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Association of an Endemic Mountain Pine Beetle Population with Lodgepole Pine Infected by Armillaria Root Disease in Utah

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ABSTRACT

A random sample of 42 mature lodgepole pines revealed a significant and consistent association between infection by the root pathogen Armillaria mellea *and the incidence of infestation by low population (endemic) levels of mountain pine beetle* (Dendroctonus ponderosae). *Of 21 trees with visual indicators of parasitic* A. mellea *infection, 19 were infested by the beetle, while only three of 21 trees with no visible indicators of* A. mellea *were infested. This is the first documentation of the association in lodgepole pine that may be an important factor affecting the dynamics of endemic level populations of the beetle.*

KEYWORDS: *Dendroctonus ponderosae, Pinus contorta, Armillaria mellea*

INTRODUCTION

The mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) is the most destructive insect infesting lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) (Amman 1978). Infestations of MPB have reached outbreak levels throughout much of the lodgepole pine type in northern Utah (Thier and Hoffman 1982) and elsewhere in the Western United States and Canada (USDA Forest Service 1983). Because little can be done to reverse the trend of an outbreak once under way (Amman and Baker 1972), prevention of outbreaks is a sensible approach to limit tree killing. Consequently, a part of the mountain pine beetle research program funded by the U.S. Department of Agriculture, Forest Service, has been directed toward understanding the dynamics of low population (endemic) levels (Cole 1979), with the ultimate objective to develop strategies to prevent outbreaks.

Studies by Schmitz to characterize lodgepole pine infested by low population levels of MPB include measures of the incidence and severity of stem disease and insects and disease affecting the roots. Preliminary observations made in lodgepole pine stands growing in the Uinta Mountains in northeastern Utah revealed that many trees infested by endemic mountain pine beetle populations had roots infected by *Armillaria mellea*

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(Vahl. ex. Fr.) Kummer, sensu lato[3]. The evaluation described here was conducted to determine the proportion of lodgepole pine infected with *A. mellea* that was attacked by the mountain pine beetle and to determine whether the infections were of a saprophytic or parasitic nature. This report documents the first record of an association between the mountain pine beetle and the root disease caused by *A. mellea* in lodgepole pine.

Although root pathogens have been implicated repeatedly as important biotic agents responsible for predisposing conifers to bark beetle attack, definitive evidence documenting the extent of their involvement has been difficult to obtain (Cobb and others 1974). Understandably, the time and effort required to excavate root systems to document the incidence and severity of these rots have slowed efforts to gain a meaningful understanding of their role in the dynamics of bark beetle populations.

Armillaria mellea infection causes butt rot, growth reduction, and perhaps eventual death of the infected tree (Morrison 1981). Some suspect that *A. mellea* is the most common root pathogen infecting lodgepole pine (Krebill 1975). In northern Idaho, this pathogen caused a high percentage of the rot in roots of western white pine (*Pinus monticola* Dougl.) but was not thought to increase the probability of attack by the mountain pine beetle (Ehrlich 1939). However, Kulhavy and others (1984) excavated entire root systems of white pine (*Pinus monticola* Dougl.) with explosives and found a strong association between the presence of *A. mellea* and MPB. They postulated that establishment of *A. mellea* is aided by infection from another pathogen, blister rust (*Cronartium ribicola* Fisch.), that girdles the bole, causing a decline in host condition. *Armillaria mellea* was found infecting ponderosa pine (*Pinus ponderosa* Laws.) infested with several species of bark beetles in Idaho (Partridge and Miller 1972), California (Cobb and others 1974), Colorado (Fuller 1983), and New Mexico (Livingston and others 1983). In South Dakota, examination of the roots of 115 ponderosa pines killed or currently infested by MPB revealed a statistically significant association between beetle-killed trees and the presence of *A. mellea* (Hinds and others 1984). Examination of 16 lodgepole pine stands in central Idaho revealed that, although *A. mellea* was occasionally present in root systems within the study area, none of the trees examined were infested with bark beetles, including the mountain pine beetle (Kulhavy and others 1978). These results were in keeping with an earlier study that found the incidence of root diseases and infestation by MPB did not show a strong correlation in mature stands of lodgepole pine (Partridge and Miller 1972). In contrast, investigation of an apparent association between fire-scarred lodgepole pine and the fungus *Poria asiatica* (Pilat) Overholts in Oregon revealed that trees with advanced stages of this disease were susceptible to attack by MPB (Geiszler and others 1980; Gara and others 1985).

STUDY AREA

The lodgepole pine stand in which the association was discovered was on the North Slope of the Uinta Mountains, elevation 8,500 feet (2 600 m), approximately 22 miles (35 km) south of Mountain View, WY, on the Wasatch National Forest. The 90-acre (36-ha) stand covered had a mean age of 112 years, diameter at breast height (d.b.h.) of 6.8 inches (17.2 cm), and basal area of 48 ft^2 per acre (118 m^2 per ha). The community type is *Pinus contorta/Vaccinium scoparium* (Steele and others 1983). The area experienced major outbreaks of the mountain pine beetle in the 1930's and 1950's. Until summer 1982, MPB populations were considered endemic, but during summer 1983, three tree groups were infested, suggesting populations were building toward the outbreak phase common in stands east of the study area.

METHODS

Twenty variable-radius plots (BAF 10) were established in the stand during October 1983 at 5-chain (100.6-m) intervals along two randomly located transects, 10 chains (201.2 m) apart. On each plot, a maximum of three trees were examined for the presence of root diseases. The trees were classified as live (not infested by MPB), currently infested (infested during mid-August 1983 by MPB), or dead (killed by MPB previous to 1983). Currently infested trees were examined within 6 weeks of MPB attack; therefore, ratings of disease severity had not been affected by saprophytic spread. Eight additional trees infested by MPB in August 1984 were examined in October 1984. The first tree of each category encountered in a clockwise rotation from true north was selected for disease diagnosis. In addition, 31 trees categorized as infested or dead, which were outside the survey transects but within the 90-acre (36-ha) study area, were also examined for the presence of root rot.

Roots of each tree were excavated out to 3 feet (0.9 m) from the bole and down to 1.5 feet (0.5 m) below ground line. The root collar was examined for evidence of resinosis or mycelial fans of *A. mellea* (figs. 1, 2). Next, individual roots were examined for resin-encrusted lesions or subcortial mycelial fans with rhizomorphs, characteristic external indicators of *A. mellea* infection (figs. 3, 4). The degree that primary roots were infected by *A. mellea* was rated by percentage as follows:

0	No apparent infection
1	1 to 25 percent
2	26 to 50 percent
3	51 to 75 percent
4	76 to 100 percent

Resinosis on the roots was considered an indicator of parasitic infection that was present prior to beetle infestation (Cobb and others 1974). Root sections from

[3]AUTHORS' NOTE: Recent taxonomic and genetic studies have segregated several biological species in the *Armillaria mellea* complex (Wargo and Shaw 1985). Techniques for determining the biological species of diploid field isolates were not available when this study was completed. The isolates collected during this study will be paired with known haploid testers to determine their taxonomic position.

Figure 1.—Lower bole and excavated root collar of lodgepole pine with outer bark removed showing mycelial fans of *A. mellea*.

Figure 2.—Lower bole of lodgepole pine with outer bark removed to show *A. mellea* mycelial mats immediately adjacent to galleries of the mountain pine beetle.

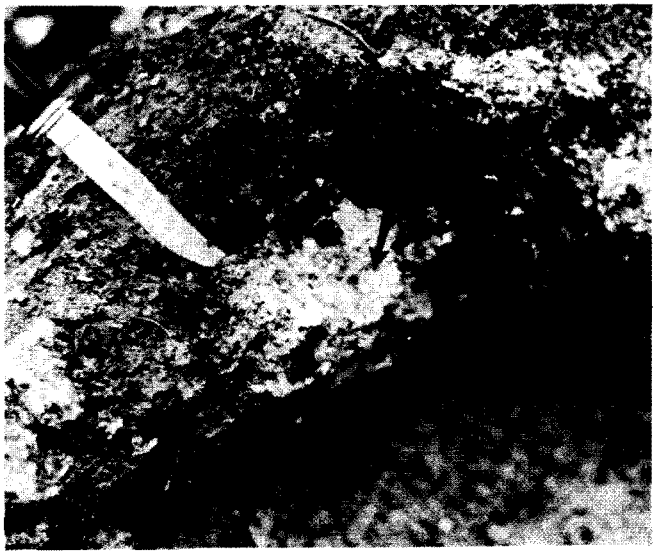

Figure 3.—Primary root showing resin-encrusted lesion common on many roots of trees infected with *A. mellea*.

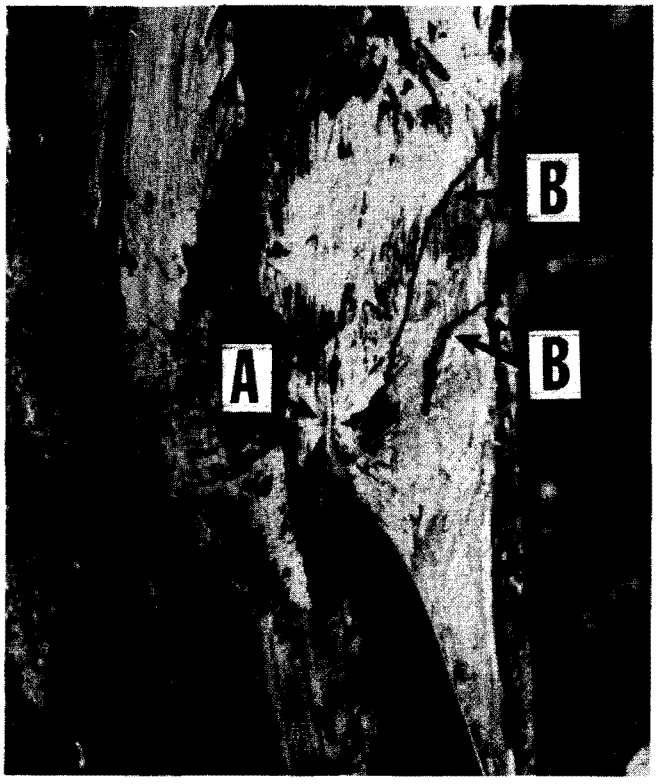

Figure 4.—Primary root with outer bark removed to show mycelial mat (A) and rhizomorph (B) of *A. mellea*.

each tree were transported to the laboratory for isolation of fungi. Wood chips from these roots were aseptically placed on 2 percent malt agar and incubated for 2 months at room temperature to encourage growth of fungi for identification (fig. 5). The root sections were also incubated for 6 months in moist sand to promote *A. mellea* rhizomorph growth (fig. 6).

All trees were also rated for severity of comandra rust (*Cronartium comandrae* Pk.) (Brown 1977) and dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) (Hawksworth 1977) infection.

Contingency tables were used to analyze the association of MPB infestation and mortality and disease incidence for trees sampled on the 20 variable plots. The associations were considered significant ($p \leq 0.05$) if chi-square values exceeded 5.99. Contingency tables were also constructed to analyze the following pest associations: dwarf mistletoe and MPB, comandra rust and MPB, dwarf mistletoe or comandra rust and MPB, dwarf mistletoe and *A. mellea*, comandra rust and *A. mellea*, dwarf mistletoe or comandra rust and *A. mellea*.

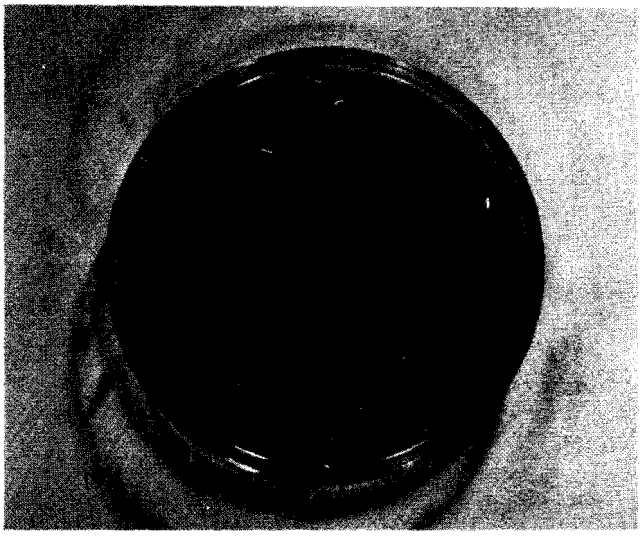

Figure 5.—Wood chips from root sections suspected of being infected with *A. mellea* were incubated in the laboratory to promote development of identifying characteristics such as rhizomorphs.

RESULTS

A total of 42 trees were examined on the 20 plots. Of these, 20 were classified as live and uninfested, 12 as currently infested with beetles, and 10 as previously killed by beetles. *Armillaria mellea* was positively identified on two live uninfested trees, 11 currently infested trees, and eight dead trees (table 1). This includes only those trees that had external indicators of parasitic *A. mellea* infection or yielded *A. mellea* in culture. Of 21 trees with the visual indicators of parasitic *A. mellea* infection, 19 were infested by MPB, while only three of

Table 1.—Contingency table comparing the number of trees infested by mountain pine beetle (MPB) with the presence of parasitic *Armillaria mellea* (AM) infection in a selected lodgepole pine stand, Wasatch National Forest, UT, 1983-1984

A. mellea incidence	MPB infestation category			Subtotal
	Live (not infested)	Currently infested	Dead	
AM present[1]	2	11	8	21
AM absent	18	1	2	21
Subtotal	20	12	10	42
Chi-square value = 24.73				

[1]Presence determined by existence of external indicators of *A. mellea* mycelial fans on roots of host tree or by laboratory culture yielding *A. mellea* isolates.

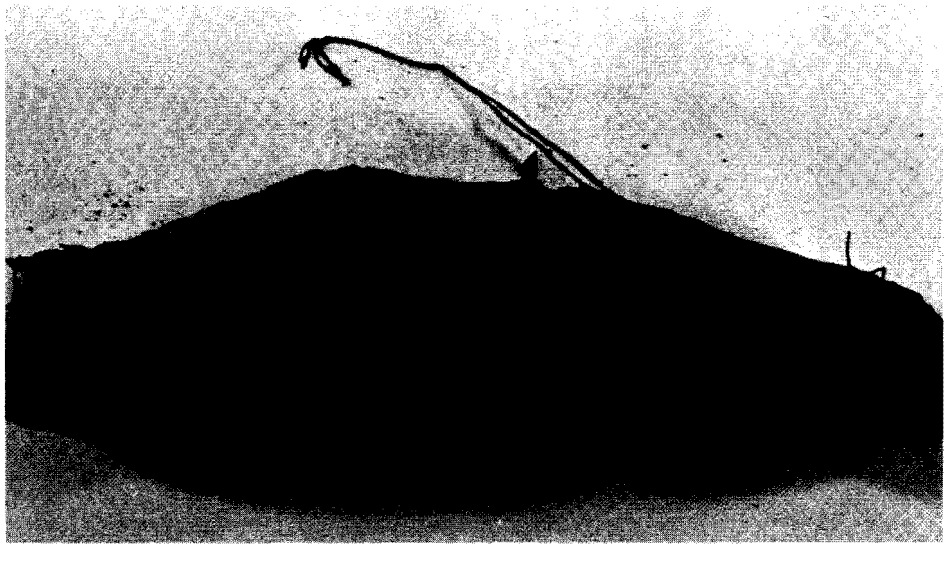

Figure 6.—Primary root showing *A. mellea* rhizomorphs that developed from lesions after incubation in moist sand.

Table 2.—Comparison of the number of trees infested by the mountain pine beetle (MPB) with the severity of *A. mellea* (AM) infection ratings in primary roots of lodgepole pine, Wasatch National Forest, UT, 1983-1984

MPB infestation category	Severity of primary root infection by *A. mellea*[1]					
	0	1	2	3	4	Subtotal
Live (not infested)	18	0	1	1	0	20
Currently infested	9	9	12	6	3	39
Dead	2	2	0	1	9	14
Subtotal	29	11	13	8	12	73

[1]Rating based on percentage of primary roots infected with *A. mellea:*
0 No apparent infection (as indicated by absence of *A. mellea* signs or failure to culture pathogens)
1 1 to 25 percent of primary roots infected
2 26 to 50 percent
3 51 to 75 percent
4 76 to 100 percent.

21 trees with no visible *A. mellea* indicators were infested (table 1). The chi-square value for the association in table 1 is 24.73, which indicates that the associations are significant at the $p \leq 0.05$ level. Analysis of the association of comandra rust and dwarf mistletoe with *A. mellea* and MPB revealed that none of the associations were significant at the $p \leq 0.05$ level.

Table 2 gives root disease ratings for all 73 trees examined (42 on variable plots and 31 in beetle-infested areas). Live trees (unattacked) tended to have lower severity of infection ratings than trees currently infested or killed previously by the beetle. The higher ratings for dead trees probably resulted from saprophytic spread of *A. mellea* following the death of the host tree as reported earlier by Ehrlich (1939).

All of the beetle-killed and infested trees exhibited some resinous lesions on the roots, indicating infection by *A. mellea* was present prior to beetle attack. No other root disease fungus was identified. Several trees yielded unidentified imperfect fungi. These isolates are being examined further to determine if they are associated with root diseases or stains.

DISCUSSION

This initial survey revealed that mature lodgepole pine infected with *A. mellea* were infested by endemic population levels of the mountain pine beetle with greater frequency than uninfected lodgepole pine (table 1). The results emphasize the need to determine the mechanism by which those host trees are located. Although this study was not designed to determine the host selection mechanism, several explanations for such associations have been formulated by those studying other bark beetle-root rot associations (Cobb and others 1974; Hertert and others 1975; Alexander and others 1981).

Basically, two hypotheses have been developed to explain the associations between *A. mellea*-infected ponderosa pine and bark beetles. The most frequently proposed explanation is based on the premise that bark beetles attack trees at random (Vité and Wood 1961; Wood 1972), and that the presence of disease—particularly root rot—reduces a tree's resistance to beetle attack. Those supporting this hypothesis reason that water uptake is restricted, thereby limiting wound response in the form of resin exudation (Rudinsky 1962; Shrimpton 1978). Because *A. mellea* is a root pathogen that kills the phloem and decays the stem, it likely interferes with water absorption, resulting in a moisture deficit similar to that caused by drought. However, we do not know the degree of root infection and resultant moisture stress needed to reduce resin exudation below the threshold that permits successful attack by endemic populations. Attempts to simulate drought stress by freezing the root collars of ponderosa pine to disrupt water uptake did not significantly increase the landing rate of the mountain pine beetle on the treated trees compared to the untreated controls (Moeck and others 1981).

A second hypothesis is based on the premise that diseased trees are more attractive to dispersing beetles than are uninfected trees. Geiszler and others (1980) found that during the first few years of an outbreak, more fire-scarred lodgepole pines than unscarred were killed by MPB . More recently, measures of MPB host-selection behavior revealed that dispersing beetles preferentially select fire-scarred trees, primarily those infected by *P. asiatica* (Gara and others 1984). In contrast, field experiments by Moeck and others (1981) that were designed to determine whether pioneer beetles detect diseased hosts by olfaction, revealed no significant difference in landing rates of the mountain pine beetle on ponderosa pine infected with the root pathogen *Verticicladiella wageneri* Kendrick. The researchers concluded there was no evidence that trees infected with root disease produced primary attractants that guided inflight populations to these trees. More recently, Conn and others (1984), studying the quantity of pheromone production by axenically reared *D. ponderosae*, revealed that these microorganism-free beetles produce six times more trans-verbenol than wild beetles infected with associated microorganisms. These researchers also concluded that wild beetles produce less trans-verbenol because the internal microorganisms present either inhibit production of this pheromone or use it as a substrate that is converted to other compounds.

Additional tests and bioassays are needed to determine if such microorganisms play a role in primary attraction as suggested by Geiszler and others (1980).

Data presented here do not favor either of the host-selection hypotheses but do document an association between the mountain pine beetle and host trees infected with root rot. This association appears to be an important factor affecting the dynamics of endemic level populations. Within the 20 plots, the endemic populations present tended to concentrate on trees infected with *A. mellea*. Regardless of the host selection mechanism, the need to concentrate scattered populations on suitable hosts during the endemic period is essential to ensure mating and overcoming host resistance. While diseased trees likely have a reduced wound response favoring successful attack, they also tend to grow more slowly, resulting in thin phloem (Cole 1973). Thin phloem reduces brood survival, offsetting the increased brood survival likely to result from reduced wound response (Amman 1969; Cole and Amman 1969).

To determine the importance of this bark beetle—root rot association to the dynamics of low population levels, there is need to determine the incidence of *A. mellea* by habitat type within the lodgepole pine type and the frequency with which such trees are infested by endemic populations. Although, the association between comandra rust or dwarf mistletoe or both, and *A. mellea* was not significant, we suspect the high incidence of these two stem diseases in the stand may contribute to the spread of *A. mellea*. Accordingly, there is need to evaluate the interactions of these pathogens. There is also need to measure brood survival in the infected trees. Studies under way address these needs and seek to determine if the association serves as a triggering mechanism that allows endemic populations to reach outbreak status.

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