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**

The southeastern U.S. is the most likely source of the strains now found in California.
California and Florida isolates share the same multi-locus haplotype

<table>
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<tr>
<th>Isolate</th>
<th>Location</th>
<th>Haplotype</th>
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<td>FSP 74</td>
<td>California</td>
<td>AAABAAAAAA</td>
</tr>
<tr>
<td>FL 1</td>
<td>Florida</td>
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<tr>
<td>FSP 132</td>
<td>California</td>
<td>BAABAAAAAA</td>
</tr>
<tr>
<td>FL 52</td>
<td>Florida</td>
<td>BAABAAAAAA</td>
</tr>
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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 pathogen is seedborne in southern pines

The most likely vehicle for transport of the pathogen is seed
Pine seeds have frequently been shipped to California to produce seedlings for reforestation in the southeast.
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

= Christmas tree farm
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.
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.

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This study documents that twig beetles cannot locate declining branches prior to landing.
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
Infected trees die

Logs moved by campers contributed to spread of the disease.
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

Heavily infested areas

Isolated infestations

Native populations of *Pinus radiata*

Why is pitch canker restricted to the coast?
Monterey Peninsula

Monitoring plots were established in 1996
The dynamics of an introduced pathogen in a native Monterey pine (*Pinus radiata*) forest

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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

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**ABSTRACT**


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

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Suggests 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.
Isolated infestations

Heavily infested areas

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

- **> ten years**: 160 trees, mean lesion length 13.6 mm
- **≤ two years**: 160 trees, mean lesion length 27.4 mm
Stands in areas where the disease is well established have a greater proportion of resistant trees.
Evidence for the occurrence of induced resistance to pitch canker, caused by *Gibberella circinata* (anamorph *Fusarium circinatum*), in populations of *Pinus radiata*

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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 seedlings 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 1000 spores / gram 100 spores / gram
Effect of exposure to soilborne inoculum on susceptibility

Soil infestation level

Average lesion size (mm)

Control 100 spores/gram 1000 spores/gram
Do natural infections lead to SIR?
Sources of support for our research

Tom Gordon
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