

Interactions of Root Disease and Bark Beetles¹

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Abstract: Associations between root diseases and bark beetles (Scolytidae) constitute some of the most serious pest complexes affecting forests in North America and elsewhere. The interactive functioning of these pests derives from the following relationships: 1) root diseases predispose trees to bark beetle infestation by lowering resistance, and perhaps increasing attractiveness, of trees to the attacking beetles; 2) bark beetles may be vectors of root disease fungi or may create infection courts for them.

Symbioses between bark beetles and fungi are common in nature, and previous reviewers (e.g., Graham 1967) have identified several types of these symbiotic relationships, some of which appear to be beneficial to both (mutualism), and others which apparently benefit only one (competition, predation, parasitism). These relationships will be discussed in relation to interactions between root diseases and bark beetles. Others, which benefit neither (i.e., commensalism or cohabitation), are not considered to be true interactions as defined here, and will not be further mentioned.

VECTERING

Virtually all bark beetles vector fungi to host trees, inoculating the phloem and xylem as they mine in the cambial region. Much studied are the pathogenic blue- and brown-staining fungi, vectored by stem- and twig-infesting beetles. These fungi largely infect above-ground host tissues and thus are not true root pathogens. Bark beetles can also carry propagules of saprot fungi

(Castello and others 1976; Harrington 1980), which may explain the rapid decay of sapwood following tree-killing by bark beetles. Despite much research, vectoring of root disease fungi by stem-infesting bark beetles has not yet been firmly established, but they have been implicated as vectors of Peniophora gigantea (Fr.) Jul., a fungal antagonist of Heterobasidion annosum (Hunt and Cobb 1982). Recently, however, a species of root-colonizing bark beetle in the genus Hylastes and root-colonizing species of the weevil genera Steremnius and Pissodes have been implicated in vectoring Leptographium (Verticicladiella) wageneri (Kendr.) Wingf., the fungus causing black-stain root disease in Douglas-fir (Harrington and others 1985; Witcosky and others 1986a). As these vectors readily breed in roots of recently cut stumps, their populations evidently increase in stands after thinning (Harrington and others 1985; Witcosky and others 1986b). Previously, another root-colonizing species of Hylastes had been implicated as a vector of this fungus in ponderosa pine (Goheen and Cobb 1978). As other root-colonizing beetles are studied, more species will probably be implicated as vectors of root disease fungi.

Vectoring of H. annosum by bark beetles has not been confirmed. Nuorteva and Laine (1968) and Hodges (1969) reviewed literature on the possibility of insect vectoring. Nuorteva and Laine showed that various beetles could become contaminated with conidia by walking across agar cultures of H. annosum. Hunt and others (1976, 1982) discussed the possibility of insect vectoring of H. annosum in western North America. They concluded that even though conidia and basidiospores are produced on stumps, it is unlikely that insects play a major role in dissemination of H. annosum. However, circumstantial evidence and the observations that annosus root disease can appear in stands with no history of cutting suggest that the possibility of at least occasional spread of H. annosum by insect vectors cannot yet be excluded. Because the initiation of new centers of annosus-caused mortality in western timber stands appears to be a relatively rare event, even infrequent insect vectoring could be important. The initiation of one or two such centers per acre over an 80-year rotation could have serious impacts.

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PREDISPOSITION

The role of root diseases in predisposing trees to bark beetles was largely ignored in early studies of bark beetle population dynamics and control. More recent studies (Partridge and Miller 1972, Cobb and others 1974, Lane and Goheen 1979, Alexander and others 1980) have revealed that, where bark beetle populations are not in outbreak phase, a high proportion of trees killed by bark beetles also are root-diseased. However, Cobb and others (1974) found that, where bark beetle outbreaks are in progress, the proportion of killed trees that also are root-diseased tends to be lower, suggesting that root-diseased trees act as foci from which bark beetle outbreaks can spread during droughts or other widespread tree stress.

Physiologically, the predisposition of root-diseased trees to bark beetle attack has been shown to involve such indications of subnormal physiology as increased moisture stress and reduced resin exudation pressure, both of which are known to signify reduced tree resistance to bark beetle attack (Stark and Cobb 1969, Ferrell and Smith 1976). There is also some evidence that ponderosa pines with black-stain root disease are attractive to certain species of Dendroctonus bark beetles before they initiate mines and concomitantly produce attractants (Goheen and others 1985). Similarly, in Douglas-fir, segments of roots with black-stain root disease were more attractive to the Hylastes and Steremnius vectors of the black-stain fungus than were segments of uninfected roots (Witcosky and others 1987).

Other than the vectoring of pathogenic fungi to trees, there is presently little evidence supporting the idea that bark beetles predispose their host trees to root diseases. However, even if root-colonizing beetles are not vectoring fungal pathogens, their feeding wounds in roots may create infection courts for pathogenic fungi present in soil or other, infected, roots. For example, in precommercially thinned Douglas-fir stands, Harrington and others (1985) found numerous feeding wounds of Hylastes beetles in roots of residual trees. None of these wounds was observed to be infected by black-stain disease, but field observations have long implicated lesions in the root cortex as infection courts for H. annosum (see review by Nuorteva and Laine 1968). Hendrix and Kuhlman (1964) found that pine roots could be infected by H. annosum through root wounds, including wounds made by insects. It is therefore likely that insect wounds in roots are important infection courts for H. annosum.

COMPETITION

Compared to mutualistic relationships, competitive or other antagonistic interactions between bark beetles and root disease fungi have not been widely reported. But in stumps or at the base of trees, in galleries of stem-infesting beetles invaded by H. annosum, the beetles are sometimes observed to be dead and enveloped by mycelium of the fungus (Stark and Borden 1965, Hunt and Cobb 1982). However, root disease infections rarely spread far upward in stems. Thus, on a tree-wide basis, beetle survival would likely not be much reduced by this mortality except for a species like Dendroctonus valens LeConte which seldom attacks its host pines more than two meters above ground.

Competitive or other antagonistic interactions may also occur between the fungal symbionts of stem-infesting bark beetles and root disease fungi. Such interactions could be particularly important in reducing stump colonization by H. annosum in trees felled for bark beetle control. Hunt and Cobb (1982) observed that fungal symbionts of bark beetles frequently co-occur with H. annosum in pine stumps in California. They concluded that although these fungi may reduce the amount of H. annosum colonization somewhat, they had not colonized enough stump surface or volume to reduce H. annosum colonization in pine stumps to a level acceptable to forest managers.

Other interactions may be envisioned. For example, root systems of trees killed by bark beetles might deteriorate too rapidly to provide suitable substrate for root disease fungi. If so, it is possible that early killing of infected trees or their healthy neighbors by bark beetles might reduce the rate of enlargement of root disease centers.

CONCLUSION

Our understanding of the various ways in which bark beetles and root diseases interact remains limited. Interactions in addition to those discussed above may also be important. For example, whether insectan natural enemies of bark beetles might vector root disease fungi has not been widely assessed, but it may be important to do so because of their potential introduction into new environments as biological control agents for bark beetles. With the increased recognition of the importance of interactions between bark beetles and root diseases, it is likely that this field of research will receive increased attention.

Additional research on insect/annosus interactions could greatly benefit forest managers. If spread of H. annosum by insects to roots of trees or stumps is common in some

tree species, reduction of insect activity could be an effective adjunct to treatment of stump surfaces to prevent infection by the fungus. Conversely, frequent spread by insects could compromise the effectiveness of stump treatment to prevent colonization. Since H. annosum sporulates mainly in and on stumps, burning or removal of stumps could minimize the opportunities for insects to encounter and disseminate spores. Burning is known to reduce the incidence of annosus root disease (Kallio 1965, Froelich and Dell 1967), but the mechanism of reduction is unknown.

If the maintenance of endemic beetle populations rests in large part on the availability of trees weakened by root disease, early recognition and removal of live trees that are infected or that have a high probability of infection might reduce or delay epidemic build-up of beetles.

The importance of information on these insect/annosus interactions and the opportunity to exploit such information in forest management are almost entirely speculative at present. The potential benefits from the development and use of such information certainly justify additional research effort.

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