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Research Publications of the Pringle Falls Experimental Forest, Central Oregon Cascade Range, 1930 to 1993

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Cover Photo Along east boundary, Pringle Falls Experimental Forest, May 1931.

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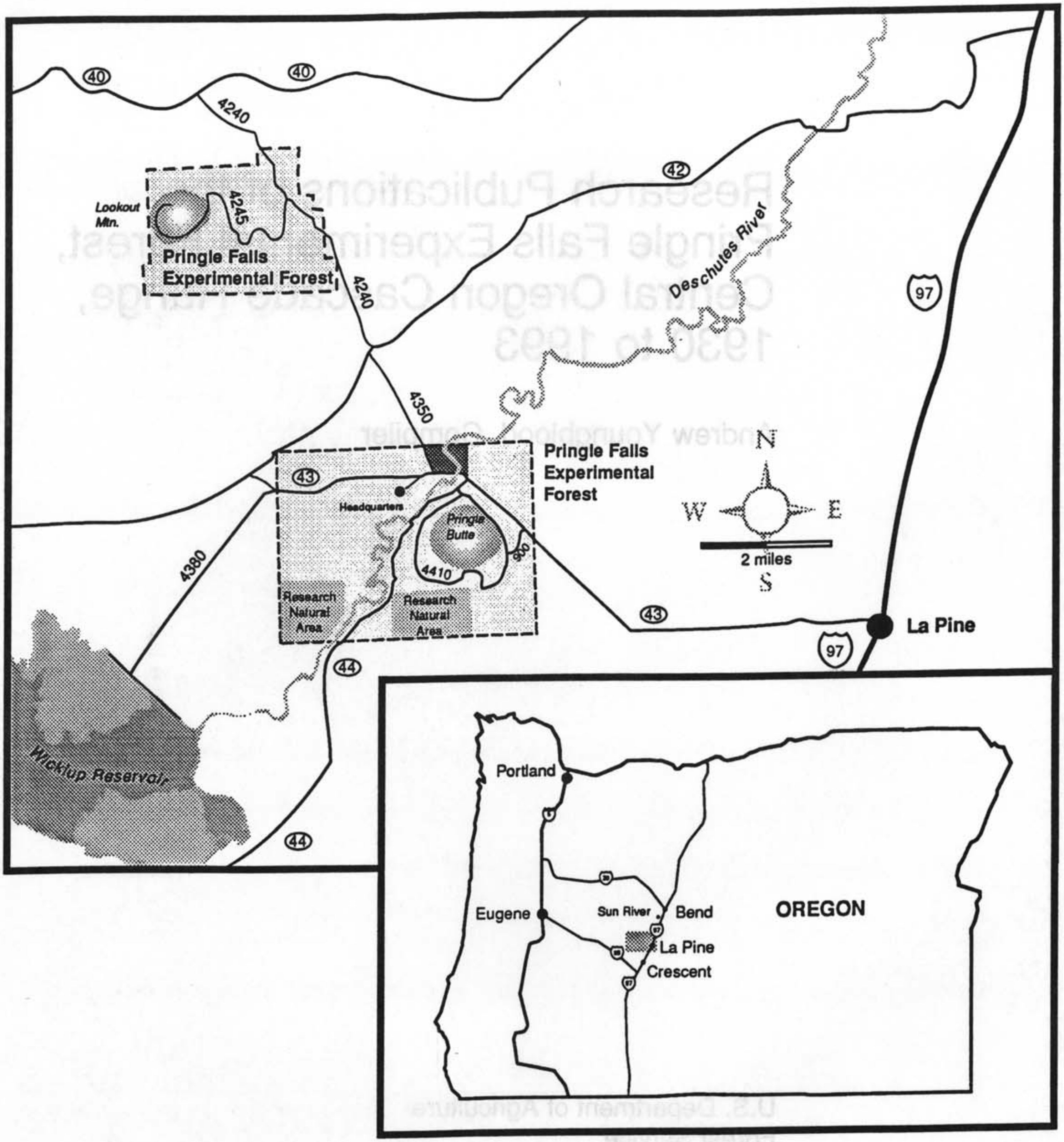
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Abstract

Youngblood, Andrew, comp. 1995. Research publications of the Pringle Falls Experimental Forest, central Oregon Cascade Range, 1930 to 1993. Gen. Tech. Rep. PNW-GTR-347. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 45 p.

An annotated bibliography of publications resulting from research at the Pringle Falls Experimental Forest, Deschutes National Forest, in central Oregon from 1930 to 1993 is presented. Over 100 publications are listed, including papers, theses, and reports. An index is provided that cross-references the listings under appropriate keywords.

Keywords: Bibliographies (forestry), Oregon (Pringle Falls Experimental Forest), Pringle Falls Experimental Forest—Oregon.

Contents

Introduction

Pringle Falls Experimental Forest, within the Deschutes National Forest in central Oregon, was formally established on May 20, 1931, as a center for silviculture, forest management, and insect and disease research in ponderosa pine[1] forests east of the Oregon Cascade Range. The 4477-hectare forest is maintained by the U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, in cooperation with the Pacific Northwest Region and Deschutes National Forest for research in ecosystem structure and function and demonstration of management techniques. It provides outstanding examples of undisturbed and managed ponderosa pine, lodgepole pine, and higher elevation mixed-conifer forests occurring on 6,600-year-old aerially deposited Mount Mazama (now Crater Lake) dacite pumice common throughout central and south-central Oregon.

Pringle Falls Experimental Forest is the oldest Experimental Forest and the site of some of the earliest forest management and silviculture research in the Pacific Northwest. Thorton T. Munger, first Director of the Pacific Northwest Research Station (then Experiment Station), and colleague and long-time friend of Gifford Pinchot, first Chief of the Forest Service, selected the site in 1914. Headquarters buildings were constructed between 1932 and 1934.

Pringle Falls Experimental Forest is characteristic of low-elevation forests within the High Cascades physiographic province. It consists of two separate units (see map) each named for the dominant volcanic feature contained within. Terrain generally is flat or gently rolling, dotted with small volcanic peaks and cinder cones. Pringle Butte, the oldest known geologic formation, is a 5-million-year-old shield volcano rising nearly 300 meters above the surrounding basin.

Together, Pringle Falls Experimental Forest and the Research Natural Area contained within provide a diverse natural laboratory used by university and government scientists.

This bibliography is comprised of 119 pieces of literature published from 1930 through 1993 that resulted from work within Pringle Falls Experimental Forest. Listed publications, including journal articles, Station papers, reports, and theses, are arranged alphabetically by author, then date and title. Authors' names are given exactly as shown on the publication. Thus, a publication with initials for the primary author's first name will be listed before one with the first name spelled out. even if the publication has a later date; for example, Seidel, K.W. (1989) occurs before Seidel, Kenneth W. (1983).

Annotation for each publication provides the research objectives, methods and techniques, and important findings. Because many of the publications report new results from long-term and previously reported studies, all publications are cross-referenced; for example, Mowat 1961 and 1948 are based on the same study as first documented by Kolbe and McKay 1939.

An index is provided after the bibliography. Publications are listed alphabetically by author under appropriate keywords. All publications in the bibliography are listed in the index.

[1]Scientific names of common tree species used throughout this bibliography are listed after the introduction.

This bibliography is not a complete compilation of research from the eastern slope of the Cascade Range or even ponderosa pine research; it is specifically restricted to the results of research at Pringle Falls Experimental Forest. Regrettably, copies of all listed publications cannot be obtained from a central location. The first source for papers is libraries, especially those serving as Federal depositories. Theses and dissertations are available from the individual schools. All listed publications are filed and available for in-house use at the Silviculture Laboratory, 1027 NW Trenton Avenue, Bend, Oregon 97701.

Tree names:

Lodgepole pine {*Pinus contorta* Dougl. ex Loud.)

Ponderosa pine {*Pinus ponderosa* Dougl. ex Laws.)

Western redcedar {*Thuja plicata* Donn ex D. Don)

Grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.)

Engelmann spruce {*Picea engelmannii Parry* ex Engelm.)

Shasta red fir (*Abies magnifica* var. *shastensis* Lemm.)

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)

Bibliography

Adams, David H. 1974. Identification of clones of *Armillaria mellea* in young-growth ponderosa pine. Northwest Science. 48(1): 21-28.

Results of a study into the usefulness of the incompatibility reaction among isolates of different ancestry to identifying individual *ArmHIaria me/tea* (Vahl) Quel. colonies are presented (see Adams 1972). *Armillaria* isolates were recovered in the field from one study plot and three infection centers at the Pnngle Butte unit. (Keywords: Ponderosa pine—diseases, Forest pathogens—fungi)

Adams, David Howard. 1972. The relation of cover to the distribution of *Armillaria mellea* in a ponderosa pine forest. Corvallis, OR: Oregon State University. 115 p. Ph.D. thesis.

Results of a study of the root fungus *Armillaria mellea* (Vahl) Quel. in the Pringle Butte unit are presented. Isolates of *Armillaria mellea* were recovered from roots of *A. mellea*-killed young-growth pine, from large stumps and roots of the former pine overstory, and from roots of living shrubs within a ponderosa pine plantation. Characteristic interactions between compatible and noncompatible mycelia in paired culture clearly distinguished group affiliations among the isolates. Inoculation of potted conifer and shrub seedlings with various group isolates revealed the presence of physiological strains of *A. mellea*. Rhizomorphs were found on the roots and root crowns of all plant species tested, but only members of a single group were pathogenic on conifer seedlings. Shrub seedlings were not killed by two group members although rhizomorphs of members of both groups were in close physical contact with living root tissue. Potentially lethal infections were found at the root crown of excavated living and *A. mellea*-attacked sapling pines, lesions of lateral roots were common but did not contribute to tree mortality. Attack by *A. mellea* stimulated the host to secrete large amounts of resin at the attack site. Cold-water extracts were made from foliage, roots, and litter of ponderosa pine and shrubs, and from underlying soils. Extracts of foliage (1:40 and 1:61 dilution) stimulated mycelial growth and rhizomorph production

and elongation. Extract dilutions of 1:168 and 1:1600 did not greatly stimulate fungal growth. Extracts of roots, litter, and soil had little effect on growth of *A. mellea* in culture. (Keywords: Ponderosa pine—diseases. Forest pathogens—fungi)

Alosi, M. Carol; Robertson, Jacqueline L. 1992. Biochemical indicators of population status of pine bark beetles. In: Hayes, Jane L.; Roberson, Jacqueline L., tech. coords. Proceedings of a workshop on bark beetle genetics: current status of research; 1992 May 17-18; Berkeley, CA. Gen. Tech. Rep. PSW-GTR-138. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 4.

Early results of a long-term study of insect-host interactions and the effects of secondary plant chemicals on mountain pine beetle *(Dendroctonus ponderosae* Hopk.) are presented. The objective was to test the hypothesis that insect population status is associated with biochemical diversity that differs over time; biochemical diversity includes those enzymes and amino acids involved in oxidation, reduction, hydrolysis, and conjugation reactions. Emerging and attacking mountain pine beetles were analyzed for levels of polysubstrate monooxygenases and glutathione S-transferase to detect changes in enzyme systems. The goal of this work was to isolate cDNA clones of expressed glutathione S-transferase genes to detect allelic variations and to identify evidence of gene amplification in relation to insect population dynamics. (Keywords: Forest insects—mountain pine beetle)

Barrett, J.W.; Youngberg, C.T. 1970. Fertilizing planted ponderosa pine on pumice soils. In: Hermann, R.K., ed. Regeneration of ponderosa pine: Proceedings of a symposium; 1969 September 11-12; Bend, OR. Corvallis, OR: Oregon State University, School of Forestry: 82-86.

A review of several studies of the effect of fertilization on planted ponderosa pine throughout central Oregon is presented. In one study, 3-year-old pine were planted and fertilized with magnesium ammonium phosphate in the planting hole and ammonium sulphate broadcast around the seedling (see Cochran and others 1991). Leader length, current needle length, and bud length were measured 3 years later. Fertilization with magnesium ammonium phosphate resulted in trees with longer, greener needles and longer terminal buds than those on unfertilized trees. Fertilized trees had greater total height than did unfertilized trees, regardless of spacing. These preliminary results suggest that fertilization, by itself, was insufficient to increase survival of seedlings by quickly forcing growth above competing vegetation. (Keywords: Ponderosa pine—fertilization)

Barrett, James W. 1960. Intensive control in logging ponderosa pine. Iowa State Journal of Science. 34(4): 603-608.

Procedures for minimizing damage to understory ponderosa pine saplings and poles during logging of mature and overmature merchantable trees are presented, based on observations of operational harvesting in the Pringle Butte unit. Procedures include identification of skidtrails before logging, directional falling, and the use of central landings. These recommendations help ensure survival of advance regeneration, thereby reducing time to rotation age by 20 to 50 years because fill-in planting is not necessary. (Keywords: Ponderosa pine—harvesting operations, Timber harvesting)

Barrett, James W. 1961. Response of 55-year-old lodgepole pine to thinning. Res. Note 206. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Results after 22 years of a lodgepole pine thinning experiment are presented. Three 0.2-hectare plots were established in 1934 in a 55-year-old, fully stocked, even-aged stand of lodgepole pine. One plot was thinned from below to a 3.6-meter spacing, one plot was thinned from below to a 4.9-meter spacing, and one plot was left unthinned as a control. Periodic measurements of diameter and height were made through 1956 (see Dahms 1971). Thinned plots responded exceptionally well to treatments; diameter growth was stimulated, mortality was reduced, and stems grew more rapidly into merchantable size classes. Thinning to a spacing of 3.6 meters at age 55 produced higher yields at age 77 than did thinning to a spacing of 4.9 meters. Undergrowth vegetation increased in productivity. (Keywords: Lodgepole pine—thinning)

Barrett, James W. 1963. Dominant ponderosa pine do respond to thinning. Res. Note. PNW-9. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Growth response of pole-size 65-year-old dominant ponderosa pine was evaluated 6 years after thinning in the Pringle Butte unit in 1953. Dominant trees, spaced about 5.2 meters apart by removing all subordinate stems, were compared to a similar number of dominant trees on unthinned plots. Annual radial increment was nearly two times greater, and lower branches remained alive longer on residual trees on thinned plots than on dominant trees on unthinned plots. Cubic volume increased significantly with thinning. There was no stimulus to height growth. (Keywords: Ponderosa pine—thinning, Timber harvesting)

Barrett, James W. 1965. Spacing and understory vegetation affect growth of ponderosa pine saplings. Res. Note PNW-27. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

This study was designed to determine the best spacing of ponderosa pine for maximum wood production, and to determine the influence of shrubs and herbaceous undergrowth on tree growth at different spacings (see Barrett 1982, Oren and others 1987). The unthinned old-growth ponderosa pine stand in the Pringle Butte unit consisted of large-diameter trees in the overstory and a dense 40- to 70-year-old understory averaging 17,300 saplings per hectare. Undergrowth consisted of mostly antelope bitterbrush {*Purshia tridentata* (Pursh) DC.), snowbrush ceanothus (*Ceanothus velutinus* Dougl.) greenleaf manzanita {*Arctostaphylos patula* Greene), and scattered graminoids. After overstory removal in 1957, residual ponderosa pine saplings on 30 rectangular 0.08-hectare plots were thinned in 1958 to 2,470, 1,235, 618, 309, and 153 trees per hectare. All logging and thinning slash was removed from the plots. Undergrowth was removed from three of the six plots of each spacing treatment; on the remaining plots, undergrowth was measured as percentage of cover by line point sampling using 100 points per plot. Initial diameter and height measurements of all residual saplings were recorded in 1959. In 1963, after four growing seasons, saplings at the lower densities had improved crown vigor with long, large needles compared to saplings at higher densities. Annual radial increment was 8.5 millimeters on plots spaced to 153 trees per hectare, twice that where 2,470 trees per hectare remained. Removal of undergrowth vegetation significantly increased diameter increment throughout the range of tree spacings and was especially pronounced on diameter increment at the wider spacing. Annual height increment of saplings also increased with wider spacing. Average percentage of cover of undergrowth vegetation tended to increase with wider tree spacing. (Keywords: Ponderosa pine—competing vegetation, Ponderosa pine—thinning, Ponderosa pine—tree spacing)

Barrett, James W. 1966a. A record of ponderosa pine seed flight. Res. Note PNW-38. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 5 p.

Wind-disseminated seedfall was measured during 1958 within a 26.3-hectare tract in the Pnngle Butte unit where the overstory trees had been completely removed. All seed was assumed to be from the adjacent stand of mature and overmature ponderosa pine which had an average height of 33.5 meters. Prevailing westerly winds accounted for an average of 80,940 sound seeds per hectare at the western edge of the cleared area and an average of 17,600 sound seeds per hectare 40 meters into the clearing. Seedfall into the clearing from the east was greatly reduced. To ensure adequate stocking from natural regeneration, clearcuts consisting of small patches or narrow strips less than 100 meters wide, orientated at right angles to the prevailing winds, are recommended. (Keywords: Forest regeneration, Ponderosa pine—silvics)

Barrett, James W. 1966b. Quick log hook, release with double tong system. Forest Industries. 93(10): 58-59.

Techniques for tractor skidding large-diameter (up to 1-meter) logs with modified winch-mounted tongs are presented. Primary concern is for protection of the residual stand, consisting of seedlings and saplings. (Keywords: Ponderosa pine—harvesting operations, Timber harvesting)

Barrett, James W. 1968. Pruning of ponderosa pine...effect on growth. Res. Pap. PNW-68. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 9 p.

Results are presented from a pruning study established in 1941 in a 55-year-old stand of ponderosa pine. Height to live crown, total height, and diameter measurements and dominance classification were made at the time of study establishment and 5, 10, and 16 years later (see Mowat 1947, Dahms 1954). The relation of existing crown length to total tree height was an important indicator of the proportion of tree crown length to be pruned from ponderosa pine and not affect tree growth rates. This relation was presented graphically, by depicting annual radial increment to be expected with removal of different proportions of live-crown length depending on live-crown length before pruning. From this, the percentage of reduction in diameter growth caused by pruning is easily estimated. (Keywords: Ponderosa pine—pruning)

Barrett, James W. 1970. Ponderosa pine saplings respond to control of spacing and understory vegetation. Res. Pap. PNW-106. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 16 p.

Eight-year-growth results are presented from a spacing study designed to give a range of alternatives from which to choose an initial spacing for ponderosa pine (see Barrett 1982, Oren and others 1987). Diameter and height growth of saplings was accelerated by increasing growing space per tree and removing competing undergrowth vegetation. Trees on plots with the widest spacing and undergrowth vegetation removed grew with an average annual radial increment of 104 millimeters over the first four growing seasons and 150 millimeters over the next four growing seasons. Average annual height increment ranged from 37 centimeters during the last four growing seasons on plots with the widest tree spacing and undergrowth vegetation removed, to 6 centimeters during eight growing seasons on plots with 2,470 trees per hectare. Increased growing space and reduced competition from undergrowth vegetation also resulted in larger tree limbs. Thinning also stimulated growth of undergrowth vegetation on plot left undisturbed. Antelope bitterbrush *(Purshia tridentata* (Pursh) DC.) and Ross sedge *(Carex rossii* Boott) were the undergrowth vegetation species most responsive to overstory removal and thinning. (Keywords: Ponderosa pine—competing vegetation, Ponderosa pine—thinning, Ponderosa pine—tree spacing)

Barrett, James W. 1971. Ponderosa pine growth and stand management. In: Precommercial thinning of coastal and intermountain forests in the Pacific Northwest: Proceedings of a short course; 1971 February 3-4; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service: 5-9.

Discussion of several recent studies in which tree growth in terms of wood fiber and undergrowth competition are evaluated for different initial tree spacings (see Barrett 1965, 1970). In general, larger, taller trees can result from controlling tree density to less than 346 trees per hectare. Wider tree spacing can, however, encourage growth of shrubs in the undergrowth. (Keywords: Ponderosa pine—competing vegetation, Ponderosa pine—thinning, Ponderosa pine—tree spacing)

Barrett, James W. 1973. Latest results from the Pringle Falls ponderosa pine spacing study. Res. Note PNW-29. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 22 p.

Twelve-year-growth results are presented from a spacing study designed to give a range of alternatives from which to choose an initial spacing for ponderosa pine (see Barrett 1982, Oren and others 1987). The greatest annual radial and height increment was obtained on plots thinned to 153 trees per hectare and undergrowth vegetation controlled. Results suggest that possibly a decade of tree growth was saved by removing undergrowth vegetation twice during the early part of the rotation. (Keywords: Ponderosa pine—competing vegetation, Ponderosa pine—thinning, Ponderosa pine—tree spacing)

Barrett, James W. 1978. Height growth and site index curves for managed, even-aged stands of ponderosa pine in the Pacific Northwest. Res. Pap. PNW-232. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 14 p.

Height growth and site index curves and equations for even-aged managed stands of ponderosa pine east of the Cascade Range in Oregon and Washington are presented. Height growth curves estimate expected heights at different ages for stands of known site index. Site index curves estimate site index of managed stands where breast-height age and total height can be determined. Data came from stem analysis of the six tallest trees on 30 stands in Oregon and Washington. Several plots were on Pringle Falls Experimental Forest. (Keywords: Ponderosa pine—growth and yield)

Barrett, James W. 1979. 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. 106 p.

The silviculture of ponderosa pine in the Pacific Northwest states of Washington and Oregon is described, based on observations, experience, and 120 pieces of relevant literature. The timber resources are first put in perspective in terms of regional timber values, commercial areas and volume, harvests, physiographic distribution, and climate. Disturbance regimes, including the role of various insects, tree diseases, and fire, are discussed. Silvicultural practices and management implications are discussed, including considerations for different silvicultural systems, regeneration methods, stand culture and development, and tentative yields. Recommendations for using fertilizers and herbicides are provided. Research needs for the future also are proposed. (Keywords: Ponderosa pine—silvicultural practices)

Barrett, James W. 1982. Twenty-year growth of ponderosa pine saplings thinned to five spacings in central Oregon. Res. Pap. PNW-301. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 18 p.

Complete results to date from a long-term study of the effects of tree spacing and undergrowth vegetation on diameter, height, and volume increment in a 40- to 70-year-old stand of suppressed ponderosa pine saplings in the Pnngle Butte unit (see Barrett 1965, 1970, 1973; Barrett and Youngberg 1965; Oren and others 1987). Trees averaged about 2.5 centimeters in diameter and 2.4 meters in height before thinning. Saplings on 30 rectangular 0.08-hectare plots were thinned in 1958 to 2,470, 1,235, 618, 309, and 153 trees per hectare. All logging and thinning slash was removed from the plots. Undergrowth was removed from three of the six plots of each spacing treatment. At the lowest density, with undergrowth vegetation controlled, trees grew an average of 12 millimeters in diameter per year compared to only 3 millimeters at the highest density where undergrowth was left to develop naturally. Stand density and undergrowth vegetation had significant effects on height growth. Undergrowth vegetation had the greatest effect on height growth at the lower density, reducing growth from 15 to 50 percent. Twenty years after thinning, low-density plots contained less wood fiber than high-density plots. Trees in low-density plots, however, were larger and collectively produced nearly as much wood volume annually as did high-density plots. Results provide an estimate of the time needed to grow trees to commercial saw-log size, and of cubic volume yield 20 years after thinning. (Keywords: Ponderosa pine—competing vegetation, Ponderosa pine—thinning, Ponderosa pine—tree spacing)

Barrett, James W. 1983. 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. 9 p.

Fifteen-year results of one of six installations of a west-wide study to determine the optimum growing-stock level in even-aged ponderosa pine are presented. Six levels of growing stock (GSL)—basal areas anticipated when trees average 25.4 centimeters or more in diameter at breast height—were tested; GSL included 6.9, 13.8, 18.4, 23.0, 27.6, and 34.4 square meters per hectare. The study occurred in a naturally regenerated 65-year-old pole stand with above-average site index in the Lookout Mountain unit. Ten years after installation and initial thinning, a second thinning was conducted. Results are presented by three 5-year growth periods. Generally, annual diameter growth rate gradually decreased from the lowest GSL to GSL 18.4, and then little difference in diameter growth occurred between the three highest GSL. The four lowest GSL grew significantly better during the 5 years after the second thinning. Periodic, gross annual basal area increment was positively correlated with stand density during each of the three growth periods, and ranged from 0.32 square meter per hectare at the lowest GSL to 0.90 square meter per hectare at GSL 27.6. Periodic annual volume increment was strongly related to GSL throughout all growth periods. During the second period, when growth peaked in all GSL, annual plot increment ranged from 4.5 cubic meters per hectare at GSL 6.9 to 11.9 cubic meters per hectare at GSL 34.4. After initial thinning, mortality associated with mountain pine beetle *(Dendroctonus ponderosae* Hopk.) attacks was greatest in the higher GSL; attacks occurring at the low GSL were on trees of low vigor only (see Larsson and others 1983). Although trees at GSL 6.9 grew much faster in diameter, developed vigorous crowns, and suffered no mortality from beetle attack, considerable yield was sacrificed by thinning to this low level. (Keywords: Forest insects—mountain pine beetle, Ponderosa pine—insects, Ponderosa pine—thinning, Ponderosa pine—stocking levels)

Barrett, James W.; Newman, Richard P. 1974. 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. 12 p.

Thirty-year results from a case study of the effects of thinning from above in a 94-year-old naturally regenerated stand of ponderosa pine are presented. The study was located in the Lookout Mountain unit. Thinning occurred in 1938 (see Mowat 1947a), and consisted of removing dominant and codominant trees about 43 centimeters in diameter representing 20 percent of the original volume. Individual tree sampling was started 2 years after thinning in five plots that were thinned and in two adjacent unthinned plots. Results are tabulated for growth periods ending in 1951, 1961, and 1970. Response to release was greatest during the first growth period. Growth over the 30 years in the thinned plots remained nearly constant, whereas growth in the unthinned plots declined. Thinned plots grew less gross cubic wood but greater net increment than unthinned plots. Results are compared to Meyer's normal yield tables; net cubic volume increment was over 250 percent of normal yield table growth in the thinned plots. The pattern of mortality during the 30 years of observation in small merchantable trees, caused by mountain pine beetle *(Dendroctonus ponderosae* Hopk.), suggests the potential to use light and frequent thinning from below to maintain the productive capacity of the stand. (Keywords: Forest insects—mountain pine beetle, Ponderosa pine—insects, Ponderosa pine—thinning)

Barrett, James W.; Roth, Lewis F. 1985. Response of dwarf mistletoe-infested ponderosa pine thinning: 1. Sapling growth. Res. Pap. PNW-330. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

Results of a study of the effects of thinning sapling-sized ponderosa pine parasitized by dwarf mistletoe *(Arceuthobium campylopodum* (Engelm.) Gill) are presented (see Roth and Barrett 1985). In 1947, six 0.08-hectare plots were established in 40- to 70-year-old saplings infested by dwarf mistletoe; plots were thinned from 19,770 to 618 trees per hectare with residual trees uniformly spaced. Preference for retention was given to infested trees; 32 percent of the residual saplings were visibly parasitized. Six plots in adjacent but uninfested saplings also were established and thinned to the same density by retaining the best trees. The magnitude of growth reduction caused by dwarf mistletoe in thinned, infested stands was determined by periodic measurements of stem diameter and total height. A second thinning in 1971 to a density of about 222 trees per hectare, in addition to herbicide application to reduce shrub competition, gave the remaining trees further opportunity to accelerate growth. After the second thinning, tree growth and dwarf mistletoe development were monitored for 11 growing seasons. Visible infestation increased to 89 percent in the 10-year period after the first thinning. The average number of visible plants per parasitized tree increased from 4 in 1959 to 36 in 1969. Average diameter, height, and volume in the infested and uninfested plots were similar. Rate of height growth increased after the second thinning, partly in response to additional release from both tree and shrub competition and partly in response to greater time since the first thinning. Dwarf mistletoe plants remained largely limited to lower portions of tree crowns. Height growth of individual trees, whether parasitized by dwarf mistletoe or not, may be increased by controlling stand density and further augmented by controlling undergrowth competition. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases, Ponderosa pine—thinning)

Barrett, James W.; Tornbom, Stanley S.; Sassaman, Robert W. 1976. Logging to save ponderosa pine regeneration: a case study. Res. Note PNW-273. Portland, OR: U.S. Department of Agriculture, Forest Service. Pacific Northwest Forest and Range Experiment Station. 13 p.

Results from a case study of the effects of marking for protection leave tree saplings before overstory removal are presented. Logging occurred in 1973 in a single 16-hectare stand of mature ponderosa pine where about 183 uniformly spaced understory saplings and poles per hectare were marked to save. In addition, the effect of two- versus three-stage logging on residual marked trees was evaluated. Two methods of disposing of wood fuel were compared. Final stocking was evaluated on thirty-eight 0.16-hectare circular sample plots. About one-half and one-third of the volume was removed in each stage of the two- and three-stage logging, with individual trees marked by stage depending on their potential to damage the understory. Logging slash on half of the unit was piled with a crawler-type tractor and brush blade and on the other half with a grapple-type, front-end loader. Damage to marked leave trees was monitored after each of the stages of overstory falling, skidding, slash piling, and burning. Falling overstory trees caused twice as much damage to understory leave trees as did skidding. Two-stage logging resulted in slightly more mortality of marked leave trees than did three-stage logging. A front-end grapple did less damage to residual understory trees in piling slash than did a crawler tractor with slash blade, but the grapple could move only the larger pieces of wood. Based on economic considerations of the time, procedures used in the study, if applied operationally, would cost less than regeneration efforts involving a clearcut harvest, site preparation, and replanting. (Keywords: Ponderosa pine—harvesting operations, Timber harvesting)

Barrett, James W.; Youngberg, C.T. 1965. Effect of tree spacing and understory vegetation on water use in pumice soil. Soil Science Society of America Proceedings. 29(4): 472-475.

This study examined the effect of initial tree spacing and competition from ground vegetation on tree growth, both as competition between trees is first detected and as full productive capacity of the site is attained. Soil moisture use was calculated as an indicator of site occupation and thus wood production. Soil moisture measurements were begun 2 years after overstory removal and thinning of residual ponderosa pine saplings to 153, 309, 618, 1,235, and 2,470 trees per hectare, and continued for three successive growing seasons (see Barrett 1982, Oren and others 1987). Water use increased with increased sapling density; total amount of water use was 1.6 times greater on plots containing 2,470 trees per hectare than on plots containing 153 trees per hectare. The most rapid use of soil moisture occurred during midsummer when almost no precipitation occurred. (Keywords: Ponderosa pine—tree spacing, Soils)

Beckman, Kent M.; Roth, Lewis F. 1968. The influence of temperature on longevity and germination of seed of western dwarf mistletoe. Phytopathology. 58(2): 147-150.

Results of laboratory tests on the effects of temperature dwarf mistletoe *(Arceuthobium campylopodum* (Engelm.) Gill) seed germination are presented. Seed was collected during a 3-year period from more than 2,000 mistletoe plants on young ponderosa pine trees in central Oregon, including Pnngle Falls Experimental Forest. Dwarf mistletoe seed viability was inversely related to temperature; 60 percent of the seeds stored at 1.5 °C were viable after 160 days whereas all seeds stored at 20 °C were dead. The optimum constant temperature for germination was between 17 and 19 °C. The most favorable alternating night-day temperature intervals were 12 hours at 5 and 15 °C. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

Bolon, Natalie A.; Fight, Roger D.; Cahill, James M. 1992. PP PRUNE users guide. Gen. Tech. Rep. PNW-GTR-289. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

Documentation for a computer spreadsheet program that can be used to conduct a financial analysis for pruning ponderosa pine is provided. The spreadsheet program, named PP PRUNE, will aid forest managers in deciding whether the increase in value from pruned logs is sufficient to justify investments in pruning. The program estimates the increase in product value from pruning 5-meter butt logs. It is based on lumber volume and grade recovery information obtained from a pruning study in the Pringle Falls Experimental Forest (see Cahill 1991, Fight and others 1992). The analysis requires ponderosa pine lumber prices by grade, the cost of pruning per log, and tree descriptions. (Keywords: Ponderosa pine—pruning)

Bork, Joyce L. 1984. Fire history in three vegetation types on the eastern side of the Oregon Cascades. Corvallis, OR: Oregon State University. 94 p. Ph.D. thesis.

Results of a study of the historic role of fire and the historic fire return interval in three different ponderosa pine vegetation types are presented. Objectives of the study were to calculate mean fire return intervals for different sites and determine the effect of regional climatic patterns on ponderosa pine growth based on tree-ring chronologies. Trees at three sites were sampled; sites were selected to reflect relatively high, intermediate, and low precipitation in ponderosa pine forests of central Oregon. The sites were on the Lookout Mountain unit, Pnngle Butte unit, and outside the Experimental Forest in Fort Rock Ranger District, Deschutes National Forest. Dendrochronological techniques were used with increment cores and cross-sectional disks to develop a master chronology from fire-scarred trees. At least 139 fires were determined to occur between 1362 and 1900 at Pringle Butte. The calculated mean fire return interval was 4 years. At least 37 fires occurred at the Lookout Mountain site between 1416 and 1900; the mean fire return interval was 8 years. Composite fire-interval analysis was used to estimate fire size, which was generally small. Mean sensitivities of tree-ring chronologies for the three sites were relatively low compared to other Oregon chronologies. Serial correlation was higher than the accepted range for estimating climatic change. These statistics indicated that the study chronologies were of marginal use for climatic analysis. (Keywords: Forest dynamics, Forest fire, Ponderosa pine—stand dynamics)

Briegleb, Philip A. 1943. Growth of ponderosa pine by Keen tree class. Res. Notes 32. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Experiment Station. 15 p.

The first compilation of stand growth rates by Keen tree class (see Keen 1936, 1943) is presented. It is based on increment core and tree volume measurements from almost 8,000 trees on 4-hectare plots in unmanaged ponderosa pine forests of eastern and central Oregon. Normal 10-year growth in diameter at breast height, normal 10-year gross growth in volume per tree, and normal annual gross growth as a percentage of volume are tabulated by Keen tree class and diameter. (Keywords: Ponderosa pine—growth and yield)

Cahill, James M. 1991. Pruning young-growth ponderosa pine: product recovery and economic evaluation. Forest Products Journal. 41(11/12): 67-73.

Results from a lumber recovery study comparing pruned and unpruned young-growth ponderosa pine are presented. Pruning occurred in 1941 in a 55-year-old stand (see Barrett 1968, Dahms 1954, Mowat 1947b). The study trees were cut and processed in summer 1988; 47 years of growth had occurred after pruning. The sample consisted of 98 pruned and 60 unpruned 4.9-meter logs. Logs were processed into Select, Shop, and Common lumber. Regression equations were developed to predict lumber volume, lumber value, and log value recovery. Lumber grade recovery from the pruned logs was significantly improved over the unpruned sample. Average lumber values increased as much as 40 percent, and average log values increased as much as 57 percent with pruning. A present-value economic analysis of pruning, conducted on four hypothetical young-growth trees, indicated the range in cost per tree that could be incurred in pruning similar trees at 4-percent interest (see Bolon and others 1992, Fight and others 1992). (Keywords: Ponderosa pine—pruning)

Cochran, P.H. 1969. Lodgepole pine clearcut size affects minimum temperatures near soil surface. Res. Pap. PNW-86. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 9 p.

Results of a study relating width of the cutting strip in lodgepole pine clearcuts to minimum temperatures near the soil surface are presented. Sky exposure (view factors) were calculated for circular and rectangular opening of various sizes. Minimum temperatures at 6.4 centimeters above the soil surface were determined at various distances from the edge of the opening every 2 hours for several days at weekly intervals throughout the growing season. Circular openings provided more protection against low soil-surface temperatures than did long strips with the same width. Strip clearcuts should not be wider than twice the height of the residual stand. (Keywords: Forest regeneration, Lodgepole pine—silvics, Soils)

Cochran, P.H. 1970. Seedling ponderosa pine. In: Hermann, R.K., comp., ed. Regeneration of ponderosa pine: Proceedings of the symposium; 1969 September 11-12; Corvallis, OR. Corvallis, OR: Oregon State University: 28-35.

A review and synthesis of current literature and personal observations relating to successful direct seeding of ponderosa pine. Factors affecting seeding success include small mammal and bird densities, seedling loss to insect and disease, temperature extremes, frost heaving, drought, and mechanical properties of soils. Seeding practices involve site preparation, small mammal control, consideration of sowing rate, and cost. Nearly 40 literature citations are provided. (Keywords: Forest regeneration, Ponderosa pine—silvics, Ponderosa pine—silvicultural practices)

Cochran, P.H. 1972a. Temperature and soil fertility affect lodgepole and ponderosa seedling growth. Forest Science. 18(2): 132-134.

Results of a study of early growth responses to temperature differentials and soil-fertility levels are presented. Lodgepole and ponderosa pine seedlings, germinated from seed collected at Pnngle Falls Experimental Forest, were transplanted to pots and assigned to one of four nutrient levels (each level an increase of N, P, and S) and one of nine temperature regimes (day-night temperature combinations resulting from day temperatures of 16, 23, and 30 and night temperatures of 1, 8, and 16 °C). Fertilization increased growth of both species under all nine temperature regimes. Lodgepole pine growth was not as sensitive to night temperature fluctuations as was ponderosa pine growth. The number of daily degree hours necessary for maximum growth increased with increasing soil fertility level for night temperatures of 16 °C. (Keywords: Forest regeneration, Ponderosa pine—fertilization, Ponderosa pine—silvics, Lodgepole pine—fertilization, Lodgepole pine—silvics)

Cochran, P.H. 1972b. Tolerance of lodgepole and ponderosa pine seeds and seedlings to high water tables. Northwest Science. 46(4): 322-331.

Results of a greenhouse study to determine effects of high soil water levels on seed germination, seedling survival, and early growth of lodgepole pine are presented. Seeds and soil were taken from Pringle Falls Experimental Forest. Seed and seedlings of lodgepole and ponderosa pine had high tolerance to very wet soils and low oxygen diffusion rates. High soil water levels did not cause significant mortality of either species even when the saturation period lasted for 52 weeks. Growth of both species tended to be lower with high soil water levels. Top-root ratios of ponderosa

pine decreased more with decreasing water levels than those of lodgepole pine. This study showed that for the seed source used, the influence of high soil water content alone on initial survival and growth of both species is not a factor governing "wet-site" occupancy by lodgepole pine on mineral soils. (Keywords: Lodgepole pine—silvics, Ponderosa pine—silvics, Soils)

Cochran, P.H. 1973a. Natural regeneration of lodgepole pine in south-central Oregon. Res. Note PNW-204. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 18 p.

Results of several studies of natural regeneration of lodgepole pine in the Pringle Butte unit are summarized with additional observations made in the field and laboratory. Lodgepole pine seed was sown and protected from small mammals in seed beds in fall 1969, 1970, and 1971. Subsequent germination, growth, and mortality were monitored. Seedling mortality was attributed to exposure to low night temperature, drought and heat injury, and frost heaving. The sequence of events necessary for establishment of lodgepole pine is discussed in terms of seed production, seed germination, low night temperatures during germination, frost heaving, high soil surface temperatures and drought, probabilities for seedling establishment, methods to improve chances for seedling establishment, and the beneficial effects of slash. (Keywords: Forest regeneration, Lodgepole pine—silvics)

Cochran, P.H. 1973b. Response of individual ponderosa pine trees to fertilization. Res. Note PNW-206. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

Results of several studies of the effect of fertilization on individual tree growth are presented. For that portion in the Pringle Butte unit, 24 trees were selected within a ponderosa pine stand that was thinned to a 4.3-meter spacing in 1962 when 72 years old (see Cochran 1977). Individual trees were selected for one of two levels of fertilizer application or control. Nitrogen, phosphorus, sulfur, and boron were applied by hand around each test tree with grass seeders; each treatment area had a radius of 11.3 meters with the test tree in the center. Treatments were replicated outside Pringle Falls Experimental Forest, and with only nitrogen, in northeastern Oregon. Total height and diameter at breast height were measured after four growing seasons. Diameter, basal area, and volume growth increased with fertilization. Height growth increased where results were not confounded by top damage. (Keywords: Ponderosa pine—fertilization)

Cochran, P.H. 1977. Response of ponderosa pine 8 years after fertilization. Res. Note PNW-301. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 7 p.

Results of several studies of the effect of fertilization on individual tree growth are presented (see Cochran 1973a). For that portion in the Pringle Butte unit, 24 trees were selected for monitoring diameter and height growth. Diameter growth and volume growth of trees in thinned stands were still responding to fertilization 8 years after treatment in three of four study areas. Height growth was no longer responding to fertilization where it previously had been. (Keywords: Ponderosa pine—fertilization)

Cochran, P.M.; Jennings, J.W.; Youngberg, C.T. 1984. Biomass estimators for thinned second-growth ponderosa pine trees. Res. Note PNW-415. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 6 p.

Regression equations to estimate biomass components for trees in precommercially thinned stands in central Oregon are presented. Biomass data were obtained by destructively sampling 23 ponderosa pine trees from two study sites; one site was on Pringle Falls Experimental Forest, and the other was between the Experimental Forest and Bend, Oregon. Equations for predicting the mass of live foliage and limbs of sapling and pole-sized ponderosa pine were developed for use with the logarithm of diameter as the only independent variable. Estimates were improved slightly by including the distance from breast height to the live crown. Other components, such as bole wood volume, bole wood mass, bark volume and mass, and total aboveground mass are predicted from equations based on tree height and diameter. These estimators are useful for studying nutrient cycling and productivity. (Keywords: Ponderosa pine—growth and yield)

Cochran, P.M.; Newman, R.P.; Barrett, James W. 1991. Fertilization and spacing effects on growth of planted ponderosa pine. Res. Note PNW-RN-500. Portland. OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 13 p.

Results of a study to determine the influence of fertilization and spacing on the growth of ponderosa pine planted in the absence of competing shrubs are presented. The study was started in 1966 with ponderosa pine seedlings planted at 1.8- by 1.8-, 2.7- by 2.7-, 3.7- by 3.7-, 4.6- by 4.6-, and 5.5- by 5.5-meter spacing in auger holes (see Barrett and Youngberg 1970). For the fertilization treatment, 113 grams of magnesium ammonium phosphate were placed in the bottom of the hole before tree planting, and after planting, 57 grams of ammonium sulfate were broadcast in a circle around each seedling. To increase tree vigor and overcome localized *Armillana* root rot, additional nitrogen in the form of urea was broadcast over fertilization plots in 1971 and 1973. Common shrubs, including antelope bitterbrush *(Purshia tridentata* (Pursh) DC.), manzanita *(Arctostaphylos uva-ursi* (L.) Spreng.), and snowbrush *(Ceanothus velutinus* Dougl.) were controlled by applications of 2, 4, 5-T applied in 1969 and 1973. Tree heights were measured annually from 1967 to 1973. Heights and diameters at breast height were measured in 1974, 1980, and 1984. From these inventories, volume, basal area, quadratic mean diameter, and average height were calculated. Fertilizer placed in the planting hole increased height growth in each of the spacings during the 1967 to 1974 period. In the later periods, the wider spacings exhibited greater height growth. Broadcast applications of fertilizer after seedlings were well established may have had little effect on growth. Fertilization produced larger trees and more volume per unit area at each spacing. (Keywords: Ponderosa pine—fertilization, Ponderosa pine—silvicultural practices, Ponderosa pine—tree spacing)

Dahms, Walter G. 1949. How long do ponderosa pine snags stand? Res. Notes 57. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 3 p.

Fire-killed ponderosa pine were monitored on a 6.1-hectare plot established in 1937, 11 years after wildfire. Twenty-two years after the fire, 78 percent of the snags were down. Smaller snags tended to fall sooner than the larger snags. These results indicated that ponderosa pine snags on pumice soils, such as at Pringle Falls Experimental Forest, continue to be a fire hazard longer than previously was expected. (Keywords: Forest dynamics, Forest fire, Ponderosa pine—stand dynamics)

Dahms, Walter G. 1950. The effect of manzanita and snowbrush competition on ponderosa pine reproduction. Res. Notes 65. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 3 p.

Observations of seedling establishment and growth in shrub fields are presented. A long strip through a dense shrub field of greenleaf manzanita *{Arctostaphylos patula* Greene) and snowbrush ceanothus *(Ceanothus velutinus* Dougl.) in the Pringle Butte unit was cleared of all brush in 1934. Examination of the strip from 1934 to 1947 showed that the density and height of brush increased on both the cleared strip and an adjacent uncleared strip. Density of snowbrush after clearing was the result of rapid sprouting. Natural germination and establishment of pine on the cleared strip was similar to that on the uncleared strip. Shrub competition reduced the height growth of pine seedlings. Seedlings that grew under manzanita were, on average, shorter than seedlings growing under snowbrush. (Keywords: Forest regeneration, Forest shrubs, Ponderosa pine—competing vegetation)

Dahms, Walter G. 1951. Intensity of cut as related to ponderosa pine management—a statistical approach to the problem of isolating cutting effect. Syracuse, NY: State University of New York. 116 p. M.S. thesis.

Results of a study of selection cutting methods in ponderosa pine are presented (see Kolbe and McKay 1939; Mowat 1948, 1961). Seven plots, totaling 205 hectares, were established in 1937 as a solid block on the Pringle Butte unit. Intensities of cut were 20-, 40-, 60-, and 80-percent volume removal. For each degree of cut except 80 percent, two contrasting policies in marking were applied: a "thrift" marking in which the trees of poorest vigor and growth and of highest insect susceptibility were cut, and a "value" marking in which the trees of high value and low earning power were removed. In both types of marking, trees of highest risk were of first priority for cutting regardless of value. These were cut to salvage what would be lost and to reduce the likelihood of epidemic losses. Large differences existed in tree growth between the different cutting methods. There was no way to sort out that part caused by the treatments from that part due to original plot differences, however. The experiment did not provide evidence to either support or reject the hypothesis that heavy cutting and value marking reduced growth. Considerations for improving the experimental design are presented and discussed, including size of treatment areas, need for treatment replication, and use of a covariance analysis. (Keywords: Ponderosa pine—silvicultural practices, Timber harvesting)

Dahms, Walter G. 1952. Service life of treated and untreated fence posts on the Pringle Falls Experimental Forest. Res. Note 80. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 4 p.

Results of a study comparing lodgepole pine and western redcedar posts are presented. Service life was monitored for 355 cedar posts over 19 years and for 517 lodgepole pine posts over 16 years. Lodgepole pine posts were divided nearly equally into four wood preservative treatments applied to the portion of the post in contact with soil: application by brush of carbolineum, an open tank hot-and-cold creosote bath, an application of arsenic paste, and a control. Untreated lodgepole pine posts gave an average service life of 13.5 years. Lodgepole pine posts treated with arsenic or creosote and cedar posts were expected to at least double the life of untreated lodgepole pine. Carbolineum-treated lodgepole pine posts deteriorated faster than untreated pine posts. (Lodgepole pine—harvesting operations)

Dahms, Walter G. 1954. Growth of pruned ponderosa pine. Journal of Forestry. 52: 444-445.

The effect after 10 years of pruning different proportions of live crown on diameter and height growth are presented (see Mowat 1947b). As much as one-third of the live crown length of ponderosa pine may be pruned away to increase production of clear, knot-free wood without significant reduction in both height and diameter growth. (Keywords: Ponderosa pine—pruning)

Dahms, Walter G. 1955. Chemical brush control on central Oregon ponderosa pine lands. Res. Note 109. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 5 p.

Results of small-plot trials to determine which chemicals will kill greenleaf manzanita *(Arctostaphylos patula* Greene) and snowbrush ceanothus *(Ceanothus velutinus* Dougl.) are presented. Chemicals tested were low-volatile ester of 2, 4-D (propylene glycol butyl ether esters); butyl ester 2, 4-D; low-volatile ester 2, 4, 5-T; mixed low-volatile esters of 2, 4-D and 2, 4, 5-T; and low-volatile ester 2, 4, 5-TP. Effective control of manzanita was found with low-volatile ester 2, 4-D in a diesel oil carrier (see Dahms 1961). (Keywords: Forest shrubs, Ponderosa pine—competing vegetation)

Dahms, Walter G. 1960. Long-suppressed ponderosa pine seedlings respond to release. Res. Note 190. Portland, OR: U.S. Department of Agriculture. Forest Service, Pacific Northwest Forest and Range Experiment Station. 3 p.

Supplemental results of a study of the effects of releasing suppressed ponderosa pine seedlings (see Mowat 1950). The study was begun in 1934 when suppressed ponderosa pine seedlings and saplings were 40 years old and 0.4 meter in height. An adjacent untreated 0.4-hectare plot was established in 1937. Remeasurements were recorded in 1940, 1943, 1947, 1952, and 1958. In 1958, released trees were nearly three times the height of unreleased trees. This work demonstrated that ponderosa pine reproduction, severely suppressed for 40 years or more by an overstory of lodgepole pine, will recover vigor after overstory removal. (Keywords: Forest regeneration, Lodgepole pine—harvesting operations, Ponderosa pine—silvicultural practices)

Dahms, Walter G. 1961. Chemical control of brush in ponderosa pine forests of central Oregon. Res. Pap. 39. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 17 p.

Results of a study to refine techniques for chemical control of undesired shrubs are presented. The objectives were to determine if greenleaf manzanita *(Arctostaphylos patula* Greene), snowbrush ceanothus *{Ceanothus velutinus* Dougl.), or golden chinquapin *(Castanopsis chrysophylla* (Dougl.) DC.) could be controlled without injury to intermingled ponderosa pine seedlings and saplings; and to determine if sprouting of snowbrush and chinquapin could be eliminated or greatly reduced by chemical treatment. Various herbicides were applied to shrubs and trees with a hand sprayer. Percentage of dead shrub cover was used to rate effectiveness of herbicide treatments. Shrub cover was assessed at 100 points within small plots. Efficacy on ponderosa pine was rated by mortality of terminal buds. Plots were evaluated after a full growing season. Recommendations for rate, carrier, and time of herbicide application differ depending on target species. Manzanita was most susceptible from late May until mid-July. Chinquapin was killed with a relatively low rate of application during the growing season. Vigorous sprouting of snowbrush followed all treatments. (Keywords: Forest shrubs, Ponderosa pine—competing vegetation)

Dahms, Walter G. 1966. The biological aspect—how is stand development influenced by stand density? In: Proceedings of the annual meeting of Western Reforestation Coordinating Committee; 1966 December 7-9; Portland, OR. Portland, OR: Western Forestry and Conservation Association.

A discussion of the effect of thinning on stand development is presented. In contrast to the classic notion of even-aged growth and suppression depicted by normal yield tables, some stands develop under different disturbance regimes that result in lower growth rates. Thinning can modify this kind of development and ensure the best possible rate of individual tree growth. Stand development is discussed in relation to spacing studies at Pringle Falls Experimental Forest. (Keywords: Forest dynamics, Ponderosa pine—stand dynamics, Ponderosa pine—thinning, Ponderosa pine—tree spacing)

Dahms, Walter G. 1971. Fifty-five-year-old lodgepole pine responds to thinning. Res. Note PNW-141. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 13 p.

Results of a lodgepole pine thinning study are presented. Three 0.2-hectare plots were established in 1934 in a 55-year-old, fully stocked, even-aged stand of lodgepole pine (see Barrett 1961). One plot was thinned from below to a 3.6-meter spacing, one plot was thinned from below to a 4.9-meter spacing, and one plot was left unthinned as a control. Periodic measurements of diameter and height were made through 1966. Diameter growth was fastest on the most heavily thinned plot and slowest on the unthinned plot. Height of the leading trees on all plots was similar, although height to the tree of average diameter increased more rapidly on the thinned plots than on the unthinned one. Changes in gross and net cubic volume increment and annual board-foot increment are discussed. (Keywords: Lodgepole pine—thinning)

Dahms, Walter G.; Barrett, James W. 1975. Seed production of central Oregon ponderosa and lodgepole pines. Res. Pap. PNW-191. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 13 p.

Results of several studies in which production and dispersal of ponderosa and lodge-Pole pine seed were monitored over a 22-year period are presented (see Barrett 1966a). Seed traps were placed in a mature ponderosa pine stand, an immature, even-aged ponderosa pine stand, and a mature lodgepole pine stand to estimate size and frequency of seed crops at the Pringle Falls Experimental Forest. Dispersal of lodgepole pine seed also was estimated from seed traps placed in clearcut areas in the Winema National Forest. Seed-production estimates indicated sufficient lodgepole pine seed was produced to provide for satisfactory natural regeneration during 3 out of 4 years if other conditions were favorable. In contrast, ponderosa pine produced only five good seed crops during the same period. (Keywords: Forest regeneration, Lodgepole pine—silvics, Ponderosa pine—silvics)

Dahms, Walter G.; James, George A. 1955. Brush control on forest lands—with emphasis on promising methods for the Pacific Northwest—a review of selected references. Res. Pap. 13. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 81 p.

A literature review and bibliography of work concerning the control of undesirable herb, shrub, and tree species. Major topics include chemical methods of control such as 2, 4-D and 2, 4, 5-T, and their application and equipment; mechanical methods of control such as dozers, cabling, and plows, and their costs; control by prescribed burning, including techniques and costs; biological control; and combination methods. A total of 239 pieces of literature are referenced and indexed. (Keywords: Forest regeneration, Forest shrubs, Lodgepole pine—competing vegetation, Ponderosa pine—competing vegetation)

Dealy, J. Edward. 1966. Bitterbrush nutrition levels under natural and thinned ponderosa pine. Res. Note PNW-33. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 6 p.

Results of a study to determine nutrimental differences in antelope bitterbrush *(Purshia tridentata* (Pursh) DC.) as affected by different ponderosa pine stocking levels. A mature overstory was removed and understory thinned (see Barrett 1965). Current-year leaders from bitterbrush plants were collected from plants in thinned and unthinned plots, and samples were analyzed for percentage of crude fiber, ash, crude fat, crude protein, and nitrogen-free extract. Samples from natural, unthinned plots contained a higher percentage of ash and nitrogen-free extract, and a lower percentage of crude fiber content than did plants under the thinned stands. There was little or no difference in crude fat and crude protein on the two sites. Plants growing under canopy shade had lower crude fiber and were more succulent; observations of deer feeding habits do not support the assumption that these more succulent plants are preferred. Ash content is hypothesized as contributing, by means of some undetected mineral component, to deer selection for open-grown bitterbrush. (Keywords: Forest shrubs, Ponderosa pine—competing vegetation, Wildlife)

Edgerton, Paul J. 1983. Response of the bitterbrush understory of a central Oregon lodgepole pine forest to logging disturbance. In: Tiedemann, Arthur R.; Johnson, Kendall L, comps. Proceedings—research and management of bitterbrush and cliffrose in western North America; 1982 April 13-15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 99-106.

Results of a study of antelope bitterbrush *(Purshia tridentata* (Pursh) DC.) response to logging disturbance are presented (see Edgerton and others 1975). Objectives were to determine the extent of soil disturbance and reduction of shrub understory and to document subsequent understory recovery due to growth response of surviving shrubs and the establishment of new shrubs and herbaceous plants. The study occurred in a lodgepole pine stand logged between 1969 and 1971. Ground disturbance caused by logging and slash disposal was estimated in 1972. Changes in bitterbrush crown area were recorded in 1972 and 1975. Logging and slash disposal caused extensive soil disturbance and physical damage to the bitterbrush undergrowth. After 5 years, substantial recovery had occurred due to increased twig growth of surviving shrubs and establishment of shrub seedlings on disturbed soils. Overall species diversity increased with additional herbaceous species. (Keywords: Forest shrubs, Lodgepole pine—competing vegetation, Lodgepole pine—harvesting operations, Timber harvesting)

Edgerton, Paul J.; McConnell, Burt R.; Smith, Justin G. 1975. Initial response of bitterbrush to disturbance by logging and slash disposal in a lodgepole pine forest. Journal of Range Management. 28(2): 112-114.

Results of a study of antelope bitterbrush *(Purshia tridentata* (Pursh) DC.) response to logging disturbance are presented (see Edgerton 1983). Logging destroyed most of the bitterbrush crown area, and created conditions favoring establishment of new plants. Two years after final logging, total shrub density was similar to that before logging. There was no difference in deer and elk use between logged and unlogged areas. (Keywords: Forest shrubs, Lodgepole pine—competing vegetation, Timber harvesting, Wildlife)

Evans, Lynn B. 1983. Hydrophobicity of Cindery Typic Cryorthents. Corvallis, OR: Oregon State University. 118 p. M.S. thesis.

Results of a study to determine the effect of prescribed burning on soils and the formation of a water repellent layer are presented. Fieldwork occurred in the Lookout Mountain unit in soils formed in cinders and ash from Mount Mazama. The objectives of the study were to determine (1) whether or not prescribed burning causes the formation of a water repellent layer, (2) which variables affect the hydrophobicity of the soil after burning, (3) the horizontal and vertical extent of the hydrophobic layer, and (4) how long the hydrophobicity persists in the soil. Critical surface tension (CST) was measured to characterize hydrophobicity. Two units, averaging 12.5 hectares, were burned under prescription for slash disposal in June and September 1982 and were sampled to meet the first three objectives. The fourth objective was met by sampling six additional sites where the time since burning ranged from 9 to 51 months. The presence of preburn hydrophobicity, believed to be caused by fungal products, complicated determining the effects of burning on the hydrophobicity of the soil. Preburn hydrophobicity was more extensive on the site sampled in September than on the site sampled in June. This difference was attributed to seasonal variation in the presence of fungal hyphae and differences in soil moisture. The June burn caused an increase in the hydrophobicity of the soil, at a depth of 2 to 3 centimeters. This increased hydrophobicity was explained by the degree of litter combustion. On the site burned in September, most sampling points were hydrophobic before burning because of the presence of fungal products. Hydrophobicity decreased in the upper 2 centimeters of the soil. It was postulated that the hydrophobic fungal products were volatilized by the high temperatures of the prescribed burn and diffused deeper into the soil where they then condensed. Measurements of litter depth and water content did not explain the variation in postburn hydrophobicity of the soil at either site. There was a significant decrease in hydrophobicity with time since burning. (Keywords: Forest fire, Forest pathogens—fungi, Soils)

Fahnestock, George R. 1968. Fire hazard from precommercial thinning of ponderosa pine. Res. Pap. PNW-57. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 16 p.

Results of a study of the quantity and quality of slash resulting from thinning ponderosa pine stands are presented. Objectives were (1) to develop a basis for estimating the weight of slash produced by thinning operation, (2) to estimate the weight of slash expected from thinning normal stands of known site and age to various spacings, (3) to make inferences regarding flammability and difficulty of fire control for at least 5 years, and (4) to make suggestions of research needed for aiding in slash control. Quantity of slash in terms of weight was determined for ponderosa pine and its principal associates by breast-height diameter class. Weight of slash per unit area was determined for various tree spacings, age, and site index classes. Results showed that thinning well-stocked stands to wide spacings produced fuels that rated high in rate of spread and resistance to fire control for at least 5 years after cutting. (Keywords: Forest fire, Ponderosa pine—thinning)

Fight, Roger D.; Bolon, Natalie A.; Cahill, James M. 1992. Financial analysis of pruning ponderosa pine. Res. Pap. PNW-RP-449. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 17 p.

Results of a financial analysis of the financial return from pruning ponderosa pine in central Oregon are presented. The analysis was based on lumber recovery from pruned and unpruned trees in the Pringle Falls Experimental Forest (see Cahill 1991). The cost of pruning at which the investment would yield an expected 4-percent real rate of return was positive on sites where individual tree growth was fairly high, pruning was done as early as biologically possible given crown removal limitations, and the final tree harvest was 30 to 70 years after pruning. The better situations showed a break-even cost of $11 dollars per tree. Pruning ponderosa pine is likely to be an investment yielding returns in excess of the 4-percent rate desired from resource investments on Federal lands. (Keywords: Ponderosa pine—pruning)

Greene, Lula E. 1992. Qualitative genetics of mountain pine beetle in central Oregon. In: Hayes, Jane L; Roberson, Jacqueline L, tech. coords. Proceedings of a workshop on bark beetle genetics: current status of research; 1992 May 17-18; Berkeley, CA. Gen. Tech. Rep. PSW-GTR-138. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 3.

Early results of a long-term study of insect-host interactions and the effects of secondary plant chemicals on mountain pine beetle *(Dendroctonus ponderosae* Hopk.) are presented. The objective was to develop a better understanding of host-induced genetic changes in bark beetles by monitoring changes in allelic frequencies and genotype structures of populations for trends that indicate changes from endemic to epidemic levels in the population. Esterase enzymes revealed a single locus that seemed promising as a diagnostic indicator of host preference and population status. (Keywords: Forest insects—mountain pine beetle)

Hall, F.C. 1972. Pringle Falls Research Natural Area. In: Franklin, Jerry F.; Hall, Frederick C.; Dyrness, C.T.; Maser, Chris. Federal research natural areas in Oregon and Washington—a guidebook for scientists and educators. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: PR-1 to PR-11.

A description of the Pringle Falls Research Natural Area is provided. This 470-hectare tract, consisting of two blocks within the Pringle Butte unit, was established June 1936 to exemplify the topographically related mosaic of lodgepole and ponderosa pine forests characteristic of a large area of aerially deposited Mount Mazama pumice in south-central Oregon. The description includes a discussion of access and accommodations, environment, biota, history of disturbance, research to date, and maps and photographs of typical plant communities. (Keywords: Research Natural Area)

Johnson, Floyd A.; Dahms, Walter G.; Hightree, Paul E. 1967. A field test of 3P cruising. Journal of Forestry. 65(10): 722-726.

Results of a study comparing methods of cruising ponderosa pine trees marked for cutting on Pringle Falls Experimental Forest are presented. The sale unit consisted of 1,848 old-growth trees; 35 trees were sampled in the 3P cruise and 88 trees were sampled in the conventional manner of choosing one tree at random out of a group of 5 to 10 consecutively marked trees. In the 3P cruise, sample-tree volume was measured with a dendrometer. Cruising with the 3P method was found to be superior to the standard method in terms of sampling error, bias, and cost. (Keywords: Ponderosa pine—silvicultural practices, Timber harvesting)

Keen, F.P. 1936. Relative susceptibility of ponderosa pine to bark-beetle attack. Journal of Forestry. 34(10): 919-927.

Tree classes for determining the susceptibility of ponderosa pine to western pine beetle *(Dendroctonus brevicomis* LeConte) attack are defined, based on study of over 22,000 trees (see Keen 1943). The bark-beetle susceptibility classification was based on considerations of age, dominance, and vigor, with 16 classes described. Susceptibility was determined by monitoring tree mortality from 1928 to 1931. Application of the classification is discussed in terms of marking by individual tree selection for salvage of valuable trees and marking for reduction of mortality rates. (Keywords: Forest insects—western pine beetle, Ponderosa pine—insects, Ponderosa pine—silvics, Timber harvesting)

Keen, P.P. 1937. Climatic cycles in eastern Oregon as indicated by tree rings. Monthly Weather Review. 65(5): 175-188.

Results of a study relating radial growth of ponderosa pine to long-term climatic cycles in central and eastern Oregon are presented. Tree-ring sections were taken from 1,240 ponderosa pines in 44 different sites across Oregon and northeastern California. From 12 to 15 cores were taken from each site from dominant trees between the ages of 100 and 250 years. In addition, V-shaped radial sections were taken from freshly cut stumps to assess long-term fluctuations. From 30 to 90 stumps were obtained from each of five widely separated areas of Oregon. After core and section preparation, decadal measurements were made to the nearest 0.1 millimeter and then plotted. There was consistent growth decline between 1916 and 1917; growth was above average in 1921, 1923, and 1928; and in 1924 and 1929, the slowest growth in the decade occurred. Growth of individual trees and across the region is discussed in terms of disturbance events, such as fire and insect defoliation, and is correlated to regional patterns of precipitation. The tree-ring record indicated that during the past 650 years, there has been no consistent trend toward either drier or wetter climatic conditions; major fluctuations prevail and are alternating. (Keywords: Forest dynamics, Ponderosa pine—stand dynamics)

Keen, F.P. 1940. Longevity of ponderosa pine. Journal of Forestry. 38(7): 597-598.

Results of age determinations of ponderosa pine stands of eastern Oregon are presented. Sections were taken from stumps left after logging and were examined under a binocular microscope. From a sample of 46 stump sections collected on Pringle Falls Experimental Forest in 1935, 27 were older than 300 years. The oldest was 606 years with central ring dating back to 1330 A.D. A stump section from Klamath County, Oregon, was 726 years old, with central ring dating back to 1212 A.D. (Keywords: Forest dynamics, Ponderosa pine—silvics. Ponderosa pine—stand dynamics)

Keen, F.P. 1943. Ponderosa pine tree classes redefined. Journal of Forestry. 41(4): 249-253.

Tree classes for determining the susceptibility of ponderosa pine to western pine beetle *(Dendroctonus brevicomis* LeConte) attack are redefined, based on an additional study of 3,700 trees (see Keen 1936). Morphological characteristics of bark color and form, tree height, crown shape, branch form, and tree diameter were used to distinguish maturity, growth capacity, and beetle susceptibility over a relatively long period. (Keywords: Forest insects—western pine beetle, Ponderosa pine—insects, Ponderosa pine—silvics, Timber harvesting)

Keen, F.P. 1946. A tree-class slide rule. Journal of Forestry. 44(10): 755-757.

An alignment chart integrating ponderosa pine bark color and form, tree height, crown shape, branch form, and tree diameter in slide rule form is presented. It is applicable throughout central and eastern Oregon as an aid in determining individual tree crown vigor and maturity classification. (Keywords: Forest insects—western pine beetle, Ponderosa pine—insects, Ponderosa pine—silvics, Timber harvesting)

Knutson, Donald M. 1975. Dwarf mistletoe-infected ponderosa pines survive top-pruning. Journal of Forestry. 73(12): 774-775.

Results of a study of the effects of top-pruning ponderosa pine are presented. Seventeen trees, ranging from 4.2 to 9.1 meters tall, were pruned from the top to remove all branches infected with dwarf mistletoe *(Arceuthobium campylopodum* (Engelm.) Gill). A skirt of lower branches for photosynthetic production was retained until a new crown formed, and then the lower branches were removed. Most trees survived the treatment, but with an expected loss of diameter growth. The new crown on treated trees displayed better color and longer needles than comparably aged needles on lower branches. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases, Ponderosa pine—pruning)

Kolbe, Ernest L.; McKay, Donald F. 1939. Seven methods of cutting tested at Pringle Falls. Res. Notes 27. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Experiment Station. 1 p.

Initial results of a study of selection cutting methods in ponderosa pine are presented (see Mowat 1948, 1961; Dahms 1951). Seven plots, totalling 205 hectares, were established in 1937 as a solid block on the Pringle Butte unit. Intensities of cut were 20-, 40-, 60-, and 80-percent volume removal. For each degree of cut except 80 percent, two contrasting policies in marking were applied: a "thrift" marking in which the trees of poorest vigor and growth and of highest insect susceptibility were cut, and a "value" marking in which the trees of high value and low earning power were removed. In both types of marking, trees of highest risk were of first priority for cutting regardless of value. These were cut to salvage what would be lost and to reduce the likelihood of epidemic losses. (Keywords: Ponderosa pine—silvicultural practices, Timber harvesting)

Koonce, Andrea Lavender. 1981. Interactions between fire and dwarf mistletoe in ponderosa pine. Corvallis, OR: Oregon State University. 53 p. Ph.D. dissertation.

Young stands of precommercial saplings and small pole-sized ponderosa pine with variable dwarf mistletoe *(Arceuthobium campylopodum* (Engelm.) Gill) intensity ranging from no apparent infection to severe infestation were studied to evaluate the effects on fuel within "time-lag" size classes, and the degree of mistletoe reduction in crop and noncrop trees as a result on prescribed burning. Work occurred on the Pringle Butte unit. Dwarf mistletoe was found to affect both surface and aerial fuels. There was a 20-percent increase in the proportion of fine fuels to the total fuel weight. There was also an increase in dwarf mistletoe-infected branchwood persisting in the surface fuels, either because of increased diameter or because of increased resin content. Dwarf mistletoe-infected branches in tree crowns resisted natural pruning and lowered the bottom of the live crown, thereby increasing the amount of fuel close to surface fires. Diseased trees were more susceptible to crown scorch and had greater levels of mortality than did healthy trees. In general, 30 percent of crown scorch was sufficient to kill 80 percent of severely infected branches and reduce the mistletoe rating from severe to moderate. (Keywords: Forest fire, Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

Koonce, Andrea L.; Roth, Lewis F. 1980. The effects of prescribed burning on dwarf mistletoe in ponderosa pine. In: Martin, Robert E.; Edmonds, Robert L.; Fulkner, Donald A. [and others]. Proceedings, 6th conference on fire and forest meteorology; 1980 April 22-24; Seattle, WA. Bethesda, MD: Society of American Foresters: 197-203.

Results of a study examining relations between dwarf mistletoe *(Arceuthobium campylopodum* (Engelm.) Gill) reduction and fire intensity after prescribed understory burns in released or shaded understory stands of ponderosa pine are presented. Prescribed burn and unburned control plots were examined for fuel loading and dwarf mistletoe characteristics (see Koonce 1981). Dwarf mistletoe was partially sanitized from thinned and unthinned stands by prescribed understory burning. Scorch heights between 30 and 60 percent of the live crown length were required to reduce the proportion of dwarf mistletoe in the crowns of crop trees. Mistletoe levels were reduced from severe to tolerable levels when the crowns were not severely infected throughout their length. (Keywords: Forest fire, Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

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

The relation between tree vigor, defined as grams of wood produced per square meter of leaf area, and level of mountain pine beetle *(Dendroctonus ponderosae* Hopk.) attack is examined. As part of a west-wide levels-of-growing stock study, the distribution of mountain pine beetle attacks over a range of tree vigors was determined within a stand in the Lookout Mountain unit (see Barrett 1983). Six levels of growing stock, ranging from 6.9 to 34.4 square meters per hectare, were established in a 65-year-old stand of ponderosa pine in 1965. Each level was replicated three times and applied to 0.2-hectare plots. In 1981, nine 0,02-hectare unthinned control plots were added. Cumulative beetle-caused mortality was determined in 1970, 1975, and 1980. In addition, trees with more than five visible pitch tubes in 1981 were considered attacked. Tree-vigor rating was based on sapwood thickness and the previous years growth ring measured from increment cores. From sapwood area, leaf area was estimated and converted to leaf area index. Vigor decreased as both tree basal area and leaf area index increased. Low vigor trees were more often attacked by beetles than were high vigor trees. Attacks increased below a vigor threshold of about 100 grams of wood produced per square meter of leaf area per year, corresponding to a basal area of 21 square meters per hectare or a leaf area index of 2.0 square meters of foliage per square meter of ground surface. (Keywords: Forest insects—mountain pine beetle, Ponderosa pine—insects, Ponderosa pine—silvics, Ponderosa pine—stocking levels)

Martin, Robert E. 1982a. Fire history and its role in succession. In: Means, Joseph E., ed. Forest succession and stand development research in the Northwest: Proceedings of the symposium; 1981 March 26; Corvallis, OR. Corvallis, OR: Oregon State University, Forest Research Laboratory: 92-99.

Review of current literature relating fire return intervals to fire severity and effect on successional stage for various North American vegetation types. Intervals between fires are longer in warm, dry sites where little fuel accumulation limits fire spread, and in cool, wet sites where burning conditions limit fire spread despite large accumulations of fuels. Between these extremes, the shortest fire return intervals occur where an optimum combination of flammable fuel and ignition sources exist. A U-shaped model depicting this relation of years between fires to fuel conditions is presented. Based on a range of 3 to 16 years in ponderosa pine and 3 to 15 years in ponderosa pine-grand fir, Pnngle Falls Experimental Forest has a short fire-return interval. (Keywords: Forest fire, Forest dynamics, Ponderosa pine—stand dynamics)

Martin, Robert E. 1982b. Shrub control by burning before timber harvest. In: Baumgartner, David M., comp., ed. Site preparation and fuels management on steep terrain: Proceedings of a symposium; 1982 February 15-17; Spokane, WA. Pullman, WA: Washington State University: 35-40.

Results of a study of the effects of prescribed burning for shrub control before timber harvesting are presented. The study was conducted on the Lookout Mountain unit in a stand containing overstory ponderosa pine and some grand fir saplings. Target shrubs included snowbrush ceanothus {*Ceanothus velutinus* Dougl.), golden chinquapin {*Castanopsis chrysophylla* (Dougl.) DC.), antelope bitterbrush {*Purshia tridentata* (Pursh) DC.), and greenleaf manzanita {*Arctostaphylos patula* Greene). Plots were first burned in 1976, and then a portion were reburned in 1979 and 1980. The first fire reduced fuel loads, top-killed most shrubs, and caused many shrub seed to germinate. The second fire killed all the new shrub seedlings and greatly reduced sprouting of shrubs. (Keywords: Forest fire, Forest shrubs, Ponderosa pine—competing vegetation)

Martin, Robert E. 1983. Antelope bitterbrush seedling establishment following prescribed burning in the pumice zone of the southern Cascade mountains. In: Tiedemann, Arthur R.; Johnson, Kendall L, comps. Proceedings—research and management of bitterbrush and cliffrose in western North America; 1982 April 13-15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 82-90.

Results of a study of antelope bitterbrush {*Purshia tridentata* (Pursh) DC.) regeneration and reestablishment after prescribed fires are presented. Data were collected from 21 prescribed burning units at five locations in central Oregon and northeastern California. Burning occurred from 1972 to 1978; field sampling occurred in 1980. Bitterbrush seedlings occupied from one-quarter to five times as many of the sampling plots as did old plants. Sprouting of old bitterbrush was low and might be attributed to site factors, stress from competition, and burning conditions. Use of fire in these stands to develop a mosaic of vigorous bitterbrush in mixture with older plants, perhaps enhancing wildlife habitat, is advocated. (Keywords: Forest fire, Forest shrubs)

Martin, Robert E.; Frewing, David W.; McClanahan, James L. 1981. Average biomass of four northwest shrubs by fuel size class and crown cover. Res. Note PNW-374. Portland. OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 6 p.

Data on shrub fuel loads from several locations in Oregon and northern California, including Pringle Falls Experimental Forest, are presented. Shrub species include antelope bitterbrush {*Purshia tridentata* (Pursh) DC.), big sagebrush {*Artemisia tridentata* Nutt), snowbrush ceanothus {*Ceanothus velutinus* Dougl.), and greenleaf manzanita {*Arctostaphylos patula* Greene). For each species, average fuel loading in tons per hectare for live and dead components of fuel in timelag classes by percentage of crown cover is presented. With 100-percent shrub crown cover, average biomass of bitterbrush, big sagebrush, snowbrush, and manzanita was 11.3, 13.9, 24.0, and 36.0 tons per hectare, respectively. (Keywords: Forest fire, Forest shrubs)

Martin, Robert E.; Driver, Charles H. 1983. Factors affecting antelope bitterbrush reestablisment following fire. In: Tiedemann, Arthur R.; Johnson. Kendall L, comps. Proceedings—research and management of bitterbrush and cliffrose in western North America: 1982 April 13-15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 266-279.

The biology and ecology of antelope bitterbrush (*Purshia tridentata* (Pursh) DC.) in relation to fire is discussed, based on observations, experience, and nearly 70 pieces of relevant literature. Topics include the effect of genetics and morphology, phenological condition, plant age, competition, soil type, soil-moisture burning conditions, site history, fuel load, and browsing pressure on sprouting ability; seed supply, rodent population, site quality, burning condition, plant competition, and browsing pressure on seedling establishment; insects and diseases; and artificial seeding and planting. (Keywords: Forest fire, Forest shrubs)

Mazany, Terry; Thompson, Mama Ares. 1983. Fire scar dates from the Pringle Falls area of central Oregon. Tucson, AZ: University of Arizona, Laboratory of Tree-Ring Research. 14 p.

Nine fire-scarred ponderosa pine cross sections from Pringle Falls Experimental Forest area were examined to determine the potential for fire history studies. Individual ring series contained sufficient shared sensitivity for cross-dating and development of a Pringle Falls skeleton plot chronology. The oldest pith date was 1362. A total of 160 fire scars were identified on the nine sections, forming perhaps the longest record of fire history yet developed for one region. (Keywords: Forest fire, Forest dynamics, Ponderosa pine—stand dynamics)

Mitchell, Russel G.; Sower, Lonne L. 1991. Life history of the western pine shoot borer (Lepidoptera: Olethreutidae) and effects on lodgepole pine in central Oregon. Journal of Economic Entomology. 84(1): 206-211.

Results of a study of infestation patterns, effects on height growth, and seasonal history of the western pine shoot borer *(Eucosma sonomana* Kearfott) are presented. Pringle Falls Experimental Forest was one of four study sites, all characterized by lodgepole pine regeneration in clearcuts surrounded by nearly pure stands of sawtimber-sized lodgepole pine. Seasonal history of the shoot borer was determined in relation to plant phenology and heat accumulation in degree-days. Timing of oviposition was established from estimating the number of larvae infesting lodgepole pine terminal leaders collected and dissected weekly. Phonological development was established by monitoring development on 10 to 20 tagged plants on sample plots. Plants included lodgepole pine, antelope bitterbrush (*Purshia tridentata* (Pursh) DC.), squaw current *(Ribes cereum* DougL), tall gray rabbitbrush *(Chrysothanmus nauseousus* (Pall.) Britt), and various forbs. The effect of the shoot borer on tree growth was estimated by comparing vertical growth of terminals exposed to attack with growth of terminals protected from attack. Protection was provided by means of fine-mesh nylon bags. Borer attack density was related to stand elevation; infestation level was at least 65 percent in stands below 1800 meters, and zero in stands above 2000 meters. Needles at the distal end of infested terminals were often shorter than those at the proximal end. Height growth was reduced and the distal ends of terminals were frequently killed. Trees protected from infestation increased in height growth by about 24 percent per year for 3 years. Seasonal history of the shoot borer was nearly the same as that previously determined for ponderosa pine. (Keywords: Forest insects—western pine shoot borer, Lodgepole pine—insects)

Morrow, Robert J. 1986. Age structure and spatial pattern of old-growth ponderosa pine in Pringle Falls Experimental Forest, central Oregon. Corvallis, OR: Oregon State University. 80 p. M.S. thesis.

Results of a study of the dynamics of old-growth ponderosa pine forests in the Pringle Butte unit are presented. Age structure and spatial pattern of ponderosa pine within the Pringle Falls Research Natural Area, coupled with the fire history of the area, were used to interpret stand development within two 1.0-hectare permanent reference stands in the *Pinus ponderosa/Purshia tridentata-Ceanothus velutinus/Stipa occidentalis* community type. Age data were taken from 392 ponderosa pine and 280 lodgepole pine. Spatial dispersion of trees within age cohorts was tested by using Monsita's Index. The historical development of both stands since 1500 was examined by using a chronosequence of the location of stems of known ages. Associations using chi-square tests were examined for the identified cohorts of both species. Three age cohorts were identified. Regeneration of both species since 1900 was not dependent on the presence of fire-prepared mineral seedbeds. Variation in clumping within all three cohorts ranged from 25 to 3500 square meters. Two scales of pattern were identified: high mortality during periods of increased fire activity produced long-term temporal and coarse-grained aggregated patterns in broad age cohorts, and fine-grained spatial and shorter temporal patterns resulted from contemporaneous reproduction in small areas. Chi-square associations indicated that the spatial and temporal patterns of the older cohorts have been maintained for the last 250 years. Fire exclusion has caused a deterioration in both types of patterns. Frequent (7 to 20 years) low-intensity bums, coupled with infrequent, larger or hotter burns must be reintroduced to maintain coarse-grained spatial and long-term temporal patterns representative of prefire exclusion patterns. (Keywords: Forest fire, Forest dynamics, Ponderosa pine—stand dynamics)

Mowat, Edwin L. 1947a. Effect of pruning on growth of ponderosa pine. Res. Notes 38. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Experiment Station. 3 p.

Results of a study of pruning various proportions of the crowns of young ponderosa pine trees on growth, vigor, and mortality are presented. The study was started in 1941 in a 55-year-old stand, and involved pruning only dead limbs, pruning one-fourth, one-half, and three-fourths of the length of live crown. Pruning treatments were assigned at random to 384 dominant or codominant crop trees in four plots or blocks. Diameters and heights were remeasured after 5 years. Pruning of more than one-fourth of the live crown reduced diameter growth but had little effect on height growth. Removing only the lower one-fourth of the live crown had a negligible effect on growth (see Barrett 1968, Dahms 1954). (Keywords: Ponderosa pine—pruning)

Mowat, Edwin L. 1947b. High yields from young-growth ponderosa pine. Res. Notes 37. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Experiment Station. 3 p.

Results of one of the earliest studies of thinning in young ponderosa pine in central Oregon are presented (see Barrett and Newman 1974). Thinning from above occurred in 1938 in a 16-hectare tract of 94-year-old, even-aged ponderosa pine on the Lookout Mountain unit. Before thinning, the stand contained a volume of 190.0 cubic meters; thinning removed about 35.6 cubic meters. Annual growth and mortality on five permanent thinned plots and two adjacent unthinned plots was followed for the period 1940 to 1946. By 1946, when the stand was 102 years old, the mean annual increment on the thinned plots, including the volume removed by thinning, was almost 2.0 cubic meters. This rapid growth, just slightly less than that of unthinned plots, suggested the need to further refine management prescriptions for these high-yield sites. (Keywords: Ponderosa pine—growth and yield, Ponderosa pine—silvicultural practices, Ponderosa pine—thinning)

Mowat, Edwin L. 1948. Selection cutting reduces ponderosa pine losses at Pringle Falls. Res. Notes 45. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Experiment Station. 3 p.

Results of a study to define levels of selection cutting in ponderosa pine are presented (see Kolbe and McKay 1939, Mowat 1961). Seven plots, totalling 205 hectares, were established in 1937 as a solid block on the Pringle Butte unit. Intensities of cut were 20-, 40-, 60-, and 80-percent volume removal. For each degree of cut except 80 percent, two contrasting policies in marking were applied: a "thrift" marking in which the trees of poorest vigor and growth and of highest insect susceptibility were cut, and a "value" marking in which the trees of high value and low earning power were removed. In both types of marking, trees of highest risk were of first priority for cutting regardless of value. These were cut to salvage what would be lost and to reduce the likelihood of epidemic losses. Mortality after the cuttings was assessed by annual 100-percent tallies. The average volume loss from insects and related causes on the cuttings was six times greater in the adjacent uncut forest. The thrift marking showed lower losses by insect attack than did the value marking. The 20-percent cut was as effective as the heavier cuts in reducing total mortality. (Keywords: Forest dynamics, Ponderosa pine—silvicultural practices, Timber harvesting)

Mowat, Edwin L. 1949. Preliminary guides for the management of lodgepole pine in Oregon and Washington. Res. Notes 54. Portland, OR: U S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 10 p.

A summary of the state of knowledge of lodgepole pine management in Oregon and Washington is presented. Work reviewed includes general ecological studies, limited mensurational analyses, results of test thinnings on several National Forests and the Pringle Falls Experimental Forest, and a survey of partial cuttings. Recommendations to enhance management include restricting extensive and heavy selection cutting, designing harvest units to provide protection from winds, and integrated usage considering present and future products and markets. (Keywords: Lodgepole pine—silvicultural practices, Timber harvesting)

Mowat, Edwin L. 1950. Cutting lodgepole pine overstory releases ponderosa pine reproduction. Journal of Forestry. 48(10): 679-80.

A brief overview of the results from a 0.4-hectare test plot cleared of overstory lodge-Pole pine by Civilian Conservation Corps labor in 1934 (see Dahms 1960). At the time of treatment, the lodgepole pine averaged 75 years old, and suppressed ponderosa pine seedlings and saplings were 40 years old; their average height was 0.4 meter. An adjacent untreated 0.4-hectare plot was established in 1937. Remeasurements were recorded in 1940, 1943, and 1947, at which time the average height of released seedlings was 1.7 meters and the average height of seedling on the untreated plot was 0.8 meter. This work demonstrated that ponderosa pine reproduction, even though severely suppressed for 40 years or more by an overstory of lodgepole pine, could recover vigor after overstory removal. Loss of seedlings to animal browsing was considered minor and was offset by natural establishment of both lodgepole and ponderosa pine from surrounding seed-bearing trees. (Keywords: Forest regeneration, Lodgepole pine—silvicultural practices, Ponderosa pine—silvicultural practices)

Mowat, Edwin L. 1953. Thinning ponderosa pine in the Pacific Northwest—a summary of present information. Res. Pap. 4. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 24 p.

The first detailed progress report of various thinning studies in eastern Oregon and Washington is presented. Thinning occurred in ponderosa pine "thickets" that developed after abundant regeneration during the 1890s and early 1900s was protected from fire with the advent of suppression activities. Five permanent plots were established on the Pringle Falls Experimental Forest in 1938; two of these were thinned to 2.7-meter spacing, one was thinned to 2.1-meter spacing, and two were left unthinned. Age of the stand at the time of thinning was 46 years. An additional thinning in 1941, in a 53-year-old stand, was designed to evaluate thinning around only selected crop trees. Results from all thinning plots are discussed in terms of diameter and height growth, comparison with normal stands, mortality after thinning, effect on ground vegetation, costs, comparison to thinning studies in other ponderosa pine regions, and the need for additional studies. Early results indicated that practically all forms and degrees of thinning tested were beneficial to residual trees, and that thinning should be relatively severe when only one operation is planned. (Keywords: Ponderosa pine—thinning, Timber harvesting)

Mowat, Edwin L. 1954. A guide to the Pringle Falls Experimental Forest. Portland, OR: U.S. Department of Agriculture, Forest Service. 24 p.

A brief description of the setting and ongoing research at the Pringle Falls Experimental Forest is provided in a small booklet. Emphasis is on describing demonstration plots accessible for viewing. (Keywords: Experimental Forest management)

Mowat, Edwin L. 1960. No serotinous cones on central Oregon lodgepole pine. Journal of Forestry. 58(2): 118-119.

Both young and mature lodgepole pine from 13 locations on the east slopes of the Cascade Range between Bend and Crater Lake, Oregon, were sampled to determine viability of seed older than those of the current year. Number of cones produced and the persistence of old cones differed widely between individual trees and sample stands but had no apparent relation to elevation or crown position. No viable seeds were found in cones older than those of the current year. Recognition of this nonserotinous cone habit is important in planning for natural regeneration of lodgepole pine. (Keywords: Forest regeneration, Lodgepole pine—silvics)

Mowat, Edwin L. 1961. Growth after partial cutting of ponderosa pine on permanent sample plots in eastern Oregon. Res. Pap. 44. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 23 p. (plus 28 p. supplement).

Between 1913 and 1938, seven sets of permanent sample plots were established on four National Forests in eastern and central Oregon to study the results of various methods of selection cutting in old-growth ponderosa pine stands. This report describes these studies and gives growth and mortality statistics as related to method of cutting. The supplement provides more detailed descriptions of each of the seven study areas, the methods of cutting, and more detailed stand descriptions. Seven plots were established at Pringle Falls Experimental Forest in 1936 on 205 hectares in a solid block in the Pringle Butte unit (see Kolbe and McKay 1939, Mowat 1948). Intensities of cut were 20-, 40-, 60-, and 80-percent volume removal. For each degree of cut except 80 percent, two contrasting policies in marking were applied: a "thrift" marking and a "value" marking. This work pointed out several principles for ponderosa pine management, including the need to control understory lodgepole pine competition. The greatest increase in stand growth was obtained by releasing young trees from overstory and side competition or intermediate or improvement cuttings, which left stands with thrifty, well-spaced trees to supply an additional intermediate harvest plus a final harvest. (Keywords: Forest dynamics, Lodgepole pine—growth and yield, Lodgepole pine—silvicultural practices, Ponderosa pine—growth and yield, Ponderosa pine—silvicultural practices, Timber harvesting)

Nissley, S.D.; Zasoski, R.J.; Martin, R.E. 1980. Nutrient changes after prescribed surface burning of Oregon ponderosa pine stands. In: Martin, Robert E.; Edmonds, Robert L.; Fulkner, Donald A. [and others]. Proceedings, 6th conference on fire and forest meteorology; 1980 April 22-24; Seattle, WA. Bethesda, MD: Society of American Foresters: 214-219.

Results of a study to determine the nutrient losses and redistribution after prescribed fire are presented. Ponderosa pine stands at three locations on the Lookout Mountain unit were burned in fall 1976. Litter, duff, understory biomass, and scorched foliage samples were analyzed for nutrient content. Low-intensity prescribed fire resulted in a 38-percent loss of nitrogen and a 43-percent loss of sulfur from the litter and duff. Nitrogen loss was well correlated with fuel consumption, as indicated by pH changes in the litter and duff. Losses of other elements were low. (Keywords: Forest fire, Soils)

Oren, R.; Waring, R.H.; Stafford, S.G.; Barrett, J.W. 1987. Twenty-four years of ponderosa pine growth in relation to canopy leaf area and understory competition. Forest Science. 33(2): 538-547.

The effect of stocking control and removal of understory (undergrowth) vegetation on the growth of ponderosa pine at equivalent canopy densities, expressed as projected surface area of foliage or leaf area index (square meters of foliage per square meters of ground) was evaluated with tree height and diameter data collected over 24 years (see Barrett 1982, Barrett and Youngberg 1965). Leaf area was estimated with the assumption that it has a linear relation with sapwood cross-sectional area at the base of the live crown. Growth efficiency of individual trees was estimated based on growth in stemwood biomass and the estimated leaf area. The hypothesis that stand growth is directly proportional to canopy leaf area generally was supported; at very low leaf area indices, wood production per unit of leaf area was more efficient, particularly in stands where the undergrowth had been removed. Tree growth efficiency decreased rapidly as the canopy developed. Leaf area index appeared to be approaching maximum at the densest stocking levels (2,470 trees per hectare). The main effect of undergrowth vegetation removal was expressed at low leaf area indices and was attributed to increased available water in the soil profile. Available water was used more rapidly in stands with low leaf area and an undisturbed undergrowth. (Keywords: Ponderosa pine—growth and yield, Ponderosa pine—tree spacing, Soils)

Reaves, Jimmy L; Alien, Thomas C.; Shaw, Charles G., III [and others], 1988. Occurrence of viruslike particles in isolates of *Armillaria.* Journal of Ultrastructure and Molecular Structure Research. 98: 217-221.

This paper reports the occurrence of intercellular aggregates of elongated viruslike particles and free elongated viruslike particles in isolates of *Armillaria,* including isolates from ponderosa pine collected at Pringle Falls Experimental Forest. Aggregates were observed within cells by using transmission electron microscopy, and were proteinaceous as shown by their degradation by a protease and RNase. (Keywords: Forest pathogens—fungi, Ponderosa pine—diseases, Soils)

Reaves, Jimmy L.; Shaw, Charles G., III; Martin, Robert E.; Mayfield, John E. 1984. Effects of ash leachates on growth and development of *Armillaria mellea* in culture. Res. Note PNW-418. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 11 p.

Results of a study of the effect of ash leachates from recently burned ponderosa pine litter on growth and development of *Armillaria mellea* (Vah.) Quel in culture are presented. Ash was collected from the forest floor after prescribed burning at Pringle Falls Experimental Forest. Two isolates were used; one from an infected western hemlock and the other from an infected ponderosa pine. Colonies started with mycelia from the pine isolate and grown on agar discs supplemented with 5 grams ash leachate had significantly less growth than controls or cultures grown on media with 10 grams leachate. (Keywords: Forest fire, Forest pathogens—fungi, Ponderosa pine—diseases. Soils)

Reaves, Jimmy L; Shaw, Charles G., III; Mayfield, John E. 1990. The effects of *Trichoderma* spp. isolated from burned and non-burned forest soils on the growth and development of *Armillaria ostoyae* in culture. Northwest Science. 64(1): 39-44.

Results of field and laboratory studies of the effects of *Trichoderma* species on the development of *Armillaria ostoyae* (Romangn.) Herink. and the effects of prescribed fire on the distribution of *Armillaria ostoyae* rhizomorphs in soil are presented. Prescribed fire and inoculation of ponderosa pine roots occurred in the Pringle Butte unit (see Reaves 1985). Isolates of *Trichoderma* species obtained from burned and nonburned soils beneath ponderosa pine were strongly antagonistic to *Armillaria ostoyae* in culture. *Trichoderma citrinoviride* Bissett occurred more frequently in burned soils, and T. *harzianum* Rifai was more common in nonburned soils. *Trichoderma citrinoviride* was more antagonistic to *Armillaria ostoyae* than was *T. harzianum.* These results suggest that fire may play a role in controlling *Armillaria* root disease in ponderosa pine forests. (Keywords: Forest fire, Forest pathogens—fungi, Ponderosa pine—diseases, Soils)

Reaves, Jimmy Lee. 1985. Interaction between Armillaria root disease, *Trichoderma,* and prescribed fire in a ponderosa pine forest. Atlanta, GA: Atlanta University. 146 p. Ph.D. dissertation.

Results of field and laboratory studies of the effects of *Trichoderma* species on the development of *Armillaria mellea* (Vah.) Quel and the effects of prescribed fire on the distribution of *A. mellea* rhizomorphs in soil are presented. Prescribed fire and inoculation of ponderosa pine roots occurred in the Pringle Butte unit. *Trichoderma vinde* Raf. and other *Trichoderma* species were strongly antagonistic to the fungi *A. mellea,* reducing its growth on liquid and solid media and totally inhibiting rhizomorph production on solid medium. Leachates from ash layers resulting from a prescribed fire increased the dry weights of *Trichoderma* species in liquid culture. When *A. mellea* was grown in medium amended with cations from the leachate, colony dry weights were reduced. Field studies showed no definite correlations between prescribed burning and *A. mellea* infection on artificially inoculated roots of stumps. Prescribed burning did not seem to affect rhizomorph distribution in soil; distribution of rhizomorphs in burned and unburned plots was, however, correlated with the moisture level of the soil. *Trichoderma* species formed a higher percentage of the fungal microflora at 10 centimeters below the soil surface than at 5 or 20 centimeters in burned and unburned plots. *Trichoderma* species consistently formed a higher percentage of the fungal microflora in burned plots than in unburned plots at the 10-centimeter depth. (Keywords: Forest fire, Forest pathogens—fungi, Ponderosa pine—diseases, Soils)

Roth, L.F. 1953. Pine dwarf mistletoe on the Pringle Falls Experimental Forest. Res. Note 91. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 3 p.

Results of a study of the relation between dwarf mistletoe *(Arceuthobium campylopodum* (Engelm.) Gill) in the crowns of overstory trees and its intensity and distribution in the surrounding regeneration are presented. Greatest spread of infection was from overstory to understory trees. Infections in the understory trees were greater on the side of the tree toward the overstory source of infection. No mistletoe occurred in an even-aged stand of young ponderosa pine established after a fire, except where infection spread from isolated old-growth trees that survived the fire. Distribution of infection was patchlike on 65 hectares of old-growth; heavy infection rarely occurred.

The presence of heavily broomed branches in overstory trees was not a reliable indicator of infectiousness. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

Roth, L.F. 1971. Dwarf mistletoe damage to small ponderosa pines. Forest Science. 17(3): 373-380.

Results of two experimental plantings of ponderosa pine, one intended as a demonstration of dwarf mistletoe *(Arceuthobium campylopodum* (Engelm.) Gill) impact, and the other a dwarf mistletoe-resistance test, are presented. Planting occurred in 1955 in the Pnngle Butte unit. In the first experiment, 25 infected and 25 healthy scions were side-grafted to seedlings planted at close spacing, and growth of competing shrubs controlled by grubbing. After 12 years, 33 percent of the infected trees had been killed and the remainder were only half as tall as the uninfected trees. The endophytic system of the dwarf mistletoe bridged the graft union in 30 percent of the infected trees. This work points out the ability of dwarf mistletoe to severely reduce host growth and to kill when the main stem near the ground is involved. The second experiment was a completely randomized outplanting of 84 container-grown seedlings; 51 seedlings had scions grafted from trees thought to be resistant to dwarf mistletoe, and 33 were ungrafted seedlings serving as controls. Annual manual inoculation with dwarf mistletoe seed was conducted from 1955 through 1959, and in 1962, 1965, and 1969. Annual height growth of the main tree stem was measured, and the number of dwarf mistletoe plants on each tree was counted. Fifteen years after the first inoculation, all trees had two or more main-stem infections and additional branch infections. Mean height growth of infected saplings was reduced in relation to the number of dwarf mistletoe plants per tree and competitive suppression from competing vegetation. Pathogenic suppression of growth was greatest where suppression by trees in adjacent stands was heaviest. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

Roth, Lewis F. 1959. Perennial infection of ponderosa pine by *Elytroderma deformans.* Forest Science. 5(2): 182-191.

Development of needle blight fungus *(Elytrodurma deformans* (Weir) Darker) on ponderosa pine is described based on field observations and experimentation in the Pringle Butte unit. Trees in three disease conditions and trees apparently healthy were transplanted to three locations to test the effect of climate and proximity to known spore sources. Branchlets were systematically infected, and the infection was perennial and extended back into woody branches several years old. (Keywords: Forest pathogens—fungi, Ponderosa pine—diseases)

Roth, Lewis F. 1966. Foliar habitat of ponderosa pine as a heritable basis for resistance to dwarf mistletoe. In: Breeding pest-resistant trees: Proceedings of a symposium; 1964 August 30-September 11; [University Park], PA. [Pennsylvania State University]. Oxford: Pergamon Press: 221-228.

Biology and ecology of dwarf mistletoe *{Arceuthobium campylopodum* (Engelm.) Gill), based in part on fieldwork and observations in Pringle Falls Experimental Forest, are discussed. The role of fire in maintaining infection centers is presented. Some degree of susceptibility may be related to variation in pine needle erectness because trees with drooping needles are uniquely precluded from infection. This hypothesis is suggested for testing, and implications for tree breeding are discussed. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

Roth, Lewis F. 1974a. Juvenile susceptibility of ponderosa pine to dwarf mistletoe. Phytopathology. 64(5): 689-692.

Results from an experiment testing the hypothesis that differences in susceptibility to dwarf mistletoe *(Arceuthobium campylopodum* (Engelm.) Gill) between the ponderosa pine seedlings and susceptible scions is the result of age are presented. In 1965, scions from (1) 3-year-old seedlings, (2) trees aged 4 to 15 years in plantations, and (3) an even-aged 40-year-old stand, were grafted to potted 3-year-old nursery stock. Each age group included scions from five trees. Grafted trees were outplanted in the Pringle Butte unit in 1966 in three randomized blocks of 50 trees each. Trees were manually inoculated immediately after planting and again the following year with dwarf mistletoe seed collected nearby. Five years after the last inoculation, dwarf mistletoe plants were counted. The number of dwarf mistletoe plants decreased progressively with increasing physiological age of the supporting trees and thus susceptibility, measured as infection frequency, was fit to a negative exponential function of tree age. Results are discussed in relation to trees that are highly susceptible to infection but resistant to damage, and trees that may have reduced susceptibility to infection but are highly susceptible to damage. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

Roth, Lewis F. 1974b. Resistance of ponderosa pine to dwarf mistletoe. Silvae Genetica. 23(4): 116-120.

Factors leading to natural susceptibility of ponderosa pine to dwarf mistletoe *(Arceuthobium campylopodum* (Engelm.) Gill) are discussed, including limits of dwarf mistletoe seed dispersal, loss by fire of pine progeny with improved resistance, and stand reestablishment from seed of trees not previously subjected to dwarf mistletoe selection pressure. Trees with useful resistance characteristics, however, are occasionally found. Susceptibility to infection and growth responses of clonal progeny of seven resistant trees are reported (see Roth 1971, 1974a). (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

Roth, Lewis F.; Barrett, James W. 1985. Response of dwarf mistletoe-infested ponderosa pine to thinning: 2. Dwarf mistletoe propagation. Res. Pap. PNW-331. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 20 p.

Population trends of dwarf mistletoe *(Arceuthobium campylopodum* (Engelm.) Gill) were examined in crowns of 54 parasitized ponderosa pine saplings over a 30-year period simultaneous to consideration of tree growth (see Barrett and Roth 1985). Branches were dissected at bud scars and annual growth segments measured, examined for dwarf mistletoe plants, and used to construct a scale diagram of each tree depicting dwarf mistletoe plant location relative to crown development and height growth. Before the stand was thinned, mistletoe plants gradually increased. After thinning, dwarf mistletoe propagation accompanied accelerated growth of tree crowns and increased rapidly in a flush of latent and invisible plants previously established. Height growth accelerated after a 5-year lag. There was no significant difference in tree height growth attributable to the number of dwarf mistletoe plants per branch segment; the amount of dwarf mistletoe had no effect on tree height growth. Distribution of dwarf mistletoe plants within tree crowns was similar. Dwarf mistletoe propagation relative to crown development was similar among dominant, codominant, and intermediate trees, thereby suggesting that smaller trees that are parasitized may be saved if given an opportunity to respond to stand release. Suitability of parasitized ponderosa pine stands for silvicultural treatment depends on whether trees have the potential to grow in height at a rate of 25.4 centimeters per year. Guidelines for identifying stands suitable for releasing parasitized saplings through stocking control and pruning are provided. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases, Ponderosa pine—pruning, Ponderosa pine—thinning)

Roth, Lewis F.; Strand, Mary A. 1971. Estimating dwarf mistletoe seed production in small ponderosa pines. Forest Science. 17(1): 73-78.

A method of estimating the amount of dwarf mistletoe *{Arceuthobium campylopodum* (Engelm.) Gill) seed produced under various stand conditions and degrees of infection is presented. Tabular results characterize four fruiting density classes by the number of dwarf mistletoe shoots, habit of growth, lateral extent of shoot emergence around the pine branch, and density of fruit set. For each density class, calculated mean number of fruits per female dwarf mistletoe plant is presented by a two-dimensional size matrix. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

Sartwell, Charles. 1971. *Ips pini* (Coleoptera: Scolytidae) emergence per exit hole in ponderosa pine thinning slash. Annals of the Entomological Society of America. 64(6): 1473-1474.

Results of a study to determine pine engraver (*Ips pini* Say) emergence densities in slash felled in precommercial thinnings of ponderosa pine are presented. Bolts were cut from naturally infested thinning slash and caged to collect emerging beetles. An overall average emergence across different bolt diameters and bolts cut at different times was 1.3 new adults per exit hole. This work suggests that fairly reliable estimates of pine engraver emergence from ponderosa pine thinning slash can be obtained by applying a factor of 1.3 to exit hole counts. (Keywords: Forest insects—pine engraver, Ponderosa pine—insects)

Scharpf, Robert F.; Roth, Lewis F. 1992. Resistance of ponderosa pine to western dwarf mistletoe in central Oregon. Res. Pap. PSW-RP-208. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 9 p.

Results of comparisons of natural resistance to infestation from dwarf mistletoe (*Arceuthobium campylopodum* (Engelm.) Gill) are presented. The objectives of the study were (1) to determine the resistance of clonally propagated ponderosa pines from apparently resistant and susceptible trees, (2) to determine the survival of resistant and susceptible trees with different levels of infection, and (3) to determine whether resistance was correlated with tree size, foliar habit, or crown characteristics. Scions taken from trees on the Ochoco, Rogue River, and Deschutes National Forests thought to be resistant to infection were grafted to seedlings planted from 1967 to 1969 at the Pringle Falls Experimental Forest in a stand of pines heavily infested with dwarf mistletoe. Tree survival, growth, crown size, and number of dwarf mistletoe infections were recorded in 1989. High levels of resistance were found in grafts produced from resistant selections of ponderosa pines on the Deschutes and Ochoco National Forests. Mortality of both susceptible and resistant selections from the Rogue River National Forest was higher than other sources. The drooping needle form of pine, common in the Rogue River source, did not develop when grown in central Oregon, and showed no resistance to dwarf mistletoe. Dwarf mistletoe-resistant pine in central Oregon may be an important component of forest biodiversity, and identification, preservation, and use in future tree improvement and pest management programs are recommended. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

Seidel, K.W. 1974. Freezing resistance of hardened and unhardened grand fir seedlings. Northwest Science. 48(3): 195-202.

Results of tests to determine the time-freezing temperature relations causing mortality in 1-week-old (unhardened) and 6-month-old (hardened) grand fir seedling are presented. Seeds from Pringle Falls Experimental Forest were collected and germinated, and seedlings were potted and grown in a greenhouse. Unhardened seedlings were placed in a refrigerated growth chamber and subjected to a temperature regime approximating the natural diurnal change found in central Oregon during spring and fall. A completely random 4 by 5 factorial design with -1.7, -5.0, -6.7, -7.8, and -11.1 "C, and the exposure of 10, 30, 60, and 120 minutes was used. After 24 hours, seedlings were returned to the greenhouse for 1 week; surviving seedlings were counted and the results expressed as a survival percentage. Hardened seedlings were started in the greenhouse and then moved outdoors under shading for the full growing season. Seedlings were then subjected to freezing temperature in a refrigerated growth chamber in a 3 by 3 factorial design, with temperatures of -12.2, -17.8, and -20.6 °C, and 4, 10, and 24 hours of exposure. A final survival count was made the following spring after growth of the surviving seedling had begun. Temperatures lower than -5 °C resulted in considerable mortality of unhardened seedlings when exposed longer than 10 minutes. In contrast, hardened seedlings were unaffected by a 10-hour exposure to -12.2 °C. "Isosurvival curves" indicating the time-temperature combinations of similar survival suggests an increasingly rapid mortality rate for hardened seedlings per unit of time after 10 hours of exposure. Although unhardened seedlings may easily be killed by a combination of temperature and duration of exposure immediately after germination, lethal temperatures for hardened seedlings are rarely met in the field. (Keywords: Grand fir)

Seidel, K.W. 1977. Suppressed grand fir and Shasta red fir respond well to release. Res. Note PNW-288. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 7 p.

Results after 5 years of release and thinning in a 43-year-old, suppressed, even-aged grand and Shasta red fir stand of advance regeneration are presented. The study occurred in the Lookout Mountain unit. The lodgepole pine overstory was killed with herbicide and left intact to prevent logging damage and provide a partial shade of fir seedlings. In 1970, four spacings (1.8, 3.7, 5.5, and 7.3 meters) were created by thinning in plots ranging from 0.06 to 0.26 hectare, replicated twice. Each plot contained 24 trees. In a second part of the study, eight 0.10-hectare plots were thinned to 1.8-meter spacing. Bole and crown diameter, height to live crown, and total tree height were measured in 1971 and 1975. Both diameter and height growth of the seedlings and saplings responded immediately after removal of the lodgepole pine overstory—the growth rate increased two to three times above the 5-year prerelease rate. Spacing treatments had no differential effect on growth response of the fir understory; both species responded similarly except for a greater number of epicormic branches on grand fir. (Keywords: Grand fir, Shasta red fir)

Seidel, K.W. 1985. A ponderosa pine-grand fir spacing study in central Oregon: results after 10 years. Res. Note PNW-429. Portland. OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 7 p.

Results after 10 years of a spacing study are presented. The study occurred in the Lookout Mountain unit. The plantation was in a 8.1-hectare clearcut within a mixed-conifer forest. Shrubs in the clearcut were controlled with herbicide. Seedlings were planted at three initial spacings (1.8, 3.6, and 5.5 meters) and three species combinations (pure ponderosa pine, pure grand fir, and 50 percent of each species). Each spacing was replicated three times, and within each spacing plot, three subplots contained species combinations.-Total height and diameter at breast height were measured on 24 trees in the interior of each plot. Height growth of pure pine was about twice as great as that of pure fir because of damage to the fir from frost and animals; growth of the pine-fir mixture was intermediate. Both basal area and total cubic volume increment per acre increased at the narrower spacing, but diameter growth per tree was less. (Keywords: Forest regeneration, Grand fir. Ponderosa pine—tree spacing)

Seidel, K.W. 1986. Tolerance of seedlings of ponderosa pine, Douglas-fir, grand fir, and Engelmann spruce for high temperatures. Northwest Science. 60(1): 1-7.

Results of a study designed to estimate and compare the relation between lethal high temperature for four Pacific Northwestern conifer species and time of exposure to high temperatures are presented. Species of interest included ponderosa pine, Douglas-fir, grand fir, and Engelmann spruce. Seeds of ponderosa pine and soil used in the tests came from the Pringle Falls Experimental Forest. The experiment was a completely randomized design with a 6 by 8 factorial arrangement of treatments for each species. Six temperatures (48.9, 51.7, 54.4, 57.2, 60.0, and 62.8 °C) and eight exposure times (1, 5, 10, 20, 30, 60, 180, and 300 minutes) were tested; each treatment combination was replicated twice. Heat was applied directly to the lower stem of 7 to 10 seedlings by means of a dry water bath. The number of seedlings that survived after 5 months in each treatment combination was counted and expressed as a survival percentage. Isosurvival curves indicating the time-temperature combinations that resulted in about equal survival were constructed for each species. Small (2 to 4 °C) but significant differences in heat tolerance were found among species, with ponderosa pine having the greatest tolerance and Engelmann spruce the least. Douglas-fir and grand fir generally were intermediate in heat tolerance. These results could be used with data on soil surface temperature obtained in regeneration units to better evaluate causes of seedling mortality. (Keywords: Douglas-fir, Engelmann spruce, Grand fir, Ponderosa pine—silvics) '

Seidel, K.W. 1987. Fifteen-year results from a grand fir-Shasta red fir spacing study. Res. Note PNW-RN-458. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 9 p.

Results after 15 years of release and thinning in a 43-year-old, suppressed, even-aged grand and Shasta red fir stand of advance regeneration are presented (see Seidel 1977). The study occurred in the Lookout Mountain unit. Both grand fir and Shasta red fir responded to release and thinning. Diameter growth during the second and third 5-year periods after release increased significantly over that of the first 5 years. Differences in spacing had no effect on diameter growth during the first 5 years, but growth at the wider spacings increased considerably during the second and third periods. Increased growth after release suggested that saving true fir advance reproduction can be a desirable option, but the potential for losses from heart-rot also should be considered. (Keywords: Grand fir, Shasta red fir)

Seidel, K.W. 1989. A ponderosa pine-lodgepole pine spacing study in central Oregon: results after 20 years. Res. Pap. PNW-RP-410. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 14 p.

Results of a study comparing productivity of pure and mixed stands of ponderosa pine and lodgepole pine at several spacings are presented. The study was installed in 1967, and this paper reports results from three growth periods: 1973-77, 1978-81, and 1982-86. Five initial spacings (1.8, 2.7, 3.6, 4.6, and 5.5 meters) and three species combinations (pure ponderosa, pure lodgepole, and a mixture of 50 percent of each species) were tested in a completely randomized split plot design. Planted seedlings were 2-0 bare root seedlings grown locally. Total height and diameter at breast height were measured on 24 trees in the interior of each subplot. Ponderosa pine grew faster in diameter than lodgepole pine at all five spacings. Height growth of lodgepole pine was faster than that of ponderosa pine. Growth of the mixed species stands generally was intermediate. Gross annual volume growth was related to spacing as was basal area growth—greatest growth occurred at narrow spacings and decreased as spacings increased. These data provide information on tradeoffs between diameter growth and volume yields at various stand densities. (Keywords: Forest regeneration, Lodgepole pine—tree spacing, Ponderosa pine—tree spacing)

Seidel, Kenneth W. 1983. Growth of suppressed grand fir and Shasta red fir in central Oregon after release and thinning—10-year results. Res. Note PNW-404. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 7 p.

Results after 10 years of release and thinning in a 43-year-old, suppressed, even-aged grand and Shasta red fir stand of advance regeneration are presented (see Seidel 1977). The study occurred in the Lookout Mountain unit. Both grand fir and Shasta red fir responded to release and thinning with diameter and height growth two to three times the prerelease rate. The response began immediately after the overstory was killed with herbicide. Diameter growth during the second 5 years after release increased significantly over that of the first 5 years. Spacing had no effect on growth. Increase growth after release suggests that saving advance true fir reproduction is often desirable. (Keywords: Grand fir, Shasta red fir)

Sikorowski, Peter P.; Roth, Lewis F. 1962. *Elytoderma* mycelium in phloem of ponderosa pine. Phytopathology. 52(4): 332-336.

Results of microscopy studies of the location and extent of hyphae elongation of *Elytoderma deformans* (Weir) Darker on ponderosa pine growing at Pringle Falls Experimental Forest are presented. Damaged phloem occurred in stems, buds, and needles. Hyphae were shown to enter the buds as they form. Upon bud break, hyphae extend into the new shoot and needles and finally into the new bud, perpetuating the disease in the absence of new spore inoculation. (Keywords: Forest pathogens—fungi, Ponderosa pine—diseases)

Sikorowski, Peter Paul. 1960. Dissemination of spores of *Elytoderma deformans* (Weir) Darker. Corvallis, OR: Oregon State College. 58 p. M.S. thesis.

Results of studies of the process of dissemination of ascospore of *Elytoderma deformans* (Weir) Darker and the actual pathological anatomy on host ponderosa pine are presented. In the Pringle Falls area of central Oregon, E. *deformans* occurs as widely scattered, rather definite patches of pine needle blight. Time of spore discharge, rate of spore discharge as affected by weather, and the distribution of spores in and around patches of blight were described. Spore traps showed that most spores were discharged during the fall after moist weather or periods of high humidity; only a few spores were released during winter, spring, and summer. Spore collection indicated that ascospores were not carried horizontally beyond the limits of the infected patch. *Elytoderma deformans* mycelium was identified in the phloem of infected needles and also in buds and twigs. The relation of infected buds to newly formed needles indicated that the fungus present in the current years needles was derived from hyphae in the phloem of young stems, and thus systemic. (Keywords: Forest pathogens—fungi, Ponderosa pine—diseases)

Sowder, James E. 1951. A sanitation-salvage cutting in ponderosa pine at the Pringle Falls Experimental Forest. Res. Pap. 2. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 24 p.

This paper describes a sanitation-salvage cutting made on almost 1500 hectares of the Pringle Butte unit during 1950. Objectives of the cutting were to (1) remove live trees highly susceptible to insect attack and thereby reduce current and future insect losses, (2) remove merchantable trees that were dead or dying from all causes and thereby salvage timber that otherwise would be lost, (3) establish a permanent road system for future operations, and (4) reduce fire hazard and aid fire control. Recognition of trees susceptible to insect attack was based on a "penalty system for rating high risk trees" developed by Jack W. Bongberg, Bureau of Entomology and Plant Quarantive, Forest Insect Laboratory, Berkely, California, 1949. (Keywords: Ponderosa pine—silvicultural practices, Timber harvesting)

Sowder, James E. 1953. Lumber grade recovery from young ponderosa pine. Res. Note 88. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 2 p.

Lumber grade recovery was compared between open-grown and close-grown ponderosa pine. A commercial thinning was made in 1949 in a 105-year-old, even-aged stand. Logs were selected from dense and open portions of the stand and milled in Bend, Oregon. Close-grown trees produced 18 percent more volume per unit area and a higher grade of lumber than did open-grown trees; open-grown trees, however, contained more than twice the board-foot volume per tree. (Keywords: Ponderosa pine—growth and yield, Timber harvesting)

Strand, Mary Ann Sail. 1973. Simulation of population changes of western dwarf mistletoe on ponderosa pine. Corvallis, OR: Oregon State University. 121 p. Ph.D. dissertation.

Computer simulation is used to study the spread of dwarf mistletoe *(Arceuthobium campylodum* (Engelm.) Gill) in ponderosa pine. Study objectives were (1) to formulate a mathematical description of the process of dwarf mistletoe disease spread in a pine forest, (2) to use this description to predict the spread in a few cases of interest, and (3) derive some general hypotheses concerning the process. The relation of size, position, and number of susceptible branches was computed in a tree-growth submodel. A seed production submodel was used to relate the amount of inoculum present to plant age. Probabilities associated with events from mistletoe seed production to interception by a susceptible branch were computed in a seed-dispersal submodel. An infection establishment submodel is used to compute the probabilities of subsequent events leading to infection. Simulation was based on a young-growth, managed ponderosa pine stand, where the trees were evenly spaced at 2.7, 4.0, and 5.5 meters apart, were 3.0 to 7.6 meters in height, and were lightly to moderately infected (2 to 4 plants per infected tree) or heavily infected (15 plants per infected tree). The model indicated that the probability of reinfection decreases as the crown volume around a given height becomes larger and the foliage becomes sparser. The probability of infection due to contagion was found to decrease by about half for an increase in stand spacing of 1.5 meters. In a stand with an initial infection rate of 0.60 and a spacing of 2.7 meters, the expected number of new infections per 100 trees at the end of the fifth year was 283 plants beginning with 2 plants per infected tree and 644 plants beginning with 4 plants per infected tree. Results of the model suggested that mistletoe plants in upper portions of the crown are the most important in disease spread, vertical spread is accomplished by reinfection at moderate infection levels and tree spacing greater than 2.4 meters, vigorous trees may outgrow infections, and increased spacing between trees reduces the probability of both reinfection and contagion. (Keywords: Forest pathogens—dwarf mistletoe, Ponderosa pine—diseases)

Tarrant, Robert F. 1947. First forest soil survey gives significant results. Res. Notes 36. Portland. OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Experiment Station. 4 p.

Results of the first soil survey on National Forest lands in the Pacific Northwest are presented. The survey, completed in 1946 at the Pringle Butte unit of the Pringle Falls Experimental Forest, was made to establish soil, site, and type relations to aid in ponderosa pine reforestation. Soils were classified into three series or groups tentatively named Lapine, Wickiup, and Dilman. Poorly drained soils in the Dilman and Wickiup series were found to support lodgepole pine but not ponderosa pine. The well-drained to excessively well-drained soils in the Lapine series support ponderosa pine. (Keywords: Soils)

Tarrant, Robert F. 1953. Soil moisture and the distribution of lodgepole and ponderosa pine (a review of the literature). Res. Pap. 8. Portland, OR: U.S. Department of Agriculture. Forest Service, Pacific Northwest Forest and Range Experiment Station. 10 p.

A review of observational studies and more rigorous research investigating the distinction in lodgepole and ponderosa pine site requirements is presented. Work reviewed was conducted between 1913 and 1947, and is linked to the distribution of pines and soil types at Pringle Falls Experimental Forest. (Keywords: Lodgepole pine—silvics, Ponderosa pine—silvics, Soils)

Tarrant, Robert F. 1957. Soil moisture conditions after chemically killing manzanita brush in central Oregon. Res. Note 156. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 4 p.

Results of a study to determine the effect of shrub control on soil moisture requirements for artificial regeneration are presented (see Dahms 1955). After aerial application of herbicide to kill greenleaf manzanita {*Arctostaphylos patula* Greene) in 1954, plots were established to represent three conditions: green (live) shrubs, dead shrub, and cleared (shrubs killed and removed). Soil moisture samples were taken at two depths through the growing season. Moisture decline was two to three times more under green shrubs than under either dead shrubs or cleared conditions. Killing the manzanita cover with chemicals greatly reduced the loss of soil moisture during summer. (Keywords: Forest shrubs, Soils)

U.S. Department of Agriculture, Forest Service. 1938. A guide to the Pringle Falls Experimental Forest, LaPine, Oregon. Portland, OR: U.S. Department of Agriculture, Forest Service. 18 p.

A brief overview of Pringle Falls Experimental Forest, its setting and establishment history, forest types, and management objectives are provided. Principal research projects are described and referenced on area maps. (Keywords: Experimental Forest management, Research Natural Area)

Wollum, A.G.; Youngberg, C.T. 1964. The influence of nitrogen fixation by nonleguminous woody plants on the growth of pine seedlings. Journal of Forestry. 62(5): 316-321.

The influence of snowbrush ceanothus *(Ceanothus velutinus* Dougl.) on root morphology and foliar nitrogen of ponderosa pine was investigated as part of a study to determine whether symbiotic nitrogen fixation by certain shrubs had any appreciable effects on the growth and nitrogen nutrition of pine seedlings and the approximate amounts of nitrogen that could be fixed. Seedlings grown under or in association with snowbrush and in the open were excavated. After soil was washed off, comparisons were made of the root systems. Needle samples from terminal leaders were collected from pine growing in the open and in association with snowbrush for nitrogen determinations. The nitrogen content of pine foliage growing under snowbrush was higher than that of open grown pine, probably resulting from a combination of improved environmental conditions known to exist under the shrub canopy. (Keywords: Forest regeneration, Forest shrubs, Ponderosa pine—fertilization, Soils)

Youngberg, C.T. 1975. Effects of fertilization and thinning on the growth of ponderosa pine. Soil Science Society of America Proceedings. 39(1): 137-139.

Results of a study of thinning and fertilizer application as a means of increasing timber production are presented. Five treatments, replicated three times, were established in 45-year-old thinned and unthinned stand by using 0.02-hectare plots. Fertilizer treatments included magnesium ammonium phosphate, and various rates of ammonium sulfate and ammonium nitrate. Thinning reduced the basal area from 25 square meters per hectare to 12 square meters per hectare. After the first full growing season, needle samples were collected from the thinned plots from current years foliage from the top one-third of the crown. Diameter and basal area data were collected after the fifth growing season. Fifth-year diameter and basal area increments after fertilization revealed fertilizer response in both thinned and unthinned stands. Thinning effects were greater than fertilizer effects, and a combination of thinning and fertilizers gave the best growth response. Thinning is recommended in ponderosa pine stands of this type to a basal area of no greater than 18 square meters per hectare to obtain satisfactory responses to nitrogen additions. (Keywords: Ponderosa pine—fertilization, Ponderosa pine—thinning)

Youngberg, C.T.; Dahms, W.G. 1970. Productivity indices for lodgepole pine on pumice soils. Journal of Forestry. 68(2): 90-94.

Results of a study correlating understory (undergrowth) plant communities with forest site productivity for lodgepole pine are presented. A total of 153 plots were examined throughout the central Oregon pumice zone; on each plot, a soil pit was excavated and soils characterized. Canopy cover of all undergrowth vegetation was estimated. Ten discrete lodgepole pine plant communities were recognized based on characteristic undergrowth species. Productivity was assessed by means of tree height, site index, basal area, and current volume increment. Tree height differences existed between plant communities along a gradient from antelope bitterbrush (*Purshia tndentata* (Pursh) DC.), through bitterbrush-currant, and currant, to huckleberry. Stratifying stands on the basis of undergrowth plant communities provided a better indication of productivity than did stratification on the basis of soil characteristics when basal area, site index, and volume-increment data were used as measures of productivity. (Keywords: Forest shrubs, Lodgepole pine—growth and yield, Soils)

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Fungi

Adams 1972, 1974; Evans 1983; Reaves 1985; Reaves and others 1984,1988, 1990; Roth 1959, Sikorowski 1960, Sikorowski and Roth 1962

Forest dynamics

Bork 1984; Dahms 1949, 1966a; Keen 1937, 1940; Martin 1982a; Mazany and Thompson 1983; Morrow 1986; Mowat 1948, 1961

Forest fire

Bork 1984; Dahms 1949; Evans 1983; Fahnestock 1968; Koonce 1981; Koonce and Roth 1980; Martin 1982a, 1982b, 1983; Martin and Driver 1983; Martin and others 1981; Mazany and Thompson 1983; Morrow 1986; Nissley and others 1980; Reaves 1985; Reaves and others 1984, 1990

Forest insects

Mountain pine beetle

Alosi and Robertson 1992, Barrett 1983, Barrett and Newman 1974, Greene 1992, Larsson and others 1983

Pine engraver

Sartwell 1971

Western pine beetle

Keen 1936. 1943, 1946

Western pine shoot borer

Mitchell and Sower 1991

Forest regeneration

Barrett 1966a; Cochran 1969, 1970, 1972a, 1973b; Dahms 1950, 1960; Dahms and Barrett 1975; Dahms and James 1955; Mowat 1950, 1960; Seidel 1985, 1989; Wollum and Youngberg 1964

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Dahms 1950, 1955, 1961; Dahms and James 1955; Dealy 1966; Edgerton 1983; Edgerton and others 1975; Martin 1982b, 1983; Martin and others 1981; Martin and Driver 1983; Tarrant 1957; Wollum and Youngberg 1964; Youngberg and Dahms 1970

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Growth and yield

Barrett 1978; Bnegleb 1943; Cochran and others 1984; Mowat 1947a, 1961; Oren and others 1987; Sowder 1953

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Barrett 1960, 1966b; Barrett and others 1976

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Barrett 1968, Bolon and others 1992. Cahill 1991, Dahms 1954, Fight and others 1992, Knutson 1975, Mowat 1947b. Roth and Barrett 1985

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Barrett 1966a; Cochran 1970, 1972a, 1972b; Dahms and Barrett 1975; Keen 1936, 1940, 1943. 1946; Larsson and others 1983; Seidel 1986, Tarrant 1953

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Barrett 1979; Cochran 1970; Cochran and others 1991; Dahms 1951, 1960; Johnson and others 1967; Kolbe and McKay 1939; Mowat 1947a, 1948, 1950. 1961 ;Sowder 1951

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Bork 1984; Dahms 1949, 1966a; Keen 1937, 1940; Martin 1982a; Mazany and Thompson 1983; Morrow 1986

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Barrett 1965, 1970. 1971, 1973, 1982; Barrett and Youngberg 1965; Cochran and others 1991; Dahms 1966; Oren and others 1987; Seidel 1985, 1989

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Barrett 1960, 1963, 1966b; Barrett and others 1976; Dahms 1951; Edgerton 1983; Edgerton and others 1975; Johnson and others 1967; Keen 1936, 1943, 1946; Kolbe and McKay 1939; Mowat 1948, 1949. 1953, 1961; Sowder 1951, 1953

Wildlife

Dealy 1966, Edgerton and others 1975

Youngblood, Andrew, comp. 1995. Research publications of the Pringle Falls Experimental Forest, central Oregon Cascade Range, 1930 to 1993. Gen. Tech. Rep. PNW-GTR-347. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 45 p.

An annotated bibliography of publications resulting from research at the Pringle Falls Experimental Forest, Deschutes National Forest, in central Oregon from 1930 to 1993 is presented. Over 100 publications are listed, including papers, theses, and reports. An index is provided that cross-references the listings under appropriate keywords.

Keywords: Bibliographies (forestry), Oregon (Pringle Falls Experimental Forest), Pringle Falls Experimental Forest—Oregon.

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