IMPACT OF PITCH CANKER ON ORNAMENTAL MONTEREY PINES IN SANTA CRUZ COUNTY, CALIFORNIA, U.S., 1987–2000

by Donald Owen and David Adams

Abstract. Long-term observations of ornamental Monterey pine (*Pinus radiata*) showed that pitch canker severity varies considerably from one tree to the next and over time. Most Monterey pines proved susceptible to the disease, but many sustained only light to moderate levels of infection and some never developed any disease symptoms. We developed a rating system that proved useful in assessing pitch canker's impact. Although the majority of trees sustained heavy levels of infection, mortality was not a foregone conclusion for even the most heavily damaged trees. After an initial outbreak of pitch canker activity, the incidence of new infections decreased and eventually dropped to an undetectable level. Trees are now recovering in the absence of new infections. Application of this information will contribute to better predictions of disease impact. It should not be presumed that pitch canker will necessarily result in a high rate of mortality among Monterey pines.

Key Words. Pitch canker; Monterey pine; disease impact; disease rating; *Fusarium circinatum*; *F. subglutinans* f.sp. *pini*; *Pinus radiata.*

Pitch canker, a disease of pines caused by the fungus *Fusarium circinatum* (= *F. subglutinans* f.sp. *pini*) was discovered in California, U.S., in 1986 (McCain et al. 1987). An initial survey conducted in 1987 located the disease in five counties, primarily in ornamental Monterey pine *(Pinus radiata)* and centered in the area from Santa Cruz County to south Alameda County (Interagency Working Group 1987). This distribution suggested the disease had been present in California for at least a few years prior to its discovery. Genetic studies have shown a limited diversity within the *F. circinatum* population in California, indicating the pathogen is not native to the state (Correll et al. 1992; Gordon et al. 1996).

Monterey pine is highly susceptible to pitch canker disease. Trees of all ages can be infected and eventually killed. The hallmark of the disease is a resinous canker (dead area) found on woody portions of the tree, including roots, trunk, and branches. Cankers exhibit copious external resin flow as well as resin-soaked bark and wood. Cankers can girdle and kill young trees and branches directly, whereas cankers on the larger-diameter trunk of the tree typically are not girdling. Branches anywhere in the crown of the tree may be killed, distinguishing pitch canker from pest-caused damage that is restricted to weakened branches. Susceptible trees experience a progressive decline due to branch dieback and top kill. Bark beetles are consistently found in dying, pitch-canker-diseased Monterey pines and appear to contribute to tree mortality, except for young trees that are killed directly by cankers. The importance of wounding to infection and disease development was demonstrated by Kuhlman et al. (1982). In the southeastern United States, wounding by a variety of biotic and biotic agents has been associated with pitch canker disease (Matthews 1962; Blakeslee et al. 1978; Kelley and Williams 1982; Dwinell et al. 1985). In California, bark beetles and other insects may serve as vectors of the pitch canker pathogen and/or as wounding agents and play a significant role in the epidemiology of the disease (summarized by Storer et al. 1997; Storer, Wood et al. 1999).

Monterey pines vary significantly in their response to artificial inoculation with the pitch canker pathogen (Schultz et al. 1990; Correll et al. 1991; Gordon et al. 1998; Storer, Bonello et al. 1999), and a positive correlation has been shown between inoculation results, i.e., lesion length, and subsequent development of disease symptoms (Storer, Bonello et al. 1999). This work provides the basis for current efforts to identify and propagate resistant Monterey pines using artificial inoculation as a screening tool (Sammon et al. 1999).

In response to the initial discovery of pitch canker in California, we established plots in 1987 to monitor the long-term impacts of the disease on Monterey pine. This report summarizes the impact of pitch canker on ornamental Monterey pine from the area where the disease was first discovered.

METHODS

Ornamental Monterey pine in Santa Cruz County were monitored from 1987 through 2000 at three locations: San Lorenzo Park in Santa Cruz, Soquel High School in Soquel, and Ramsay Park in Watsonville. The three plots are situated along the north to northeast side of Monterey Bay, 1.4, 2.4, and 6.3 km (0.9, 1.5, and 3.9 mi), respectively, from the ocean (Figure 1). Trees ranged in diameter from 25 to 84 cm (10 to 33 in.) at breast height in 1987. Numbers of trees per plot were 31, 32, and 34, respectively. Individual trees were mapped and given an identifying number at the first visit. Plots were visited eight or nine times from 1987 through 1992 and then three more times—once each during 1994–95, 1998, and 2000.

During each visit, the crown and bole of each tree were separately rated for pitch canker severity using a numerical rating of 0 through 3. A 0 rating meant no pitch canker was evident, and ratings of 1 through 3 indicated increasing levels of infection. The separate crown and bole ratings were combined to provide an overall tree rating of 0 through 6 (Table 1). Crown rating was based on the estimated percentage of terminal branch ends (Figure 2) that were killed by pitch canker. Individual branches can have more than one canker and can experience dieback in stages. To produce consistency, only the terminal ends of branches were considered when making the crown rating; the death of side branches did not count toward the rating. The bole rating was based on the total number of cankers present on the main stem. Data were also collected on top kill, which presumably occurred due to the girdling effect of cankers and/or bark beetle attack; and when a tree died, bark was removed from the lower bole (up to 8 ft) to assess bark beetle colonization.

Although this rating system provided a good picture of the level of pitch canker infection in a tree, it did not adequately reflect old versus new infections (cankers), both of which were factored into our rating. Cankers do not spread indefinitely but appear to become inactive, as indicated by a cessation of resin flow. In 1989, we noted that the rate of new infections appeared to be decreasing. In

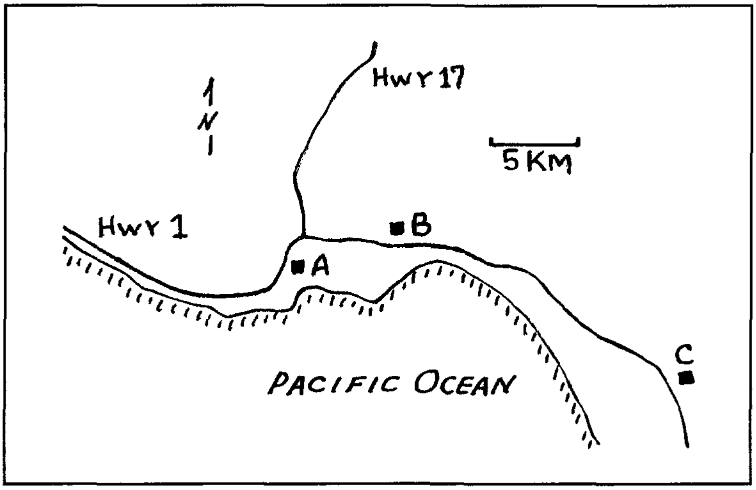

Figure 1. Plot locations: A = San Lorenzo Park; B = Soquel High School; C = Ramsay Park.

Table 1. Crown and bole ratings and corresponding levels of pitch canker severity. A tree's overall pitch canker rating was obtained by adding the crown and bole ratings, for a possible rating of 0 to 6.

Crown rating	Percentage of terminal branch ends killed by cankers	Bole rating	Number of bole cankers
0	0%	0	0
1	1%–20%	1	1 or 2
2	21%–79%	2	3 or 4
3	≥ 80%	3	≥ 5

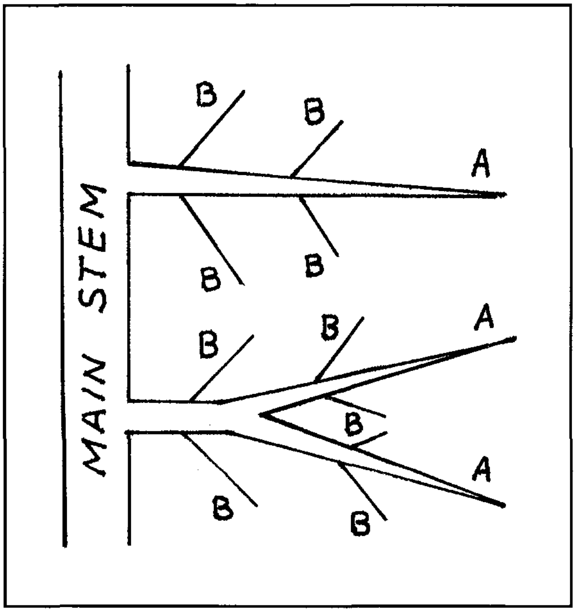

Figure 2. Crown rating was based on the estimated percentage of terminal branch ends (A) killed by pitch canker. As illustrated on the lower branch, major divisions within a branch can result in more than one terminal branch end. The fate of side branches (B) was not considered when making the rating.

1992, we started recording whether or not active branch and bole infections were present on each tree. All infections were considered (as opposed to only infections that counted toward a tree's pitch canker rating). An active bole canker was defined as one with fresh resin flow, and an active branch infection was defined as one associated with recent dieback, i.e., the presence of yellowing (fading) or brown needles distal to the girdling canker. In contrast, old bole cankers had dried, dull, and usually opaque resin. Old branch cankers were indicated by dead branch ends free of needles.

Ratings were made from ground level with no special aids, except that binoculars were used when necessary to confirm the characteristic external resin flow caused by pitch canker and eliminate other possible causes of injury. Bark beetle and pitch moth attack, western gall rust, Diplodia blight (caused by the fungus *Sphaeropsis sapinea*), and various types of mechanical injury all have their own signs and/or symptoms that distinguish them from pitch canker. While Diplodia blight (Owen 1998) also produces a resinous canker, the disease typically produces a different pattern and extent of dieback, and the cankers lack the copious external resin flow of pitch canker.

RESULTS

At the beginning of the study, 39 trees had little or no pitch canker (rating of 0 or 1) and 58 had moderate to high levels of infection (rating of 2 through 6). In 1992, 20 trees had little or no pitch canker, including eight trees that showed no symptoms of infection whatsoever. The remaining trees had moderate to high levels of pitch canker, including 17 trees that died (Table 2). Of the trees that died, all had pitch canker branch infections, 16 had bole cankers, 14 had a pitch canker rating of 4 or higher, and eight had dead tops prior to death. No trees died without being colonized by bark beetles. The red turpentine beetle *(Dendroctonus valens)* colonized the lower bole and root collar, and Ips beetles (*Ips paraconfusus* and/or *I. mexicanus*) colonized the bole above this. Red turpentine beetle pitch tubes were often noted on diseased trees prior to death, but this was not consistent across all three plots.

Table 2. Number and percentage of trees for different pitch canker ratings, 1987 versus 1992.

Pitch canker rating	1987		1992	
0	18		8	
		40%		21%
1	21		12	
2	21		10	
		32%		26%
3	10		15	
4	10		16	
5	9		6	
		28%		54%
6	8		13	
Dead	0		17*	

*Of the 17 trees that died:
- All 17 had pitch canker branch infections (crown rating ≥ 1).
- 16 had pitch canker bole infections (bole rating ≥ 1).
- 14 had overall pitch canker ratings ≥ 4.
- 8 had dead tops.
- All 17 were attacked and colonized by bark beetles.

Table 3 shows tree mortality from 1987 through 1992 for different pitch canker ratings. The percentage of mortality was substantially less for trees with ratings 0 through 3 versus trees with ratings of 4 or higher. This same pattern continued in the Soquel High School plot, where an additional five trees died after 1992, all of which had a rating of 4 or higher prior to death.

Because we visited the three plots on an irregular basis after 1992, it was difficult to determine which trees died naturally and which were removed while still alive. At the San Lorenzo and Ramsay plots, enough live trees were cut that additional information on tree decline and mortality was deemed unreliable after 1992. At Soquel High School, we were able to confirm that no live trees were cut. Hence, this plot provided reliable information on decline and natural mortality after 1992. Table 4 compares the number and percentage of trees alive in each plot in 1992 and 2000. All three plots were similar in percent trees alive in 1992, but by 2000 there was a large difference between Soquel High School and the other two plots. Of 34 trees alive on the Soquel High plot in 1987, 11 trees (32%) died between 1987 and 2000. This is in sharp contrast to a 75% to 81% loss of the trees from the other two plots.

Data on active versus old cankers show a decline in pitch canker activity on all the plots from 1992 to 2000. For the Soquel High School plot, we estimated that out of 26 trees with a history of infections (i.e., susceptible trees), 23 trees had active or current infections in 1992. In 1998, of 21 previously infected trees, only four had active infections, and in 2000 we found no active infections among these 21 trees, including five trees that previously received a rating of 6. Past pitch canker damage on many trees, i.e., dead tops and dead branch segments, has gradually been obscured by new, uninfected growth. By 2000, it was difficult to tell that some trees

Table 3. Number and percentage of trees that died from 1987 to 1992 for different pitch canker ratings (χ^2 = 8.415; p = .0149).

Pitch canker rating*	Total number of trees	Number of trees that died	Percentage mortality
0	8	0	
			5%
1	13	1	
2	12	2	
			7%
3	15	0	
4	20	4	
5	10	4	29%
6	19	6	

*For live trees, pitch canker ratings are those recorded in 1992. For trees that died, pitch canker ratings are those recorded at the last observation before death.

Table 4. Number and percentage of trees remaining in each plot in 1992 and 2000.

Year/plot	San Lorenzo	Ramsay	Soquel
1992*	25 (81%)	27 (84%)	28 (82%)
2000**	6 (19%)	8 (25%)	23 (68%)

*χ^2 = 0.152; p = .927
**χ^2 = 19.523; p = .0000576

had previously been infected. The five trees that survived despite pitch canker ratings of 6 were among the most heavily infected trees in our plots throughout the period of observations:

- All five had moderate to high levels of pitch canker at the start of the study in 1987. Three had initial ratings of 5 and the other two had initial ratings of 3 and 4.
- Two trees progressed to ratings of 6 by the end of the first year, and the remainder progressed to ratings of 6 by the third year of the study (1989).
- All developed dead tops ranging in length from 1 to 6 m (3 to 20 ft).

DISCUSSION

These observations show that the impacts of pitch canker on Monterey pine vary considerably from one tree to the next and over time. The majority of trees developed high levels of infection, but many developed only light to moderate levels of infection, and some never showed any evidence of infection. Mortality was greatest among trees with the highest pitch canker ratings, but mortality was not a given for even the most heavily damaged trees. At present, trees are recovering in the absence of new infections. It is unknown why some heavily damaged trees died while others did not and why pitch canker activity has declined to an undetectable level in the study plots. The results of this study have apparent implications for the management of Monterey pine in California, although it remains unclear what the ultimate impact of pitch canker will be.

The rating system used in this study is a simple and objective means of ranking trees for damage from pitch canker. There is a need for such objectivity because the symptoms of pitch canker can be visually dramatic and hence potentially misleading. In areas where pitch canker is just beginning to impact trees, changes in ratings should be expected and trees should be monitored. If the disease is well established in an area and a tree's rating has remained fairly constant, the rating should provide a good indication of a tree's relative susceptibility to the disease.

Although pitch canker is quite obvious on trees with moderate levels of damage (ratings of 2 or 3), there was a low level of mortality among trees with ratings of 3 or less. Coupled with an opportunity for recovery, it seems pitch canker damage alone should not justify removing such trees.

In contrast, trees with ratings of 4 and above had a significantly higher level of mortality, indicating that this level of damage deserves special management considerations. Based on the heavy tree removals from our plots, we surmise that most land managers will consider these trees a liability and choose to remove them. Not all of these trees are expected to die, and, if the trees can survive long enough, recovery is a possibility. Consider removing dead limbs and tops to improve the appearance and safety of surviving trees. Pruning cankers from trees, however, does not control pitch canker (Schultz 2000, personal communication).

These results do not support the predictions of Templeton et al. (1997) who assumed that 80% of infected trees would die. This predicted level of mortality is consistent with the removal of trees from the San Lorenzo and Ramsay plots, but it is not consistent with the mortality observed at the Soquel High plot, where no live trees were cut. Although it represents only one site, the 32% mortality in the Soquel High plot from 1987 through 2000 offers a substantially lower expectation for natural mortality.

Because even heavily infected trees can survive and potentially recover, the role of bark beetles in bringing about the death of infected trees becomes a relevant management concern.

Reporting on an outbreak of pitch canker in slash pine, Blakeslee and Oak (1979) found Ips beetles colonizing many of the dead trees but concluded that the beetles contributed little to mortality. Although the degree to which bark beetles contribute to the death of pines with pitch canker is debatable, even a small contribution becomes relevant if it results in the death of trees that otherwise would survive. It is concluded that bark beetles contributed to tree mortality in the Santa Cruz County plots because 1) many Monterey pine trees survived in spite of having levels of pitch canker similar to or more severe than trees that died, and 2) no trees died without concurrent colonization by bark beetles. Our results support the view that it may be possible to prolong the life of some Monterey pines by treating them with a pesticide registered as a preventative against pine bark beetle attack. To avoid unnecessary pesticide use, we would recommend treatment only in situations where a bark beetle threat can be identified and only for high value, specimen trees. A tree's overall health, in addition to pitch canker, should be taken into consideration before deciding on a course of action. Trees suffering from chronic stress with no expectation of improved health are poor candidates for pesticide treatment.

Pitch canker activity in the southeastern United States is described as occurring in epidemics or outbreaks. Although apparent contributing factors have been identified, these are not necessarily consistent from one outbreak to the next, and multiple outbreaks have not been observed in a given stand of trees (Dwinell et al. 1985; Dwinell 2000, personal communication). Our observations also span an event that might be labeled an outbreak, characterized by a high initial level of pitch canker activity followed by a decline and eventual disappearance of the disease in the plots by 2000. This same trend is apparent in other parts of Santa Cruz County, where the disease has been present the longest. In Monterey County to the south, where the pathogen was more recently introduced, pitch canker is still quite active. The newness of the disease in California would seem an important factor in its activity.

Moisture stress can contribute to an increase in the incidence of pitch canker (Schmidt et al. 1976; Blakeslee et al. 1992). A noteworthy potential influence on our observations was California's protracted drought from 1987 through 1992. Reoccurring periods of drought have resulted in widespread conifer mortality in California (Smith et al. 1994), and we would suspect drought influenced at least the first 6 years of our observations. We are aware of one stand of Monterey pine in Santa Cruz County that suffered higher levels of mortality than did our plots during these drought years. An evaluation of soil conditions in that stand determined that most trees were planted on ancient sand dunes and fill soils with poor water-holding capacity (Smith and Munn 1987). When California enters another drought, we would anticipate heightened bark beetle activity and presumably a concomitant increase in pitch canker. Mortality is likely to be greatest on sites that are poorly suited for Monterey pine or in stands with a high percentage of overmature and decadent trees.

The complex interaction of various components of the disease—pathogen, host, bark beetles, and environmental influences—presents a challenge in trying to explain the dynamics of pitch canker over time. The results reported here will not necessarily apply to other locations or other times, but they do increase our understanding of the dynamics of pitch canker on Monterey pine and can be used as a reference point for evaluating the impacts of the disease in the future.

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Résumé. Des observations à long terme sur le pin radial ont démontré que le degré de sévérité du chancre résineux variait considérablement d'un arbre à un autre et dans le temps. La plupart des pins radiaux se sont avérés susceptibles à la maladie, mais plusieurs tolèrent un degré d'infection allant de léger à modéré, et certains ne développent jamais aucun symptôme de la maladie. Nous avons développé un système d'évaluation qui s'est avéré utile pour déterminer les impacts du chancre résineux. Même si la majorité des arbres avaient des degrés élevés d'infection, la mortalité n'était pas une conclusion automatique, et ce même pour les arbres les plus endommagés. Après une première phase d'exsudation de résine, l'incidence de nouvelles infections diminue et chute vers des niveaux non détectables. Les arbres se rétablissent donc en l'absence de nouvelles infections. L'application de cette information va contribuer à émettre de meilleure prédictions sur l'impact de la maladie. On ne devrait pas présumer que la présence de chancre résineux va nécessairement déboucher sur des taux élevés de mortalité parmi les pins radiaux.

Zusammenfassung. Bei Langzeit-Untersuchungen von Monterey-Kiefern wurde festgestellt, dass der Befallsdruck durch Baumkrebs zwischen den Jahren erheblich variiert. Die meisten Monterey-Kiefern sind anfällig für diese Krankheit, aber viele entwickeln nur leichte Symptome und andere sind ganz frei von Krankheitszeichen. Wir entwickelten ein Erfassungssystem, welches sich als nützlich bei der Untersuchung der Auswirkungen des Krankheitsbefalls erwiesen hat. Obwohl die Mehrzahl der Bäume starken Befall zeigte, war das Absterben nicht die schlussendliche Konsequenz aus der Erkrankung. Nach dem initialen Ausbruch der Krebsaktivität sank die Rate neuer Infektionen und fiel eventuell auf einen nicht zu bestimmenden Grad ab. Die Bäume erholen sich nun in der Abwesenheit neuer Infektionen. Die Anwendung dieser Information kann dazu beitragen, bessere Vorhersagen zu dieser Krankheit zu machen. Es sollte nicht grundsätzlich daraus geschlossen werden, dass ein Befall mit Krebs bei Monterey-Kiefern zum Tode führt.

Resumen. Observaciones a largo plazo en pinos ornamentales Monterey mostraron que la severidad del cancro varía considerablemente de un árbol a otro y a través del tiempo. La mayoría de los pinos Monterey probaron susceptibilidad a la enfermedad, pero muchos presentaron solamente leves a moderados niveles de infección y otros nunca desarrollaron síntomas de la misma. Se desarrolló un sistema de valoración que probó su utilidad para evaluar el impacto del cancro. A pesar que la mayoría de los árboles presentaron altos niveles de infección, la mortalidad no fue la consecuencia, aún para los árboles más severamente dañados. Después de un brote inicial del cancro, la incidencia de nuevas infecciones decreció y eventualmente cayó a niveles imperceptibles. Los árboles están ahora recobrándose en ausencia de nuevas infecciones. La aplicación de esta información contribuirá a hacer mejores predicciones del impacto de la enfermedad. No podría presumirse que el cancro resultará necesariamente en una alta tasa de mortalidad de los pinos Monterey.