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Interactions Among Root Disease Pathogens and Bark Beetles in Coniferous Forests

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Department of Plant Pathology, University of California, 147 Hilgard Hall, Berkeley, CA 94720 USA

SUMMARY

At least two interactions exist among these important groups of organisms: (1) that of the bark beetles as vectors; and (2) that of root pathogens as predisposers of trees to beetles. Bark beetles might be important vectors of root decay fungi, but there is as yet little supporting evidence. However, some beetles may have primary roles as vectors of non-decay pathogens such as *Leptographium wageneri*, *L. procera*, and *L. terebrantis*. Possibly of greater importance is predisposition of trees by the pathogens. Evidence continues to build supporting the relationship, and there is a suggestion that beetles can maintain a relatively high population level in areas with above average disease activity. A few studies have shown effects on host physiology that may be related to increased susceptibility to bark beetles, and one or two have even suggested effects on primary attraction. A review of the literature in both forest pathology and forest entomology shows a serious deficiency in research on these interactions and their significance in resource management.

INTRODUCTION

Of the various, possible interactions between root diseases and bark beetles, three types emerge as potentially important: beetles as vectors, beetles as agents predisposing trees to root pathogens, and root diseases as predisposing agents for beetles. The roles of bark beetles in the transport of tree inhabiting fungi have long been recognized by such luminaries as Schmidberger in 1837 and Hartig in 1978 (Cobb, et al, 1968), but the fungi involved were mostly Hypomycetes and other Ascomycetous fungi that were not associated with root diseases.

BARK BEETLE VECTORS

The recent emergence of several Leptographium species, most notably L. wageneri, L. procerum, L. terebrantis, as root pathogens (Harrington, et al, 1988) has provided a new prospective on the importance of some bark beetles in forest pathology. Members of the genus Hylastes which breed and feed in roots have been strongly implicated in overland spread of at least L. wageneri, cause of black stain root disease, and possibly L. procerum as well. Both the red and the black turpentine beetles (Dendroctonus spp.) vector L. terebrantis, a rather virulent staining fungus often found in roots.

The role of bark beetles as vectors of Hymenomycetous root pathogens is still quite uncertain. Some evidence has been accumulating that beetles do vector several decay fungi (Harrington, et al, 1981), but their importance as vectors has not been established. Studies to determine if the turpentine beetles can act as a vector of Heterobasidion annosum have yielded conflicting results. For example, Himes and Skelly (1972) isolated H. annosum from the beetle in various stages of development and concluded that it was probably a vector. On the other hand, Hunt and Cobb (1982) found evidence that the beetles died in the presence of H. annosum and were colonized by the fungus. Although bark beetle dissemination of H. annosum and other similar fungi may occur, an important role of these insects as vectors of root decay fungi appears unlikely.

PREDISPOSITION

Especially in discussions with entomologists, the question arises, "Other than as vectors, do bark beetles weaken trees and predispose them to root disease pathogens?" In other words, which comes first, the chicken or the egg? By the very nature of the organisms, the answer should be clear. Bark beetles are notorious for attacking weakened trees and, with their fungal associates (blue-stain, etc.), killing the successfully infested trees. Thus, there are few trees that are attacked and weakened by bark beetles to the point of being predisposed to root pathogens. It has been difficult to convince many entomologists who still wish to think that their bark beetles infest perfectly healthy trees and kill them, even without the aid of the "blue-stain" fungi.

Probably the most important interaction worldwide is the predisposition of trees to bark beetles by root pathogens. Substantial numbers of supporting observations have been made in Europe (Franke-Grossman, 1963; Kisielowski, 1978), but most of the published studies specifically addressing the phenomenon appear to have been done in North American (Alexander, et al, 1980; Byler, et al, 1979; Cobb, et al, 1968; Cobb et at, 1974; Gara, et al, 1985; Goheen and Cobb, 1980; Hertert, et al, 1975; Highley and Tartar, 1985; James and Goheen, 1981; James, et al, 1984; Kulhavy, et al, 1984; Lane and Goheen, 1979; Livingston, et al, 1983; Morrison and Hunt, 1988; Tkacz and Schmitz, 1986). All of these studies support the position that root diseases are a dominant factor predisposing infected trees to bark-beetles. Some of the data indicate that 80-90 percent of the beetle-infested trees were infected by root pathogens prior to beetle attack (e.g., Byler et al, 1979; Cobb, et al, 1974; Kulhavy, et al, 1984). Such a high association can be expected only when the beetle population is relatively low and stable. However, it has very strong implications. For example, entomologists and pathologists alike have misdiagnosed apparent bark beetle-caused tree mortality because they failed to look beyond the beetles. Techniques on use of a shovel should be a requirement before bestowing a PhD. A misdiagnosis not only leads to dramatic under estimates of the impact of root diseases; it also leads to totally erroneous control or pest management decisions and to predictive models that are less than useless.

MECHANISMS OF PREDISPOSITION

Various hypotheses have been proposed to explain resistance and susceptibility of conifers, especially pines, to bark beetles. Water balance or deficit, oleoresin yield, crystallization rate and exudation pressure, proportion of various monoterpenes in phloem and xylem resins, phloem thickness and carbohydrate content (Cobb, et al, 1968), increased susceptibility to fungus (e.g. mycangial) associates, and increased primary attraction (Gara, et al, 1985; Goheen, et al, 1985) have been suggested. In the symposium on Leptographium (Harrington and Cobb, ed., 1988, pp-52-54), I summarized much of our research on the effects of black-stain root disease on these factors in ponderosa pine. These studies were intended to be the beginning of a long-term research project, but the lack of funding terminated the effort. Nevertheless, several interesting results emerged: (1) oleoresin yield and exudation pressure initially increased in diseased trees before they fell dramatically; (2) resin quality and phloem carbohydrates were unchanged; (3) water content of tissues dropped slightly, as did radial growth; and (4) reaction to fungus associates appeared to increase in the initial stages of disease and to drop precipitously near the end. With respect to primary attraction, we (Goheen, et al, 1985) obtained evidence supporting the contention that diseased trees were more attractive to bark beetles. Gara et at (1985) also presented evidence of attraction in lodgepole pine infected by Phaeolus schweinitzii and other root decay fungi.

It should be noted that root diseases are not the only disease type implicated as agents of predisposition to bark beetles. Other diseases that affect the stems (e.g. Kulhavy, et al, 1984) and crowns (Cobb, et al, 1968), such as rusts, dwarf mistletoes and air pollution injury, can have the same ultimate effects. However, the other disease types appear to take much longer and cause severe debilitation of the above-ground portions of the tree before beetle infestation, compared to little or no detectable crown symptoms in the case of root disease. Obviously, the roots of the trees with above-ground diseases have become seriously affected by the time of beetle attack. Thus, one could hypothesize that the key to disposition often resides in the roots.

INFLUENCE OF ROOT DISEASES ON BEETLE POPULATION DYNAMICS

The role of root diseases in the population dynamics of bark beetles has not been studied adequately. By causing stress in trees, these diseases are providing substrate to maintain beetle populations. The higher the incidence of root disease, the larger the amount of substrate available to the beetles, and presumably the larger the beetle populations which will be sustained. If something occurs in the environment, even on a relatively short-term basis, such as reduction in natural control agents (e.g. predators and parasites) or a drought that creates stress in the general tree population, the larger beetle populations associated with diseased trees can build rapidly to levels with substantial economic impact.

We believe that some of the data presented to this group 15 years ago (Cobb, et al, 1974) reflect that pattern. During a period when the population of bark beetles in northern California was generally low, areas with beetle "problems" often coincided with areas of high root disease incidence. Ten years ago, when northern California had a 2-yr drought, areas with the heaviest mortality of trees presumably caused by bark beetles often were areas with a chronically high incidence of root disease (U.S. Forest Service, Region 5 detection reports, 1978-1979).

In spite of such indications and much talk about integrated forest pest management in the U.S., we have not yet been able to implement the types of studies needed to evaluate the importance of root diseases (or other diseases) on bark beetle population dynamics. Such studies are likely to be large scale and require many resources and cooperation among managers, silviculturists, entomologists and pathologists.

With shrinking resources for forest pathology and entomology research and education, the task has become even more difficult. We must reach the forest resource manager who, with his yield models and computers, is increasingly ignoring the information that we have for him. To sustain the productivity of the forest, he must have and apply the best information that we can provide. To paraphrase a friendly entomologist (Gara, et al, 1985), "Understanding the interactions of fungi and bark beetle populations is a tool that forest managers must have in their attempts to minimize the effects of scolytid epidemics." However, at this point he must appreciate the need, but we must develop the understanding first before we can pass it on to him.

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Forestry Canada
Pacific Forestry Centre
506 West Burnside Road
Victoria, British Columbia
Canada, V8Z 1M5
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