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Radial Growth of Grand Fir and Douglas-Fir 10 Years After Defoliation by the Douglas-Fir Tussock Moth in the Blue Mountains Outbreak

Boyd E. Wickman

Author

BOYD E. WICKMAN is supervisory entomologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, Route 2, Box 2315, La Grande, Oregon 97850.

Abstract

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Radial-growth recovery related to amount of tree defoliation was measured 10 years after a severe outbreak of Douglas-fir tussock moth (*Orgyia pseudotsugata* (McDunnough). For the period 1978-82, growth of grand fir surpassed and was significantly greater than in the preoutbreak period, 1968-72. Douglas-fir growth during the postoutbreak period showed similar patterns, but it was not significantly different from preoutbreak growth for every defoliation class. Growth of undefoliated trees was also greater during the postoutbreak period, indicating that above-normal precipitation aided tree recovery and masked the thinning effect of tree mortality.

Keywords: Increment (radial), insect outbreaks, Douglas-fir tussock moth, grand fir, Douglas-fir, Blue Mountains, Oregon, Washington.

Summary

Radial growth of individual trees was related to degree of defoliation 10 years after an outbreak of Douglas-fir tussock moth (*Orgyia pseudotsugata* (McDunnough). Study plots located in the Blue Mountains of Oregon and Washington during the outbreak in 1972 and 1973 were used to study various forms of tree damage. Trees on the same plots were measured in 1983 to determine growth recovery 10 years after the outbreak.

Increment cores were taken from every dominant and codominant grand fir (*Abies grandis* (Doug. ex D. Don) Lindl.) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) on the plots; a sample of nonhost trees was also cored. Nondefoliated host trees were cored from each of five check areas contiguous with the outbreak. Growth rates were compared for individual tree-defoliation classes between the preoutbreak and postoutbreak periods by using regression analysis and analysis of covariance to test for differences among these linear relations.

Growth recovery since the outbreak brought average radial growth to rates higher than those just before the outbreak for most grand fir defoliation classes. Growth recovery for Douglas-fir was similar, but not as pronounced. The difference between 5-year preoutbreak (1968-72) and 5-year postoutbreak (1978-82) growth was significant for all grand fir defoliation classes except the 90-percent class. For Douglas-fir, postoutbreak growth significantly surpassed the preoutbreak growth for the 25-, 50-, and 75-percent classes. Growth recovery from 1978-82 was apparently not strongly related to degree of defoliation. Above-average annual precipitation during the postoutbreak period caused all classes of trees—defoliated, nondefoliated, and nonhost—to respond positively, apparently masking growth differences caused by defoliation. These defoliated trees will be measured again in 1988; this remeasurement may reveal growth relations that have not yet become evident.

Contents

Introduction

The Douglas-fir tussock moth (*Orgyia pseudotsugata* (McDunnough) is an important defoliator of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) and true fir (*Abies* spp.) in western North America. Periodic outbreaks have caused severe timber losses. Tree mortality and top-kill account for most of the loss (Wickman 1978a), but reduced radial growth may add significantly to the damage (Wickman and others 1980).

The decline in growth of white fir (*Abies concolor* (Gord. & Glend.) Lindl.) caused by tussock moth defoliation is one of the most drastic on record for a forest defoliator (Koerber and Wickman 1970). The radial-growth configurations are so distinctive that old outbreaks can be easily identified from increment cores or disks cut from host trees (Wickman 1963, Wickman 1986, Brubaker 1978).

White fir, grand fir (*Abies grandis* (Doug. ex Don) Lindl.), and Douglas-fir defoliated by tussock moth in California, Oregon, and Washington have shown severe radial-increment loss during and immediately after defoliation (Wickman 1963, 1978b; Wickman and others 1980). The growth reduction was also related to degree of defoliation: trees defoliated 75 to 90 percent had more than double the growth reduction of trees defoliated less than 25 percent. Growth recovery was usually not complete until 4 or 5 years after defoliation. Stand conditions and tree growth were studied 10 years after a severe outbreak in California (Wickman 1978b). In that study, white fir recovery—as evidenced by increased radial growth—was well established 10 years after severe defoliation. Growth of both host and nonhost trees in the defoliated area surpassed preoutbreak rates; the reverse was true for nearby nondefoliated host trees.

An extensive outbreak in the Blue Mountains of Oregon and Washington in 1972-74 offered the opportunity to study tree damage resulting from defoliation by extremely dense tussock moth populations. The objective of studies begun in 1972 was to use defoliation intensity in 1972 and 1973 as a predictor of tree damage during and after the outbreak. Three important forms of damage—tree mortality, top-kill, and radial-growth reduction—have been summarized from these studies (Wickman 1978a, Wickman and others 1980). The three forms of damage have also been mathematically represented in the tussock moth outbreak and stand prognosis models (Overton and Colbert 1978, Monserud and Crookston 1982).

This study related radial growth of individual trees 10 years after the outbreak to degree of defoliation. The information can be used for mathematical representation in the tussock moth outbreak model and for updating the stand-prognosis model.

Methods

Plot Location and Defoliation Classes

More than 300 1/50th-acre plots were established in conjunction with 22 tussock moth population study areas (Mason 1976) in the Blue Mountains to study the effects of defoliation (Wickman 1978a). The area consisted of a 100-km transect of a tussock moth outbreak on the Umatilla and Wallowa-Whitman National Forests and included four additional, severely defoliated areas not included in the population study. Defoliation of each plot tree was estimated in seven classes immediately after the year of most intense defoliation (1972 or 1973). Defoliation classes were based on the percentage of crown length totally defoliated, as described in Wickman (1978a).

Sampling Techniques

Clusters of 10 to 15 damage plots were systematically gridded at each of the population study points and at some additional, severely defoliated areas in the Wenaha-Tucannon Wilderness. Every tree over 1-in d.b.h. on the 1/50th-acre circular plots was tagged and measured, and its defoliation was estimated. Complete information on plot establishment and tree measurements has been published (Wickman 1978a).

From July 15 to September 15, 1983, increment cores were taken from every dominant and codominant grand fir and Douglas-fir on the plots. These were the same trees that were cored in 1978 (less a few logged or killed trees). In addition, one dominant or codominant nonhost tree (if present) was cored on each plot. Twenty-one mature ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) were sampled from a pine stand on a dry ridge (sensitive site) in the outbreak area to compare general tree-growth patterns to climate (Fritts 1976). Nondefoliated host trees were cored from each of five check areas contiguous with the outbreak. Controls were 1 to 8 km from defoliated stands.

Two increment cores, including at least the last 20 years of growth, were taken from each tree at breast height. The cores were from two quadrants at 90 degrees, usually the north and west if possible, as suggested by Fritts (1976). Cores were glued to blocks of wood and sanded smooth.

A Bannister incremental-measuring machine coupled to an Apple II computer was used to measure annual increment to the nearest 0.01 mm (Stokes and Smiley 1968).[1] Measurements were tabulated and stored on discs by the Apple II and analyzed later on a mainframe computer. Because some cores were taken before 1983 growth was complete, growth measurements only through 1982 were used.

Analysis

Growth patterns for the 10-year outbreak and postoutbreak period (1973-82) were obtained from the following sets of trees: defoliated grand fir and Douglas-fir on the plots; nonhost trees on the plots; and nondefoliated hosts, grand fir, and Douglas-fir near the plots. Average radial growth was graphed by individual tree-defoliation classes for grand fir and Douglas-fir (figs. 1, 2). Growth averages for the years 1968-78 are the averages obtained from 1978 measurements (Wickman and others 1980). Average annual growth from 1979 to 1982 was added to each of the defoliation-class curves used in that earlier report.

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[1] Use of a trade name does not imply endorsement or approval of any product by the USDA Forest Service to the exclusion of others that may be suitable.

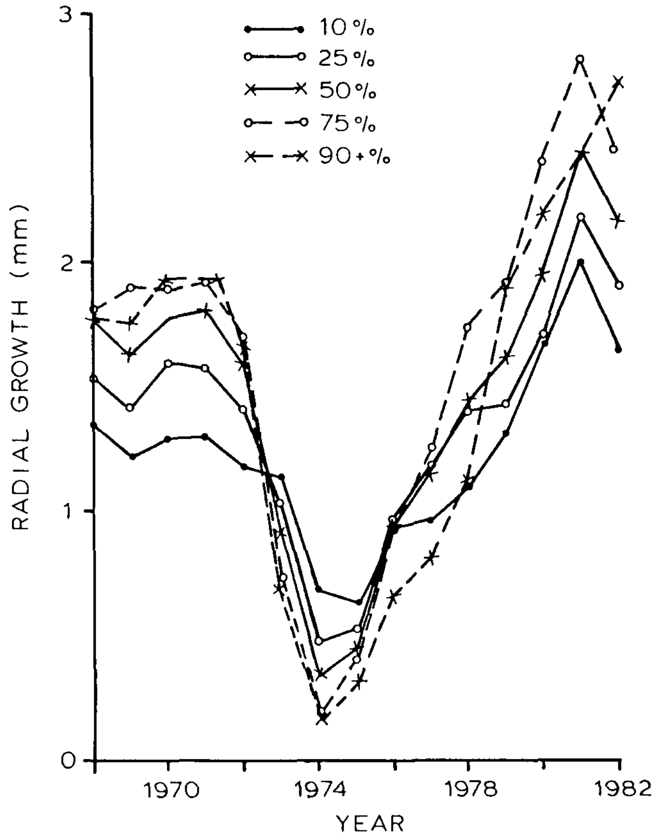

Figure 1—Average radial growth of grand fir tree-defoliation classes, 1968-82, in the Blue Mountains, Oregon and Washington.

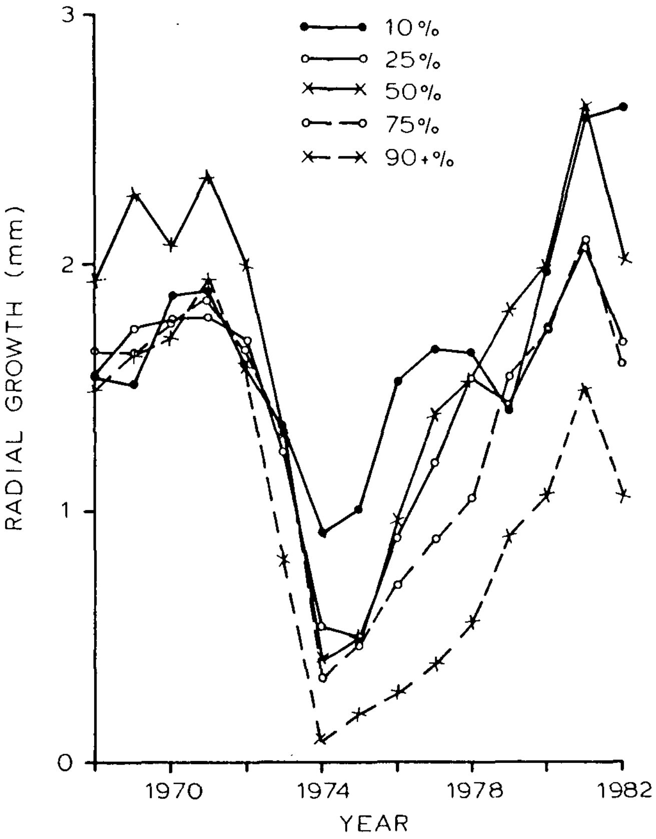

Figure 2—Average radial growth of Douglas-fir by tree-defoliation classes, 1968-82, in the Blue Mountains, Oregon and Washington.

Comparisons of average annual radial growth for defoliated host and nondefoliated host were made for five preoutbreak years (1968-72), the outbreak and recovery period (1973-77), and five postoutbreak years (1978-82). A paired t-test was used to compare preoutbreak with postoutbreak mean annual growth of individual trees within each of the two tree classes. This analysis indicates whether postoutbreak growth is significantly greater than preoutbreak growth in the defoliated-tree class.

Growth rates for individual tree-defoliation classes between the preoutbreak and postoutbreak periods were compared using regression analysis and analysis of covariance to test for differences among these linear relations. Independent random sampling of trees was assumed even though trees occurred in groups by plot clusters.

Results and Discussion

Both grand fir and Douglas-fir exhibited continuous improvement in growth until 1981. In 1982, all classes declined except the 90-percent class for grand fir and the 10-percent class for Douglas-fir, which were still on an upward trend. Growth recovery since the outbreak raised average radial growth to rates higher than those just before the outbreak for most grand fir defoliation classes (fig. 1). Growth of Douglas-fir defoliated 90 percent had not reached preoutbreak rates by 1981, but small sample size (seven trees) makes this curve suspect (fig. 2). The growth recovery for the three most severely defoliated classes of grand fir was greater than the lighter defoliation classes (fig. 1). Because most of the trees in these classes occurred in areas that also sustained severe tree mortality, the resulting decrease in stocking may have improved radial growth. The growth trend increased annually from 1975, coinciding with the pattern of average annual precipitation recorded at a nearby weather station (fig. 3) until 1982, when growth inexplicably declined for most defoliation classes.

Figure 3—Annual precipitation at Meacham, Oregon adjusted from Gibbon, Oregon, annual precipitation.

The sample of 21 ponderosa pine from a pure pine stand on a dry ridge surrounded by defoliated stands provided additional insight because pines are more sensitive than fir to changes in soil moisture (Fritts 1976). The year (1974) of greatest pine-growth depression (fig. 4) also coincided with the year of greatest growth reduction of defoliated fir, indicating that the unfavorable environment increased the effects of defoliation (Wickman and others 1980). In 1976, pine exhibited greatly increased growth, as did other species of nonhost trees (fig. 5). Precipitation thus played a positive role in the recovery of defoliated trees for at least 2 years after the outbreak.

During 1977-82, the sensitive pine did not always respond positively to increased precipitation (for example, in 1979), nor did other nonhost trees on the sample plots (fig. 5). The reason for this anomaly is not known, but it does illustrate the variability often found in relating tree growth to precipitation. Annual precipitation, for instance, may not indicate available moisture during the growing season.

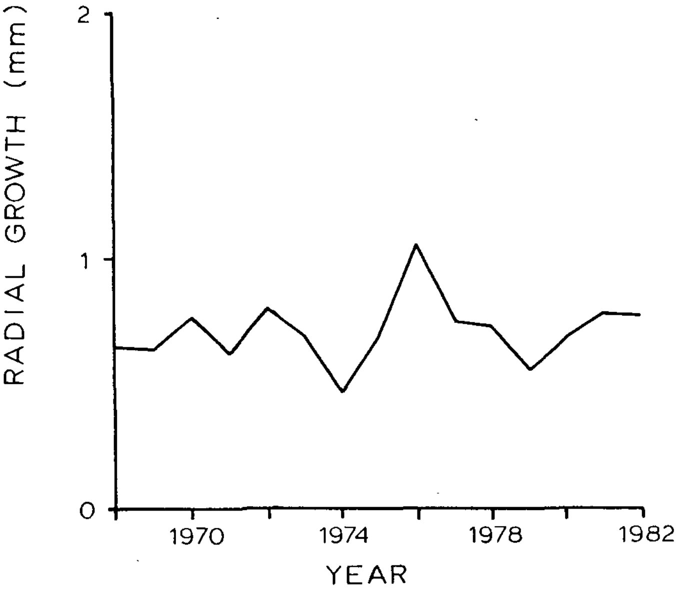

Figure 4—Average annual diameter growth of ponderosa pine from dry ridge surrounded by defoliated stands in the Blue Mountains, Oregon and Washington.

Figure 5—Average radial growth of nonhost trees, 1968-82, in the Blue Mountains, Oregon and Washington.

Growth rates declined in 1982 in all but two defoliation classes. This 1982 decline also occurred in the nonhost species on the plots, except for western larch (*Larix occidentalis* Nutt.) on which growth increased after 4 years of decline (fig. 5). Nondefoliated host near the plots had the same general pattern of growth as defoliated host trees for the period 1978-82, only the growth was greater (fig. 6). This response likely resulted from higher precipitation during the recovery period and because most of the nondefoliated trees were from better sites, such as canyon bottoms (Wickman and others 1980).

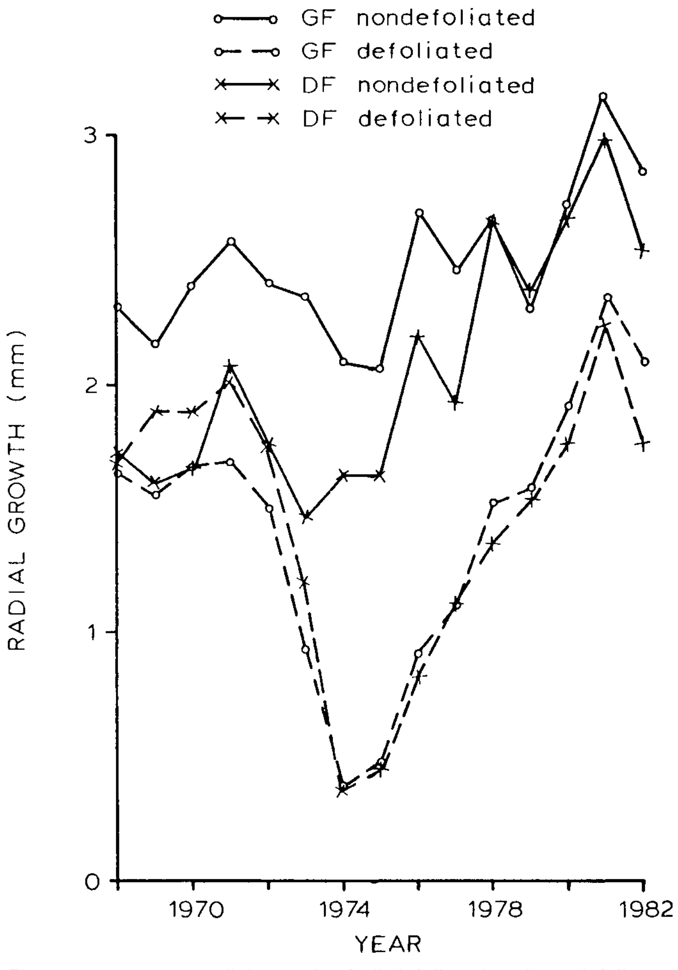

Figure 6—Average radial growth of all defoliated and nondefoliated grand fir and Douglas-fir in the Blue Mountains, Oregon and Washington.

Growth between the preoutbreak and postoutbreak periods of both defoliated and nondefoliated hosts responded similarly (table 1). Above-average precipitation probably played an important role in the similar growth patterns of both tree classes in the postoutbreak period. The effects of adequate precipitation masked whatever enhanced growth might have occurred from reduced competition for resources in the defoliated areas. Postoutbreak growth of defoliated trees was greater ($p < = 0.001$) than preoutbreak growth. Defoliated trees demonstrated good recovery, but not at the rate found in California outbreaks (Wickman 1978b, Wickman 1980).

Table 1—Comparisons of average annual growth of defoliated and nondefoliated trees during preoutbreak (1968-72), outbreak (1973-77), and postoutbreak (1978-82) periods, using a paired t-test in the Blue Mountains, Oregon and Washington

	Means of radial growth		
Tree class	Preoutbreak	Outbreak	Postoutbreak
		Millimeters	
Defoliated host	1.68	0.80	1.90
Nondefoliated host	2.61	2.59	2.84
Preoutbreak with postoutbreak:			
	t-value		Significance
Defoliated host	5.19		0.001
Nondefoliated host	2.75		.01

The difference between 5-year preoutbreak (1968-72) and 5-year postoutbreak (1978-82) was significant ($p < = 0.01$) for all grand fir defoliation classes except the 90-percent class ($p < = 0.05$) (table 2, fig. 7). For Douglas-fir, the postoutbreak growth surpassed the preoutbreak growth ($p < = 0.01$) for 25-, 50-, and 75-percent tree-defoliation classes. The 10- and 90-percent classes showed no significant increase of postoutbreak growth (table 2, fig. 8). Thus, growth recovery from 1978 to 1982 was apparently not strongly related to degree of defoliation.

Table 2—Regressions of preoutbreak (1968-72), x, and postoutbreak (1978-82), y, growth for host trees by defoliation class, Blue Mountains, Oregon and Washington

Tree class	n	a	b	r^2	P
Grand fir:					
Nondefoliated	42	0.968	0.707	0.665	0.01
Defoliated (percent)—					
10	29	.444	.876	.548	.01
25	142	.384	.880	.434	.01
50	149	.817	.657	.236	.01
75	55	.888	.737	.319	.01
90+	13	−.009	1.165	.315	.05
Douglas-fir:					
Nondefoliated	30	.428	.953	.477	.01
Defoliated (percent)—					
10	3	−.220	1.174	.587	NS
25	12	.395	.831	.654	.01
50	19	.300	.762	.568	.01
75	12	−.177	1.185	.629	.01
90+	5	−1.223	1.254	.530	NS

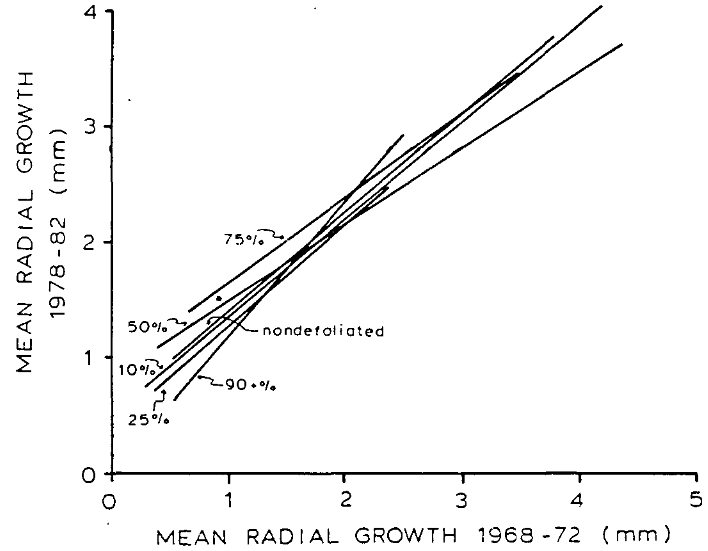

Figure 7—Radial growth of grand fir by percentage of defoliation, comparing preoutbreak with postoutbreak periods in the Blue Mountains, Oregon and Washington.

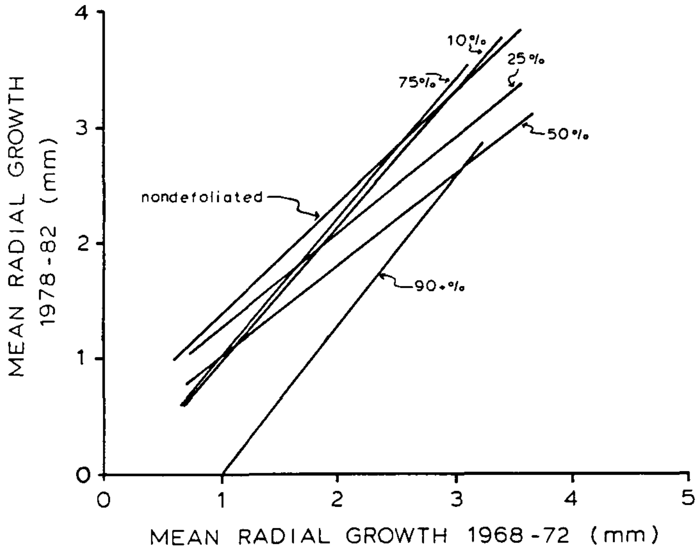

Figure 8—Radial growth of Douglas-fir by percentage of defoliation, comparing preoutbreak with postoutbreak periods in the Blue Mountains, Oregon and Washington.

Above-average annual precipitation caused all classes of trees—defoliated, nondefoliated, and nonhost—to respond positively, masking subtle differences caused by other factors like defoliation (tables 1-3). This response seemed consistent for all years except 1982, when the situation was reversed for unknown reasons. These results were not as positive as those from data collected in California, where 10 years after a tussock moth outbreak, defoliated trees exhibited significantly greater growth than nearby nondefoliated hosts (Wickman 1978b). Precipitation there was on a downward trend during a similar 5-year postoutbreak period.

The vagaries of tree-growth response in different outbreak areas and years point out the problem of using radial increment as a consistent indicator of a forest's response to defoliation and subsequent recovery. Effects of site, nutrient cycling, competition, and local environmental conditions all contribute to tree growth, and any one factor may tend to mask some of the other influences. Even one factor, such as precipitation, can have different effects on growth depending on timing and distribution. Such relations are still not clearly understood. Pest managers should be cautious in using radial growth data for justifying management practices, understanding that short-term tree-growth responses to defoliation may not always relate strongly to long-term stand development. Measurements of these defoliated trees scheduled for 1988 may reveal growth relations not yet evident.

Table 3—Average annual radial growth of grand fir and Douglas-fir during preoutbreak (1968-72), outbreak (1973-77), and postoutbreak (1978-82) periods, Blue Mountains, Oregon and Washington

Tree class	Preoutbreak (1968-72)	Outbreak (1973-77)	Postoutbreak (1978-82)
		Millimeters	
Grand fir:			
Nondefoliated	2.67	2.62	2.85
Defoliated (percent)—			
10	1.46	.87	1.72
25	1.51	.83	1.71
50	1.74	.75	1.96
75	1.82	.68	2.24
90+	1.76	.53	2.05
Douglas-fir:			
Nondefoliated	2.52	2.54	2.83
Defoliated (percent)—			
10	1.99	1.27	2.12
25	1.67	.79	1.79
50	2.18	.88	1.96
75	1.81	.74	1.97
90+	1.71	.35	0.92

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Pacific Northwest Research Station
319 S.W. Pine St.
P.O. Box 3890
Portland, Oregon 97208

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U.S. Department of Agriculture
Pacific Northwest Research Station
319 S.W. Pine Street
P.O. Box 3890
Portland, Oregon 97208