Role of the Red Turpentine Beetle in Predicting the Survival of Monterey Pine in the Urban Landscape

David L. Wood, Mo-Mei Chen, Paul L. Dallara, Kenneth R. Hobson, Carlton S. Koehler, Isao Kubo, Kenneth Q. Lindahl, Jr., Linda J. McPheron, James E. Milstead, T. Ohtsuka, J. Richard Parmeter, Jr., Steven J. Seybold and Carey W. Slaughter

Monterey pine (*Pinus radiata*) is one of the most widely planted tree species in the heavily urbanized areas of California, especially the San Francisco Bay Area, Los Angeles Basin, and San Diego area. The number of these trees in California may exceed 50 million, and more than 100,000 are planted each year. A very large number were planted 20 to 40 years ago and have reached physiological maturity with a concomitant increase in their susceptibility to naturally occurring pests. Monterey pine is normally a short-lived species with a life span rarely lasting more than 100 years on its best sites. In drier and warmer "off-site" plantings this life span is commonly reduced to 15 to 30 years. Private owners and municipalities have a great interest in caring for and protecting these trees.

The most destructive agents of Monterey pine are bark beetles (Coleoptera: Scolytidae) in the genus *Ips,* namely, the California 5-spined ips *(I. paraconfusus)* and the Monterey pine ips species *(I. mexicanus* and *I. plastographus maritimus).* The red turpentine beetle, *Dendroctonus valens,* is commonly associated with these bark beetles. *D. valens* is known to preferentially attack living trees that are under stress from such agents as root and/or stem injury, old age, or root diseases, or it will infest the roots, root collar and lower trunk of trees recently infested by the above *Ips* species.

Predicting Tree Mortality

Attacks by the red turpentine beetle may be an important indicator of stress in trees because its attacks occur well before the tree dies and thereby either attracts the tree-killing bark beetles and/or weakens the tree so that it may be more readily colonized by this beetle. Signs of attack on living trees are conspicuous large pitch tubes on the lower trunk and at the root collar. By itself, *D. valens* rarely kills a tree, but its attack often precedes that of other, more aggressive bark beetles capable of killing trees in a few days.

***D. valens* females tunnel through the outer bark and phloem and injure the xylem resin ducts. Pitch tubes form around this entrance tunnel.**

We have shown such a relationship in the central Sierra Nevada where western pine beetle *(Dendroctonus brevicomis)* and mountain pine beetle *(D. ponderosae)* are more likely to kill ponderosa pines (*P. ponderosa*) that have sustained attacks by *D. valens* than unattacked trees. We suspect a similar relationship with the California 5-spined ips in Monterey pine. For the past two years we have been recording the presence of *D. valens* on Monterey pines in three locations representing a decreasing moisture gradient from native stands in Carmel to Berkeley/El Cerrito on the western side of the Oakland/Berkeley hills to Lafayette/Walnut Creek on the eastern side of those hills. However, before a final conclusion about this relationship can be made, observations must be continued until a sufficient number of trees have died.

We made many collections of bark beetles found in dead and dying Monterey pines in the San Francisco Bay Area. These collections show that *I. mexicanus, I. paraconfusus* and *I. plastographus maritimus* are sometimes found infesting the same dying tree. However, in most cases only *I. mexicanus* and *I. paraconfusus* occur simultaneously, with *I. paraconfusus* 10 to 75 times more abundant than *I. mexicanus.* A review and analysis of the collection history of *I. paraconfusus* indicates that it may have become associated with Monterey pine early in the 20th century. *I. paraconfusus* is rare in the three native coastal populations of Monterey pine (Cambria, Monterey and Año Nuevo). However, we could not establish whether the increased abundance of *I. paraconfusus* was due to migration from nearby host species—knobcone pine (*P. attenuata*), Digger pine (*P. sabiniana*), Coulter pine (*P. coulteri*) and/or ponderosa pine (*P. ponderosa*)—or from its introduction in firewood or logs from other, more distant locations. It is also possible that Monterey pine is a coevolved host of *I. paraconfusus* and that the high densities of that ips species are due to the extensive plantings of Monterey pine since the 1940s.

Host Resistance

A pine tree's resistance to bark beetle infestation can be divided into two systems: 1) a preformed system which exists prior to beetle attack, and 2) an induced system which forms after initial beetle attack. The preformed system consists of vertical and horizontal resin ducts in the xylem (water-conducting tissue termed sapwood) and to a lesser extent in the phloem (food-conducting tissue). After the beetle tunnels through the outer bark and phloem to the surface of the xylem, a healthy tree will release copious amounts of resin. This resin when mixed with beetle boring dust forms a resin mass or pitch tube. A short time later a secondary resinosus or hypersensitive reaction is induced. In response to wounding by the beetles and the presence of fungi carried into the tree by the beetles, living cells in the area around the wound undergo an active cellular degeneration. A tree's resistance to bark beetle attack may depend upon its ability to produce a large initial resin flow and to quickly induce a strong secondary resinosus. There are no studies comparing the relative importance of these resin systems in the Monterey pine/red turpentine beetle association.

We have demonstrated the pathogenicity of the fungus *Leptographium terebrantis* and other "bluestain" fungi (wood is discolored by pigmented hyphae of these fungi) to ponderosa pine seedlings. We isolated *L. terebrantis* from *D. valens, I. paraconfusus* and *I. mexicanus,* which were found infesting Monterey pines, and then inoculated those fungi into living Monterey pines. After 9 to 10 weeks, we felled the trees, cut a section from each which contained the inoculations, and immersed those in dye.

Ponderosa pine inoculated with *L. terebrantis.* Green dye is present in areas conducting water. Occlusion (non-conduction) caused by *L. terebrantis* is indicated by non-dyed areas.

These studies showed that all *L. terebrantis* isolates caused blockage of water transport in the xylem. Thus, attacks by *D. valens* may be debilitating the tree by interrupting water flow to the crown. These studies indicate that the death of the tree caused by *Ips* spp. may result from inoculation of *L. terebrantis* into the tree. The lesion length caused by *L. terebrantis* isolated from *D. valens* was significantly less than isolates taken from *I. mexicanus.* This indicates that the *I. mexicanus* isolates are more pathogenic than the *D. valens* isolates.

Tree Protection

D. valens has been observed to attack living ponderosa pines repeatedly for many years without causing tree mortality, but such repeated attacks may stress those trees in such a way that they are more attractive to tree-killing *Dendroctonus* species. If such a relationship is established in Monterey pine with tree-killing *Ips* species, then preventing attacks by the red turpentine beetle and *Ips* species would protect valuable trees in the urban landscape.

Naturally-occurring behavior-modifying compounds found in the trees and the beetles offer considerable promise as effective and environmentally safe treatments for protection of trees from infestation by bark beetles. Recently we have discovered that *D. valens* discriminates the optical isomers (optical isomers rotate polarized light to the right (+) or to the left (-)) of *alpha*-pinene, a terpene hydrocarbon that occurs naturally in pine oleoresins. The (+)isomer is an attractant and the (-)isomer is an interruptant, that is, it lowers the catch of *D. valens* at traps baited with (+)*alpha*-pinene. If the (-)isomer interrupts the attractant response to other attractive compound(s) found in oleoresin, then we have a potentially useful treatment that would prevent attacks on injured trees.

Males of *I. paraconfusus* produce a powerful attractant pheromone (a compound that influences the behavior of individuals of the same species) after they penetrate the outer bark and feed on host phloem tissue. This pheromone draws hundreds to thousands of males and females onto the host tree in a period of only a few days to a week. The death of the tree usually follows these mass aggregations. In the early 1980s, verbenone, which is produced by *D. brevicomis* males, was shown to interrupt the response of *I. paraconfusus* and *D. brevicomis* to their aggregation pheromones. In the laboratory we found that high doses of verbenone significantly interrupted both female and male responses to an extract of naturally produced volatile attractants collected from Monterey pine logs infested with *I. paraconfusus* males. Ninety-nine-point-one percent (+) and 98 percent (-)isomers of verbenone increased the time required for beetles to reach the source of attractants. Ninety-eight percent (-) and 90-95 percent (-)verbenone, but not 99.1 percent (+)verbenone decreased the number of females responding to the attractant pheromone.

In field studies on East Bay Municipal Water District lands near Berkeley, we have demonstrated that both 99 percent (+) and 90-95 percent (-)verbenone substantially decrease the number of *I. paraconfusus* caught at traps baited with male-infested logs. Furthermore, the effectiveness of verbenone increases with increasing release rate of verbenone. We believe that these results are sufficiently promising to undertake large-scale efficacy tests. Our long-term goal is to develop a treatment method that will prevent attacks by *D. valens, I. paraconfusus* and *I. mexicanus* on Monterey pines in the urban landscape.

David L. Wood is Professor, Isao Kubo is Professor, Carlton S. Koehler is Extension Entomologist, James E. Milstead is Staff Research Associate, T. Ohtsuka is Postgraduate Researcher, Paul L. Dallara, Kenneth R. Hobson, Linda J. McPheron, and Steven J. Seybold are Graduate Student Researchers, in the Department of Entomological Sciences; J. Richard Parmeter, Jr., is Professor, Carey W. Slaughter is Staff Research Associate, Mo-Mei Chen is Visiting Scientist, People's Republic of China, Department of Plant Pathology; and Kenneth Q. Lindahl, Jr., is a Programmer/Analyst, Information Systems and Technology, University of California, Berkeley.