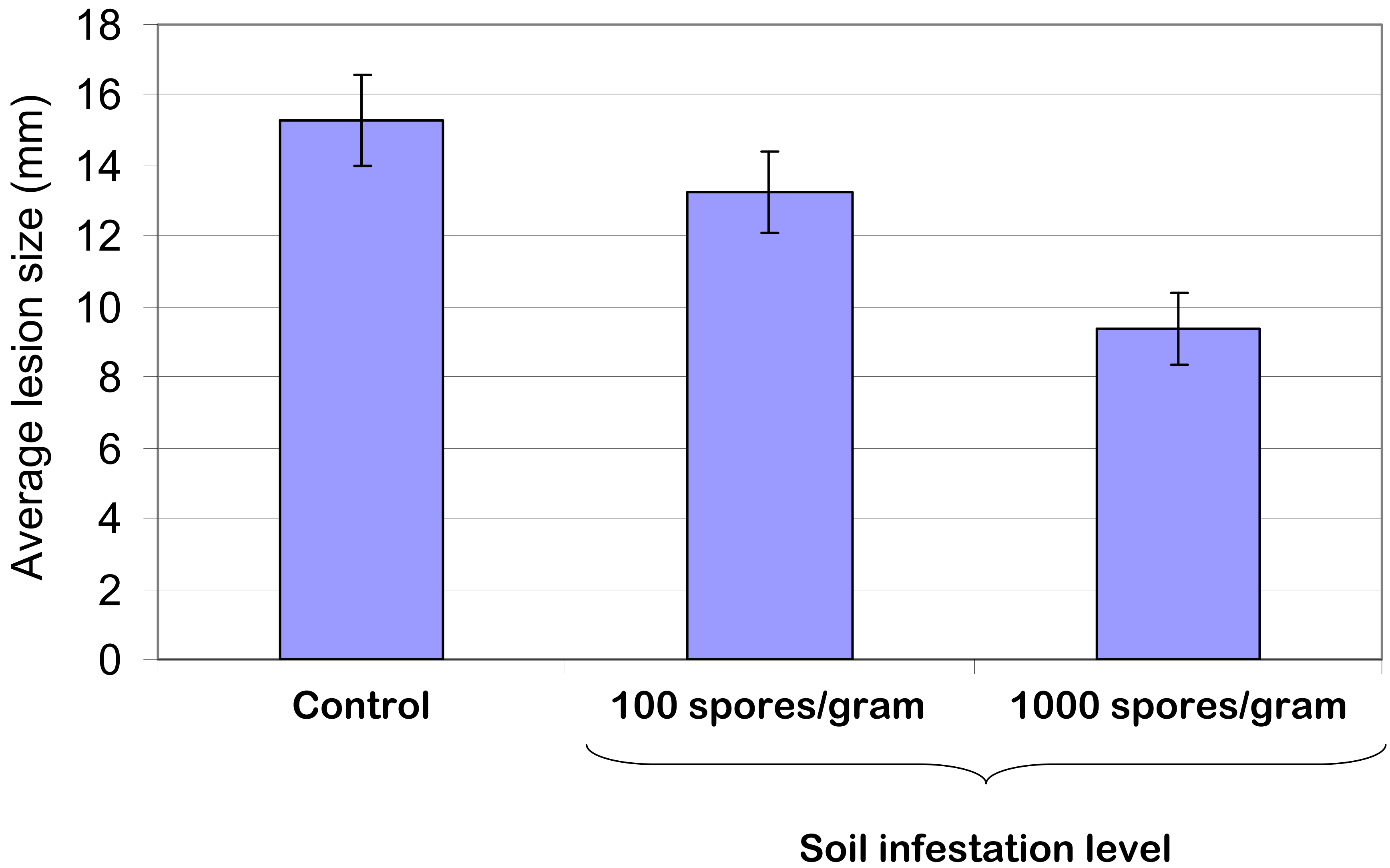
1.6mm wound

Inject 25 spores in 2 µL

Results

Non-Induced | 100 spores / gram | 1000 spores / gram

Effect of exposure to soilborne inoculum on susceptibility



Do natural infections lead to SIR?

CAL FIRE
California Department of Forestry and Fire Protection

PEBBLE BEACH COMPANY

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

Del Monte Forest FOUNDATION

USDA United States Department of Agriculture
Cooperative State Research, Education, and Extension Service

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Tom Gordon

Department of Plant Pathology

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