United States
Department of
Agriculture

Forest Service

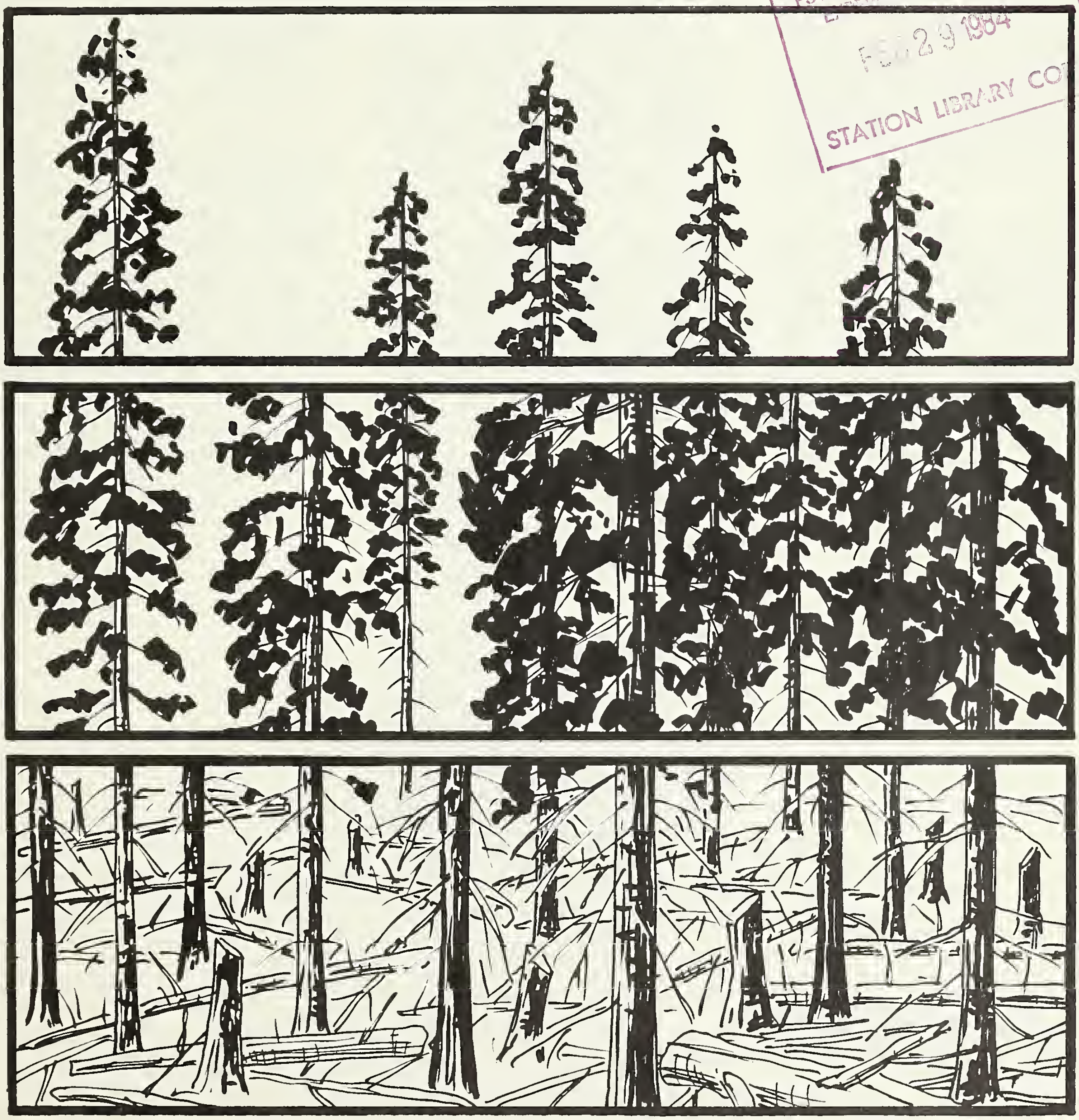
Pacific Northwest
Forest and Range
Experiment Station

Research Paper
PNW-311

December 1983

Growth of Ponderosa Pine Poles Thinned to Different Stocking Levels in Central Oregon

James W. Barrett



Author

JAMES W. BARRETT is a silviculturist, Silviculture Laboratory, Pacific Northwest Forest and Range Experiment Station, Bend, Oregon 97701.

Abstract

Barrett, James W. Growth of ponderosa pine poles thinned to different stocking levels in central Oregon. Res. Pap. PNW-311. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1983.** 9 p.

This paper presents 15-year results of one installation of a west-wide study of growing-stock levels in even-aged ponderosa pine. Growth was related to growing-stock level in a 65-year-old pole stand on an above average site. Periodic growth is presented for 10 years after the initial thinning and for 5 years after a second thinning to six assigned growing-stock levels.

Annual growth in diameter during the 5 years after initial thinning ranged from an average of about 0.28 inch at the lowest growing-stock level to 0.10 at the highest. These rates increased slightly during the following decade, but differences between growing-stock levels remained about the same. These growth relations resulted in much larger trees at the lower growing-stock levels 15 years after the initial thinning.

Keywords: Growing stock (-increment/yield, thinning effects, even-aged stands, improvement cutting, stand density, ponderosa pine, *Pinus ponderosa*.

Summary

Some of the most productive ponderosa pine stands in central Oregon are composed of densely stocked pole-size trees that are approaching merchantable size. These high densities should be reduced by thinning to concentrate the potential of the site to produce useful wood on trees that are merchantable or will soon reach merchantable size. In addition, evidence is mounting that reducing density will reduce the incidence of mountain pine beetle attack. Optimum stocking for these stands is the subject of this paper. The study, one of six initiated in the West, looked at the desirability of various growing-stock levels in a 65-year-old pole stand with above-average site index. Six growing-stock levels (GSL's)—basal areas anticipated when trees average 10 inches or more in diameter at breast height (d.b.h.)—ranging from 30 to 150 square feet per acre were tested.

Annual growth in diameter during the 5 years after initial thinning ranged from an average of about 0.28 inch at the lowest GSL to 0.10 at the highest. These rates increased slightly during the following decade but differences between GSL's remained about the same. These growth relationships resulted in much larger trees at the lower GSL's 15 years after the initial thinning.

Gross basal-area increment was positively correlated with stand density during each of the three growth periods. Annual growth ranged from 1.4 square feet per acre at the lowest GSL to 3.9 at one of the higher densities.

Growth in cubic volume was related to GSL. Large amounts of wood were produced on the higher GSL's, but this was accompanied by mortality from mountain pine beetle; growth was distributed on many trees that may never reach merchantable size. Timber stands in the midrange levels (GSL 80, 100 square feet) grew reasonable amounts of wood without serious beetle attack.

Preface

Growth of ponderosa pine, one of the most widely distributed pines in North America, is under study by the western Forest and Range Experiment Stations of the Forest Service, U.S. Department of Agriculture. This study is in response to increasing demands for better and more precise estimates of yields possible in intensively managed stands.

The Lookout Mountain thinning study in central Oregon is part of a westwide growing-stock levels study in even-aged ponderosa pine (Myers 1967). From a common study plan, each installation evaluates growth response to thinning in stand sizes growing on site qualities common to each region. Each installation is scheduled to run at least 20 years, with measurements at 5-year intervals and thinning at 10-year intervals, if appropriate.

Two of the six installations in this study are in the Black Hills of South Dakota, two are in Oregon, one is in northern Arizona, and one is in a plantation on the west slope of the Sierra Nevada in California.

This paper presents 15-year results from one installation in a naturally regenerated stand in central Oregon on the Pringle Falls Experimental Forest, Deschutes National Forest.

Contents

The Lookout Mountain Study

Previous publications on this study are:

Myers, Clifford A. Growing stock levels in even-aged ponderosa pine. Res. Pap. RM-33. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; **1967.** 8 p.

Schubert, Gilbert H. Growth response of even-aged ponderosa pines related to stand density levels. J. For. 69(12): 857-860; **1971.**

Schubert, Gilbert H. Silviculture of southwestern ponderosa pine: the status of our knowledge. Res. Pap. RM-123. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; **1974.** 71 p.

Schubert, Gilbert H. Silvicultural practices for intensified forest management. In: Trees—the renewable resource: Proceedings, Rocky Mountain Forest Industry conference; 1976 March; Tucson, AZ, **1976:** 37-54.

Severson, Keith E.; Boldt, Charles E. Options for Black Hills forest owners: timber, forage, or both. Rangeman's J. 4(1): 13-15; **1977.**

Oliver, William W. Growth of planted ponderosa pine thinned to different stocking levels in northern California. Res. Pap. PSW-147. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; **1979.** 11 p.

Six growing-stock levels of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) are being tested in the Lookout Mountain study, on the Deschutes National Forest, 25 miles southwest of Bend, Deschutes County, Oregon. The study area lies at an elevation of about 5,000 feet (lat. 43° 46′ N.; long. 121° 43′ W.) on the east slope of the Cascade Range. Plots are on the south-facing slope of Lookout Mountain in the Pringle Falls Experimental Forest.

Average annual precipitation is estimated to be 40 inches, only about 10 percent of which falls during the May through September growing season. A snowpack of 3 feet is common. Daytime temperatures during the growing season range between 70° and 90° F. Nights are cool, and frost may be expected any time of the year.

The soil is a deep, well-drained, cindery over medial (loamy) Typic Cryorthent, formed in dacite pumice originating from the eruption of Mount Mazama (Crater Lake) 6,600 years ago. The pumice averages 3 feet deep and is underlain by buried sandy loam material developed in older volcanic ash containing some cinders and basalt fragments.

The *Pinus ponderosa/Ceanothus velutinus* plant community (Franklin and Dyrness 1973) (in an *Abies concolor/Ceanothus velutinus* climax association) covers extensive areas on the mountainside. In the study area, snowbrush ceanothus (*Ceanothus velutinus* Dougl. ex Hook.) predominates, with an occasional golden chinkapin (*Castanopsis chrysophylla* (Dougl.) DC.). Western prince's-pine (*Chimaphila umbellata* (L.) Bart.) is abundant.

A few, very old ponderosa pine were scattered throughout the area and probably furnished seed for establishment of the stand under study. The average site index estimated from these dominant and codominant old-growth trees is 92 feet at 100 years (Meyer 1961).

Before thinning, the timber stand was dense and tree crowns were narrow, with only about 25 percent of total tree height in crown. Pretreatment average stand characteristics compared to normal (Meyer 1961) were:

	Pretreatment stand average	**Normal site index 92, age 65**
Trees per acre	1,133.0	462.0
Stand d.b.h. (inches)	6.3	9.3
Basal area (ft^3/acre)	240	216
Height (feet)	48	—
Volume (ft^3/acre)	4,704	5,335

Average height of trees left after thinning was only loosely related to growing-stock level; it varied from 55 to 67 feet and averaged 61.5 feet, which would relate to a site index of only about 80. Apparently, excess density had a suppressing effect on height growth. The 100 largest trees per acre averaged about 11 inches d.b.h. and 65 feet tall.

Methods

The six growing-stock levels (GSL's) being tested at Lookout Mountain are 30, 60, 80, 100, 120, and 150 (fig. 1). These GSL's are the basal area in square feet per acre that the stand has—or will have—after thinning, when the stand diameter averages 10 inches or more. The actual basal area after thinning stands less than 10 inches can be determined from figure 1. Each growing-stock level was replicated three times. Treatments were assigned at random to 18 one-half-acre plots with 33-foot buffer areas. Plots were scattered throughout a quarter section where site and stand density differences could be minimized. A pretreatment stand inventory was made by measuring d.b.h. of each tree. Reserve trees were marked, and the plots precommercially thinned in the fall of 1965 when the stand was 65 years old. The stand was rethinned to the various assigned GSL's later.

Thinning slash was lopped and scattered. Special precautions were taken to keep large pieces of slash several feet from leave trees because the slash was heavily invaded after thinning by pine engraver beetles (*Ips pini* Say). Fortunately, only two leave trees were lost when beetles emerged from the slash. All trees were tagged the following spring and d.b.h. measured to the nearest 0.1 inch. Fifteen trees on each thinned plot were selected for measuring with an optical dendrometer. Selection of these trees was made by constructing a diameter-distribution series for each plot and then selecting trees at random from each diameter class so that the complete range of diameter classes was represented. Stem volume inside bark in cubic feet and board feet were calculated by Grosenbaugh's (1964) STX computer program. All trees measured with an optical dendrometer from one GSL treatment were combined (45 trees), and an equation of the form Log vol. = a + b log d.b.h. was computed. A separate equation for each measurement period was calculated. These equations were used to determine volume of individual trees on each plot.

An estimate of average total tree height at each measurement period was calculated by using tree heights from the 45 measured trees per treatment in an equation of the form Total height = a + b log d.b.h. Each plot, except plot 9, was rethinned to its assigned GSL 10 years after the initial thinning. Many trees in and around plot 9 were attacked by bark beetles; thus we decided to forego any thinning at this time. Actually, few trees were killed by the attack, but several may have been weakened.

Analysis of variance was used to test for differences in treatment and the interaction between treatment and growth period. Where significance at the 5-percent level of probability was found, separate GSL and period differences were tested by Tukey's test. The original long-term intent of the west-wide study was to use response-surface techniques to look at the relationships of growth GSL on various sites after all data from the six studies have been collected for 20 years.

Stand characteristics are presented in table 1 and figure 2.

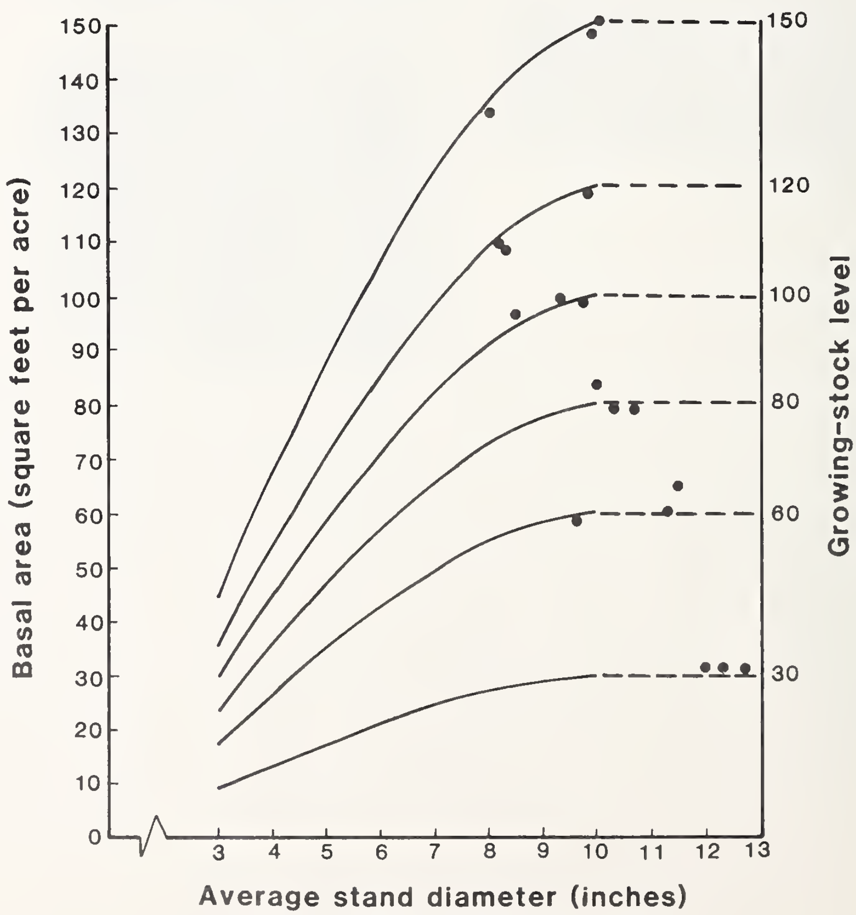


Figure 1.—Relation of basal area to average stand diameter. Black dots represent basal area and average diameters of plots after initial thinning on this study. Solid curves represent guiding curves, set forth by Myers (1967), for stands with average diameters less than 10 inches after thinning. Dashed lines show that basal area or GSL is to be held constant by repeated decadal thinning after the stand averages 10 inches or more.

Table 1—Average stand characteristics per acre for each growing-stock level in an even-aged ponderosa pine stand on an above-average site in central Oregon

Growing-stock level	Total	D.b.h. 1/	Height	Basal area	Volume: Total 2/	Volume: Merchantable 3/
Square feet/acre	Number of trees	Inches	Feet	Square feet/acre	Cubic feet	Board feet
TREES CUT IN INITIAL THINNING						
30	925	6.4	50	209.5	4,482	--
60	1,032	5.7	42	181.8	3,546	--
80	915	5.7	42	160.9	2,731	--
100	1,015	5.3	39	154.5	2,356	--
120	1,193	4.3	35	119.2	1,883	--
150	650	4.9	37	86.0	1,554	--
TREES REMAINING AFTER THE FIRST THINNING AT AGE 65						
30	38	12.3	67	31.49	775	2,726
60	97	10.8	65	61.20	1,441	4,180
80	140	10.3	63	81.10	1,792	4,787
100	215	9.2	59	98.53	2,071	3,992
120	272	8.7	55	112.81	2,357	4,452
150	308	9.3	60	144.03	3,235	7,122
TREES CUT IN SECOND THINNING AT AGE 75						
30	16	14.4	73	18.22	496	2,023
60	35	11.0	62	23.30	576	1,824
80	51	10.4	64	30.02	735	2,096
100	64	8.5	56	25.46	528	565
120 4/	79	8.1	54	28.21	610	600
150	73	8.0	58	25.70	583	671
TREES REMAINING AFTER SECOND THINNING AT AGE 75						
30	22	15.8	76	29.89	827	3,539
60	58	13.8	72	60.04	1,624	6,473
80	88	13.0	71	80.68	2,126	8,025
100	146	11.2	67	99.64	2,341	7,491
120 5/	207	10.5	63	123.77	3,000	8,616
150	223	11.1	70	148.99	3,975	12,894

1/Quadratic mean diameter breast high.

2/Volume inside bark from ground to tip.

3/Scribner board feet to a 5-inch tip inside bark and an 8-foot minimum log length; that is, most logs are 9 inches d.b.h. outside bark and larger.

4/Average of two plots. One plot not thinned at age 75.

5/Average of three plots.

Figure 2.—Ten years after thinning the Lookout Mountain study to growing-stock levels of 30 (A), 100 (B), and 150 (C).

Results

Growth Related to Stocking Level

Diameter—Growing-stock level had some influence on periodic annual diameter growth. Trees in the lowest GSL grew the most rapidly at the annual rate of 0.28 inch in the first period, 0.30 in the second, and 0.32 in the third period—compared to only about 0.11 inch at the highest GSL in all three periods (table 2). Generally, growth rate gradually decreased from GSL 30 to GSL 100, and then not much difference occurred between the three highest GSL's (fig. 3). Specifically, no significant differences in diameter growth rate occurred between the three highest GSL'S (100, 120, 150) during the last period (fig. 3, table 2). Each successive GSL from 100 through 30 grew significantly better during the 5 years after the second thinning.

A trend of increasing diameter growth with time was found, but this was significant only in the 30, 60, 80, and 100 GSL's. No significant difference in growth from the second to the third period occurred in any of the GSL's, although a thinning took place just at the start of the third growth period.

Before thinning, snowbrush ceanothus was sparsely distributed. After the initial thinning, this understory vegetation was completely covered by thinning slash. A very sparse distribution of these plants is beginning to appear 15 years after the first thinning, but their effect on diameter growth is considered negligible in comparison to the significant influence observed in thinned sapling stands within a few miles of this study area (Barrett 1973).

Basal Area—Periodic, gross annual basal-area increment was significantly and positively correlated with stand density during each of the three growth periods (fig. 4, table 2). Trees in plots thinned to GSL 30 in the first period grew 1.4 square feet per acre compared to a minimum growth rate of 3.9 square feet at one of the higher densities in the second period. Significance of gross growth-rate differences is complex (table 2).

Table 2—Mean periodic annual growth 5 and 10 years after initial thinning and during the 5 years after the second thinning

		Basal area		Volume			
Growing-stock level 1/	D.b.h. 2/	Gross	Net	Gross	Net	Gross	Net
Square feet/acre	Inches	Square feet/acre		Cubic feet/acre 3/		Board feet/acre 4/	
		0 TO 5 YEARS AFTER INITIAL THINNING					
30	5/ 0.28 a	1.4 a	1.4 a	45 a	45 a	228 a	228 a
60	0.18 b	2.0 ab	1.6 a	68 a	59 ab	353 ab	336 ab
80	0.16 b	2.6 b	2.6 a	93 c	93 ab	455 bc	455 b
100	0.10 cd	2.3 b	2.1 a	55 ab	51 a	307 ad	307 ab
120	0.12 ce	2.7 b	2.2 a	91 c	81 ab	384 bd	381 ab
150	0.10 de	3.5 c	3.2 a	117 d	112 b	540 c	537 b
		5 TO 10 YEARS AFTER INITIAL THINNING					
30	5/ 0.30 a	1.9 a	1.9 a	65 c	65 a	338 a	338 a
60	0.22 b	2.8 b	2.8 ab	93 a	93 ab	487 b	487 acd
80	0.19 bc	3.3 bd	3.3 ab	121 b	120 b	611 b	611 bd
100	0.14 cd	3.2 bef	3.2 ab	109 ab	109 bc	506 b	506 acd
120	0.14 ce	3.9 cde	3.8 b	130 b	129 bd	578 b	578 b
150	0.11 de	3.7 cdf	2.9 ab	170 d	153 cd	795 c	751 b
		0 TO 5 YEARS AFTER SECOND THINNING					
30	5/ 0.32 a	1.3 a	1.3 a	39 a	39 a	208 e	208 a
60	0.25 b	2.2 bc	1.9 a	73 b	63 a	383 a	340 ab
80	0.21 b	2.7 bd	2.6 a	82 b	80 a	423 abd	420 bc
100	0.16 d	2.9 cd	2.9 a	84 bc	84 a	408 ac	408 ab
120	0.14 d	3.1 d	2.8 a	95 bc	85 a	502 abc	471 bd
150	0.12 d	3.2 d	1.6 a	107 c	65 a	533 dc	397 acd

1/Stand density expressed as the basal area per acre that will remain after thinning when average stand diameter is 10 inches or more.

2/Based only on trees living through the period.

3/Volume inside bark from ground to tip.

4/Scribner board feet to a 5-inch top inside bark and an 8-foot minimum log length, that is, most 9 inches d.b.h. outside bark and larger.

5/Means within growth periods not showing the same letter differ significantly ($P \leq 0.05$ by Tukey tests).

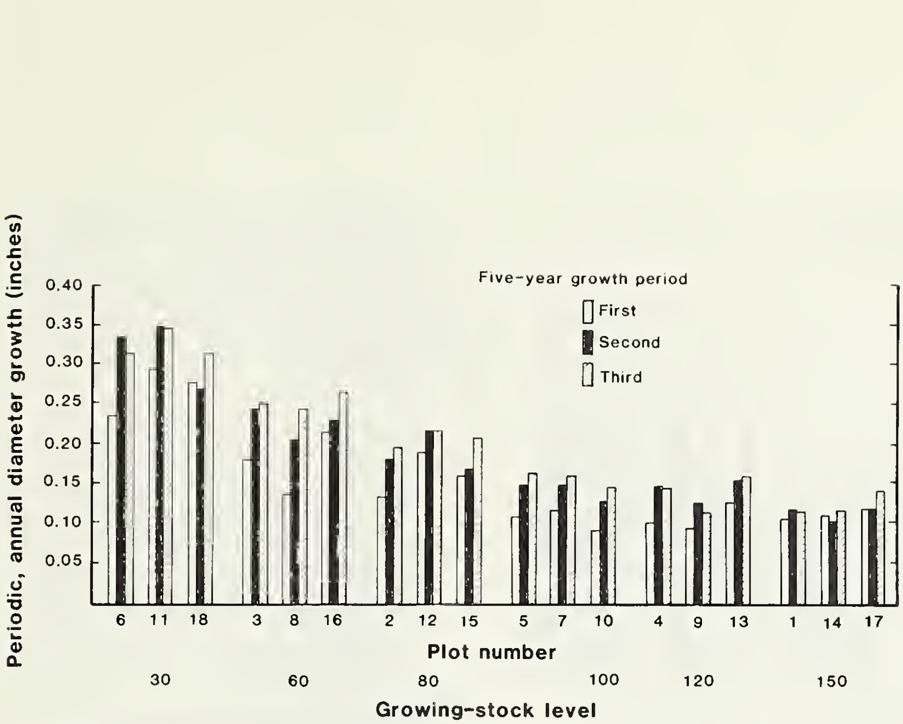


Figure 3.—Periodic, annual growth in diameter of ponderosa pine poles thinned to six different growing-stock levels on a productive site in central Oregon.

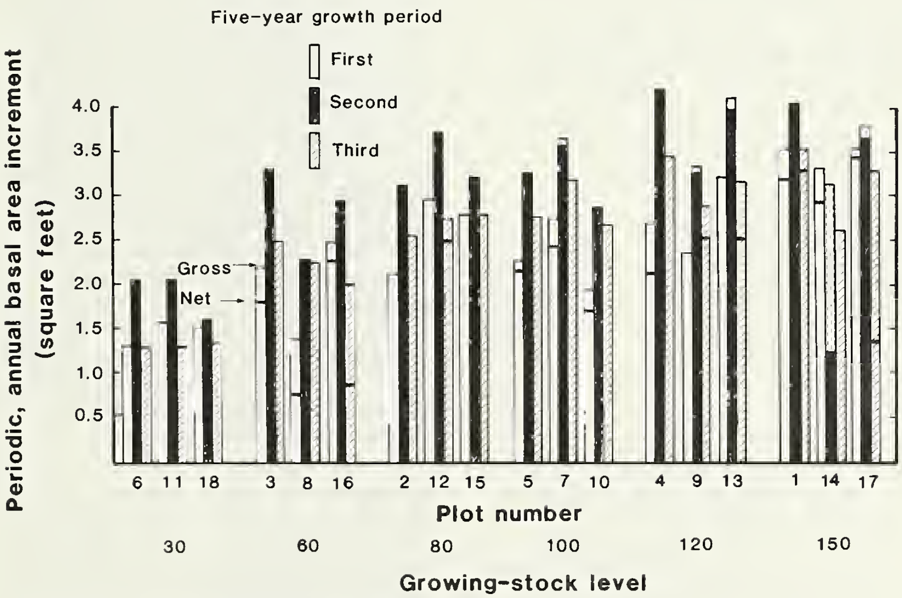


Figure 4.—Periodic, annual basal-area increment of ponderosa pine poles thinned to six different growing-stock levels on a productive site in central Oregon.

Significant differences in net basal-area increment were observed only in the second growth period, but net differences are not very useful or meaningful because of the erratic nature of mortality. Only 5 of the 18 plots had losses in basal area that exceeded 10 percent of gross growth. Two of the five occurred in GSL 150 plots. No losses in basal area occurred in the GSL 30 plots.

Height—Attempts to detect differences in height growth between growing-stock levels was difficult because of the limited sample of heights (15 per plot) and the within-treatment variation encountered. Analysis of variance with the data available indicated no significant differences in height growth between GSL's.

Volume—Periodic growth in total stem volume was strongly related to growing-stock level throughout all periods (fig. 5). Net growth was adversely affected by mortality on some plots, especially during the last period. GSL 100 was a poor producer during the first period in all replications, for some reason. Increment consistently rose from the first 5-year period to the second in all plots and then dropped consistently in the third period after the second thinning. Growth dropped even on plot 9, which was not thinned. During the second period, when growth peaked in all GSL's, annual plot increment ranged from 65 ft^3/acre at GSL 30 to 170 ft^3/acre at GSL 150.

During the first two periods, differences in volume growth were large and significant among the lowest and highest GSL's, similar to what Oliver (1979) reported in the GSL study in California. Some differences in intermediate GSL's were observed, probably because of the peculiar lower production of intermediate GSL 100. During the third period, differences were large and significant among the lowest and highest GSL's, but were smaller and nonsignificant among the intermediate GSL's and their adjacent treatment level (table 2). If we look at periodic growth during the first decade as a function of initial basal area or GSL (fig. 6), we find a steady rise in volume production up to the highest GSL, similar to Oliver's (1979) observation during the first 5 years. During the 5-year period after the second thinning (fig. 6), there is a

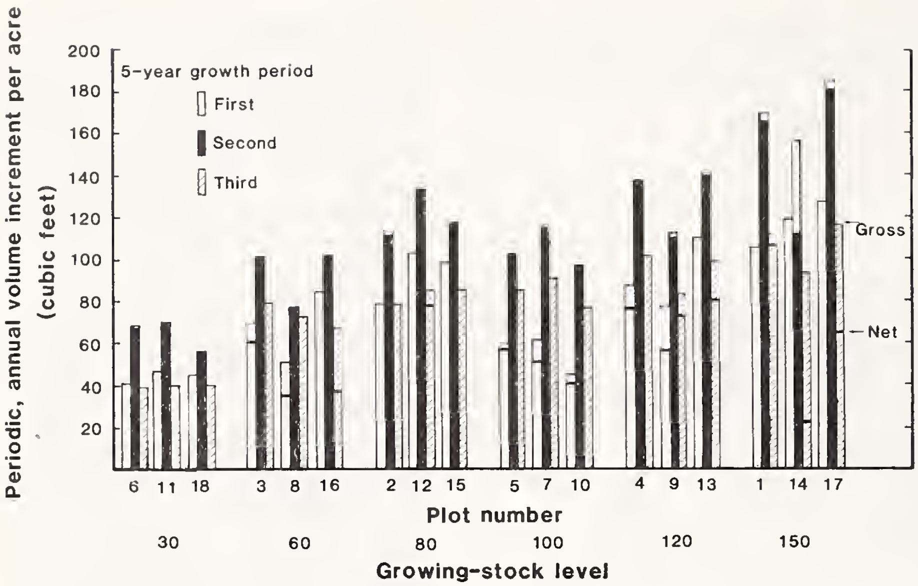


Figure 5.—Periodic, annual net- and gross-volume increment of ponderosa pine poles thinned to six different growing-stock levels on a productive site in central Oregon.

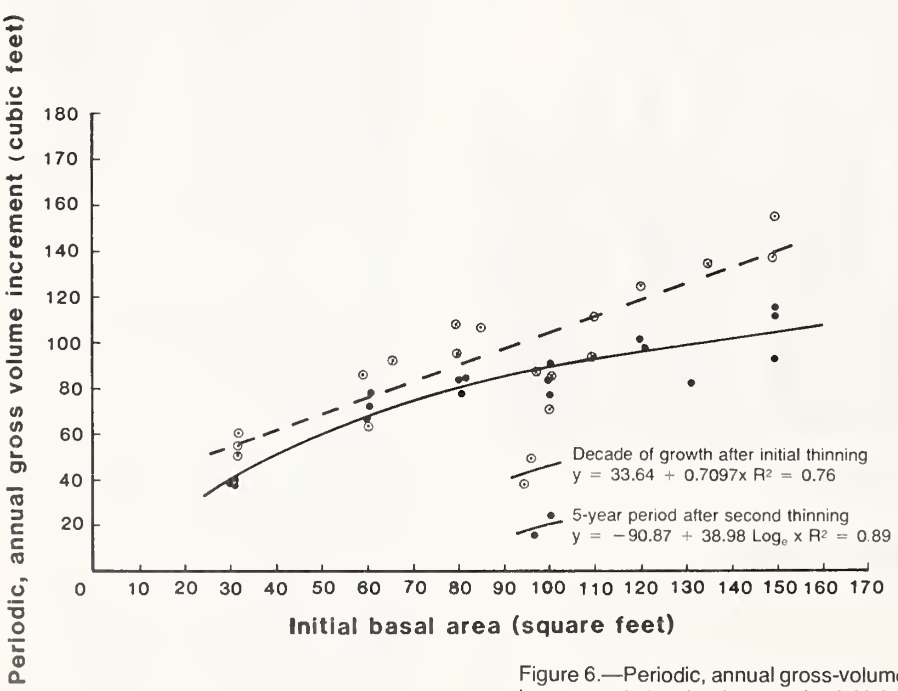


Figure 6.—Periodic, annual gross-volume increment during the decade after initial thinning and during the 5 years after the second thinning.

suggestion of leveling off in volume production at the higher levels. This may simply reflect having to cut relatively more trees at the higher GSL's to accommodate the required thinning to the desired growing-stock level after 10 years of growth.

Board-foot volume and volume growth are presented (tables 1, 2), but have limited meaning relative to GSL because many trees at the higher GSL's are growing into board-foot sizes. The smallest tree considered merchantable was 9 inches d.b.h., capable of producing an 8-foot log with a 5-inch top inside bark at the small end, a realistic utilization on many operations in eastern Oregon.

Total Yield and Tree Size

Although drawing conclusions about long-term yield would be premature, the outlook is favorable. Total yield, including the second thinning only, 15 years after initial thinning, increased with higher growing-stock levels (fig. 7). The highest GSL yielded about 5,000 cubic feet of wood and the lowest GSL 1,500 cubic feet. Although the highest GSL yielded substantially higher amounts of wood than other GSL's, it contained many (94 per acre) trees below 9 inches d.b.h. (fig. 8) when the second thinning from below was made. For example, in the second thinning at GSL 150, 73 trees were thinned from below that averaged 8.0 inches d.b.h., yielding only 671 board feet of merchantable wood. In comparison, GSL 80 had only 9 trees below 9 inches d.b.h. To cut the stand back to GSL 80, 51 trees were cut, with an average d.b.h. of 10.4 inches and 2,096 board feet.

Although trees at GSL 30 grew much faster in diameter, developed vigorous crowns, and suffered no mortality from beetle attack, considerable yield was sacrificed (fig. 7) by thinning to this low level. Considerable growth loss has also occurred at GSL 60.

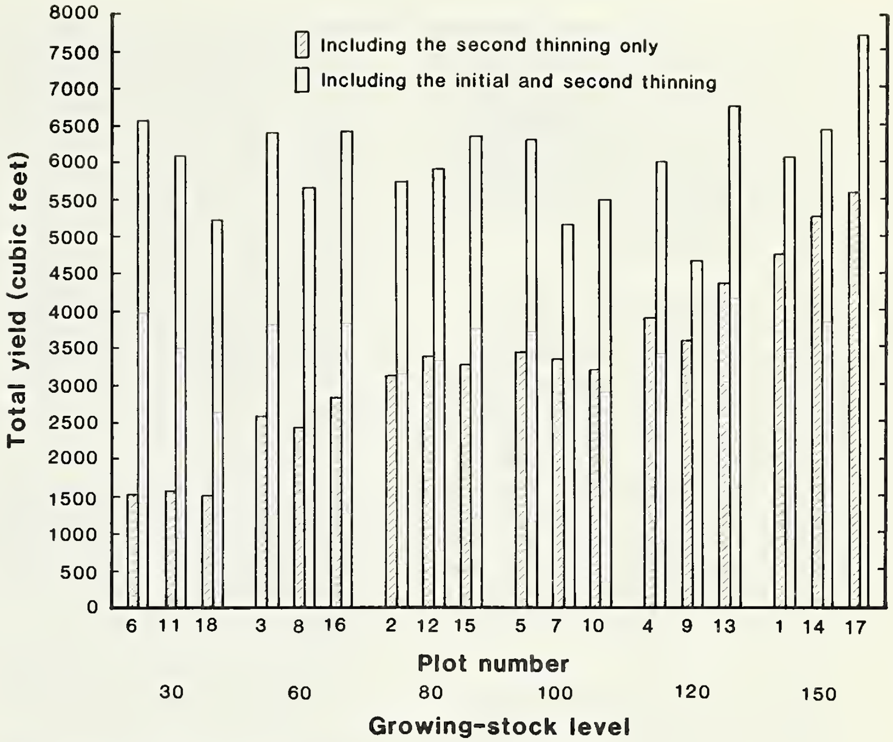


Figure 7.—Gross total yield 15 years after the initial thinning.

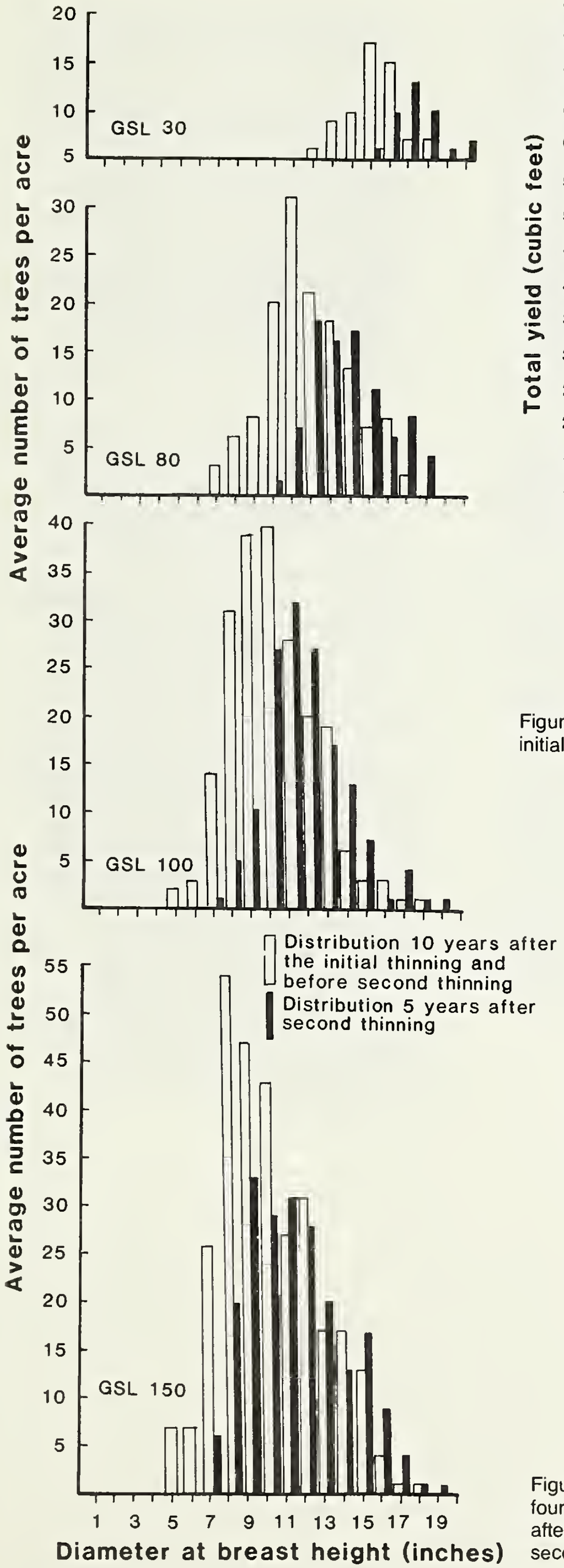


Figure 8.—Average diameter distribution on four of the six growing-stock levels 10 years after the initial thinning, and 5 years after the second thinning.

Mortality

All of the tree deaths could be associated with mountain pine beetle (*Dendroctonus ponderosae* Hopk.) attacks. Damage from the insect in this study was found to be closely related to tree vigor (Larsson et al. in press). No agents such as dwarf mistletoe, needle blight, or root rot could be found contributing to low vigor on the trees attacked by beetles.

Visible, cumulative beetle mortality before thinning from age 0 to 65, as observed in pretreatment inventory, averaged 26 trees per acre, with consistent mortality on all plots. After initial thinning, this pattern began to change, and the distribution of mortality was altered—by far the highest number of trees being attacked by beetles were in the greater growing-stock levels, (figs. 4, 5, and 7), although this was erratic from plot to plot. Attacks occurring at the low GSL's were on trees of low vigor only.

Larsson et al. 1983 concluded, however, that the population of beetles was relatively low during the last two periods of observation, because only 6 percent of all trees attacked were killed.

Sartwell and Stevens (1975) concluded from studies in both Oregon and South Dakota that stand basal area of 148 square feet per acre should be a critical maximum, above which stands are likely to become severely infested. In our study, Larsson et al. 1983 also found this basal area provided most trees with sufficient vigor to withstand at least moderate attack. Maintaining stands at still lower stocking levels, as recommended for intensive management by Barrett (1979), should insure a greater margin of safety from attack by mountain pine beetle.

Conclusions

This stand is producing periodic volume increments at the higher GSL's far in excess of what might be anticipated from Meyer's (1961) yield table for site index 92. This is not an unusual observation for this area. A thinning study in a 100-year-old adjacent stand produced above-normal volume growth during a 30-year period (Barrett 1974). The stand under study here had a structure far different from normal, which retarded past volume growth. After thinning, mortality was probably reduced and net growth increased substantially even with reduced growing stock. (See page 7 for comparison with a normal stand.)

Although growth of this stand appears to be above normal, similar stands in this plant community may not perform as well. A site class can have more than one productive potential (Assman 1970), and that may be what is reflected here.

Precommercial thinning of pole stands, such as that described here, does not seem operationally feasible. Board-foot volume differences between the highest GSL and subsequent lower GSL's indicate that a light commercial thinning could be made instead. In the process of thinning and slash treatment, whether mechanical or prescribed fire, unwanted trees could be destroyed and the GSL left that is compatible with other resource-management objectives. Productive sites such as this should be precommercially thinned at an early age, so that the growth capacity of the site can be concentrated on trees that will eventually be used.

Another reason for thinning pole stands is safety against beetle attack. Beetle populations were low in this area; losses were minimal compared to other places, where beetle populations are high on sites with average-to-good indexes, and tree losses frequently unacceptable. Another advantage in commercially thinning these overdense pole-sized stands is that diameter growth is increased, and trees reach merchantable size classes faster, thus helping to fill the existing size-class gap between advanced sapling-sized reproduction and old-growth that exists in many pine stands in eastern Oregon.

Selecting the most appropriate GSL is a compromise between GSL's producing high amounts of wood fiber and GSL's that will produce target diameters in a desired time frame. In the 15-year period of observation in this study, some latitude is apparent in the choice of an appropriate GSL between 60 and 100 square feet, without sustaining an undesirable loss in periodic increment or eventual yield.

Managers may want to compare results from this study with existing stocking-level curves for ponderosa pine (Barrett 1979), where site index is IV or better (Meyer 1961). Comparisons show roughly that GSL's 60, 80, and 100 stay within reasonable distance of the recommended and maximum curves during the 15 years of observation. GSL 30 is below the minimum stocking curve, and GSL's 120 and 150 are far above the maximum curve in an area that approaches the critical maximum above which stands are likely to become severely infested with mountain pine beetle (Sartwell and Stevens 1975).

Literature Cited

Assman, E. The principles of forest yield study. New York: Pergamon Press; **1970.** 506 p.

Barrett, James W. Latest results from the Pringle Falls ponderosa pine spacing study. Res. Note PNW-209. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1973.** 22 p.

Barrett, James W. High yields from 100-year-old ponderosa pine. Res. Note PNW-220. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1974.** 12 p.

Barrett, James W. Silviculture of ponderosa pine in the Pacific Northwest: the state of our knowledge. Gen. Tech. Rep. PNW-97. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1979.** 106 p.

Franklin, Jerry R.; Dyrness, C. T. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1973.** 417 p.

Grosenbaugh, L. R. STX-FORTRAN 4 program estimates of tree populations from 3P sample-tree-measurements. Res. Pap. PSW-13. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; **1964.** 49 p.

Larsson, S.; Oren, R.; Waring, R. H.; Barrett, J. W. Attacks of mountain pine beetle as related to vigor in ponderosa pine. For. Science 29(2): 395-402; **1983.**

Meyer, Walter H. Yield of even-aged stands of ponderosa pine. Tech. Bull. 630. Revised. Washington, DC: U.S. Department of Agriculture; **1961.** 59 p.

Myers, Clifford A. Growing stock levels in even-aged ponderosa pine. Res. Pap. RM-33. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; **1967.** 8 p.

Oliver, William W. Growth of planted ponderosa pine thinned to different stocking levels in northern California. Res. Pap. PSW-147. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; **1979.** 11 p.

Sartwell, Charles; Stevens, R. E. Mountain pine beetle in ponderosa pine: prospects for silvicultural control. J. For. 73(3): 136-140; **1975.**

Metric Equivalents

1 inch = 2.54 centimeters
1 foot = 0.3048 meter
1 acre = 0.405 hectare
1 square foot/acre = 0.2296 square meter/hectare
1 cubic foot/acre = 0.069 97 cubic meter/hectare
1 tree/acre = 2.471 trees/hectare

Barrett, James W. Growth of ponderosa pine poles thinned to different stocking levels in central Oregon. Res. Pap. PNW-311. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1983.** 9 p.

This paper presents 15-year results of one installation of a west-wide study of growing-stock levels in even-aged ponderosa pine. Growth was related to growing-stock level in a 65-year-old pole stand on an above average site. Periodic growth is presented for 10 years after the initial thinning and for 5 years after a second thinning to six assigned growing-stock levels.

Annual growth in diameter during the 5 years after initial thinning ranged from an average of about 0.28 inch at the lowest growing-stock level to 0.10 at the highest. These rates increased slightly during the following decade, but differences between growing-stock levels remained about the same. These growth relations resulted in much larger trees at the lower growing-stock levels 15 years after the initial thinning.

Keywords: Growing stock (-increment/yield, thinning effects, even-aged stands, improvement cutting, stand density, ponderosa pine, *Pinus ponderosa*.

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

The U.S. Department of Agriculture is an Equal Opportunity Employer. Applicants for all Department programs will be given equal consideration without regard to age, race, color, sex, religion, or national origin.

Pacific Northwest Forest and Range
Experiment Station
809 N.E. Sixth Avenue
P.O. Box 3890
Portland, Oregon 97208