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Limb Rust Damage to Pine

by
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INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE
OGDEN, UTAH

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Research on limb rust builds on the foundation laid by J. L. Mielke, Forest Service (retired). Figures 1 and 3 are from his photographs.

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Limb Rust Damage to Pine

INTRODUCTION

Limb rust is a pine-killing disease in the western United States and southward to Guatemala. It was first recognized as a serious problem in 1913, when Hedgcock (8)[1] reported it to be the most destructive rust of western pines. In view of the later discovery of white pine blister rust in the West, Hedgcock's statement cannot now stand. However, limb rust remains the most destructive rust attacking ponderosa and Jeffrey pines throughout most of their geographic distributions. These pine species are extremely important for timber, watershed, and aesthetic values.

Mielke in 1952 reviewed and greatly extended our knowledge of limb rust of ponderosa pine (11). The present paper is a further review and extension of knowledge, presenting additional host, geographic, and biological data based on several years' observations. Included, too, are results from a sampling in 1965 of limb rust in Bryce Canyon National Park, and comparisons with data taken in 1935 from the same transect.

EFFECTS ON PINES

Unlike other pine rusts, limb rust is a systemic disease: infection can spread throughout a tree rather than being restricted to a canker or gall. The principal symptom, at least for old infections, is the pattern of branch death (fig. 1). Surrounding a zone of dead branches that have lost their needles and twigs are branches more recently killed that bear red-brown or gray needles. Live branches bearing spore sacs of one of the causal fungi (fig. 2) can usually be found near the zone (or zones) of recently killed limbs.

There is only one final effect of limb rust on pine: death of infected trees. No way is known to stop the killing process once the fungus grows into the bole from the branch originally infected (16). Death appears to result from loss of photosynthetic tissue and from energy demands of the fungus. Mielke (11) estimated that death comes after loss of about 80 to 90 percent of the crown, measured linearly along the bole (fig. 3). This loss is very slow because linear spread proceeds at the slow rate of about 1.5 feet per year, or half that in each direction.

Many trees die from secondary effects before 80 percent of the twigs are killed by the fungus. The principal secondary effect is loss of rust-weakened pines to attack by bark beetles (3, 19).

Height and diameter growth rates of infected trees become negligible after about 50 percent of their crowns are dead (11). Thus, appreciable wood is lost long before the rust kills trees.

PINE SPECIES ATTACKED

Unlike the gall, canker, and cone rusts of hard pines, each of which attacks pine species in several taxonomic groups, limb rust appears to be restricted to species that are usually placed in a single group--*Ponderosae*. The known hosts are ponderosa pine (*pinus ponderosa*) including its southern variety, Arizona pine (*P. ponderosa* var. *arizonica*), Jeffrey pine (*P. jeffreyi*), Apache pine (*P. engelmannii*), and ocote blanco or pino de montezuma (*P. montezumae*). There are also unconfirmed reports from Mexico of infection in other species of the group; for instance, pino amarillo (*P. cooperi*) in the State of Durango.

[1] Underlined numbers in parentheses refer to Literature Cited, pp. 9-10.

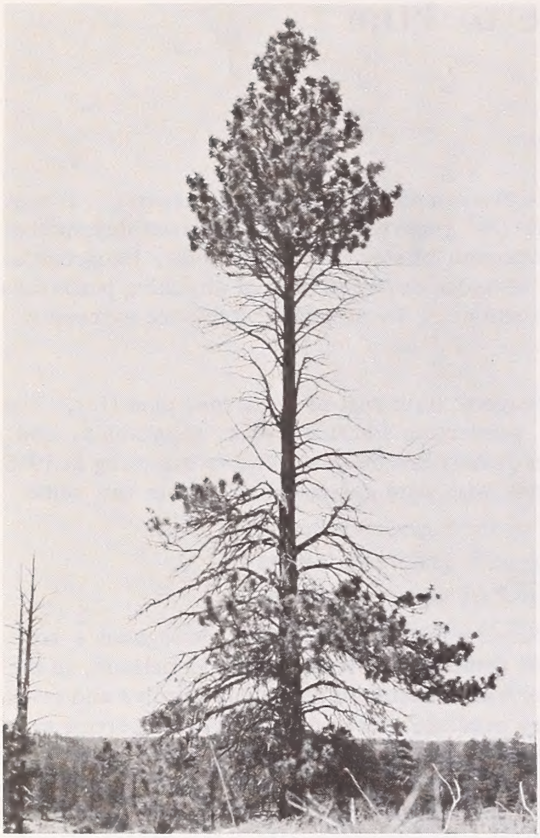

Figure 1.--Symptoms of limb rust infection in mid-crown typically include a zone of dead, leafless branches. Above and below this zone are recently killed branches that retain discolored needles and then branches that are still living.

No intensive outbreaks of limb rust have been found in species other than ponderosa and Jeffrey pines. The west coast form (var. ponderosa) of ponderosa is seldom attacked, but the Rocky Mountain form (var. scopulorum) suffers more from limb rust than any other pine.

CAUSAL FUNGI

Several related rust fungi cause limb rust. All of them are in or are apparently derived from the species group called Cronartium coleosporioides. Two distinctly different forms of this group, Peridermium stalactiforme and Peridermium filamentosum, are associated with limb rust on pine.

P. stalactiforme causes limb rust of Jeffrey pines in California and western Nevada. Its alternate hosts are Indian paintbrushes (Castilleja) and related plants. Infection of pine results only from spores that are produced on these alternate hosts. P. stalactiforme causes cankers rather than limb rust on most pine species that it infects; hence "limb rust" designates a kind of disease or symptom, not a distinct group of fungi.

P. filamentosum consists of at least three races in the United States and probably others in Mexico. One race alternates to Indian paintbrushes, thereby resembling P. stalactiforme in life cycle (but not in appearance). It is common in the Rocky Mountains and the Southwest. Alternate hosts are unknown for the other two races. One of them attacks ponderosa pine in Utah and adjacent States; the other is on Jeffrey pine throughout most of that tree's distribution. Spores of these races are believed to carry infection directly from pine to pine.

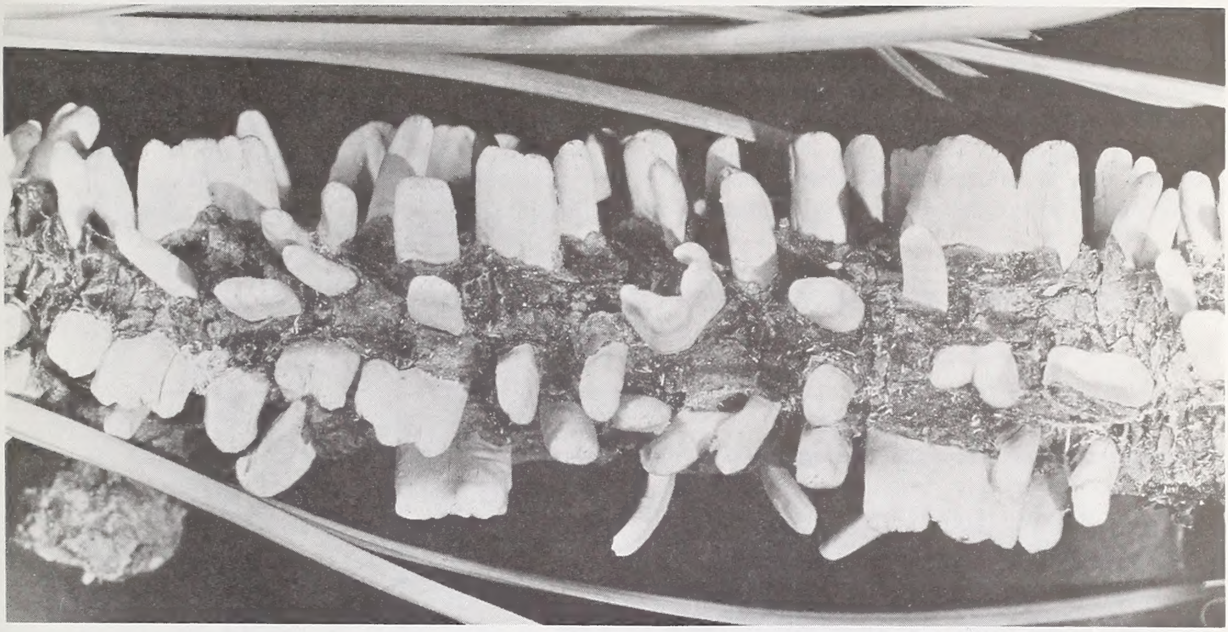

Figure 2.--Limb rust fungi produce white aecia containing orange spores on twigs near the zone of killed branches. This is Peridermium filamentosum. The aecia of P. stalactiforme are broader and shorter.

PATTERNS OF INFECTION

Peridermium stalactiforme in the Sierra Nevada usually occurs in immature pines in concentrated infection centers, often near lakes or streams, and often in obvious relationship to the presence of its alternate hosts. Most infections to be found now are low in the tree crowns.

Peridermium filamentosum in the Sierra Nevada and in southern Utah is found mostly in scattered mature and overmature pines. Occasional concentrations of fairly high percentage infection occur without apparent reference to topography. Low-, mid-, and top-crown infections are about equally common.

Limb rust in the Rocky Mountains and the Southwest does not fall neatly into either of the foregoing patterns of infection, at least in part because it is caused by mixed populations of two races of P. filamentosum. Known outbreaks in very young pines, for instance in the Black Hills National Forest and Grand Canyon National Park, are caused by the race that alternates to Indian paintbrush. Infections in older ponderosa pines are caused both by this host-alternating race and a race that does not infect paintbrush. In some areas, the lack of rust in young trees is due to the long interval since conditions favored infection, not to resistance to the causal fungus in young trees.

DISTRIBUTION

Limb rust occurs in the Rocky Mountains and Sierra Madre Occidentale from western South Dakota and northeastern Utah southward through Colorado, New Mexico, and Arizona to Chihuahua (5, 7, 11, 13, 15, 16). It is found in the Sierra Nevada, southern Coast Ranges, and Sierra de San Pedro Mártir from Plumas County, California, to northern Baja California (20, and author's reconnaissance). It has also been recorded in Guatemala (9).

A

Figure 3-A.--Ponderosa pines infected by limb rust are shown before and after (below) a 5-year interval.

Figure 3-B.--Three years after this photo was taken, the tree at the right was killed by bark beetles.

B

Within this large territory, centers of infection by limb rust have been observed in most of the National Forests where there are ponderosa or Jeffrey pines, but distribution of the disease is not continuous. Infection centers have been observed as follows: In the Black Hills and Medicine Bow National Forests in Wyoming; in the Roosevelt, Arapaho, Pike, San Isabel, Rio Grande, San Juan, and Uncompahgre National Forests and Rocky Mountain National Park in Colorado; in the Ashley, Fishlake, Manti-LaSal (both parts), and Dixie (all divisions) National Forests and Bryce Canyon National Park in Utah; in all 12 National Forests and on both rims of Grand Canyon National Park in New Mexico and Arizona; in ponderosa pine stands of the Charleston Division and in Jeffrey pine stands of the Mono Division of the Toiyabe National Forest in Nevada; in Jeffrey pine stands in the Plumas National Forest and the 11 National Forests south of it as well as in Kings Canyon and Sequoia National Parks in California; and in the Parque National Sierra de San Pedro Mártir in Baja California.

Although there are several other rusts of pine trunks and branches in eastern North America, Europe, and Asia, limb rust has not been reported in these regions.

REPORTED DAMAGE

Concern expressed by forest managers in southern Colorado prompted Hedgcock's studies and early reports of limb rust (7, 8). He found the disease to be abundant, long-established, and destructive in the San Juan National Forest. Garrett's observations in 1920 (5) revealed a destructive outbreak of long standing in what is now Bryce Canyon National Park.

Subsequent records did not reflect serious concern by land managers about limb rust until W. Drew Chick made a survey at Bryce Canyon in 1935, as reported by Mielke (11). Chick concluded that limb rust and dwarfmistletoe were causing the most serious damage to ponderosa pine in the Park. One speculation in his file report is of particular interest: "If rust and the Black Hills beetle should work in association (there is little present indication in the stand), the results are likely to reach disastrous proportions."

During the 1940's, forest managers began to seek advice regarding limb rust problems in Arizona, New Mexico, and the Dixie National Forest in Utah: prime mature and large overmature pines were being lost to the disease. In response, Mielke summarized available information on limb rust in a report distributed in 1944 to National Forests in the Southwest. He recommended that rust infection be considered a major factor in selection of trees for harvest. He pointed out that a drastic job of selective cutting would be needed on the Powell (now included in the Dixie) National Forest because the number of infected mature trees was so large. Management guidelines for this Forest at that time called for a 50-year cutting cycle, which was too long an interval if infected trees were to be salvaged without serious losses. Mielke later reported that about 11 percent of pines 3.6 inches d.b.h. or larger were infected by limb rust in one area on this Forest and that the percentages were much higher in selected plots (11). Damage was concentrated in trees 12 inches d.b.h. and larger.

In the Southwest generally, where infection levels are lower than those on the Dixie, the prospect of losses from limb rust didn't appear too serious. In the supposedly hard-hit Apache National Forest, F. G. Hawksworth in 1951 found that symptoms like those of limb rust were probably related to drought and insects rather than to rust; rust trees occurred at the low rate of five or fewer per hundred acres (17). Infection at this level or at the higher levels found in some districts could be handled almost without loss by the "improvement selection system" combined with short (not over 20-year) cutting intervals that had been recommended by Pearson (12).

In the Sierra Nevada, the limb rust problem became apparent on the Inyo National Forest in 1948. Wagener provided information the following year that was used as a basis for a program of salvage logging for infected Jeffrey pines.[2] By this means, as in ponderosa pine stands in the Southwest, incidence of limb rust has been steadily reduced in managed stands. Additional centers of heavy infection are being found, but the percentage of trees infected appears low over broad areas (4, and author's reconnaissance).

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[2] Memorandum to Inyo Forest Supervisor dated June 3, 1949.

Except for the Dixie National Forest, the serious concentrations of limb rust damage that remain toda are in recreational and wilderness areas. Such infection centers are found in Rocky Mountain National Park near Estes Park, Colorado; near several main points of attraction on both rims of Grand Canyon National Park; in San Jacinto Wild Area of the San Bernardino National Forest; in Big Pines Recreation Area of the Angeles National Forest; and in Mammoth Recreation Area of the Inyo National Forest. Probably most serious is the outbreak in Bryce Canyon National Park, where limb rust is common along at least 80 percent of the canyon rim.

BRYCE CANYON SURVEY

Most reports of limb rust damage have been based on general observation. To provide more exact data on incidence of limb rust and other problems in a high-value recreation area, especially on the relation of limb rust to tree size and to bark beetle attack, part of W. D. Chick's 1935 survey line in Bryce Canyon National Park was re-run in 1965 by personnel of the National Park Service and the Forest Service.

Unfortunately, the 1935 and 1965 transects were not exactly comparable. They probably failed to coincide by several yards along most of their lengths, and the 1965 survey was run for only 4.0 miles as compared to 12.6 miles covered by Chick's survey. However, the 1965 survey included much more than half of the ponderosa pine included in Chick's survey, the southern part of which ran mostly through fir and Douglas-fir stands.

The transect belt was 66 feet wide and extended from a point on the canyon rim about 1 mile north-northeast of Fairyland Viewpoint southward and southwestward to the junction of the Inspiration Point and Paria View roads. The northern 2.1 miles of the 1965 sample run east of the main Park road through pine stands in which relatively little pest control work has been done during the past 30 years. The adjoining southern 1.9 miles lie mostly west of the main road. In this area, intensive control work was directed against dwarfmistletoe and bark beetles during the 1950's. Control measures included the use of pruning, silvicides, and insecticides. Some limb rust infected trees in this area were heavily pruned.

Both the 1935 and 1965 surveys used somewhat subjective standards to categorize limb rust infections. "Early infection" indicates that limb rust was present but that only one or two primary branches of the tree had been killed; "intermediate infection" indicates that several branches or a small group of branches had been killed; "advanced infection" indicates that a large section of the crown was dead; and "near-lethal" indicates that more than 80 percent of the crown was rust-killed and the tree was likely to die within 2 years.

The 1965 surveyors probably were more conservative inasmuch as they were required to see spore sacs of the causal fungus before rating a tree as rusted. Chick's file report indicates that such was not required in 1935, but only that it was "often possible" to see spore sacs. Apparently all spike-topped trees were judged as rusted by the 1935 surveyors. This probably accounts for one or two percentage points' difference between the results in these surveys.

Pines smaller than 6 inches d.b.h. were not included in Chick's survey. These were found to be completely free of limb rust in the 1965 sample although occasional infections on small trees were observed outside the transect.

From table 1 it appears probable that limb rust is somewhat less common now in the northern part of the Park than it was throughout the Park in 1935. Judging from this difference plus the observed similarity of limb rust infection in the northern and southern parts of the Park (in spite of the different elevations and different percentages of ponderosa pine in the stands), it seems likely that there has been an overall decrease in the percentage of rusted pines during the past 30 years.

This putative decrease is in line with the relative shift away from "early infections" and toward "advanced infections": it appears that many infected trees have died during the 30 years but that infection has not kept pace. Most of today's "advanced infections" are "early," "intermediate," or even "advanced" infections of 30 years ago, judging from Mielke's data (11) on growth rates and from the one photographic series that goes back that far. Three photographs of one tree taken in 1935, 1947, and 1959 (2) show that a pine with 30 percent of its crown killed (an "advanced" infection) can still be alive 24 years later. This tree is shown in a photograph taken in 1948 (fig. 1).

Table 1.--Amount of limb rust infection in Bryce Canyon National Park in 1935 and 1965 by percentages of live pines 6 inches d.b.h. or larger in a belt transect[1]

Infection class	1935	1965		
	(Basis: 1401 trees)	North (basis: 462 trees)	South (basis: 459 trees)	Average (North-South)
	Percent			
Early	5.0	1.7	0.7	1.2
Intermediate	4.9	4.3	1.7	3.0
Advanced	4.7	6.5	4.1	5.3
Near-lethal	3.2	0.7	0.7	0.7
Total	17.8	13.2	7.2	10.2

[1] Length of the base transect surveyed in 1935 was 12.6 miles. Only 4.0 miles of the same transect were examined in 1965. The 4-mile transect is divided into a northern part 2.1 miles long and a southern part 1.9 miles long.

In the 1965 survey, 94 live pines from 6 to 37 inches d.b.h. were found to be infected by limb rust, their average diameter being 20.0 inches. The 827 rust-free pines, also 6 to 37 inches d.b.h., averaged only 11.8 inches. To reflect this major disparity, data in the last three columns of table 1 were recalculated in terms of percentage of basal area as follows:

Infection class	North (Percent)	South (Percent)	Average (Percent)
Early	2.5	2.1	2.3
Intermediate	6.7	4.0	5.4
Advanced	14.8	11.8	13.4
Near-lethal	0.8	1.4	1.1
Total	24.8	19.3	22.3

The 10 percent of trees that were rusted include about 22 percent of the basal area, with most of the increase over table 1 occurring in the "advanced" infection class. Percentages of volume would show an even greater relative importance of limb rust.

In the survey transect, there were 30 ponderosa pines that had recently died. They still retained considerable bark and most of them were still standing. These were examined for bark beetle galleries, dwarfmistletoe symptoms, lightning cracks, and, using blocks and stained sections (16), for limb rust mycelium.

Because blocks could be taken only from near the bottoms of standing trees, limb rust may have escaped detection in a few trees that had top-crown infections. Nonetheless, limb rust was detected in 22 of the 30 trees. Average diameter of these trees was 20.2 inches, as compared to 16.2 inches for the rust-free trees. Eighty percent of the basal area, consequently, was in infected trees.

Seven of these dead pines had been poisoned with silvicide to control dwarfmistletoe, and only one of the seven was also rusted; thus 21 of 23 trees (91 percent) that died natural deaths had limb rust infections. One of the other two was killed by lightning, and the last died of unknown cause. In the northern 2.1 miles of the transect--relatively undisturbed forest--15 of 16 (94 percent) of the dead pines had limb rust infections.

Of the 23 dead trees not killed by man in the 1965 transect, 9 had been attacked by *Dendroctonus* bark beetles: 3 by Black Hills beetle (*D. ponderosae*), 1 by roundheaded beetle (*D. adjunctus*), and 5 by western pine beetle (*D. brevicomis*). Three others may have been attacked: 2 "probably" attacked by red turpentine beetle (*D. valens*) and 1 "possibly" attacked by western pine beetle (these doubtful galleries were obscured by secondary borers). Of these 12 "beetle" trees, all but the last three were also infected by limb rust. No live trees were found that had been attacked by Dendroctonus.

Rust fungi are primary pests, favored by vigorous host trees rather than weakened ones (1), but bark beetles, at least in endemic conditions, are favored by weakened trees (6). It thus seems highly probable that all or nearly all the endemic beetle population observed in the sample existed because of rust-weakened or rust-killed pines.

Although some pines with advanced rust infections can survive for many years, it was observed in the Park that beetles tend to eliminate trees with limb rust even where infection is still in the "intermediate" stage. For example, in the Yovimpa Pass area (not in the transect) only two of the many large trees were rust-infected in 1965, both with "intermediate" infections. These were also the only two trees in the area attacked by bark beetles (one in 1964 and one in 1965).

DISCUSSION AND CONCLUSIONS

It appears fairly clear that timber losses due to limb rust can be held to an acceptable minimum by selective cutting and short cutting cycles where infection levels are normal. Cutting cycles up to 25 years probably are short enough. This assumes that tree markers can and do spot rust infections at early stages and that they eliminate the rusted trees wherever it is economic to do so. Cutting cycles shorter than 25 years would be needed where reduction of endemic bark beetle populations is critical.

In some National Forests, rust trees are being eliminated by wise selective marking and cutting; in others, the rust goes unrecognized. The Powell Ranger District of the Dixie National Forest provides the only known example of careful cutting of rust trees over a long (20-year) period where rust has not yet been reduced to an acceptable level. The problem is that there was too much rust at the outset.

In some areas a shift is being made from individual tree selection to block cutting followed by planting. If--as seems likely--plantations are as susceptible to limb rust damage as are natural stands, block systems will be in trouble where limb rust outbreaks occur. Whether block cutting could be continued without losses to rust would depend upon the times of infection in relation to times of thinning and of final harvest.

In stands managed to maintain or to regain the appearance of natural conditions rather than for timber, limb rust continues to be a real problem. In such recreational and wilderness areas the knowledge that good silvicultural practices can control limb rust damage is little comfort. These stands may appear ragged even where less than 20 percent of trees are infected because it is the larger and more conspicuous trees that are usually damaged (fig. 4). More serious than the ragged appearance--at least in Bryce Canyon National Park--is the likelihood that a large part of the endemic bark beetle population exists in rusted trees. Should conditions again favor a beetle outbreak, such as has occurred in the past at Bryce Canyon, limb rust--by affecting the endemic population base--will be partly responsible for the extent of damage. Limb rust is undoubtedly one of the damaging agencies with which these pine stands have always had to contend; therefore elimination of the disease would be undesirable where one management objective is to maintain the environment as a "museum" of the living forest. However, a new factor has been introduced where heavy use by people precludes normal regeneration of pine. Trees killed by disease are not replaced as they are in the pristine forest, and continued infection leads to unnatural depletion of the desired stand. An even greater source of worry is that diseased, heavily trampled stands may be susceptible to catastrophic outbreaks of bark beetles.

We do not understand the patterns in time and space of limb rust outbreaks. There are analogies with outbreaks of the better known comandra blister rust. For instance, at Bryce Canyon, present damage appears to be the result of a wave or waves of infection three or more decades old that are not being repeated now. This situation parallels that of comandra rust in lodgepole pine further north (10). Outbreaks of limb rust in southern Colorado that probably occurred in the nineteenth century (7) have not recurred to a serious extent, just as the early comandra rust outbreaks in ponderosa pine in that area have not recurred (14).

Figure 4.--Limb rust can markedly reduce the beauty of pine stands, as in this example in Bryce Canyon National Park.

Although limb rust outbreaks are widely spaced in time and although local changes in intensity can appear abruptly (18), it seems likely that limb rust maintains a fairly constant population over its whole distribution area. At least there is no good evidence substantiating an overall increase in the rust; no large concentrations of young infections have been reported recently. If future outbreaks are identified early, serious damage can be avoided where silvicultural practices can be used.

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AFOAMA/67/3/7

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