

Association of Root Diseases and Bark Beetles (Coleoptera: Scolytidae) with *Pinus ponderosa* in New Mexico

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ABSTRACT

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Heterobasidion annosum and *Verticicladiella* spp. were isolated from roots of ponderosa pine before and after attack by bark beetles (*Dendroctonus adjunctus*, *D. valens*, *Hylurgops planirostris*, *H. subcostulatus*, *Ips knausi*, and *I. pini*). These root pathogens should be considered in future assessments of ponderosa pine mortality in New Mexico.

The roundheaded pine beetle (*Dendroctonus adjunctus* Blandf.) has killed large numbers of ponderosa pine (*Pinus ponderosa* Laws.) in New Mexico (8). Root diseases have been thought to predispose ponderosa pine to bark beetle attack in other regions (1,4,11), and root-inhabiting bark beetles may vector disease fungi (3,6). Such relationships have not been considered in the southwestern United States. This paper reports the results of two studies on the association of diseased roots and other bark beetles with *D. adjunctus* on ponderosa pine. The first study (1978) was a survey to ascertain the presence of diseased roots on ponderosa pine killed by bark beetles. The second study (1979) examined live ponderosa pines for diseased roots before successful bark beetle attack.

MATERIALS AND METHODS

Forty-eight locations (mortality centers) with 10 or more dead ponderosa pines in the Lincoln National Forest and Mescalero Apache Indian Reservation were mapped by personnel of the Forest Pest Management Office, U.S. Forest Service, Albuquerque, NM, in the

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summer of 1977. Four centers were chosen randomly from this map, and during October 1978, five ponderosa pine within each center were examined for root diseases and bark beetles in the stems and roots. All trees examined were greater than 8 cm in diameter 1.4 m above the ground (dbh) and had died within the previous year. Bark beetles were still in the trees or had just emerged. At least one-third of the outer bark was removed from the bottom 2 m of the main stem of each tree. Bark beetle adults were identified using keys (12) and the New Mexico State University Forest Entomology Collection containing specimens identified by S. L. Wood (Department of Zoology, Brigham Young University, Provo, UT). If adults were not present, gallery patterns were used for identifications (A. C. Mangini, unpublished).

The root collar and the proximal 1 m of all primary roots of each tree were excavated and examined for bark beetles and symptoms of disease. Samples of stained or decayed wood in the roots were taken to the laboratory and incubated at room temperature (~20 C) on 2% malt agar; any fungi that developed colonies on the medium were identified (7,9,10).

In 1979, six ponderosa pine were

chosen at random from 23 trees whose boles were colonized by bark beetles in a 5-ha stand of pole-size trees located in Otero County, NM. The closest live ponderosa pine (whose bole was not colonized by bark beetles) of about the same dbh, age, height, and crown class was paired with each of the six infested trees. The trees were 12.7–28.7 cm dbh, 14–18 m high, and 24–50 yr old. None of the twelve trees sampled were heavily infected with dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum* (Engelm.) Hawksworth and Wiens).

The stem of each ponderosa pine was sampled for bark beetles. Sample points started 1 m above the stump and continued at 3-m intervals along the stem. A 0.024-m² area of bark was removed on opposite sides of the stem at each sample point. The bark beetles present were identified as described earlier.

Root systems were exposed using a stream of water. Soil was washed away to a depth of 1 m and up to 3 m from the stump. Each primary-root system was examined for evidence of disease and bark beetles. A primary-root system included the main root originating at the stump and the rest of the root system connected to the main root for a distance of 1 m. Any stained or decayed wood was noted. The percentage of the primary-root systems with diseased tissue was calculated for each tree. A nonparametric test (2) was used to compare the differences in the percentages of diseased primary-root systems between living and dying trees. Samples of diseased wood were taken to the laboratory and cultured; fungi were identified as described earlier. Bark beetles from roots

Table 1. Diseased primary-roots with stained or decayed wood on ponderosa pine colonized and not colonized by bark beetles in 1979^a

Pair of trees examined	Proportion of diseased primary roots		Sign test
	Trees colonized by bark beetles	Uncolonized trees	
1	6/6	5/9	+
2	11/11	4/16	+
3	6/11	0/7	+
4	4/8	0/8	+
5	5/6	6/11	+
6	8/8	2/10	+

^aProbability that uncolonized trees have more diseased primary roots than colonized trees is $P(T) = 0.0156$.

Table 2. Occurrence of root fungi and bark beetles on paired ponderosa pine examined in 1979 whose boles were completely colonized or not colonized by bark beetles

Pair of trees examined	Root fungi isolated ^a		Root bark beetles ^b		Stem bark beetles ^c	
	Colonized trees	Trees not colonized	Colonized trees	Trees not colonized	Colonized trees	Trees not colonized
1	Ha	Ha, VA ^d	Hp	Hp, Dv	Da	Da ^e
2	Cs, Gs, VA, Va	Ha, VB	Hp	...	Da, Hs, Ip	...
3	Cs, Va	...	Hp	...	Da, Hs, Ip	...
4	VA	...	Hp, Dv	...	Da	...
5	Va	...	Hp	...	Da, Hs, Ip	...
6	VA	Ha	Hp, Dv	Hp, Dv	Da, Ha, Ip	...

^aCs = *Ceratocystis* spp., Gs = *Graphium* spp., Ha = *Heterobasidion annosum*, VA = *Verticicladiella* A, VB = *Verticicladiella* B, and Va = *V. abietina*.

^bDv = *Dendroctonus valens* and Hp = *Hylurgops planirostris*.

^cDa = *Dendroctonus adjunctus*, Hs = *Hylurgops subcostulatus*, and Ip = *Ips pini*.

^dAssociated with *D. valens* attack.

^eColonization was limited to one-fifth of the bole circumference and was within 0.5 m of the root collar.

were identified as before and adults were placed in sterile vials, taken to the laboratory, sectioned, and placed on 2% malt agar. Resulting fungal cultures were identified.

RESULTS

In plots examined in 1978, all 20 ponderosa pine attacked by bark beetles also had stained and/or decayed roots. *Heterobasidion annosum* (Fr.) Bref. (syn. *Fomes annosus* (Fr.) Cooke) and *Armillariella mellea* (Vahl) Karst. were isolated from two and three trees, respectively. Also, three species of *Verticicladiella* were found. One was identified as *V. abietina* (Peck) Hughes, and the other two, being undescribed species, are referred to in this paper as *Verticicladiella* sp. A and sp. B. Isolates of *V. abietina* and *Verticicladiella* sp. B were used by T. C. Harrington (5) for pathogenicity studies and were assigned culture numbers NMA-103 and NMP-103, respectively. *V. abietina*, *Verticicladiella* sp. A, and *Verticicladiella* sp. B were isolated from three, four, and two trees, respectively. *Verticicladiella* sp. A and sp. B were isolated from the same tree on two occasions. Failure to isolate known staining or decay fungi from other diseased root tissue does not mean the fungi were not present. Growth of bacteria, yeast, and molds frequently contaminated the cultures used in these studies and prevented growth and identification of the stain or decay fungi.

Bark beetles were present in the stems on 18 of the trees examined. *D. adjunctus* and *Ips knausi* Swaine were found on 14 and 10 trees, respectively, of the ponderosa pine. Bark beetles were also found in 18 of the tree root systems. Root and stem bark beetles occurred together on 17 of the trees. Species of *Hylurgops* (mostly *H. planirostris* (Chapuis)) infested the roots on 19 of the trees, and *D. valens* LeConte was found in seven of the root systems examined.

In the 1979 study, ponderosa pine colonized by bark beetles had more diseased primary-root systems than adjacent live trees (Table 1) ($P(T) = 0.0156$). *Ceratocystis* spp., *Graphium* spp., *H. annosum*, *V. abietina*, and

Verticicladiella sp. A were isolated from diseased root tissue on infested trees (Table 2). *H. annosum* and *Verticicladiella* sp. B were isolated from roots on three living trees and one living tree, respectively. Both fungi were isolated from diseased roots where resin had impregnated the bark, phloem, and wood. Bark beetles were not present in these roots.

Larvae and pupae of *D. adjunctus* were found in the stems of all trees colonized by bark beetles (Table 2). *I. pini* (Say) and *Hylurgops subcostulatus* (Mannerheim) were found on four of six infested trees. One live tree was successfully attacked by *D. adjunctus*. Attacks were limited to one-fifth of the circumference and were within 0.5 m of the root collar.

H. planirostris successfully attacked roots of all ponderosa pine colonized by bark beetles (Table 2). Larvae were found as far as 1.5 m from the root collar. Roots of two infested ponderosa pine were attacked by *D. valens*. Larvae and attacking adults of *H. planirostris* and attacking adults of *D. valens* were also found in roots of the same live tree attacked by *D. adjunctus*. *Verticicladiella* sp. A was isolated from stained wood near a successful *D. valens* attack. Not all attacks of *D. valens* and *H. planirostris* resulted in egg laying. Another tree also had unsuccessful attacks of *D. valens* and *H. planirostris*.

Twenty-seven *H. planirostris* were collected for fungal isolations. *Verticicladiella* sp. A and *V. abietina* were isolated from two adults each, *Graphium* spp. were isolated from four adults, and *Ceratocystis* spp. and *Graphium* spp. were isolated from three adults. Of the 10 *D. valens* adults used for fungal isolation, *Graphium* spp. and *Verticicladiella* sp. A were isolated from one adult each.

DISCUSSION

Diseased roots were found on all ponderosa pine successfully attacked by *D. adjunctus*, *H. subcostulatus*, *I. knausi*, and *I. pini*. Of the 12 trees examined in 1979, only those with diseased tissue in at least 50% of the primary-root systems had been attacked successfully by bark beetles. *Heterobasidion annosum* and *Verticicladiella* sp. B were isolated from

diseased roots on ponderosa pine that bark beetles had not attacked successfully, indicating that these fungi infect trees before beetle infestation. Other studies also indicate *H. annosum* can predispose ponderosa pine to bark beetle attack (1,11). Inoculation studies (5) showed isolates of *Verticicladiella* sp. B (NMP-103) killed ponderosa pine seedlings with wounded roots, indicating this fungus could be involved in predisposing ponderosa pine to bark beetle attack.

H. planirostris and *D. valens* were found in living and dying ponderosa pine. *Ceratocystis* spp., *Graphium* spp., and *Verticicladiella* spp. were isolated from adults of these bark beetles. It is possible that *H. planirostris* and *D. valens* are capable of vectoring these fungi successfully from dead to live trees.

We believe that root diseases and bark beetles all contributed to the death of the ponderosa pine examined in these studies. Future assessments of ponderosa pine losses should consider the roles of root pathogens (particularly *Heterobasidion annosum* and *Verticicladiella* spp.) as well as bark beetles in tree death.

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