Research Contribution 14 October 1996

Regenerating Coastal Forests in Oregon: An Annotated Bibliography of Selected Ecological Literature

by

Donna M. Loucks
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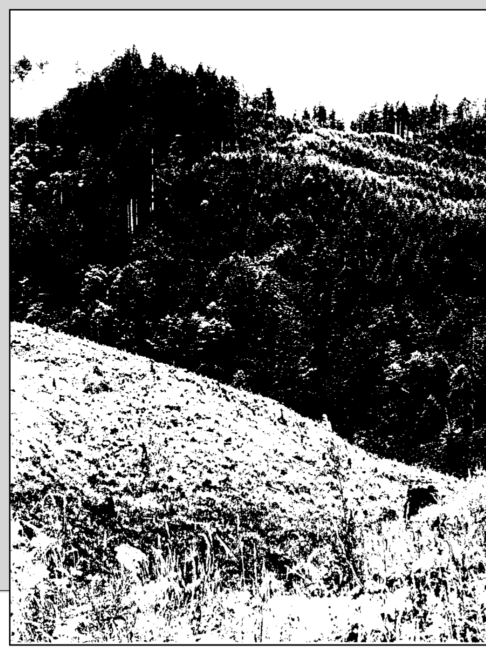

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Acknowledgment

This bibliography was funded by the Coastal Oregon Productivity Enhancement (COPE) program, a cooperative effort by the College of Forestry at Oregon State University, the USDA Forest Service's Pacific Northwest Research Station, the USDI Bureau of Land Management and National Biological Survey, Oregon Department of Forestry, other federal and state agencies, forest industry, city and county governments, and the Oregon Small Woodlands Association.

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Introduction

Regeneration is a critical step in the development and subsequent management of forests in Oregon and the Pacific Northwest region. Events that occur early in the development of a stand largely determine its future composition and productivity. Initial seedling size and quality, site preparation, competing vegetation, animal damage, climatic events, and edaphic features influence the survival and growth of Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] and other young conifers in western Oregon. Several states have adopted specific legal standards on reforestation. For example, the Oregon Forest Practices Act requires that 200 well-spaced and free-to-grow trees per acre (494 trees/hectare) must be established within 6 years of harvesting.

While increasingly complex decisions about reforestation operations need to be made daily, few tools exist that improve the manager's abil-ity to do so. Furthermore, the relationships among important factors affecting successful forest regeneration are sometimes not fully understood. Compounding the problem is the fact that much of the information already collected is not readily available to managers and researchers. However, such information is needed to identify and evaluate regeneration alternatives for specific sites within the framework of ecological, economic, environmental, legal, and political restraints. Moreover, a synthesis of such information from various sources would be valuable in understanding the regeneration process, identifying gaps in knowledge, and prescribing treatments that meet regeneration standards and objectives.

This annotated bibliography was compiled to provide a comprehensive list of sources on the ecological factors that affect forest regeneration. Another important purpose was to develop an information base for a computer-based decision support system for forest regeneration, Coast R_x, which is scheduled to be released in 1996. Abstracts of 494 publications are organized into 4 major sections and indexed by author, subject, and species.

- Section 1, "Effects of Site Factors on Vegetation," includes literature on abiotic factors, including light, moisture, nutrition, soils, temperature, and topography; biotic factors, including allelopathy, animals, mycorrhizae, pathogens, and plant associations; and stand and site history, including disturbance frequency, fire, logging, and stand age.
- Section 2, "Effects of Vegetation on Development of Young Forests," includes literature on aerial and soil resources, such as soil and air temperature, humidity, water-holding capacity and infiltration, light interception, nitrogen fixation and nutrient cycling, soil chemistry, and soil structure; and influences on stand development, including competition, plant succession, and tree growth and survival.
- Section 3, "Management of Vegetation," includes references on animal damage control, injury to the residual stand, microsite selection, planting stock type, planting density, prescribed burning, release (biological, chemical, grazing, manual, mechanical, and mulching), silvicultural systems, slash, site preparation, soil disturbance, and yarding methods.
- Section 4, "Response of Vegetation to Silvicultural Activities," includes citations on autecology, density and abundance, spatial and temporal

distribution of plants, diversity, germination, growth, relative height, reproduction, succession, and survival and mortality.

This bibliography predominately pertains to the coastal variety of Douglas-fir, which occurs west of the Cascade Range in Oregon and Washington; however, we included applicable citations pertaining to Alaska, British Columbia, and California. Citations for associated conifers (noble fir, western hemlock, Sitka spruce, ponderosa pine, and lodgepole pine), hardwoods (bigleaf maple, vine maple, red alder, and tanoak), and shrubs (salmonberry, thimbleberry, salal, ceanothus, and manzanita) were also indexed, as are earlier bibliographies on animal damage, prescribed fire, herbaceous vegetation, and effects of competition (see citations 89, 358, 405, and 459, respectively). Citations on forest tree genetics, seeds, seedling physiology, and insects were not included, although these are important aspects of reforestation. To avoid omitting key reforestation literature and, at the same time, to avoid overburdening the bibliography, we excluded information pertaining to research methods from most abstracts.

Effects of Site Factors on Vegetation

A. Abiotic Factors

1. **Adams, R.S., J.R. Ritchey, and W.G. Todd. 1966. Artificial shade improves survival of planted Douglas-fir and white fir seedlings. California Division of Forestry, Sacramento, California. State Forest Notes 28. 11 p.**

   Artificial shading measurably increased survival of planted Douglas-fir and white fir seedlings on a variety of sites in northern California. In 5 studies, tests were conducted in conditions that ranged from critical valley exposures to a mild coastal climate. Survival of shaded seedlings was 2 to 3 times greater than that of unshaded seedlings. The greatest differences in survival between shaded and unshaded seedlings were on the harsher sites.

2. **Atzet, T. 1981. Operational environment and factors limiting reforestation in the Siskiyou Mountains. P. 6-10 *in* Reforestation of Skeletal Soils. Proceedings of a Workshop. S.D. Hobbs and O.T. Helgerson, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.**

   Plant growth and survival are directly affected by the operational environment, which includes temperature, light, water, and nutrients. Although these factors and their variability on a given site may be difficult to measure, they must be evaluated in order to prescribe the appropriate regeneration system. To help determine the average and extremes in environment on sites in southwestern Oregon, a conceptual framework and a table of indicators are provided.

3. **Bailey, A.W., and C.E. Poulton. 1968. Plant communities and environmental interrelationships in a portion of the Tillamook burn, northwestern Oregon. Ecology 49:1-13.**

   Specific environmental requirements govern growth and survival of both shade-intolerant, early seral species and shade-tolerant, late seral or climax species. The red alder/swordfern association occurs on north-facing, lower slope positions, predominantly at elevations below 1200 ft. The red alder/thimbleberry association usually occurs at slightly higher elevations and on steep, north-facing slopes. Although the vine maple/swordfern association was arbitrarily classified into xeric and mesic phases and is found on all aspects between

700 and 1200 ft, it is usually associated with steep, lower slope positions. The thimbleberry/ starflower association is found above 1200 ft on all aspects and on steep, upper slopes. On all aspects above 1200 ft elevation, gentle middle- and upper-slope positions are usually occupied by stands of bracken fern/deervetch associations. The red blueberry/salal association is found at elevations of 700 to 2100 ft on south-facing, convex slopes or ridgetops. Some of the causes of vegetation heterogeneity are also discussed.

4. **Brix, H. 1967. An analysis of dry matter production of Douglas-fir seedlings in relation to temperature and light intensity. Canadian Journal of Botany 45:2063-2072.**

Dry matter production of Douglas-fir seedlings was affected in opposing ways by increased light intensity: (1) the rate of photosynthesis per unit leaf area increased and (2) the leaf area added per unit of dry matter produced decreased. When temperatures increased from 13 to 18°C, the subsequent pronounced increase in growth resulted from temperature influence on leaf area production, rather than increased photosynthesis per unit of leaf area. At all light intensities, net assimilation rates decreased with increased temperatures.

5. **Brix, H. 1970. Effect of light intensity on growth of western hemlock and Douglas-fir seedlings. Bi-Monthly Research Notes 26:34-35.**

For dry matter production of hemlock, the most favorable light levels were 50% and 70%. For Douglas-fir, an increase in light up to 50% increased total dry matter production. Total production was not significantly affected by further increases to full light, but the dry weight of leaves and of stems plus branches decreased and root dry weight increased. For stem, branch, and leaf elongation and production of branches, 50% light was optimum.

6. **Brix, H. 1971. Growth response of western hemlock and Douglas-fir seedlings to temperature regimes during day and night. Canadian Journal of Botany 49:289-294.**

Western hemlock seedlings had a pronounced optimum temperature for growth of 18°C, especially at high light. Douglas-fir seedlings had a broad optimum temperature range of 18 to 24°C for growth. High temperature was more detrimental to growth of western hemlock than to that of Douglas-fir. For both species, a constant day-night temperature regime was as good as or better than alternating temperatures. Day temperature was more effective in increasing growth than was night temperature. For most temperature regimes, light intensity had a pronounced effect on the production of dry matter. It had less effect on stem diameter, and little or none on stem length.

7. **Brix, H. 1979. Effects of plant water stress on photosynthesis and survival of four conifers. Canadian Journal of Forest Research 9:160-165.**

In Douglas-fir, hemlock, spruce, and pine, rates of photosynthesis declined when plant water potential decreased from -10.0, -10.7, -12.4, and -6.6 bars, respectively. When potentials were -53.9, -39.7, -28.6, and -22.4 bars, respectively, photosynthesis rates became zero. Hemlock had a consistently lower potential than Douglas-fir, and spruce had a lower potential than pine when grown together in the same pot and exposed to soil drought. Seedlings of Douglas-fir, spruce, and pine survived potentials to -110 bars, whereas hemlock survived potentials of -40 to -60 bars.

8. **Childs, S.W., H.R. Holbo, and E.L. Miller. 1985. Shadecard and shelterwood modification of the soil temperature environment. Soil Science Society of America Journal 49:1018-1022.**

Heat capacities of both fine and coarse soil were used to estimate soil heat fluxes on steep, south-facing slopes in southwest Oregon. Soil temperatures were approximately 6°C lower in shelterwoods than in clearcuts at depths of 20 and 320 mm. Shadecards were effective in reducing daily heat flux but generally had little effect on the soil temperature regime. Shelterwoods significantly ameliorated seasonal soil temperatures and may be appropriate where cumulative soil heating has limited the success of reforestation.

9. **Cleary, B.D. 1970. Effect of plant moisture stress on the physiology and establishment of planted Douglas-fir and ponderosa pine seedlings. Ph.D. thesis, Oregon State Uni-**

versity, Corvallis, Oregon. 85 p.

Differences in growth and survival of Douglas-fir and ponderosa pine seedlings were related to moisture stress levels during 3 years of measurement. There were distinct differences between the relative net photosynthetic responses of Douglas-fir and ponderosa pine to moisture stress. Douglas-fir photosynthesis appeared to decline almost linearly from a maximum when plant moisture stress (PMS) was less than 9 atm to 20% of maximum at 22 atm. Ponderosa pine, however, showed little decline in photosynthesis until about 15 atm PMS, when it declined abruptly. There was no measurable photosynthesis after 20 atm PMS.

10. **Drew, A.P., and W.K. Ferrell. 1977. Morphological acclimation to light intensity in Douglas-fir seedlings. Canadian Journal of Botany 55:2033-2042.**

Conditions of partial shade and moderate temperatures resulted in maximum growth of Douglas-fir seedlings. As light intensity decreased, seedlings allocated progressively more dry matter to shoot growth than to root growth during the 1st year. During the 2nd year, however, seedlings favored root growth at the expense of shoot growth. During both years, structural alterations of shoots favored enhanced photosynthesis under low light. An interaction between light, temperature, and seedling size can explain acclimative changes. When grown under low light, seedlings set a terminal bud earlier in the fall and broke bud earlier the next spring than did seedlings grown under high light. Seedlings grown under low light also suffered more spring frost damage than did seedlings preconditioned to high light and showed greater incidence of lammas growth in the 2nd year. Preconditioning during the 1st year had no evident effect on timing of budbreak in the 3rd year.

11. **Elliott, D.M., and I.E.P. Taylor. 1981. The importance of fertility and physical characteristics of soil in early development of red alder seedlings grown under controlled environmental conditions. Canadian Journal of Forest Research 11:522-529.**

Growth in height and accumulation of dry weight increased with fertilization of red alder seedlings and was lower in sand than in loam and in a mixture. Height growth did not differ between provenances. Fertilized seedlings had a lower root/shoot dry weight ratio than did unfertilized seedlings, and that ratio was greater in sand than in the other media. Variations in rooting environment had little effect on nodulation. Seedlings produced roots that varied physically, depending on the type of growth medium used and the amount of fertilization. The variations resulting from changes in growth medium and fertilization were associated mainly with differences in aeration and with the nutrient status of the growth media without fertilization.

12. **Emmingham, W.E. 1972. Conifer growth and plant distribution under different light environments in the Siskiyou Mountains of southwestern Oregon. M.S. thesis, Oregon State University, Corvallis, Oregon. 50 p.**

Both Shasta red fir and white fir occurred at lower light levels than did Douglas-fir. Douglas-fir leader elongation was greater than either true fir at intermediate light intensities, however, which suggests that it could compete successfully in thinned stands. All conifers investigated grew best at the highest light levels, which indicates that trees established in exposed locations have an advantage. Most plant species occurred across all light levels, but several herbaceous plants appeared to be indicators of low or high light regimes.

13. **Emmingham, W.H., and R.H. Waring. 1973. Conifer growth under different light environments in the Siskiyou Mountains of southwestern Oregon. Northwest Science 47:88-99.**

Douglas-fir had greater average elongation than did ponderosa pine, Shasta red fir, and white fir over most of the light gradient, although it was not found below 7% reference light (RL). Douglas-fir had greater elongation than either true fir at 10-40% RL and at about 100% RL. The true firs established themselves naturally down to 2.5% RL. At the highest light intensities, average leader elongation showed no decrease. At high light levels, therefore, the year-round advantage in net photosynthesis outweighs the detrimental effects of high radiation loads and resultant drought during the summer.

14. **Flint, L.E., and S.W. Childs. 1987. Effect of shading, mulching and vegetation control**

on Douglas-fir seedling growth and soil water supply. Forest Ecology and Management 18:189-203.

Shade, mulch, and vegetation-control treatments were used to lower soil-surface temperature and reduce both evaporation of soil water and competition for that water. These treatments affected the growth of Douglas-fir seedlings by increasing the available water as a consequence of adjusted timing of seedling growth and reduced soil water. Both final shoot volume and stem diameter of seedlings differed among treatments. Seedling growth was significantly greater in treatments where competing vegetation was controlled than in other treatments. Soil water loss was significantly lower in the mulch and vegetation-control treatments than in the shade and control treatments. In treatments where vegetation was controlled by herbicide, soil water loss was significantly less than in treatments where it was controlled by scalping. Treatments that increased the available soil water by reducing either soil surface evaporation or vegetation competition elicited the greatest growth of seedlings.

15. **Graham, J.N., E.W. Murray, and D. Minore. 1982. Environment, vegetation, and regeneration after timber harvest in the Hungry-Pickett area of southwest Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-400. 17 p.**

    On clearcut areas northwest of Grants Pass, Oregon, increases in solar radiation, temperature, rock cover, and depth of the soil A horizon increase the difficulty of regenerating forests. On areas that have been partially cut, the difficulty increases with surface gravel cover and is related to slope, aspect, and vegetation.

16. **Haeussler, S. 1987. Germination and first-year survival of red alder seedlings in the central Coast Range of Oregon. M.S. thesis, Oregon State University, Corvallis, Oregon. 105 p.**

    In the central Coast Range of Oregon, both the germination of red alder seed and the establishment of seedlings were affected by disturbance, which altered the temperature and moisture properties of the seedbed, improved light conditions, and disrupted the activities of predators and pathogens. There was no significant difference in seedling emergence between recent clearcuts and adjacent unlogged forests; emergence was higher, however, on disturbed mineral soil seedbeds than on undisturbed organic seedbeds. Mean emergence ranged from 7 to 65% of viable seed sown on disturbed seedbeds in clearcuts, and was positively correlated with spring soil-moisture conditions across the climatic gradient. On disturbed forest seedbeds, emergence did not appear to be limited by soil moisture. It ranged from 23 to 57% on disturbed seedbeds, but averaged below 10% on undisturbed seedbeds unless seedbeds remained near saturation levels and light was not limiting.

    Light levels are important to germination of seed without forest disturbance. Light conditions in the forest understory have been shown to inhibit germination in laboratory and field experiments. Red alder and other broad-leaved trees filter out red light and increase the proportion of far-red light, which inhibits germination more effectively than do conifers. Understory vegetation and litter layers also can inhibit germination.

17. **Haeussler, S., and J.C. Tappeiner II. 1993. Effect of the light environment on seed germination of red alder (*Alnus rubra*). Canadian Journal of Forest Research 23:1487-1491.**

    Germination of red alder seed was highest in clearcuts (69%) and lowest in red alder stands (12%). In Douglas-fir stands, germination was 47%. Understory vegetation, leaf litter, and unexposed mineral soil significantly reduced germination. Areas with dense understory vegetation that significantly reduced the ratio of red:far-red light had the greatest reduction in germination. Field studies of seedling establishment have shown similar results, which suggests that the phytochrome sensitivity of red alder seed is important to its success on disturbed habitats.

18. **Hallin, W. 1968. Soil surface temperatures on cutovers in southwest Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-78. 17 p.**

    In the South Umpqua drainage of southwest Oregon, shade may be necessary for establishment of natural regeneration because soil surface temperatures can exceed 138°F at elevations up to 5000 feet. Increases in temperature increase transpiration and contribute to drought-caused mortality in trees. Periods of shade, especially on southerly and westerly aspects, may help reduce drought-caused mortality of planted trees. Partial or strip cutting can provide high shade to supplement low shade. Slope, aspect, and direction of strip, as well as height of border trees, determine the strip-width necessary to prevent heat-killing of new seedlings. Clearcut strip widths of 1 chain or less usually provide adequate shade.

19. **Hallin, W.E. 1967. Soil-moisture and temperature trends in cutover and adjacent old-growth Douglas-fir timber. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-56. 11 p.**

On timbered and adjoining areas cut in 1957 and burned in the fall of 1958, seasonal trends in moisture and temperature at soil depths of 6, 18, and 36 in. are reported for 1960, 1961, and 1963. Soil moisture was similar in both areas, which indicates that moisture drain by lesser vegetation on the cutover area was nearly equal to that of the timbered area.

20. **Helgerson, O.T. 1988. Live versus dead shade — what's best for conifer seedlings. P. 157-167 *in* Proceedings, Ninth Forest Vegetation Management Conference, Redding, California. Forest Vegetation Management Conference, Redding, California.**

In southwestern Oregon and northern California, survival of conifer seedlings can be enhanced by shade. Although live brush or herbs may be used to provide shade, they require costly, complex, and uncertain vegetation management, and there is a substantial associated likelihood of reforestation failure. The use of dead vegetation for shading should cost less and have fewer risks. With adequate weed control, both shelterwoods and clearcuts with artificial shading of seedlings appear to offer much lower costs and greater certainties of reforestation success.

21. **Helgerson, O.T. 1990. Heat damage in tree seedlings and its prevention. New Forests 3:333-358.**

When the soil-surface temperature reaches approximately 52°C, tree seedlings begin to suffer stem damage or tissue death. As temperatures increase, the seedling mortality rate accelerates. As a seedling grows, however, its ability to shade its base increases, increasing its resistance to heat damage. Seedlings that are newly germinated are at risk in late spring and early summer. In mid- to late summer, larger, nursery-grown seedlings are at risk, especially on soils with low heat capacity or conductivity, or with surfaces that are dry, dark, or covered with organic matter. Heat damage usually occurs on flat or south-facing sites in regions with hot, dry summers and clear skies, but natural and planted seedlings can also suffer heat damage in wetter regions under dry, clear conditions. The basal portion of the stem can be shaded to prevent heat damage; this appears to be as effective as shading the entire stem and foliage, which can also reduce transpiration. Shade from live plants and overhead shade can reduce growth and survival.

22. **Helgerson, O.T., and J.D. Bunker. 1985. Alternate types of shade increase survival of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings in clearcuts. Tree Planters' Notes 36(4):7-12.**

Three artificial-shade methods increased survival of Douglas-fir seedlings: shadecards placed to the south of the seedlings, shadecards placed to the east of the seedlings, and Styrofoam® cups inverted around the bases of the seedlings. Shadecards south of the seedlings increased survival more than did the other 2 methods, but the cups also increased survival and cost less. In addition, deer browsed the seedlings with shadecards less than either the control seedlings or the seedlings with cups on one site; on the other site deer did not browse the seedlings.

23. **Helgerson, O.T., K.A. Wearstler, Jr., and W.K. Bruckner. 1982. Survival of natural and planted seedlings under a shelterwood in southwest Oregon. Oregon State University, Forest Research Laboratory, Corvallis, OR. Research Note 69. 4 p.**

Two years after an initial shelterwood harvest, the probabilities of survival for planted Douglas-fir (84%) and ponderosa pine (56%) were significantly greater than those for natural Douglas-fir (13%) and white fir (18%). Stress from heat and drought was the greatest cause of

mortality for both planted and natural seedlings. Survival of natural seedlings was significantly greater on shaded than on unshaded microsites, but shading did not affect survival of planted seedlings. Survival of planted seedlings seemed to be associated with root size.

24. **Hobbs, S.D. 1982. Performance of artificially shaded container-grown Douglas-fir seedlings on skeletal soils. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Note 71. 6 p.**

    After 2 yr, survival rates of 1-yr-old container-grown Douglas-fir seedlings in southwest Oregon were highest on north and south aspects, but biomass production (dry weight) was greatest on the west aspect. Shadecards increased survival by 27% on the south aspect but had little effect elsewhere. Shadecards significantly increased height growth on the west aspect but affected height less on the south aspect. Shadecards may increase Douglas-fir seedling survival under certain conditions.

25. **Hodges, J.D., and D.R.M. Scott. 1968. Photosynthesis in seedlings of six conifer species under natural environmental conditions. Ecology 49:973-981.**

    For western hemlock, grand fir, Sitka spruce, and Douglas-fir, average daily net photosynthesis rates were highest at the outer margin of a forest stand. The highest rates for Scots pine and noble fir were in fully exposed, open areas. At the border of a 35- to 40-yr-old Douglas-fir stand, the environment apparently enabled better internal water relations. Under exposed conditions, species that assimilated best appeared better able to control moisture loss than did other species. Seedlings grown in shade were capable of higher rates of net photosynthesis than were seedlings of the same species grown in sun. Photosynthetic efficiency differed by species.

26. **Isaac, L.A. 1938. Factors affecting establishment of Douglas-fir seedlings. U.S. Department of Agriculture, Washington, D.C. Circular 486. 45 p.**

    The establishment of Douglas-fir seedlings in the Wind River Valley near Carson, Washington, was governed by several environmental factors; of these, temperature of the surface soil was the most important. A surface-soil temperature of 123°F for several days after germination can injure seedlings; one of 125° or more is likely to kill them. Low soil-surface temperatures were also an important factor. Moisture content of the soil, which is controlled by precipitation and evaporation, was the 2nd most important factor affecting seedling establishment. Slash fires consume slash and duff and blacken surface soil, producing unfavorable site conditions for seedlings; thus, fires increase subsequent seedling mortality from heat and drought.

27. **Koo, C.D. 1989. Water stress, fertilization and light effects on the growth of nodulated, mycorrhizal red alder seedlings. M.S. thesis, Oregon State University, Corvallis, Oregon. 113 p.**

    When red alder seedlings were inoculated with both the mycorrhizal fungus *Alpova diplophloeus* and *Frankia*, seedling growth significantly increased by 6 to 16%. Nodule and Alpova mycorrhiza development, nitrogen (N) fixation, growth, and photosynthesis all significantly decreased with water stress of seedlings. Inoculation with *Alpova* did not improve seedling water relations. When seedlings were heavily fertilized with N (5 ml of 50µM NH_4NO_3 per seedling 3 times per week) mycorrhiza formation and N and phosphorus concentrations in leaves significantly increased, but N fixation, shoot growth, and P concentration in nodules decreased. Fertilization with P (5 µl of 5µM KH_2PO_4 per seedling 3 times per week) significantly increased total N fixation. Total plant growth, N fixation, and photosynthesis decreased significantly with light intensities below photosynthetic photon flux density of 220 $\mu mol/m^2/s$, but leaf area, shoot-to-root ratio, and concentrations of N and P in plant tissues increased. *Alpova* mycorrhiza formation decreased significantly after 3 weeks of shading but not after 10 weeks of shading. Red alder seedlings adapted morphologically to low light intensity during the long shade exposure, thus moderating negative effects on the formation of mycorrhiza; seedlings were unable to do this in the short shade period.

28. **Krueger, K.W., and W.K. Ferrell. 1965. Comparative photosynthetic and respiratory responses to temperature and light by *Pseudotsuga menziesii* var. *menziesii* and var. *glauca* seedlings. Ecology 46:794-801.**

Maximum apparent photosynthesis of 2 geographic varieties of Douglas-fir (*menziesii* and *glauca*) occurred in 35- and 65-day-old seedlings near temperatures of 20° to 25°C. For both ages, rates of photosynthesis were significantly higher for seedlings from Vancouver Island than for seedlings from Montana at certain temperatures. For both varieties, saturation intensity was near 3000 ft-c. Differences in photosynthesis and respiration between young seedlings of the 2 varieties often decreased as the seedlings grew slightly older. Comparison of 2 sources for each variety showed greater differences between seedlings of the same variety than between seedlings of the 2 varieties.

29. Krueger, K.W., and R.H. Ruth. 1969. Comparative photosynthesis of red alder, Douglas-fir, Sitka spruce, and western hemlock seedlings. Canadian Journal of Botany 47:519-527.

Red alder grew faster than 3 species of conifers because of its greater foliage surface per unit foliage weight, greater total foliage area per seedling, and higher photosynthetic rate at high light intensities. Red alder and the conifers had similar net photosynthetic rates per unit foliage area up to saturating light intensity for the conifers. The 4 species also had similar relative weights of photosynthetic and nonphotosynthetic tissue. The conifers had average maximum photosynthetic rates that were comparable to those reported for woody broad-leaved species.

30. Lavender, D.P., and W.S. Overton. 1972. Thermoperiods and soil temperatures as they affect growth and dormancy of Douglas-fir seedlings of different geographic origin. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Paper 13. 26 p.

Low soil temperatures greatly reduced growth and hastened dormancy of Douglas-fir seedlings of varieties *glauca* and *menziesii* grown under all of the thermoperiods tested. Low air temperatures generally postponed initiation of dormancy of var. *menziesii* seedlings, but warm days and cool nights were most effective in postponing dormancy of var. glauca plants. Soil temperatures had no consistent effect upon the initiation of dormancy under the 9-h photoperiod.

31. Lopushinsky, W., and M.R. Kaufmann. 1984. Effects of cold soil on water relations and spring growth of Douglas-fir seedlings. Forest Science 30:628-634.

For Douglas-fir seedlings, rates of transpiration declined linearly with decreases in soil temperature; at 1.3°C the rate of transpiration was 19% of the rate at 20.2°C. Xylem pressure potential averaged -20.0 bars for seedlings maintained under high evaporative demand for 10 d in soil at 1.3°C. Seedlings in soil at 26°C had higher potential (-13.4 bars). In cold soils, the stomatal conductance of seedlings was 50% or less than that of seedlings in warm soil. Shoot growth lessened and root growth stopped when soil temperatures were low. The reduced water uptake of seedlings planted in cold soil did not immediately cause lethal water stress. Poor field survival was probably caused primarily by suppressed root growth of seedlings at low temperatures, which subsequently increased their susceptibility to summer drought.

32. Madison, R.W. 1959. Growth and survival of a Sitka spruce plantation in coastal Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note 178. 6 p.

For young Sitka spruce in a plantation, the chief known cause of death was smothering by debris or soil movement. As trees grew, competition from vegetation caused most mortality; in 1956, the mean height of Sitka spruce was 89.5 inches. Herbaceous competition and leader damage reduced height growth. On the north slope and on burned plots, mean height growth and survival were better, but did not differ significantly. An additional initial height advantage can be gained by planting larger stock.

33. Marshall, J.D., and R.H. Waring. 1984. Conifers and broadleaf species: stomatal sensitivity differs in western Oregon. Canadian Journal of Forest Research 14:905-908.

Western hemlock, Douglas-fir, salal, chinquapin, dogwood, rhododendron, vine maple, and Oregon-grape showed increased stomatal closure in 3- and 15-yr-old clearcuts and in a 450-yr-old Douglas-fir stand as vapor pressure deficit increased. The broadleaved species were less sensitive to high vapor pressure deficit than were the conifers; the snowbrush shrub showed no stomatal closure with increased vapor pressure deficit. When these characteristics are interpreted in terms of known soil-moisture depletion patterns, they help explain why disturbed areas in western Oregon are initially colonized by broadleaved species, which are later replaced by long-lived conifers.

34. Messier, C. 1992. Effects of neutral shade and growing media on growth, biomass allocation and competitive ability of *Gaultheria shallon*. Canadian Journal of Botany 70:2271-2276.

Salal, an understory shrub, can sprout vigorously after canopy disturbance and develop a dense cover, which reduces the growth of young conifers. After 2 growing seasons in 100% sunlight, salal produced an average of 5 times as much total dry weight as it produced in 5% sunlight. Under 5% sunlight, the leaf to fine-root ratios of salal on relatively rich and poor growth media were 3.7 and 8.7 times greater, respectively, than under 100% sunlight. At 5 and 10% full sunlight, proportionally more leaf and less fine-root and rhizome biomass of salal were produced than at 30 and 100% full sunlight. Shading affected rhizome production more than it did any other component of salal. Shading increased leaf area and decreased both leaf thickness and specific leaf weight of salal. When salal biomass was reduced, the growth of both conifer species slightly increased. Salal growth, biomass allocation, and competitive ability are greatly influenced by light intensity.

35. Messier, C. 1993. Factors limiting early growth of western redcedar, western hemlock and Sitka spruce seedlings on ericaceous-dominated clearcut sites in coastal British Columbia. Forest Ecology and Management 60:181-206.

Western hemlock, western redcedar, and Sitka spruce seedlings were established on 2- and 8-yr-old clearcut sites (referred to as younger and older CH, respectively) in coastal British Columbia. These sites had previously been occupied by old-growth western hemlock and western redcedar forests. Seedlings were also established on adjacent 2-yr-old clearcut sites (referred to as younger HA) previously occupied by 2nd-growth western hemlock and Pacific silver fir forests. None of the 3 sites had soil moisture deficits at any time of year. Seedlings grew best on the younger HA sites; this growth was associated with a higher availability of N and P in the first 20 cm depth of the forest floor. On the younger and older CH sites, competing vegetation (mainly salal) was completely removed, which increased the availability of N and P and the growth of conifer seedlings. Removal of vegetation did not affect cellulose decomposition and matric soil water potential, however, and increased soil temperature only slightly. Western hemlock and Sitka spruce seedlings responded to differences in nutrient availability between sites; western redcedar did not. On the younger CH sites, all 3 conifer species had very high mycorrhizal colonization, which did not change when competing vegetation was removed. The poor growth of conifers on salal-dominated CH sites can be explained by (1) inherently low availability of forest-floor nutrients, (2) competition between conifer seedlings and salal, (3) nutrient immobilization in salal, and (4) declining availability of nutrients a few years after clearcutting.

36. Messier, C., T.W. Honer, and J.P. Kimmins. 1989. Photosynthetic photon flux density, red:far-red ratio, and minimum light requirement for survival of *Gaultheria shallon* in western red cedar-western hemlock stands in coastal British Columbia. Canadian Journal of Forest Research 19:1470-1477.

As tree cover increased, salal cover, the red: far-red ratio measured directly above it, and the global photosynthetic photon flux density (PPFD) decreased. The minimum light requirement for salal survival appears to be between 1.2 and 3.3% of global PPFD (measured in an adjacent clearing) and 0.3 to 1.8% of global PPFD under overcast and clear sky conditions, respectively.

37. Messier, C., and J.P. Kimmins. 1992. Growth of western redcedar seedlings in relation to microtopography, forest floor nutrient status, and fireweed and salal on clear-cut sites in coastal British Columbia. Canadian Journal of Forest Research 22:273-278.

The growth of western redcedar and the abundance and height of fireweed were significantly greater in depressions than on flats and mounds. Major differences in forest floor pH, cellulose decomposition, total N and P, or available NH_3 or NO_3, and phosphate P, as measured with resin bags, did not account for variations in growth or abundance, however. Western redcedar was relatively insensitive to changes in the availability of forest floor nutrients, and nutrient availability did not directly influence the growth of fireweed 4 yr after sites were logged and burned.

38. Minore, D. 1971. Shade benefits Douglas-fir in southwestern Oregon cutover area. Tree Planters' Notes 22(1):22-23.

On dry sites, dead shade has long been recognized as being beneficial to seedling survival. Competition between shade source and seedling complicates the benefits of live shade. On the west slope of an old cutover area east of Ashland, Oregon, both dead and live shade enhanced seedling survival. Seedlings planted under brush and under tree species that provided live shade had no significant reduction in growth.

39. Minore, D. 1972. Germination and early growth of coastal tree species on organic seed beds. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW-135. 18 p.

Seedlings of Douglas-fir, Sitka spruce, western hemlock, western redcedar, lodgepole pine, Pacific silver fir, and red alder in dense coastal stands, were usually larger and more abundant on rotten logs than on mineral soil, because accumulations of duff were thicker on logs and over rotten wood embedded in the soil than over soil alone. Root growth was more limited by shade than was height growth, but height growth was more limited by seedbed differences than was root growth. All conifer species had similar responses to the differences in seedbed and shade. Under lightly thinned shelterwoods in this area, the species composition of forest regeneration was probably not affected by the type of organic seedbed.

40. Minore, D., A. Abee, S.D. Smith, and E.C. White. 1982. Environment, vegetation, and regeneration after timber harvest in the Applegate area of southwestern Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-399. 15 p.

In the Applegate area of southwestern Oregon, forest regeneration is significantly related to aspect, slope, elevation, soil depth, and surface rock cover. Sites that are optimal for regeneration of clearcuts are gently sloping northern aspects below 4000 ft with deep soils. After partial cutting, natural regeneration is best where the vegetation includes more species with high indicator values than species with low values and where there is little rock cover. Residual trees often increase radial growth in response to partial cutting. This occurs most often on cool sites that have low radiation indices. More residual overstory is necessary to obtain natural regeneration on hot sites that have high radiation indices than on cool sites. Where prompt regeneration is required and seed crops are erratic, however, underplanting is recommended.

41. Minore, D., J.N. Graham, and E.W. Murray. 1984. Environment and forest regeneration in the Illinois Valley area of southwestern Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-413. 20 p.

Southwest of Grants Pass, Oregon, the difficulty of regenerating clearcuts and partial cut areas at elevations between 3000 and 4900 ft increased as coarse soil fragments, solar radiation, and slash burning increased. Between 1500 and 2900 ft, the difficulty of regenerating clearcuts increased with increasing solar radiation, shrub cover, grass cover, and surface rock plus gravel. With increases in moisture, slope, soil silt plus clay, and density of canopy, the difficulty of regenerating partial cuts increased.

42. Minore, D., and C.E. Smith. 1971. Occurrence and growth of four northwestern tree species over shallow water tables. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-160. 9 p.

Red alder, western redcedar, Sitka spruce, and western hemlock tolerate winter water tables greater than 15 cm in depth. Red alder and

Sitka spruce grew well where the water table was shallower than 15 cm with flowing groundwater; red alder and western redcedar grew well with stagnant water. Western hemlock, however, appeared to be intolerant of water tables that were less than 15 cm deep.

43. **Minore, D., C.E. Smith, and R.F. Woollard. 1969. Effects of high soil density on seedling root growth of seven northwestern tree species. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-112. 6 p.**

Differences in available nutrients influence maximum root depth, weight of roots and shoots, and total weight of Douglas-fir, Sitka spruce, western hemlock, western redcedar, lodgepole pine, Pacific silver fir, and red alder. As evidenced by their average root depths, Douglas-fir, lodgepole pine, and red alder can penetrate soil densities that Sitka spruce, western hemlock, and western redcedar cannot. The average root depth of Pacific silver fir ranks between the 2 groups.

44. **Ruth, R.H. 1967. Differential effect of solar radiation on seedling establishment under a forest stand. Ph.D. thesis, Oregon State University, Corvallis, Oregon. 176 p.**

On mineral soil, Sitka spruce, western hemlock, and Douglas-fir all became established more readily than did red alder. Solar radiation that ranged from less than 10% to nearly 70% of that in the open had little effect on the establishment of seedlings, but did affect 1st-season growth. With increasing radiation, the growth of Douglas-fir increased, and the growth of the other 3 species increased to an optimum (varying from 39 to 50% of that in the open) and then declined. The decline in growth appeared to be related to high soil moisture tension.

45. **Ruth, R.H. 1968. First-season growth of red alder seedlings under gradients in solar radiation. P. 99-105 *in* Biology of Alder. J.M. Trappe, J.F. Franklin, R.F. Tarrant, and G.M. Hansen, eds. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.**

In the 1st-season, 1 red alder seedling survived per 31 viable seeds sown on mineral soil under a thinned conifer stand near the Oregon Coast. The efficiency of red alder establishment was low compared to conifers under similar conditions. Little of the variation in growth was associated with the amount of radiation reaching the forest floor.

46. **Ruth, R.H. 1970. Effect of shade on germination and growth of salmonberry. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW-96. 10 p.**

In coastal Oregon, salmonberry can tolerate heavy shade. On a scarified plot, which received an average of only 7.2 Langleys per day (2.3% of radiation in the open), 1 seedling survived its 1st season. Under the forest canopy, solar radiation ranged up to almost 70% of radiation in the open; thus, shade level had little effect on the establishment of salmonberry seedlings. Although seedling survival was better under the canopy than in clearcuts, established salmonberry plants rooted in permanently moist soil seemed to do best in full light.

47. **Smith, N.J. 1984. Effects of density stress and soil productivity on size, mortality and nitrogen fixation in artificial populations of seedling red alder (*Alnus rubra* Bong.). M.S. thesis. Oregon State University, Corvallis, Oregon. 144 p.**

There were no differences between estimates of acetylene reduction for red alder seedlings grown on 2 soil types at 3 initial spacings. The range in values (µmol C_2H_2/g nodule/h) was from 297 at crown closure to 47 after 451 days. The densest spacings at crown closure had the highest values, although after 451 days, the trend was reversed. At the widest spacings, acetylene reduction per tree was significantly higher. Nitrogen fixation (ranked by densest initial spacings) was estimated at 680, 638, and 454 kg/N_2/ha/6 mo.

48. **Smith, N.J. 1991. Sun and shade leaves: clues to how salal (*Gaultheria shallon*) responds to overstory stand density. Canadian Journal of Forest Research 21:300-305.**

Salal shoots produced either mainly sun leaves or mainly shade leaves, depending on light and density of stand overstory. The average

of the more narrow sun leaves was 5 cm. Leaf biomass and leaf area index peaked at Curtis' metric relative density 5.9, which corresponded to 15% of available global photosynthetically active radiation. Sun leaves were produced when relative density was below 5; shade leaves were produced when relative density was between 4 and 5, depending on the uniformity of stocking. These observations can be used to reduce competition from salal or to increase salal production for browse.

49. Sorensen, F.C., and W.K. Ferrell. 1973. Photosynthesis and growth of Douglas-fir seedlings when grown in different environments. Canadian Journal of Botany 51:1689-1698.

As Douglas-fir seedlings aged, their photosynthetic rates decreased. The rates were higher for Oregon seedlings than for Montana seedlings, particularly when measured at lower temperatures. The rates also were higher for seedlings grown at high temperatures than for those grown at low temperatures, and were lowest when measured at the highest temperature. As seedlings aged, their respiration rates also declined. Those rates were slightly higher for Montana seedlings than for Oregon seedlings, and were much higher for seedlings grown at cold temperatures than for those grown at warm temperatures. At the highest measurement temperature, respiration rates were highest. Because they produced a higher proportion of leaf tissue, seedlings grown at low temperatures had lower photosynthetic rates but higher growth rates than did those grown at higher temperatures.

50. Strothmann, R.O. 1972. Douglas-fir in northern California: effects of shade on germination, survival and growth. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Paper PSW-84. 10 p.

Germination, survival, and early growth of Douglas-fir under 4 light intensities were studied on south-facing cutblocks in northwestern California. Four shade intensities (0, 25, 50 and 75%) were tested. On seeded spots, the best germination and survival occurred in 50% shade, which was significantly greater than in either no shade or 25% shade, but not significantly greater than in 75% shade. The survival of planted trees was not significantly improved by shade. Plots with the least shade generally had the best growth. Careful planting, excellent stock, periodic weeding, and deep loam soil promoted good survival on all treatments. For direct seeding, early shading appears to be desirable, though difficult to achieve. One solution may be to use a nursery crop converted to dead shade the spring after seeding.

51. Wollum, A.G., II, and C.T. Youngberg. 1969. Effect of soil temperature on nodulation of *Ceanothus velutinus* Dougl. Soil Science Society of America Proceedings 33:801-803.

More and larger nodules were formed on the east ecotype of snowbrush at 26°C than at any other temperature tested. For the west ecotype plants, however, there was no significant difference in the number and size of nodules at 22 and 26°C. Maximum plant yields occured at 26°C for the east and at 22 and 26°C for the west plants. At comparable temperatures, the east ecotype plants generally needed more time to form nodules than did the west ecotype plants. During the sampling period, the natural variation of soil temperature was found to be below 20°C for about 80% of the time and between 20 and 25°C for less than 10% of the time.

52. Youngberg, C.T., and A.G. Wollum II. 1976. Nitrogen accretion in developing *Ceanothus velutinus* stands. Soil Science Society of America Journal 40:109-112.

During the 1st year on a ponderosa pine site, 82% of the snowbrush plants were nodulated; only 42% were nodulated on a Douglas-fir site. At the end of 10 yr, above-ground snowbrush biomass production was 48,000 kg/ha for the pine site, and 54,000 kg/ha for the Douglas-fir site. More favorable temperature and moisture conditions produced higher accretion on the Douglas-fir site despite slower nodulation.

53. Zavitkovski, J., and W.K. Ferrell. 1968. Effect of drought upon rates of photosynthesis, respiration and transpiration of seedlings of two ecotypes of Douglas-fir. Botanical Gazette 129:346-350.

At soil moisture stress of 1 atm, photosynthetic rates of Douglas-fir seedlings from 2 sources declined sharply. Seedlings from a wet site had higher rates of respiration and transpiration than did seedlings from a dry site at both high and low tensions of soil moisture. Seedlings from the dry site had higher photosynthetic rates at high relative turgidities and lower rates at low relative turgidities than did those from the wet site. Relative turgidity of seedlings from the dry site varied less over a wide range of soil-moisture tensions than did that of seedlings from the wet site.

54. Zavitkovski, J., and W.K. Ferrell. 1970. Effect of drought upon rates of photosynthesis, respiration, and transpiration of seedlings of two ecotypes of Douglas-fir. II. Two-year-old seedlings. Photosynthetica 4:58-67.

Plants from mesic sites had higher rates of photosynthesis than did plants from xeric sites. Seedlings from mesic sites reached maximum photosynthesis at maximum soil moisture content (12%); seedlings from xeric sites reached maximum photosynthesis rates at soil moisture content that was just above field capacity. Transpiration rates were negatively correlated with size and/or age of the seedlings when soil moisture was high. The difference in transpiration rates was similar in magnitude to that of photosynthesis rates, and may be related to the relative needle area exposed to direct light. Seedlings responded similarly at 2 to 3 mo and at 2 yr, but rates of photosynthesis and transpiration (though not of respiration) were considerably lower in the older seedlings.

55. Zobel, D.B., A. McKee, G. Hawk, and C.T. Dyrness. 1976. Relationships of environment to composition, structure, and diversity of forest communities of the central western Cascades of Oregon. Ecological Monographs 46:135-156.

Most species of conifers can grow at a wide range of temperatures and levels of moisture stress. Many species occupy a greater variety of environments in the western Cascade Range than they do in the eastern Siskiyou Mountains of southwest Oregon. A temperature index can describe differences between vegetation zones, within which communities can be distinguished by levels of moisture stress and, to a lesser extent, by temperature. Differences in vegetation appeared to be related to low needle nitrogen contents in 2 cases.

56. Zwieniecki, M.A., and M. Newton. 1994. Root distribution of 12-year-old forests at rocky sites in southwestern Oregon: effects of rock physical properties. Canadian Journal of Forest Research 24:1791-1796.

At harsh forest sites that supported 12-yr-old stands of pure whiteleaf manzanita, pure ponderosa pine, or mixtures of Pacific madrone and Douglas-fir, distribution of root length density was analyzed. Soil dries below the wilting point of plants before the middle of the growing season on such sites; however, there is enough water in the bedrock to support a dense stand of woody plants. Of the total root length, about one-quarter to one-third is located in the rock layer. The only significant explanatory variables were linear expressions of the space penetrable by roots and depth. Bulk density had very limited explanatory power, as bedrock containing the water had high density, but the fine material in minuscule fissures in which roots were found was less dense.

B. Biotic factors

57. Amaranthus, M. 1989. The role of ectomycorrhizal fungi in ecosystem recovery following forest disturbance. Ph.D. thesis, Oregon State University, Corvallis, Oregon. 89 p.

On conifer seedlings grown in clearcut soils, only 4% of root tips were mycorrhizal at the time of outplanting; on seedlings grown in forest soils, 42% were mycorrhizal. Growth was significantly different after outplanting. In clearcut soil, seedlings averaged nearly 44% less basal area growth and 14% less height growth than in forest soil. Douglas-fir seedlings planted in whiteleaf manzanita, in an annual grass meadow, and in an open stand of Oregon white oak had differences in survival and in formation of mycorrhiza. Second-year survival for seedlings planted on the manzanita, meadow, and oak sites, averaged 92, 43, and 12%, respectively; differences in growth were similar to differences in survival. On the manzanita site, the addition of unpasteurized madrone soil nearly tripled the number of mycorrhizal root tips formed and substantially increased growth of seedlings.

58. Amaranthus, M.P., C.Y. Li, and D.A. Perry. 1990. Influence of vegetation type and madrone soil inoculum on associative nitrogen fixation in Douglas-fir rhizospheres. Canadian Journal of Forest Research 20:368-371.

The rate of acetylene reduction after 1 growing season was significantly higher in rhizospheres of uninoculated Douglas-fir seedlings from a manzanita site than that of uninoculated seedlings from a meadow site. For inoculated seedlings grown on the manzanita site, unpasteurized madrone soil increased the rate of acetylene reduction over 500%; for those grown on the meadow site, however, the madrone soil decreased it by 80%. Pasteurized madrone soil did not have a significant effect; hence, the unpasturized madrone soil influence was apparently biotic. There was no acetylene reduction in soil without seedlings. A macroaerophilic nitrogen (N_2) fixing bacterium, *Azospirillum* spp., was isolated from within the mycorrhizae of inoculated seedlings harvested from the manzanita site. After severe disturbance, early successional ectomycorrhizal shrubs and hardwood trees may be important in maintaining mycorrhizal fungi and associated N_2 fixers.

59. Amaranthus, M.P., and D.A. Perry. 1987. Effect of soil transfer on ectomycorrhiza formation and the survival and growth of conifer seedlings on old, nonreforested clearcuts. Canadian Journal of Forest Research 17:944-950.

On a high-elevation, southerly sloping clearcut where reforestation had been unsuccessful, the transfer of plantation soils to the sandy site soil increased the survival of Douglas-fir seedlings during the 1st year by 50%. On a previously burned clearcut, the transfer of plantation soil doubled the formation of mycorrhizae and tripled basal-area growth of seedlings. The transfer of soil from a mature forest did not improve seedling survival and growth. On sites at lower elevation where clay soils retained more moisture and woody shrubs had apparently preserved mycorrhizal fungi, the effects of soil transfers were less pronounced. Populations of beneficial soil biota, such as mycorrhizal fungi, decline if reforestation is delayed or other host plants are absent. Soil transfers from vigorous young plantations can restore these populations.

60. Amaranthus, M.P., and D.A. Perry. 1989. Interaction effects of vegetation type and Pacific madrone soil inocula on survival, growth, and mycorrhiza formation of Douglas-fir. Canadian Journal of Forest Research 19:550-556.

Douglas-fir seedlings planted on whiteleaf manzanita, annual grass meadow, and Oregon white oak sites had 2nd-yr survival rates of 92, 42, and 12%, respectively. Differences in growth of seedlings generally paralleled differences in survival. The addition of pasteurized and unpasteurized madrone soil had no effect on the survival of seedlings. The addition of unpasteurized madrone soil to the manzanita site greatly increased the growth of seedlings, although it had no effect on seedlings in the meadow and oak sites. Pasteurized madrone soil had no effect on seedling growth. On the manzanita site, the addition of unpasteurized madrone soil nearly tripled the formation of mycorrhizal root tips on seedlings and it resulted in the formation of a new type of mycorrhiza; the addition of this soil had little or no effect on seedlings in the meadow and oak sites, however. Root symbionts and rhizosphere organisms of manzanita and madrone appear to mediate interactions among plant species and enhance the survival and growth of Douglas-fir seedlings.

61. Aubry, K.B., M.J. Crites, and S.D. West. 1991. Regional patterns of small mammal abundance and community composition in Oregon and Washington. P. 285-294 *in* Wildlife and Vegetation of Unmanaged Douglas-fir Forests. L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, eds. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report PNW-285.

Trowbridge's shrew was the most abundant species captured in Douglas-fir stands in the Coast and Cascade ranges of Oregon and Washington. Captures of this shrew comprised 47% of the 8661 small mammals captured. The remaining captures were primarily the western red-backed vole and Pacific shrew in the Coast Range, the western red-backed vole in the Oregon Cascade Range, and the southern red-backed vole and montane shrew in the southern Washington Cascade Range. In all 3 provinces, other species each accounted for less than 6% of total captures. There were few ecologically interpretable patterns or variation among different age classes of forest; differences in species composition because of zoogeographic barriers accounted for most of the variation.

62. Bloomberg, W.J. 1990. Effect of stand conditions on advance of *Phellinus weirii* in Douglas-fir plantations. Phytopathology 80:553-559.

Stocking level and average tree diameter were higher in sectors of Douglas-fir plantations where *Phellinus weirii* had advanced than where it had not. The advance of the fungus was more strongly related to the diameter of trees; its failure to advance was more strongly related to stocking level, but was also associated with species composition and unrelated tree mortality. *P. weirii* advanced unevenly among octants of centers. Only 1 to 3% of advances in an octant followed an advance during the previous period; 76 to 96% of nonadvances followed nonadvances in the previous period. Advances were significantly different among plantations, centers, and stand ages. In plantations, the incidence of this fungus was related to both stocking level and degree of tree aggregation.

63. Bloomberg, W.J., and J.D. Beale. 1985. Relationship of ecosystem to *Phellinus weirii* root rot on southern Vancouver Island. P. 20-28 *in* Proceedings, 33rd Western International Forest Disease Work Conference. W.G. Thies, ed. Oregon State University, Corvallis, Oregon.

Site units with either very dry or wet soils had the lowest number and length of infection centers per 100 m and site units with dry or fresh soils had the greatest. Number and length of infection centers varied significantly among site units. Those with fresh soils tended to have greater numbers and length of centers per 100 m than did those with dry soils; dry, nutrient-rich soils had greater values than did dry, nutrient-poor soils.

64. Bloomberg, W.J., and G. Reynolds. 1982. Factors affecting transfer and spread of *Phellinus weirii* mycelium in roots of second-growth Douglas-fir. Canadian Journal of Forest Research 12:424-427.

In 2nd-growth Douglas-fir, *Phellinus weirii* was successfully transferred as either ectotrophic or endotrophic mycelium in 32 and 3%, respectively, of interroot contacts. Transfers were unsuccessful in 4 and 62%, respectively, of the total number of interroot contacts. In the remaining contacts, the transfers were undetermined because of the extension of mycelium to the root collar of both roots in contact. On a Douglas-fir/swordfern site, unsuccessful transfers were more frequent than on 2 Douglas-fir/salal sites. In contacts where transfers were successful, the average root diameter was greater and the average depth was lower than where transfers were unsuccessful. The type or length of contact and the relative position of roots did not significantly affect transfers. Root diameter and length of endotrophic mycelial spread, as measured by decay column, had a highly significant inverse relationship. For both proximal and distal spread, the regression of endrotrophic on ectotrophic mycelial spread along roots was highly significant. Ectotrophic mycelium had spread distally to the tip and proximally to the stump in most roots; endotropic mycelium had not.

65. Bloomberg, W.J., and G.W. Wallis. 1979. Comparison of indicator variables for estimating growth reduction associated with *Phellinus weirii* root rot in Douglas-fir plantations. Canadian Journal of Forest Research 9:76-81.

The reduction in growth caused by *Phellinus weirii* root rot in Douglas-fir can be better estimated with height variables than with dbh. The ratio of total height to dbh was the most consistent and sensitive indicator of growth reduction, although total height by 2-cm-dbh classes and ratio of annual height increment to annual dbh increment were more sensitive and less variable than the remaining indicators. In 3 plantations, the total-height-to-dbh ratio indicated reductions of 1 to 8 m over periods of 2 to 24 yr, averaging 0.9 to 1.7% annually in infected trees.

66. Buchanan, J.B., R.W. Lundquist, and K.B. Aubry. 1990. Winter populations of Douglas squirrels in different-aged Douglas-fir forests. Journal of Wildlife Management 54:577-581.

Douglas squirrel populations in the southern Washington Cascade Range varied dramatically from year to year depending on the annual production of conifer cones. Populations were generally higher in old-growth Douglas-fir forests, which appear to provide higher quality habitat than do younger forests because they have greater and more reliable quantities of conifer seeds. Douglas squirrel populations would probably decrease if old-growth Douglas-fir forests were converted to even-aged plantations of young Douglas-fir. Silvicultural strategies that increase levels of cone production in young forests may improve the quality of habitat for Douglas squirrels.

67. Castellano, M.A., D. McKay, and W.G. Thies. 1993. Ecological impacts of using chloropicrin to control laminated root rot in northwest conifer forests: growth and mycorrhiza formation of planted Douglas-fir seedlings after two growing seasons. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Paper PNW-464. 4 p.

Bareroot Douglas-fir seedlings were inoculated with *Rhizopogon* sp., processed by standard nursery procedures, and planted near Douglas-fir stumps that either had been fumigated with 2 dosages of chloropicrin to control *Phellinus weirii* infection or left unfumigated. The seedlings performed well near both fumigated and unfumigated stumps. The behavior of chloropicrin and its derivatives under various conditions of stand age, soil, and weather must be examined before this chemical can be generally recommended for stump fumigation on *Phellinus* rehabilitation sites.

68. Childs, T.W. 1970. Laminated root rot of Douglas-fir in western Oregon and Washington. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW-102. 27 p.

The abundance of laminated root rot varies greatly, even over short distances. This infection, which kills Douglas-fir and associated species, commonly spreads to new stands from the dead roots of preceding stands. The fungus most often spreads from tree to tree through vegetative growth along the roots. Although the fungus sometimes infects old-growth trees, it usually destroys immature growing stock.

69. Christy, E.J., P. Sollins, and J.M. Trappe. 1982. First-year survival of *Tsuga heterophylla* without mycorrhizae and subsequent ectomycorrhizal development on decaying logs and mineral soil. Canadian Journal of Botany 60:1601-1605.

The root systems of 1- to 5-yr-old western hemlock were colonized by *Cenococcum geophilum, Piloderma croceum*, and 4 unidentified fungi, which were distinguished by color and morphology. After the 1st growing season (2 to 7 mo), about half of the surviving seedlings were nonmycorrhizal. Although nonmycorrhizal seedlings were found most frequently on the least decayed logs, mycotrophy appeared to be advantageous to hemlock. The shoots of 1st-yr mycorrhizal seedlings were 60% longer than those of nonmycorrhizal seedlings and the roots were 47% longer. After the 2nd year, all seedlings were mycorrhizal. Western hemlock can survive its 1st growing season without mycorrhizae, which may help it to successfully colonize decaying logs containing microsites that lack ectomycorrhizal inocula.

70. Corn, P.S., and R.B. Bury. 1991. Small mammal communities in the Oregon Coast Range. P. 241-267 *in* Wildlife and Vegetation of Unmanaged Douglas-fir Forests. L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, eds. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report PNW-285.

In forested stands of the Oregon Coast Range, the most abundant species were Trowbridge’s shrews, red-backed voles, and Pacific shrews. In clearcuts, the most abundant species were vagrant shrews, deer mice, and creeping voles. Captures of red tree voles were significantly higher in old-growth stands than in mature and young stands. The abundance of Pacific shrews was significantly higher in mature stands than in either young or old-growth stands. There were no strong correlations between habitat

variables and mammal abundance. For small mammals, both abundance and diversity were greater in mature stands than in young stands; in old-growth stands, however, abundance and diversity broadly overlapped that found in mature and young stands.

71. del Moral, R., and R.G. Cates. 1971. Allelopathic potential of the dominant vegetation of western Washington. Ecology 52:1030-1037.

In western Washington, most common plant species contained inhibitory volatile compounds; many of these species also contained effective water-soluble compounds. The high inhibition values found in laboratory experiments for vine maple, Pacific madrone, and rhododendron were associated with distinct changes in the composition of ground cover below those species. Species from arid regions had higher ratios between inhibition values produced by volatile and water-soluble compounds than did species from humid regions.

72. Dosskey, M.G., R.G. Linderman, and L. Boersma. 1990. Carbon-sink stimulation of photosynthesis in Douglas-fir seedlings by some ectomycorrhizas. New Phytologist 115:269-274.

When Douglas-fir seedlings were inoculated with 3 different ectomycorrhizal fungi, they had different photosynthesis responses. The net photosynthesis rate was significantly higher in seedlings with *Rhizopogon vinicolor* than in nonmycorrhizal controls; however, *Hebeloma crustuliniforme* and *Laccaria laccata* did not provide that effect. Compared to controls, osmotic potential in the leaf symplast increased in seedlings colonized by *Rhizopogon* and *Hebeloma* but not *Laccaria*. *Rhizopogon*, *Hebeloma*, and *Laccaria* colonized 36, 93, and 73% of root tips, respectively. Seedlings colonized with *Rhizopogon* were smaller; size was unaffected by colonization with *Laccaria*. Smaller seedlings colonized with *Hebeloma* exhibited concentrations of N, P, K, and Ca that were higher than those in nonmycorrhizal controls. Ectomycorrhizal fungi, rather than nutritional factors, increased the rate of photosynthesis through their associated extensive fungal growth, which generated the increased photosynthate sink.

73. Filip, G.M. 1979. Root disease in Douglas-fir plantations is associated with infected stumps. Plant Disease Reporter 63:580-583.

In 39 of 43 plantations of 10- to 27-yr-old Douglas-fir near Quilcene, Washington, *Armillaria mellea* or *Phellinus weirii* had caused tree deaths. Although mortality averaged only 0.5 trees/ha, it was clustered within plantations. These clusters resulted in understocked openings of 0.04 to 0.10 ha. Deaths from root diseases were significantly correlated with the number of stumps infected with the diseases.

74. Friedman, J., A. Hutchins, C.Y. Li, and D.A. Perry. 1989. Actinomycetes inducing phytotoxic or fungistatic activity in a Douglas-fir forest and in an adjacent area of repeated regeneration failure in southwest Oregon. Biologia Plantarum 31:487-495.

In a clearcut area, the population density of actinomycetes was twice as high as that in an adjacent forested area. Isolates from the clearcut area had a significantly higher percentage of actinomycetes that inhibited seed germination of the test plants than did those obtained from the forested area. The phytotoxic effect of isolates from the clearcut was 5 times greater than that of isolates from the forest. Some of the actinomycetes isolated from the clearcut (4%) and from the forest (2.6%) significantly reduced the in vitro growth of 2 ectomycorrhizal fungi, *Laccaria laccata* and *Hebeloma crustuliniforme*, which are common on Douglas-fir. Fungal growth was reduced 40 and 73% by 2 isolates from the clearcut. The antifungal activity of the actinomycetes was unaffected when the nutrient in the growth medium was reduced. Phytotoxic and antifungal actinomycetes, along with other factors, may directly or indirectly suppress natural regeneration or the establishment of planted seedlings by inhibiting the germination of seed or the growth of mycorrhizal fungi.

75. Giusti, G.A. 1990. Black bear feeding on second growth redwoods: a critical assessment. P. 214-217 *in* Proceedings, 14th Vertebrate Pest Conference. University of California, Davis, California.

Black bears feed only on coastal redwood trees of specific dbh classes, not on the most abundant size class. The number of trees

damaged per ha and the percentage of stands impacted by bear feeding are estimated. A multi-management approach to bear management is proposed.

76. **Hacker, A.L., and B.E. Coblentz. 1993. Habitat selection by mountain beavers recolonizing Oregon Coast Range clearcuts. Journal of Wildlife Management 57:847-853.**

Mountain beavers recolonized areas of clearcuts in Oregon regardless of distances from edges. Beavers were likely to recolonize areas in drainages or with soft soils that had large quantities of forage plants, uprooted stumps, and woody debris that had both small (<25 cm) and large (>25 cm) diameters. To minimize tree damage without reducing recolonization, alternate food sources can be provided. When the accumulation of dead wood is minimized, numbers of colonists and suitability of habitat decrease.

77. **Hadfield, J.S. 1985. Laminated root rot: a guide for reducing and preventing losses in Oregon and Washington forests. USDA Forest Service, Pacific Northwest Region, Portland, Oregon. 13 p.**

Losses from laminated root rot can be reduced or prevented. This guide describes how to recognize the symptoms of laminated root rot and explains how the disease damages host trees and spreads to other trees. The guide also discusses how losses from the disease can be reduced.

78. **Hadfield, J.S., D.J. Goheen, G.M. Filip, C.L. Schmitt, and R.D. Harvey. 1986. Root diseases in Oregon and Washington conifers. USDA Forest Service, Pacific Northwest Region, Portland, Oregon. 27 p.**

In Pacific Northwest forests, large losses of timber are caused by root diseases. Root diseases damage all species of conifers in all forested areas. This booklet describes the most important of these root diseases, and explains how they damage host trees and how they spread. It also examines means of reducing losses from these diseases. When root diseases are controlled, productivity of infested sites can be significantly expanded.

79. **Hansen, E. 1975. *Phellinus* (*Poria*) *weirii* root rot in Douglas-fir-alder stands 10-17 years old. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-250. 5 p.**

Initial losses from *Phellinus weirii* were not reduced when red alder was grown in an even-aged mixture with 10- to 17-yr-old Douglas-fir. This study did not examine the effect of red alder on subsequent decreases in lateral spread within the stand. *P. weirii* has created openings in young stands, killing as much as 3% of the trees on 1 site. This article describes the symptoms of P. weirii infection and the distinguishing features of the disease in young trees.

80. **Hansen, E.M. 1976. Twenty-year survival of *Phellinus* (*Poria*) *weirii* in Douglas-fir stumps. Canadian Journal of Forest Research 6:123-128.**

Twenty years after harvest, 94% of the tree stumps still contained viable *Phellinus weirii*. In 68% of the stumps, the fungus was dying back; it was surviving only within roots with intact bark. Viable *P. weirii* was found on roots as small as 1.3 cm, but the average root diameter was 12.5 cm at the margin between living and dead P. weirii. This margin was often marked by a black zone line. Ectotrophic mycelium occurred in 33% of the stumps in patches on the roots.

81. **Hansen, E.M. 1979. Survival of *Phellinus weirii* in Douglas-fir stumps after logging. Canadian Journal of Forest Research 9:484-488.**

Phellinus weirii in a decay column often died without colonizing adjacent sound wood. The fungus survived for 50 yr in 26% of the stumps and 11% of the roots sampled. After 20 yr, 17% of the roots had surface mycelium; after 30 yr, the number decreased to 15%, dropping to 1% after 50 yr. On sites occupied by either red alder or Douglas-fir, the increases in survival time were similar. After 20 and 30 yr, there was no correlation between survival and stump diameter or degree of deterioration. After 50 yr, trees that died from P. weirii were found within 5 m of 45% of infected stumps.

82. **Hansen, E.M. 1980. The survival of *Phellinus weirii* in Douglas-fir stumps on sites regenerated to red alder and Douglas-fir. P. 328-332 *in* Proceedings, Fifth Interna-**

tional Conference on Problems of Root and Butt Rot in Conifers. International Union of Forest Research Organizations. Kassel, Germany.

Eighty-five percent of 20-yr-old stumps of Douglas-fir had living *Phellinus weirii*; 36% of 50-yr-old stumps had viable fungus. There were no consistent differences between the survival of red alder and Douglas-fir stands on sites of either age.

83. **Happe, P.J., K.J. Jenkins, E.E. Starkey, and S.H. Sharrow. 1990. Nutritional quality and tannin astringency of browse in clear-cuts and old-growth forests. Journal of Wildlife Management 54:557-566.**

On the Olympic Peninsula, browse in old-growth forests had proportionately more leaves, was more succulent, and had more crude protein than browse in clearcuts. Fiber content and digestibility were not consistently different in browse from either type of forest. Browse from clearcuts was higher in tannin astringency than was browse from old-growth. Tannins decrease digestible protein (DP); therefore, more DP was available to cervids browsing shrubs in old-growth forests than in clearcuts. In the Pacific Northwest, the retention of patches of old-growth forest will provide optimum year-round forage for cervids.

84. **Jenkins, K.J., and E.E. Starkey. 1993. Winter forages and diets of elk in old-growth and regenerating coniferous forests in western Washington. American Midland Naturalist 130:299-313.**

After clearcut logging, stand age, topographic landform, season, and snow accumulation affected available forage. In November, elk feces contained mainly deciduous shrubs and herbs; in midwinter, when herbaceous forage is mostly covered with snow, elk feces contained conifers and evergreen shrubs; and during early spring regrowth, they contained herbaceous forages. In 1- to 35-yr-old regenerating forests during winter, elk feces contained more herbaceous forage overall than did elk feces in old growth. Also during winter, the indices of dietary crude protein and dry matter digestibility were greater in the regenerating forest than in the old-growth forest.

85. **Johnson, A.L.S., G.W. Wallis, and R.E. Foster. 1972. Impact of root rot and other diseases in young Douglas-fir plantations. Forestry Chronicle 48:316-319.**

Forest managers have been primarily concerned with the development of *Armillaria mellea*, *Phellinus* (*Poria*) *weirii*, and *Fomes annosus* root rots. Although young stands had a high incidence of Armillaria, that will probably be of little concern when the stands are 25 to 30 yr old, unless the trees have been continuously stressed. Losses from *Phellinus weirii* and *Fomes annosus* will undoubtedly be high by the time stands reach rotation age if these diseases are present in a significant number of centers when stands are young.

86. **Kropp, B.R. 1982. Formation of mycorrhizae on nonmycorrhizal western hemlock outplanted on rotten wood and mineral soil. Forest Science 28:706-710.**

Indigenous mycorrhizal fungi readily colonized nonmycorrhizal western hemlock seedlings. Mycorrhizal fungi colonized increasing numbers of short roots throughout the season until nearly all short roots were colonized by the fall. Mycorrhizae readily colonized seedlings planted on 2 different clearcuts in both rotten wood and mineral soil. The percentage of short roots colonized was the same in wood and soil. Some types of fungi were found in either substance, but others occurred only in wood or soil. During the first growing season after outplanting, seedlings survived and grew well on both wood and soil. At the end of the season, however, seedling growth on a recent clearcut was significantly greater on mineral soil than on rotten wood. There were no other observed differences.

87. **Li, C.Y., K.C. Lu, J.M. Trappe, and W.B. Bollen. 1970. Inhibition of *Poria weirii* and *Fomes annosus* by linoleic acid. Forest Science 16:329-330.**

The growth of *Phellinus* (*Poria*) *weirii* and *Fomes annosus* in vitro was inhibited when the potassium salt of linoleic acid, a long-chain fatty acid, was incorporated into synthetic liquid media at concentrations of 0.1 mg/ml or higher. When concentrations were increased (up to 4.0 g/ml), the inhibition of growth significantly increased for both fungi. The growth of *P. weirii* was negligible at concentrations of

1.0 mg/ml or higher. Red alder can produce linoleic acid, which may in part explain its resistance to infection by *P. weirii*.

88. Littke, W.R. 1982. Nitrogen uptake by mycorrhizal fungi and mycorrhizal Douglas-fir. Ph.D. thesis, University of Washington, Seattle, Washington. 181 p.

Over time, Douglas-fir seedlings that were mycorrhizal absorbed more nitrate and ammonium and had higher concentrations of nitrogen than did seedlings that were not mycorrhizal. Mycorrhizae affected the uptake of ammonium more than the uptake of nitrate. Both the affinity and capacity for N uptake can be increased by mycorrhizae. The greater "absorbing power" of the mycobiont fungus may explain the enhanced uptake of N by mycorrhizal seedlings. Ammonium was absorbed 10 times faster by *Hebeloma crustuliniforme* than by nonmycorrhizal seedlings. The fungus could take up N 20 times faster than could the host. The effects of the source and concentration of N on the growth of mycorrhizal fungi of the Pacific Northwest was also investigated. The responses of underlying growth patterns, such as branching frequency and hyphal density, to concentrations of N in substrates were observed.

89. D.M. Loucks, H.C. Black, M.L. Roush, and S.R. Radosevich. 1990. Assessment and management of animal damage in Pacific Northwest forests: an annotated bibliography. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report PNW-GTR-262. 371 p.

This annotated bibliography of published literature is a comprehensive compilation of sources for land managers and others on the assessment and management of animal damage in the Pacific Northwest. The bibliography includes citations and abstracts from more than 900 papers indexed by subject and author. It contains information on interactions between silviculture and animal damage. Current knowledge about the management of animal species that damage forest stands and their responses to silvicultural practices is compiled; it also includes information on the alteration of silvicultural practices to prevent or limit animal damage. The bibliography complements and supplements the compendium, *Silvicultural Approach to Animal Damage Management in Pacific Northwest Forests,* edited by H.C. Black.

90. Maguire, C.C. 1989. Small mammal predation on Douglas-fir seedlings in northwestern California. Wildlife Society Bulletin 17:175-178.

Damage to Douglas-fir seedlings by animals influenced mortality less than did other factors. The primary cause of early seedling mortality was clipping by small mammals. Other causes of mortality were more common after 3 wk. Seedling predation was no longer apparent 8 wk after germination, and after 15 wk, seedling death was uncommon. Seedlings that were protected from small mammals had a greater incidence of wilt, which emphasizes the limited influence of small mammals on overall seedling mortality during the 1st growing season. Most seedlings on a xeric site will probably die during the 1st growing season regardless of predators.

91. Molina, R. 1981. Mycorrhizal inoculation and its potential impact on seedling survival and growth in southwest Oregon. P. 86-91 in Reforestation of Skeletal Soils. Proceedings of a Workshop. S.D. Hobbs, and O.T. Helgerson, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Nearly all woody plants depend on their mycorrhizal fungus symbionts for adequate mineral nutrition. Seedlings that will be planted on suboptimal sites must have well-developed mycorrhizae. The development of adequate mycorrhizae is essential for the establishment of seedlings in southwestern Oregon, where prolonged summer drought, high temperatures, and thin soils abound. Techniques have been developed for selecting highly beneficial mycorrhizal fungi for the inoculation of nursery seedlings. Inoculation with *Pisolithus tinctorius* does not improve seedling survival on cool sites; on hot sites, however, seedlings inoculated with *P. tinctorius*, especially from the Siskiyou spore source, survive better than noninoculated controls. The mycorrhizae ecology of southwestern Oregon is being studied to provide new management strategies for improving the success of reforestation. Early mortality on southwestern Oregon plantations

was not attributable to root disease but was related to deficiency in the formation and function of mycorrhizae. The formation of ectomycorrhizae was inhibited above 75°F, which indicates that trees must be planted early enough to allow the development of mycorrhizae before soil temperatures increase. Endomycorrhizae common to most shrubs and herbs can form at temperatures above 75°F. On hot sites, these plants have a competitive advantage over plants whose ectomycorrhizal fungi prefer cooler soil temperatures.

92. **Morrison, D.J. 1981. *Armillaria* root disease: a guide to disease diagnosis, development and management in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre, Victoria, B.C. Information Report BC-X-203. 15 p.**

This report is for the management of stands infested with *Armillaria mellea*. It describes the biology, signs and symptoms, damage, and distribution of A. mellea, as well as options for its management.

93. **Morse, D.R. 1979. Resistance in Douglas-fir seedlings to infection by *Phellinus weirii*. M.S. thesis. University of Washington, Seattle, Washington. 98 p.**

Natural resistance to *Phellinus weirii* in Douglas-fir was investigated by inoculating seedlings under controlled greenhouse conditions and continuously monitoring their water stress. An experimental method was used on Douglas-fir seedlings to screen for variations in their relative resistance. In seedlings with natural resistance to infection by *P. weirii*, water relations recovered to normal levels after infection and abnormally high water stress. The inoculated seedlings showed considerable variation in patterns of water stress and foliage symptoms. Resistance to infection by *P. weirii* may vary in Douglas-fir.

94. **Neal, J.L., Jr., K.C. Lu, W.B. Bollen, and J.M. Trappe. 1968. A comparison of rhizosphere microfloras associated with mycorrhizae of red alder and Douglas-fir. P. 57-71 *in* Biology of Alder. J.M. Trappe, J.F. Franklin, R.F. Tarrant, and G.M. Hansen, eds. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.**

Nonmycorrhizal suberized roots of red alder and Douglas-fir, an ectotrophic mycorrhiza of red alder, and rhizosphere microfloras of *Cenococcum graniforme* mycorrhiza of Douglas-fir were investigated. There were qualitative and quantitative differences between rhizosphere microhabitats both in microbial populations and in the most probable numbers of ammonifying and nitrate-reducing microbes. Homogenized suspensions of nonmycorrhizal Douglas-fir suberized roots and mycorrhizal red alder roots in manometric studies highly stimulated respiration of nonrhizosphere microbes, especially in the presence of glucose. In the presence of Douglas-fir mycorrhizal root suspension, however, glucose oxidation was probably suppressed by an antibiotic reportedly produced by the fungal symbiont, *C. graniforme*. When the red alder nonmycorrhizal root suspension was present, nonrhizosphere microbes had similarly repressed glucose oxidation. The growth of *Bacillus subtilis* and *B. cereus* in glucose-salts agar was inhibited by an antagonistic substance found in red alder root and nodule suspensions. The type of microorganisms found in microhabitats are probably influenced by the metabolic secretions of mycorrhizal fungi and associated suberized roots. These excreted metabolites may favor the development of specific rhizosphere microbes that form a biological barrier against root parasite attack.

95. **Nelson, E.E. 1964. Some probable relationships of soil fungi and zone lines to survival of *Poria weirii* in buried wood blocks. Phytopathology 54:120-121.**

Small blocks were cut from the heartwood of living Douglas-fir that was naturally infected with *Phellinus* (*Poria*) *weirii*. The blocks were buried for 6 to 20 mo in a young Douglas-fir stand, after which 77% showed characteristic zone lines. After 6 mo, P. weirii was found in all blocks with lines, but was isolated from only 1 block without lines. Blocks without lines had fungal flora that consisted of 80% highly antagonistic species (*Trichoderma viride, T. album*, and *Aspergillus* sp.); in blocks with lines, those species comprised only 18% of the flora. The zone lines may exclude antagonistic fungi from wood infected with *P. weirii*.

96. **Nelson, E.E. 1968. Survival of *Poria weirii* in**

conifer, alder and mixed conifer-alder stands. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-83. 5 p.

Blocks were cut from the heartwood of Douglas-fir that was naturally infected with *Phellinus* (*Poria*) *weirii*, then buried in stands of conifers, red alder, and mixed alder and conifers for as long as 18 mo. The fungus in the blocks had better survival in the soil of the conifer stand than in the soil of the red alder or mixed stands. Unlike *P. weirii*, many competing fungi, bacteria, and actinomycetes use the large amounts of NO_3-N present in red alder soil.

97. Nelson, E.E. 1969. Occurrence of fungi antagonistic to *Poria weirii* in a Douglas-fir forest soil in western Oregon. Forest Science 15:49-54.

Fungi that were consistently antagonistic to *Phellinus* (*Poria*) *weirii* on malt agar included Trichoderma viride, *Pestalotia* sp., *Gliomastix chartarum, Cephalosporium acremonium*, and an apparent mutant of *Penicillium humuli*. The number of colonies fluctuated seasonally as soil moisture content changed; total fungus colonies on soil-dilution plates did not appear to be correlated with soil organic content or pH. Soil temperature varied inversely with fungus populations. Over the 2-yr sampling period, only about 6.7% of all fungi were principal antagonists.

98. Nelson, E.E. 1975. Survival of *Phellinus weirii* in wood buried in urea-amended forest soil. Phytopathology 65:501-502.

Phellinus weirii failed to survive in wood cubes buried in soil mixed with urea or in soil on which urea had been broadcast. There was a close association between zone lines formed inside the cubes and survival of *P. weirii*. If it can also decrease survival in colonized roots of stumps and dead trees, urea could be used to control the fungus on harvested forest lands.

99. Nelson, E.E. 1976. Effect of urea on *Poria weirii* and soil microbes in an artifical system. Soil Biology and Biochemistry 8:51-53.

No *Phellinus* (*Poria*) *weirii* survived on small stem billets of red alder in urea-treated soil (147 or 294 g N/m^2) from a Douglas-fir stand. During the first 16 wk, P. weirii survival was inversely correlated with dosage of urea and populations of actinomycetes and *Trichoderma* (first observed after 8 wk).

100. Nelson, E.E. 1986. Resistance to laminated root rot by western conifers outplanted on infested sites. P. 61-63 *in* Proceedings, 34th Annual Western International Forest Disease Work Conference. S.J. Cooley, ed. USDA Forest Service, Forest Pest Management, Portland, Oregon.

On 4 sites in the Siuslaw National Forest, 11 species of conifers were outplanted 3 m from *Phellinus weirii*-infested stumps. After 10 yr, mortality records showed emerging patterns of host resistance. The least resistant species appeared to be grand fir and Douglas-fir. Western redcedar, western white pine, and lodgepole pine had no mortality and were considered among the most resistant. Redwood also had no mortality in this test; however, it is not normally included within the geographic range of *P. weirii*. Western hemlock, Sitka spruce, and noble fir had intermediate resistance. Giant sequoia was susceptible to the fungus in this test; although it does not occur naturally within the geographic range of *P. weirii*, it has been planted extensively as an ornamental.

101. Nelson, E.E., E.M. Hansen, C.Y. Li, and J.M. Trappe. 1978. The role of red alder in reducing losses from laminated root rot. P. 273-282 *in* Utilization and Management of Alder. D.G. Briggs, D.S. DeBell, and W.A. Atkinson, eds. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-70.

Red alder, either in mixture with current conifer stands or preceding stands of conifers, may reduce damage from *Phellinus weirii* on infested sites by changing soil nitrate, pH, fatty acids, phenolic compounds, and microbial populations and by physically separating susceptible root systems. Reducing saprophytic survival of the pathogen or inhibiting its spread along conifer roots may limit the incidence of disease.

102.Nelson, E.E., M.G. McWilliams, and W.G. Thies. 1994. Mortality and growth of urea-fertilized Douglas-fir on a *Phellinus weirii*-infested site in Oregon. Western Journal of Applied Forestry 9:52-56.

In an 11-yr-old Douglas-fir plantation that had been infected with *Phellinus weirii* for more than 12 yr, growth appeared better on fertilized than nonfertilized plots, but the difference was not significant. Mortality caused by the preferential feeding of bears on the inner bark of fertilized trees reduced the overall gain. Mortality caused by laminated root rot did not differ significantly among treatments.

103.Nelson, E.E., and W.G. Thies. 1981. Chemical and biological means of reducing laminated root rot inoculum. P. 71-74 *in* Proceedings, 29th Annual Western International Forest Disease Work Conference. C.G. Shaw III, ed. USDA Forest Service, Alaska Region, Juneau, Alaska.

Early test results of chemicals and antagonistic fungi used to reduce inoculum on infested, cutover sites are presented. A total of 40 Douglas-fir stumps with decay from *Phellinus weirii* were either treated with 1 l of allyl alcohol, chloropicrin, vapam, vorlex, or were left as controls. After 1 yr, stumps were carefully bulldozed from the soil with as many intact roots as possible. None of the 31 treated stumps contained *P. weirii*, whereas all control stumps still had viable *P. weirii*. Methods and timing of inoculation with a renowned fungal competitor, *Trichoderma viride*, were tested. Inoculations in February were consistently more successful than inoculations in June. In stumps with advanced decay, establishment of *Trichoderma* was good; in stained wood, establishment was lower, and in sound wood it was poor.

104.Nelson, E.E., and W.G. Thies. 1984. Potential of *Trichoderma* for biological control of laminated root rot. P. 69-73 *in* Proceedings, 32nd Annual Western International Forest Disease Work Conference. R.S. Hunt, ed. Pacific Forestry Center, Victoria, British Columbia.

On 2 harvested sites near Sweet Home, Oregon, 3 separate but interrelated studies were established. In the 1st study, the relative success of 3 isolates of *Trichoderma viride* was measured, and dowel inoculum was compared with spore-nutrient pellets. The relative success of stump inoculation in 3 decay classes was measured in the 2nd study. In the 3rd study, the effect of time of year on inoculation success was measured.

105.Parke, J.L. 1984. Inoculum potential of ectomycorrhizal fungi in forest soil from southwest Oregon and northern California. Forest Science 30:300-304.

On clearcuts where forest regeneration has repeatedly failed, Douglas-fir and ponderosa pine seedlings grown in soils from undisturbed forests had high (80 to 100%) mycorrhizal colonization after 14 to 16 wk. Seedlings grown in soils from clearcuts that had not been burned had approximately 20% fewer mycorrhizae; seedlings grown in clearcuts that had been burned had a 40% reduction in mycorrhizal colonization.

106.Parke, J.L., R.G. Linderman, and J.M. Trappe. 1983. Effect of root zone temperature on ectomycorrhiza and vesicular-arbuscular mycorrhiza formation in disturbed and undisturbed forest soils. Canadian Journal of Forest Research 13:657-665.

In soils from disturbed and undisturbed forests, both ectomycorrhizae and vesicular-arbuscular (VA) mycorrhizae formed most readily at 18.5 to 24°C. Disturbed (clearcut) and undisturbed forest soils had no significant qualitative or quantitative differences. Formation of mycorrhiza was moderate at the lowest test temperature (7.5°C), but at or above 29.5°C it was greatly reduced or even prevented. The viability of ectomycorrhizal fungus propagules did not appear to be adversely affected by 1 wk of soil treatment at 35°C; however, young mycorrhizae appeared to be severely injured after the same treatment. Because native mycorrhizal fungi can grow at low soil temperatures, they are especially important to the survival of seedlings planted where warm, dry summers follow cool, wet winters and springs.

107.Parke, J.L., R.G. Linderman, and J.M. Trappe. 1983. Effects of forest litter on mycorrhiza development and growth of Douglas-fir and western redcedar seedlings. Canadian

Journal of Forest Research 13:666-671.

Both vesicular-arbuscular and ectomycorrhizal fungi inoculum are found in litter and humus. The growth of Douglas-fir and western redcedar seedlings was usually enhanced by litter amendments, but that could not be fully attributed to the presence of either mycorrhizal inoculum or nutrients in litter. Other biological factors may stimulate the growth of conifer seedlings or the activity of mycorrhizal fungi.

108. Parke, J.L., R.G. Linderman, and J.M. Trappe. 1983. The role of ectomycorrhizae in drought tolerance of Douglas-fir seedlings. New Phytologist 95:83-95.

There was no significant difference in net photosynthetic rates of mycorrhizal and nonmycorrhizal Douglas-fir seedlings that were watered daily; however, the rate of CO_2 fixation in drought-stressed mycorrhizal seedlings was 10 times that of nonmycorrhizal seedlings. Mycorrhizal plants had lower (more negative) total leaf water potentials than did nonmycorrhizal plants, but they also recovered more rapidly. Drought affected seedlings inoculated with *Rhizopogon vinicolor* less than any of the other mycorrhizal or nonmycorrhizal treatments. Seedlings inoculated with *Rhizopogon* had 7 times the net photosynthetic rates of nonmycorrhizal seedlings 24 h after rewatering.

109. Perry, D.A., H. Margolis, C. Choquette, R. Molina, and J.M. Trappe. 1989. Ectomycorrhizal mediation of competition between coniferous tree species. New Phytologist 112:501-511.

Coniferous tree species mutually inhibited one another without added ectomycorrhizal fungi (EMF). Mutual inhibition disappeared when EMF were added. Douglas-fir seedlings were significantly larger in mixture than in monoculture, and there was no corresponding decrease in the size of ponderosa pine seedlings when 4 species of EMF were added. This was due solely to seedlings with *Laccaria laccata*, which apparently enhanced the uptake of nitrogen and phosphorus in Douglas-fir at the expense of luxury consumption by ponderosa pine. Additional EMF appear to reduce competition between plant species and perhaps increase the overall community uptake of P. In unpasteurized soils, however, patterns were specific to both EMF and tree species and were quite different.

110. Pilz, D.P. 1983. Management impacts on the ectomycorrhizal associations of *Pseudotsuga menziesii* var. *menziesii* seedlings: field and greenhouse bioassays. M.S. thesis, Oregon State University, Corvallis, Oregon. 58 p.

Both in the field and in the greenhouse, mycorrhizal associations were similar in soils from undisturbed forests and burned and unburned clearcuts on 3 sites in the west-central Cascade Range of Oregon. Regardless of soil origin, proportionately more mycorrhizae developed in clearcuts. The unburned clearcuts had more of the brown mycorrhiza type than did other treatments; the burned clearcuts had the greatest formation of *Cenococcum* mycorrhizae. In low-elevations in clay-silt soils, species of Rhizopogon formed only when the soil had been loosened and aerated. The most *Cenococcum* mycorrhizae occurred at the high-elevation site; the most Brown mycorrhizae were found on the mid-elevation site. Seedling growth and numbers of nonmycorrhizal and total root tips were higher in pasteurized soil; reinoculation of pasteurized soils reduced those numbers. A 1:9 reinoculation ratio of nonpasteurized to pasteurized soil produced as many mycorrhizae as nonpasteurized soil. The availability of fungal propagules and the effects of clearcutting and burning on soil biology and chemistry were less important to 1st-yr mycorrhizal associations than were aboveground alterations in the seedling environment. Dense or clay soils may impair the formation of mycorrhizae and soil microbiological factors may limit growth of seedlings.

111. Pilz, D.P., and D.A. Perry. 1984. Impact of clear-cutting and slash burning on ectomycorrhizal associations of Douglas-fir. Canadian Journal of Forest Research 14:94-100.

Douglas-fir seedlings were planted in soils exchanged among burned and unburned portions of clearcuts and undisturbed forest on 3 western Cascade Range sites. Twelve types of ectomycorrhizae were found on the seedlings; at least two-thirds of the ectomycorrhizal root tips were formed with *Rhizopogon* sp. and an unidentified brown type. More ectomycorrhizae formed in clearcuts than in undisturbed forest regardless of soil origin; soil origin did not affect total quantity of ectomycorrhizae.

More types of ectomycorrhizae formed in undisturbed forest soils than in clearcut soils, however, regardless of aboveground environment. In clearcut soils, seedlings had more nonmycorrhizal tips. On all sites, aboveground changes from clearcutting and site preparation influenced the formation of major (but not minor) types of ectomycorrhizae more than did alterations in soil chemistry or biology.

112. Ralph, C.J., P.W.C. Paton, and C.A. Taylor. 1991. Habitat association patterns of breeding birds and small mammals in Douglas-fir/hardwood stands in northwestern California and southwestern Oregon. P. 379-393 *in* Wildlife and Vegetation of Unmanaged Douglas-fir Forests. L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, eds. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report PNW-285.

Although 14 species of birds and 2 of mammals reached peak abundances in mature and old-growth forests of southern Oregon and northern California, none appeared limited to those forests. There was a correlation between the total number of conifer or hardwood stems and abundance for about half of the species. Many species differed in abundance among the 3 geographic regions sampled; these differences, however, may have been associated with elevation, because the northern stands sampled were generally at higher elevations than were the southern stands.

113. Rosenberg, D.K., and R.G. Anthony. 1993. Differences in Townsend's chipmunk populations between second- and old-growth forests in western Oregon. Journal of Wildlife Management 57:365-373.

In western Oregon, the density of Townsend's chipmunks was greater in old-growth than in 2nd-growth stands. Chipmunk densities ranged from 0.4 to 10.3 chipmunks/ha in old growth, and were related to large snags. In old-growth stands, the distances chipmunks moved in autumn were shorter and the proportion of young-of-the-year was greater than in 2nd-growth stands. Old-growth forests may provide better habitat for Townsend's chipmunks than do young stands of 2nd growth. The differences found in chipmunk densities may reflect important functional variations in food chains and energy flow among age classes of stands.

114. Russell, K.W., W.G. Thies, D.L. Campbell, R.I. Gara, and W.R. Littke. 1989. Effects of slash burning on forest damage from animals, insects, diseases, and adverse environment. P. 95-112 in The Burning Decision: Regional Perspectives on Slash. D.P. Hanley, J.J. Kamménga, and C.D. Oliver, eds. Institute of Forest Resources, University of Washington, Seattle, Washington. Contribution 66.

West of the Cascade Range, slash burning can have varied effects on animals, insects, or diseases that damage trees. The quality of habitat and forage has a greater influence on animal behavior than does the method of site preparation. Slash burning as a single method of site preparation does not appear to reliably benefit either wildlife or timber productivity. West of the Cascade Range, slash burning has little effect on insect damage. The buildup of insects in slash is beneficial because it increases the surface area available for decay organisms to invade. Slash burning directly and indirectly affects pathogens. High temperatures from fire stimulate the germination of dormant soilborne spores of rhizina root rot; this pathogen kills newly planted seedlings. Most of the inoculum of the other major root diseases is protected by soil and is not directly affected by slash burning. Burning can be used indirectly to convert species that are susceptible to root rot to species that are disease tolerant. Abiotic seedling problems can be affected by the amount and size of logging slash remaining on a site. When slash is completely reduced, the resulting temperature extremes, frost, and drought can kill seedlings. Logging slash acts as a heat sink, ameliorating temperature extremes and helping retain soil moisture.

115. Schoenberger, M.M., and D.A. Perry. 1982. The effect of soil disturbance on growth and ectomycorrhizae of Douglas-fir and western hemlock seedlings: a greenhouse bioassay. Canadian Journal of Forest Research 12:343-353.

Douglas-fir and western hemlock seedlings from the central Oregon Cascade Range were grown in the greenhouse in soils from various sites. Douglas-fir seedlings in soil from an unburned clearcut had the most total and ectomycorrhizal root tips; soil from both a 20-yr-old plantation that had been clearcut and burned in the late 1950s and an old-growth forest had the fewest. Douglas-fir seedlings in soil from a different old-growth forest, a recently burned clearcut, and a 40-yr-old natural burn had intermediate numbers of ectomycorrhizal root tips. Western hemlock had the fewest ectomycorrhizal and total root tips when grown in soils from the plantation and from the recently burned clearcut. Unlike Douglas-fir, western hemlock seedlings did not produce more tips in the unburned clearcut than in the old-growth forest soils. For both species, there was a significant interaction between the type of soil and the type of ectomycorrhiza. Western hemlock had predominantly *Cenococcum geophilum*, but the quantity was lower when seedlings were grown in soils from the burned clearcut and plantation. When compared to the mean for all soils, unburned clearcut soil enhanced the types of ectomycorrhizae predominant on Douglas-fir; 1 type of old-growth soil reduced ectomycorrhizae, apparently because of litter leachate.

116. Schroer, G.L., K.J. Jenkins, and B.B. Moorhead. 1993. Roosevelt elk selection of temperate rain forest seral stages in western Washington. Northwest Science 67:23-29.

In the western Olympic Peninsula of Washington, the annual home ranges of Roosevelt elk included predominantly unlogged forests within Olympic National Park and logged, regenerating forests adjacent to the park. During all seasons except winter, elk selected valley floors. In winter, elk frequently used an adjoining plateau 60 m above the floodplain, where they selected 6- to 15-yr-old clearcuts. During spring, summer, and autumn, elk selected mature deciduous forests of the valley floor; during autumn and winter they generally selected older Sitka spruce forests. Elk generally avoided young clearcuts (1- to 5-yr-old) and even-aged, regenerating stands (16- to 150-yr-old) during all seasons. Elk will benefit from management practices that retain their preferred habitats, such as deciduous forests, 6- to 15-yr-old coniferous stands, and old-growth coniferous bottomland forests, particularly on ranges managed for short-rotation, even-aged stands. Uneven-aged management, commercial thinning, and other silvicultural alternatives to typical even-aged stand management should also be considered for improving and maintaining interspersed forage and cover.

117. Shaw, C.G., III. 1978. Control of *Armillaria* root rot in managed coniferous forests — a literature review. European Journal of Forest Pathology 8:163-174.

For most effective control of *Armillaria*, hazardous sites should be avoided and stumps should be removed.

118. Shaw, C.G., III, and L.F. Roth. 1980. Control of *Armillaria* root rot in managed coniferous forests. P. 245-258 *in* Proceedings, 5th International Conference on Problems of Root and Butt Rot in Conifers. International Union of Forest Research Organizations, Kassel, Germany.

The potential impact of *Armillaria* in managed forests should be critically evaluated to insure that the level of loss justifies control. To develop a control program, determine the biological and economic information needed. First priority should be given to control through silvicultural modifications; chemical controls should be evaluated for their relative cost/benefits. When new plantations are established, sites should be carefully selected. If a site has a high disease hazard, costly preestablishment treatments, such as inoculum removals through thorough site preparation or indefinite postponement of planting, may be necessary. When chemical treatments are considered, protectants, eradicants, and remedies should be clearly differentiated. Resistant species or clones that are compatible with other forestry values should be used. Vigorous stands can be maintained by avoiding adverse sites and by preventing other agents from damaging trees.

119. Sinclair, W.A., D.M. Sylvia, and A.O. Larsen. 1982. Disease suppression and growth promotion in Douglas-fir seedlings by the ectomycorrhizal fungus *Laccaria laccata*. Forest Science 28:191-201.

When *Fusarium oxysporum* was absent, the ectomycorrhizal fungus, *Laccaria laccata* caused the dry weight of plants to increase as much as 55% more than that of nonmycorrhizal plants after 12 wk. In the presence of the pathogen, the weight of mycorrhizal plants increased 24% more than did that of benomyl-treated plants and 102% more than that of untreated plants after 14 wk. Top:root ratios indicated that top growth had been selectively stimulated by the mycorrhizal fungus through the formation of ectomycorrhizae.

120. **Sullivan, T.P. 1990. Influence of forest herbicide on deer mouse and Oregon vole population dynamics. Journal of Wildlife Management 54:566-576.**

Deer mice recruitment declined during the first summer and winter after a site was treated with the herbicide glyphosate but increased in subsequent years. There was generally little difference between control and treatment areas in recruitment of Oregon voles, and survival was also similar in both areas. In the summer and winter after spraying, however, survival of female voles was significantly better on the treated than on the control area. There were no consistent differences in body mass or growth rates of deer mice and voles during postspray periods on control and treated areas. This indicates that metabolic or general physiological processes in the development of young animals were unaffected or affected very little by glyphosate. Demographic attributes at the population level did not show the manifestation of physiological changes in individual animals that might have resulted from exposure to or ingestion of glyphosate.

121. **Sullivan, T.P. 1993. Feeding damage by bears in managed forests of western hemlock - western redcedar in midcoastal British Columbia. Canadian Journal of Forest Research 23:49-54.**

Bears most severely damaged western redcedar, which represented 13.6% of the managed stands. Bears damaged less than 0.5% of western hemlock, the major tree species, and damaged no Pacific silver fir. In the control stand, the cumulative incidence of damage to redcedar was 66.7% in 1989 and increased to 71.4% in 1990. In 1990, the annual incidence of attack was 16.7% in the control stand and 18.1% in the spaced stands. Mortality (from girdled redcedar stems) totalled 10.7% in the control and 23.3% in the spaced stands. During 1990, bear damage clearly declined, which may be related to population decreases through dispersal or removal (hunting), or to the declining numbers of undamaged redcedar trees (30%). If redcedar is not used as a crop tree, bear attacks may decrease.

122. **Tallmon, D., and L.S. Mills. 1994. Use of logs within home ranges of California red-backed voles on a remnant of forest. Journal of Mammalogy 75:97-101.**

In southwestern Oregon, downed logs in a forest remnant covered only 7% of the areas estimated to be home ranges for voles, but they coincided with 90% of the collective locations of voles. Logs in later stages of decay were used significantly more often than were logs in earlier stages of decay. Decayed logs appear to be a critical component of suitable vole habitat.

123. **Thies, W.G. 1983. Determination of growth reduction in Douglas-fir infected by *Phellinus weirii*. Forest Science 29:305-315.**

Compared with the increases expected during the 10 yr before harvest, Douglas-fir infected by *Phellinus weirii* averaged losses of 13% in growth and 7% in volume. The average losses were 32 and 12%, respectively, for trees killed by the disease. Individual tree growth varied widely in response to disease; growth of individual trees was not related to the number or size of infected roots or to crown symptoms.

124. **Thies, W.G. 1984. Laminated root rot: the quest for control. Journal of Forestry 82:345-356.**

Phellinus weirii can live saprophytically in roots for 50 yr or more after it kills the host tree. When Douglas-fir or other highly susceptible species are regenerated on an infested site, the disease nearly always causes subsequent losses in the new stand. Strategies for managing P. weirii include removal of stumps, fertilization with high levels of nitrogen, the use of chemical or biological controls such as Trichoderma, and manipulation of plant species.

125. **Thies, W.G., and E.E. Nelson. 1982. Control of *Phellinus weirii* in Douglas-fir stumps by the fumigants chloropicrin, allyl alcohol, Vapam, or Vorlex. Canadian Journal of Forest Research 12:528-532.**

Phellinus weirii was eliminated from Douglas-fir stumps and most roots when 4 fumigants were applied to holes in the stumps. There were no significant differences in the effectiveness of the chemicals. The factors that most influenced the efficacy of the treatments were stump size and condition.

126. **Thies, W.G., and E.E. Nelson. 1984. Response of Douglas-fir to the fumigant chloropicrin or methylisothiocyanate after two growing seasons. P. 55-58, 60 *in* Proceedings 32nd Annual Western International Forest Disease Work Conference. R.S. Hunt, ed. Pacific Forestry Center, Victoria, British Columbia.**

In the Oregon Coast Range, 45-yr-old Douglas-fir trees infected with *Phellinus weirii* were injected with chloropicrin or methylisothiocyanate. Most of the fumigated trees were still living after 18 mo (2 growing seasons). *Phellinus weirii* had been eliminated from most of the infested wood of trees evaluated.

127. **Thies, W.G., E.E. Nelson, and D. Zabowski. 1994. Removal of stumps from a *Phellinus weirii* infested site and fertilization affect mortality and growth of planted Douglas-fir. Canadian Journal of Forest Research 24:234-239.**

Douglas-fir seedlings were planted on a site infested with *Phellinus weirii* 4 mo after stump removal and nitrogen fertilization. Diameter at breast height and height of seedlings were recorded 5 and 9 seasons after outplanting. Where stumps had been removed, *P. weirii* killed fewer seedlings. Stump removal did not significantly affect the growth of seedlings, however, and 9.7 yr after treatment, had increased soil bulk density only 7%. Diameter at breast height and height of the seedlings increased with fertilization. On fertilized, nonstumped plots, elevated total soil nitrogen could still be detected 9.7 yr after treatment.

128. **Thies, W.G., and K.W. Russell. 1984. Controlling root rots in coniferous forests of northwestern North America. P. 379-386 *in* Proceedings, Sixth International Conference on Root and Butt Rots of Forest Trees, Melbourne and Gympie, Australia. G.A. Kile, ed. CSIRO, Melbourne, Australia.**

Decades after host trees die, inoculum of *Phellinus weirii* and *Armillaria mellea* remains in the soil. The fungi spread by direct root contact; stump removal and fumigation have been tested as methods of direct control. The best method of indirect control is the conversion of stands to resistant species.

129. **Tinnin, R.O., and L.A. Kirkpatrick. 1985. Allelopathic influence of broadleaf trees and shrubs on seedlings of Douglas-fir. Forest Science 31:945-952.**

With California-laurel, the growth of Douglas-fir seedlings was reduced to about 44% of control growth; with Pacific madrone, it was about 90% of the control. When bioassays were conducted with field soil, there was no consistent expression of allelopathy.

130. **Tkacz, B.M., and E.M. Hansen. 1979. Comparison of laminated root rot damage in a second-growth Douglas-fir stand with damage in the preceding old-growth stand. P. 87-95 *in* Proceedings, 27th Annual Western International Forest Disease Work Conference. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.**

The damage caused by *Phellinus weirii* in a 60-yr-old stand of 2nd-growth Douglas-fir was compared with the damage reconstructed for the preceding, 300-yr-old stand. Damage levels were higher for the 300-yr-old stand than for the 60-yr-old stand. In the 60-yr-old stand, however, average annual rates of damage increase were 4 times higher and the amount of potential inoculum was greater than in the 300-yr-old stand. At corresponding ages, the 2nd-growth stand would probably have greater damage than the old-growth stand. Damage in the 3rd stand would be even greater because the amount of inoculum would also be higher.

131. **Tkacz, B.M., and E.M. Hansen. 1982. Damage by laminated root rot in two succeeding stands of Douglas-fir. Journal of Forestry 80:788-791.**

The damage caused by *Phellinus weirii* in a 60-yr-old stand of Douglas-fir was less than that in the preceding 300-yr-old stand on the same site. If left to reach a comparable age, however, the newer stand would be expected to have more damage than the old stand. Damage distribution was compared between generations, with estimates based on the area of the stand affected. In the newer stand, *P. weirii* centered around stumps from the previous stand; openings in the previous stand caused by the pathogen often supported healthy trees in the newer stand. In the 60-yr-old stand, *P.*

weirii had spread beyond the rooting area of the old sources of inoculum. The 3rd generation on the site faces an area of potential inoculum that is already equal to that left by the 1st generation. When Douglas-fir is immediately regenerated on a site infested with *P. weirii*, the disease is perpetuated and perhaps increased in subsequent rotations.

132. Trappe, J.M. 1972. Regulation of soil organisms by red alder: a potential biological system for control of *Poria weirii*. P. 35-51 *in* Managing Young Forests in the Douglas-fir Region. Volume 3. A.B. Berg, ed. School of Forestry, Oregon State University, Corvallis, Oregon.

Red alder is thought to produce and add compounds to the soil that inhibit *Phellinus* (*Poria*) *weirii* and reduce the longevity of its buried inoculum. Red alder also produces relatively high levels of nitrate-nitrogen in the soil, which, together with the compounds, can cause selective increases in populations of organisms that actively compete with, inhibit, or parasitize *P. weirii*. As a species resistant to the pathogen, red alder provides no satisfactory food base to maintain the viability of *P. weirii*. If red alder prevails on a site for long enough, *P. weirii* may be eradicated.

133. Trappe, J.M., C.Y. Li, K.C. Lu, and W.B. Bollen. 1973. Differential response of *Poria weirii* to phenolic acids from Douglas-fir and red alder roots. Forest Science 19:191-196.

Phenolic acids (p-coumaric, ferulic, syringic, and vanillic) in combinations inhibited the growth of isolates of *Phellinus* (*Poria*) *weirii*. The combination of p-coumaric and vanillic, which is associated with root hydrolysates of Douglas-fir, inhibited 1 isolate and stimulated the other. Behavior and biological control of *P. weirii* and breeding for resistance to it are discussed.

134. Wallis, G.W., and G. Reynolds. 1965. The initiation and spread of *Poria weirii* root rot of Douglas-fir. Canadian Journal of Botany 43:1-9.

Douglas-fir was infected with *Phellinus* (*Poria*) *weirii* when healthy roots came into contact with infected roots of the previous stand. The spread of the mycelium was apparently very limited through natural soil alone. Mycelium grew on root bark and penetrated through even sound bark to living tissues. Mycelium could invade roots of trees that were felled at least 12 mo earlier and heartwood of Douglas-fir that had been buried for at least 12 mo. In roots as small as 2 cm in diameter, viable mycelium of *P. weirii* was isolated 11 yr after the trees had been cut. Douglas-fir and western hemlock were very susceptible to infection, but western redcedar, red alder, and bigleaf maple were resistant.

135. Wallis, G.W., and G. Reynolds. 1974. Urea and nitrate fertilizers fail to inhibit root rot. Canadian Forestry Service, Bi-Monthly Research Notes 30:25-26.

Root rot mycelium growing on the bark of Douglas-fir in a 26-yr-old plantation appeared unaffected by urea at 447, 1121, and 2240 kg N/ha, ammonium nitrate and calcium nitrate at 1121 and 2240 kg N/ha, and sodium nitrate at 1121 kg N/ha. The application of urea or nitrate fertilizers apparently will not reduce either the spread of the disease or the losses it causes.

136. Walters, B.B. 1991. Small mammals in a subalpine old-growth forest and clearcuts. Northwest Science 65:27-31.

Burned and unburned clearcuts had the highest abundance of deer mice and chipmunks. In both clearcuts and the adjacent old-growth forest, shrews were common. In all but the burned clearcut and the adjacent forest edge (edge effect) of the unburned clearcut, red-backed voles were common. In the forest, there were more adult female deer mice and the juvenile-to-adult female ratio was smaller than in the clearcuts. Clearcutting affected small mammals similarly in lowland and subalpine forests; in old-growth forests, edge effects were important.

137. West, S.D. 1991. Small mammal communities in the southern Washington Cascade Range. P. 268-283 *in* Wildlife and Vegetation of Unmanaged Douglas-fir Forests. L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, eds. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report PNW-285.

Small mammal abundance varied by year for 4 of the 11 regularly caught species. For 2 species, abundance differed between forest age classes. In old-growth forests, deer mice were caught more often, and in both mature and old-growth forests, forest deer mice were caught more often than in young forests. For 3 species, abundance differed between moisture classes of old-growth forest. Marsh shrews were caught more often in wet old-growth than in mesic forests; southern red-backed voles were caught more often in dry old growth than in either mesic or wet forests. Small mammal abundance was not strongly influenced by elevation (404 to 1218 m). In these naturally regenerated forests, the small-mammal community of the forest floor appeared adapted to a broad range of forest age and moisture conditions.

138. Wright, E., and R.F. Tarrant. 1958. Occurrence of mycorrhizae after logging and slash burning in the Douglas-fir forest type. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note 160. 7 p.

The number of mycorrhizal Douglas-fir seedlings was related to severity of burning on the Wind River forest. At the H.J. Andrews forest, the quantity of mycorrhizal seedlings was related to whether the soil had been burned, but not to the intensity of the burn. In both forests, proportionately more 2-yr-old seedlings had mycorrhizal roots than did 1-yr-old seedlings. Mycorrhizal abundance was not associated with degree of burning.

C. Stand and Site History

139. Bigley, R.E., and J.A. Henderson. 1989. Effects of slash burning on plant succession and timber stand establishment. P. 47-68 *in* The Burning Decision: Regional Perspectives on Slash. D.P. Hanley, J.J. Kammenga, and C.D. Oliver, eds. Institute of Forest Resources, University of Washington, Seattle, Washington. Contribution 66.

The establishment and growth of conifers varies considerably on burned and unburned areas. In the Pacific Northwest, controlled burning of logging slash strongly influences the establishment and development of vegetation. In coastal Washington and Oregon, conifers planted on burned areas benefit from the reduction in competitors, but may suffer from an increase in animal damage. If information on the effects of burning on vegetation were stratified by forest zones and plant associations, it could be better utilized.

140. Capell, J.F. 1976. Some effects of prescribed burning on subordinate vegetation, tree growth, and fuel loading in stands of coastal Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco]. M.S. thesis. University of Washington, Seattle, Washington. 53 p.

This study is a reexamination of John Swanson's 1973 experiment with controlled underburning to reduce wildfire hazard. Subordinate vegetation cover, diameter growth of trees, tree mortality, and litter and duff weight and volume were compared on burned and unburned plots.

141. Egeland, D.M. 1986. Vegetation-environmental relationships on two clearcuts on the western slopes of the Oregon Cascades. M.S. thesis. Oregon State University, Corvallis, Oregon. 111 p.

Establishment and growth of Douglas-fir were not limited on severely burned or compacted sites; western hemlock was most predominant on unburned sites, however. Snowbrush, redstem, and deerbrush ceanothus all had the highest percent cover on disturbed and burned sites. For vine maple, percent cover was only influenced by burning and type of habitat. Site factors, shrub cover, or nitrogen variable accounted for no more than 16% of the variation in conifer growth or stocking, but site factors could explain the most variation. Basal diameters of Douglas-fir were greater on plots with snowbrush cover; basal diameters, basal areas, and relative densities were lower on plots with redstem ceanothus. Soil or foliar N contents did not generally increase where ceanothus was present. Plots with vine maple had more mineralizable N.

142. Gockerell, E.C. 1966. Plantations on burned versus unburned areas. Journal of Forestry 64:392-393.

In the western hemlock/Pacific silver fir/western redcedar/Sitka spruce type of western Washington, logging creates heavy accumulations of slash, which should be burned so that fire hazard and mistletoe infection may be reduced and seedlings may be planted more uniformly. Planted stocking was greater but the number of natural seedlings was lower on burned areas than on unburned areas. On unburned areas, mean height of trees was greater and browsing by elk and deer was lower than on burned areas.

143. Gratkowski, H. 1964. Varnishleaf ceanothus on cutover forest lands in the Pacific Northwest. Abstracts, Weed Science Society of America 1964:58.

Germination of hard seeds of varnishleaf ceanothus was stimulated by exposure to more than 8 min of heat in the laboratory; thus, burning sites before planting trees contributes to the establishment of this ceanothus species. Some seed germinated in soil at 45 to 65°C, but optimum germination temperature was 80 to 105°C. The seed coats of varnishleaf ceanothus are composed of a palisade-like layer of sclerenchymatous Malphighian cells with a hilar fissure that acts as a valve to permit prolonged desiccation. Heat permanently opens the fissure, which prepares the seeds for germination. When stands of Douglas-fir that had no seed-bearing varnishleaf ceanothus were cut and the slash burned, 8305 ceanothus seeds per acre germinated; 1568 germinated when slash was mechanically piled before burning; and 439 germinated when slash was not burned.

144. Hermann, R.K., and W.W. Chilcote. 1965. Effect of seedbeds on germination and survival of Douglas-fir. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Paper 4. 28 p.

On a south-facing clearcut in the Coast Range of Oregon, germination and survival of Douglas-fir seed under various conditions was studied. Seedbeds included unburned, lightly burned, and severely burned soil, charcoal, litter, and sawdust at exposures of 100, 75, and 25% of full light. Germination was best on charcoal and on severely burned soil, regardless of light level, which was attributed to the moisture-holding capability of these materials. The initial advantage of high germination on charcoal and severely burned soil was still apparent after 6 growing seasons. In the 2nd half of the 1st growing season, the seedbed surface maintained temperatures of 140°F for 2 to 5 h almost every day. Perhaps because seedlings had hardened, heat-caused mortality decreased steadily despite the higher temperatures.

145. Miller, R.E., R.L. Williamson, and R.R. Silen. 1974. Regeneration and growth of coastal Douglas-fir. P. J1-J41 *in* Environmental Effects of Forest Residues Management in the Pacific Northwest: A State-of-Knowledge Compendium. O.P. Cramer, ed. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-24.

This publication describes the environmental requirements for regenerating coastal Douglas-fir and the effects of forest residues and residue treatments on natural regeneration and growth. When harvest residues are left untreated, conditions generally favor regeneration of species more shade-tolerant than Douglas-fir. Residues from old-growth stands are the most costly to eliminate, especially where they cannot be used because of economic factors. Residues have potential value either as wood products or as additional humus and nutrients in the soil. Residues can also create fire hazards or impede other land management objectives, however. Residues and their treatment influence timber yields, water, recreation, and wildlife and affect the regeneration and management of the forest. Before slash is treated, it should be examined in detail at each location. Small branches, twigs, and needles are important to site productivity, and should generally be conserved, especially where soils are immature or easily eroded.

146. Minore, D., and H.G. Weatherly. 1994. Riparian trees, shrubs, and forest regeneration in the coastal mountains of Oregon. New Forests 8:249-263.

In the coastal mountains of Oregon, riparian trees and shrubs provide the shade, bank stability, and woody debris essential for optimal stream quality and fish habitat. Woody vegetation was related to environmental variables by studying trees, shrubs, and forest regeneration in 22 riparian environments. Basal area of conifers increased with elevation, stream gradient, time since disturbance, and distance from the stream, and decreased with stream width. Covers of salmonberry and stink currant were highest and dwarf Oregon-grape and salal were lowest near the streams. Although forest regeneration increased with stream gradient, it generally was poor everywhere and decreased with total shrub cover. Where a continuing supply of coarse woody debris is necessary, existing riparian conifer stands should be retained.

147. Ruth, R.H. 1974. Regeneration and growth of west-side mixed conifers. P. K1-K21 *in* Environmental Effects of Forest Residues Management in the Pacific Northwest: A State-of-Knowledge Compendium. O.P. Cramer, ed. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-24.

In southwestern Oregon, west-side forests include coastal hemlock-spruce, upper-slope true fir-mountain hemlock, and mixed conifers. Advanced regeneration characteristically exists in the understory of mature stands. Some of those seedlings survive the logging operation and become intermixed with logging residues, the treatment of which largely determines their fate. When residues are burned, most tree seedlings are killed and forest succession reverts to an earlier stage, which may be favorable to seral tree species. Much of the total nutrient capital on a site is often contained in forest floor materials and logging residues, which should be retained where necessary for tree nutrition. On steep slopes, residues should be left to help prevent soil erosion. Before residues are treated, the various effects of all treatment alternatives should be carefully evaluated, not only from the standpoint of regeneration and growth, but for other forest uses as well.

148. Vihnanek, R.E., and T.M. Ballard. 1988. Slash-burning effects on stocking, growth, and nutrition of young Douglas-fir plantations in salal-dominated ecosystems of eastern Vancouver Island. Canadian Journal of Forest Research 18:718-722.

Slash burning significantly increased stocking, height growth, basal diameter, and foliar P, K, Ca, Fe, and B concentrations in 5- to 15-yr-old Douglas-fir and significantly reduced height and cover of salal. Burning had no significant effect on foliar concentrations of N, Mg, S, Zn, and Cu in Douglas-fir; although foliar concentrations of Mn were significantly reduced, they remained far above the deficiency threshold.

Effects of Vegetation on Development of Young Forests

A. Influences on Aerial and Soil Resources

149. Atzet, T. 1968. Selective filtering of light by coniferous forests and minimum light requirements for regeneration. M.S. thesis. Oregon State University, Corvallis, Oregon. 35 p.

The lower limit of light energy for white fir and Douglas-fir survival was 2.0 Clear Day Index (CDI); for ponderosa pine to survive, the light energy had to exceed 40.0 CDI. Moisture levels appeared to influence the light limits of a species. With adequate moisture throughout the growing season, the minimum light energy requirement for the establishment of Douglas-fir seedlings was 2.0 CDI; the minimum light requirement increased to 7.0 CDI where moisture was limited.

150. Atzet, T., and R.H. Waring. 1971. Selective filtering of light by coniferous forests and minimum light energy requirements for regeneration. Canadian Journal of Botany 48:2163-2167.

White fir and Douglas-fir could survive at light energy levels as low as 1.85 langleys per day; ponderosa pine could only survive at levels above 36.8 langleys per day. The minimum requirements for light energy appeared to be influenced by moisture levels. The lower limit of light for the establishment of Douglas-fir seedlings was 1.85 langleys per day where moisture was adequate; without adequate moisture, the lower limit of light increased to 6.64 langleys per day.

151. Berg, A., and A. Doerksen. 1975. Natural fertilization of a heavily thinned Douglas-fir stand by understory red alder. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Note 56. 3 p.

In a thinned, 62-yr-old Douglas-fir stand in Columbia County, Oregon, a light understory of red alder added 200 lb of total nitrogen to soils and a heavy understory added 780 lb. This is the equivalent of adding 435 and 1696 lb, respectively, of urea per acre.

152. Bigley, R.E. 1988. Ecological physiology of conifer seedling and sapling suppression by, and release from, competing vegetation. Ph.D. thesis. University of British Columbia, Vancouver, B.C. 190 p.

Seasonal changes in the quantity and quality of light were documented within salmonberry and below red alder canopies. The red:far-red light ratio declined exponentially as leaf area of salmonberry increased. As the deciduous canopies became more dense, the growth of grand fir, western hemlock, and Douglas-fir seedlings decreased. When the deciduous canopies were leafless, suppression of the shade-intolerant Douglas-fir seedlings was greatly reduced. Suppressed Douglas-fir saplings showed the greatest growth response when overtopping red alder canopies were removed in the spring; sapling physiology and growth suffered when the red alder canopy was completely removed during the summer. Conifer growth increased more slowly but predictably when red alder was injected with herbicide.

153. Binkley, D. 1982. Case studies of red alder and Sitka alder in Douglas-fir plantations: nitrogen fixation and ecosystem production. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 115 p.

On infertile sites, red alder greatly boosted ecosystem production and enhanced Douglas-fir growth for the first 50 yr; on fertile sites, it had the opposite effect. Sitka alder showed high potential for increasing ecosystem production when interplanted with Douglas-fir.

154. Binkley, D. 1983. Ecosystem production in Douglas-fir plantations: interaction of red alder and site fertility. Forest Ecology and Management 5:215-227.

On red alder units on a nitrogen-deficient site, soil N accretion to a depth of 50 cm was estimated at 65 kg/ha/yr for 23 yr; on a nitrogen-rich site, it was estimated at 42 kg/ha/yr. On the infertile site, the average diameter of

Douglas-fir increased when red alder was present, but basal area and basal-area growth rate were not affected. On the fertile site, average diameter, basal area, and basal-area growth of Douglas-fir decreased when alder was present. On infertile, N-deficient sites, interplanting red alder with Douglas-fir may greatly increase Douglas-fir growth and ecosystem production, but it probably will not benefit Douglas-fir on fertile, N-rich sites.

155. Binkley, D., K. Cromack, Jr., and D.D. Baker. 1994. Nitrogen fixation by red alder: biology, rates, and controls. P. 57-72 *in* The Biology and Management of Red Alder. D.E. Hibbs, D.S. DeBell, and R.F. Tarrant, eds. Oregon State University Press, Corvallis, Oregon.

The biology of nitrogen fixation by red alder, available estimates of N fixation rates for red alder stands, and the factors that control those rates are summarized and discussed. Healthy red alder trees fix large amounts of N, typically from 50 to 100 kg/ha/yr in mixed species stands and 100 to 200 kg/ha/yr in pure stands. The factors that determine N fixation rates are probably the same as those that regulate overall plant vigor. Red alder can be managed for high rates of N fixation through treatments that improve the vigor of the alder, such as managing phosphorus nutrition and controlling competition, and through genetic selection of hosts, endophytes, and combinations of these for a range of site conditions. Maximum rates of N fixation may not be a desirable goal where nitrate leaching is pronounced and where dominant, vigorous red alder impairs the growth of conifer crop trees.

156. Binkley, D., K. Cromack, Jr., and R.L. Fredriksen. 1982. Nitrogen accretion and availability in some snowbrush ecosystems. Forest Science 28:720-724.

In the Oregon Cascade Range, total soil nitrogen to a depth of 30 cm was 500 and 570 kg/ha higher in two 12-yr-old snowbrush ceanothus ecosystems than in adjacent old-growth stands. When the approximate N content of aboveground snowbrush and forest floor biomass was included, the estimate of N fixation increased to 94 to 100 kg/ha/yr over 12 yr. Although the availability index of soil N increased with snowbrush, it appeared high in all ecosystems. During early succession, snowbrush may fix enough N in these ecosystems to prevent N limitation throughout the entire successional sequence. Soil carbon also increased 40 and 60% over 12 yr when snowbrush was present.

157. Binkley, D., and S. Greene. 1983. Production in mixtures of conifers and red alder: the importance of site fertility and stand age. P. 112-117 *in* I.U.F.R.O. Symposium on Forest Site and Continuous Productivity. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-163.

Red alder can enhance site fertility and growth of interplanted conifers because it is a source of biologically fixed nitrogen. Ecosystem production rates greatly increased on infertile sites when red alder was intermixed with conifer stands. Conifer production increased after 30 yr when conifers became dominant. On fertile sites, however, productivity was not greater in mixed stands than in pure conifer stands; throughout the development of the stand, conifer production was impaired.

158. Binkley, D., and L. Husted. 1983. Nitrogen accretion, soil fertility, and Douglas-fir nutrition in association with redstem ceanothus. Canadian Journal of Forest Research 13:122-125.

Within and at the edge of redstem ceanothus patches, total soil nitrogen (0 to 15 cm depth) was 50 to 75% higher than in areas without redstem. In Douglas-fir foliage, concentrations of N, Ca, and Mg were lowest outside patches of redstem ceanothus, highest within the patches, and intermediate at the edges. Saplings at the edge of patches had the greatest foliar nutrient content because their needle weight was higher than that of saplings within patches.

159. Binkley, D., J.D. Lousier, and K. Cromack, Jr. 1984. Ecosystem effects of Sitka alder in a Douglas-fir plantation. Forest Science 30:26-35.

In a Sitka alder/Douglas-fir ecosystem, estimated annual nitrogen accretion was 30 kg/ha for 23 yr. Sitka alder did not significantly affect Douglas-fir stocking and basal area; however, current average dbh increased 13%, 5-yr average basal area growth increased 33%, and

stem biomass increment increased 40% on the Sitka alder site. With Sitka alder present, concentrations of N in Douglas-fir foliage increased significantly, but concentrations of phosphorus and sulfur decreased markedly. On the Sitka alder site, the nutrient content of litterfall was 3 to 7 times greater and the soil N availability index was 3 times greater than on sites without Sitka alder.

160. Binkley, D., and P. Sollins. 1990. Factors determining differences in soil pH in adjacent conifer and alder-conifer stands. Soil Science Society of America Journal 54:1427-1433.

The pH of soil to a depth of 0.15 m averaged 4.3 in 0.01 M $CaCl_2$ for both alder/conifer and conifer (primarily Douglas-fir) stands at a low productivity site. The stands had the same pH values, however, only because in the alder/conifer stand, the higher base saturation was offset by greater acid strength. Soil pH values at a more productive site averaged 3.7 for the alder/conifer and 4.4 for the conifer stand. The pH values were different between the 2 types of stands primarily because the acid strength of soil organic matter was greater under red alder and the base saturation of the exchange complex was lower. Qualitative changes in soil organic matter should be considered as factors that drive changes in soil pH and other parameters.

161. Bollen, W.B., C. Chen, K.C. Lu, and R.F. Tarrant. 1967. Influence of red alder on fertility of a forest soil: microbial and chemical effects. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Bulletin 12. 61 p.

In the Cascade Head Experimental Forest, the amount of bacteria was high in soils from conifers and low in soils from mixed red alder and conifer stands. Numbers of bacteria peaked in September in the F layers of soils from red alder stands and the conifer stands. In soils from the mixed stand, seasonal changes were minor, except for an increase in bacteria in the F layer in July. Nitrate nitrogen and acidity were always higher under the mixed stand than under the conifer stand. In the alder-conifer association, the higher levels of nitrate N and acidity could help inhibit fungi that cause root rot and other soil-borne diseases of conifers. Total N was always higher under both the alder and the mixed stand than under the conifer stand.

162. Borchers, S.L., and D.A. Perry. 1990. Growth and ectomycorrhiza formation of Douglas-fir seedlings grown in soils collected at different distances from pioneering hardwoods in southwest Oregon clear-cuts. Canadian Journal of Forest Research 20:712-721.

Five-month-old Douglas-fir seedlings were on average 60% taller and 2.2 times heavier and had nearly twice as many total and ectomycorrhizal short roots when grown in media containing mineral soil collected beneath hardwoods than when grown in media containing soil collected 4 m from a hardwood. Although differences in nutrient concentrations were inconsistent between types of soils, rates of mineralizable N (anaerobic) in soils from hardwood areas were from 2 to nearly 6 times greater than in soils from open areas and soil pH was higher. In clearcut areas, pioneering hardwoods appear to strongly influence soil biological activity and enhance the establishment and growth of conifer seedlings by imposing 1 or more beneficial soil patterns.

163. Bormann, B.T., K. Cromack, Jr., and W.O. Russell III. 1994. Influences of red alder on soils and long-term ecosystem productivity. P. 47-56 *in* The Biology and Management of Red Alder. D.E. Hibbs, D.S. DeBell, and R.F. Tarrant, eds. Oregon State University Press, Corvallis, Oregon.

A concept of ecosystem productivity is presented that focuses on net primary productivity as influenced by activity of all organisms. Many species play important roles in alder-dominated ecosystems. Mycorrhizae of red alder are distinct from those found under many conifers, as are understory plants, soil animals, and free-living microbes. Effects of red alder on long-term ecosystem productivity should consider the role of these other organisms as well as the role of conifers in the associative rhizosphere fixation of atmospheric nitrogen (N). Alder and its associates interact with their environment to bring about changes in soils and subsequent changes in the productive potential of the land. On young, N-deficient soils with abundant weatherable minerals, a positive feedback is likely. Initially, fixation of atmospheric N increases tree growth, which in turn provides the energy to extend roots and to produce organic acids capable of accelerated mineral weathering. Weathering and redistribution make cations and phosphorus more available and, in turn, stimulate more fixation of atmospheric N and more growth. Red alder appears especially suited to primary succession soils and soils damaged by disturbance, erosion, or repeated hot fires. On N-rich sites with deep, highly weathered substrates, a negative feedback may develop that reduces both the growth of pure alder stands and the potential productivity of subsequent ecosystems. Further additions of organic matter and N lead to the production of hydronium ions that are not countered by plant uptake or weathering. The production of nitrates leaches released cations deep into the profile. Repeated rotations of pure alder on such soils are risky. To reduce nitrate buildup or soil scarification, mixed culture may be needed to maintain long-term ecosystem productivity when alder is grown.

164. Bormann, B.T., and D.S. DeBell. 1981. Nitrogen content and other soil properties related to age of red alder stands. Soil Science Society of America Journal 45:428-432.

In the mineral soil (0-20 cm depth) beneath red alder stands, nitrogen accumulates at a nearly constant rate of about 35 kg/ha/yr. Forest floor N increased rapidly in the 1st decade of a red alder stand, then increased linearly at a rate of 15 kg/ha/yr. There were other marked differences between soils from red alder stands and from adjacent Douglas-fir stands; organic matter content was 20% higher and pH and bulk density were much lower in red alder than in Douglas-fir soils. Because red alder improves the rate of N accretion as well as other soil characteristics, it may increase yields of Douglas-fir grown with it in mixed or rotational culture.

165. Brozek, S. 1990. Effect of soil changes caused by red alder (*Alnus rubra*) on biomass and nutrient status of Douglas-fir (*Pseudotsuga menziesii*) seedlings. Canadian Journal of Forest Research 20:1320-1325.

When Douglas-fir seedlings were grown on a former red alder site, the biomass of current twigs increased 65%, older twigs increased 41%, and stems increased 45%. The biomass of foliage and roots was not significantly affected, but the root systems of seedlings were shallower and wider than those on a site formerly occupied by Douglas-fir. On the red alder site, concentrations of nitrogen in seedlings increased and those of phosphorus, calcium, and magnesium decreased. Ratios of N:P and N:K were higher and the availability of soil P was lower on the alder site, and the depletion of extractable P in the soil was accelerated. Differences in nutrient concentrations and changes in seedlings can be attributed in part to the accumulation of N and organic matter in the soil by the previous red alder forest.

166. Childs, S.W., and L.E. Flint. 1987. Effects of shade cards, shelterwoods, and clearcuts on temperature and moisture environments. Forest Ecology and Management 18:205-217.

Seedling survival was better on sites with shelterwoods or shadecards than on a clearcut alone. Both shelterwoods and shadecards affected soil temperature but in different ways. Solar radiation at the soil surface decreased under the shelterwood canopy and soil temperatures were cooler throughout the soil profile. Soil temperatures decreased, but only to a depth of 20 mm when shadecards were used. Periods of high soil temperature were shorter with both treatments. Seasonal water loss was delayed and seedling water stress (as measured by stomatal resistance) decreased with the shelterwood treatment. The use of shadecards had no significant effect on seedling stomatal resistance. Soil temperature and seedling water stress were greatly reduced with shelterwood treatment. Shadecards had less effect on soil temperatures and, therefore, on seedling survival.

167. Cole, D.W., S.P. Gessell, and J. Turner. 1978. Comparative mineral cycling in red alder and Douglas-fir. P. 327-336 *in* Utilization and Management of Alder. D.G. Briggs, D.S. DeBell, and W.A. Atkinson, eds. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-70.

Red alder mineral cycling rates were far faster than those of Douglas-fir. Through biological nitrogen fixation, the red alder ecosystem accumulated 85 kg/ha/yr more N than did the Douglas-fir ecosystem. Although the amount of nutrients stored within the trees and understory vegetation was greater in the alder ecosystem, those nutrients remained within the foliage and forest floor 2 to 5 times longer in the Douglas-fir ecosystem. The red alder ecosystem lost slightly more nutrients through leaching than did the Douglas-fir ecosystem.

168. Conard, S.G. 1986. Comparative water relations of three shrub species—preliminary results. FIR Report 7:4-5.

Soil water potential at 25 to 100 cm depth had decreased to approximately -1.5 MPa by the end of the growing season regardless of species (oceanspray, redstem ceanothus, and greenleaf manzanita) or aspect. However, soil moisture depletion was considerably more rapid under the deciduous species, indicating that those species are more severe competitors with the conifers for soil moisture. Measurements of predawn water potentials suggested that oceanspray is more shallowly rooted than the other species.

169. DeBell, D.S., M.A. Radwan, and J.M. Kraft. 1983. Influence of red alder on chemical properties of a clay loam soil in western Washington. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW-313. 7 p.

In the 0- to 20-cm soil layer beneath red alder stands, total nitrogen increased with stand age. In both the 0- to 20-cm and the 20- to 50-cm layers, pH decreased with stand age. In either soil layer, some mineral nutrients accumulated with N. As total N increased and pH decreased in the 0- to 20-cm layer, exchangeable calcium and magnesium decreased substantially.

170. Del Rio, E. 1979. Growth behavior of Douglas-fir reproduction in the shade of managed forest in the interior Coast Range of Oregon. M.S. thesis. Oregon State University, Corvallis, Oregon. 55 p.

In the spring, the development of buds in a 65-yr-old Douglas-fir stand was inversely related to light; renewed activity in the cambium was directly related to both the size of the tree and light. As light increased, height and diameter growth increased. There were linear differences among 3 thinning intensities in average leader and diameter growth and aboveground biomass production; trees grew most where thinning was heaviest.

171. Del Rio, E., and A. Berg. 1979. Specific leaf area of Douglas-fir reproduction as affected by light and needle age. Forest Science 25:183-186.

For young, natural Douglas-fir growing in the shade of a managed Douglas-fir forest, specific leaf area was related to the logarithm of daily sunlight, whether full or as low as 1.28%, received at the crown. The age of needles also influenced specific leaf area. Strategies for survival of this species change with environment; all degrees of shade leaves exist. The particular light regime in which a tree grows affects leaf morphology.

172. Del Rio, E., and A.B. Berg. 1979. Growth of Douglas-fir reproduction in the shade of a managed forest. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Paper 40. 14 p.

Understory environments beneath 3 intensities of overstory thinning in a 65-yr-old Douglas-fir stand were described in terms of sunlight, plant moisture stress, evaporative demand, air and soil temperatures, and vegetative cover. Daily sunlight reaching the natural Douglas-fir reproduction averaged 5 to 12% of full sun and was directly correlated with the intensity of overstory thinning. Tree height and sunlight interacted positively with growth increment. Mean growth increased linearly with thinning intensity and current growth was highly correlated with growth and tree height of previous years.

173. Drew, S.E. 1968. Soil moisture depletion trends under five plant species present on the Douglas-fir clear-cuts of Mary's Peak, Oregon. M.S. thesis. Oregon State University, Corvallis, Oregon. 77 p.

During a 2-yr study, soil moisture depletion trends for salal, Oregon-grape, big deervetch, velvetgrass, and vine maple were characteristic. Moisture loss rates under salal were slow at all 3 depths (6, 12, and 24 in.); rates were similar for Oregon-grape except at the 6-in. depth where losses were more rapid. Moisture trends fluctuated considerably under deervetch at 6 and 12 in., but at all 3 depths, depletion rates were rapid. At 6 and 12 in., moisture loss under velvetgrass was early and rapid, but was slightly delayed and slower at 24 in. Under vine maple, moisture losses at all

3 depths were rapid and consistent with no fluctuations.

Depletion trends became more consistent with each advancing stage and the root count decreased (except for deervetch, which had the fewest roots). The decrease in root count reflected the increase in relative root size. Vine maple, velvetgrass, and deervetch would be competitive with tree seedlings for soil moisture, especially deervetch at the deeper soil levels. Deervetch can invade and dominate velvetgrass by producing rhizomes than can grow beneath the dense root system of velvetgrass and use the moisture there, then send up shoots from the rhizomes. Stands of salal and Oregon-grape would not be as detrimental to tree seedling development as would stands of the other species.

174.Franklin, J.F., C.T. Dyrness, D.G. Moore, and R.F. Tarrant. 1968. Chemical soil properties under coastal Oregon stands of alder and conifers. P. 157-172 *in* Biology of Alder. J.M. Trappe, J.F. Franklin, R.F. Tarrant, and G.M. Hansen, eds. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Under red alder and mixed stands, organic matter, total nitrogen, and acidity were significantly greater in A horizons. Organic matter and N were on average one-third greater, and pH was 1 unit lower in A11 horizons of older stands. Under conifer stands, A horizons were an average of 3 times richer in bases than under red alder stands. In the B horizons, differences were similar but of much smaller magnitude. The observed effects of red alder on soil pH disagreed with the concept of hardwoods as base conservers. These results may indicate that production of acid decomposition products was greater in the red alder soils, which were richer in organic matter and N.

175.Fried, J.S. 1985. Two studies of *Acer macrophyllum*: I. The effects of bigleaf maple on soils in Douglas-fir forests; II. The ecology of bigleaf maple seedling establishment and early growth in Douglas-fir forests. M.S. thesis. Oregon State University, Corvallis, Oregon. 91 p.

For every macro- and micronutrient, litterfall weight and nutrient content were greater under maple than under Douglas-fir, and the forest floor biomass and nutrient turnover rates were significantly faster. On 4 of 5 sites, soil nitrogen was greater and soil organic matter content was significantly greater under maple than under Douglas-fir. When bigleaf maple seed was protected from rodents, germination rates averaged from 30 to 40% in all environments; when seed was not protected, typically less than 2% germinated. Seed predators may greatly influence seedling establishment. Light levels greatly affected seedling survival. In stand with greater than 90% overstory cover, mortality after 1 growing season was particularly high. In clearcuts, the establishment of maples will be successful only if seedlings are not shaded by competing vegetation.

176.Fried, J.S., J.R. Boyle, J.C. Tappeiner II, and K. Cromack, Jr. 1990. Effects of bigleaf maple on forest soils in Douglas-fir forests. Canadian Journal of Forest Research 20:259-266.

For every macronutrient and for most micronutrients on every site, litter fall weight and nutrient content were significantly greater under maple than under Douglas-fir. There were no consistent differences between the 2 species in forest floor biomass and nutrient content, which were extremely variable. For every nutrient at every site, turnover rates were significantly faster under maple for forest floor biomass and nutrients. Mineral soil bulk density was significantly different at only 2 sites, and was highly variable. Nitrogen levels were consistently higher and potassium levels were less consistently higher under maples. Levels of calcium, magnesium, and phosphorus showed no consistent trends. On 4 of 5 sites, soil organic carbon content was significantly greater under maple than under Douglas-fir. The more rapid turnover of forest floor under maple trees may account for these differences.

177.Harrington, T.B., R.J. Pabst, and J.C. Tappeiner II. 1994. Seasonal physiology of Douglas-fir saplings: response to microclimate in stands of tanoak or Pacific madrone. Forest Science 40:59-82.

The microclimate (light, soil water, temperature, and relative humidity) of young stands of tanoak or Pacific madrone was related to the plant water potential, leaf conductance, and photosynthesis of Douglas-fir saplings. Photosynthetically active radiation was reduced to 20 to 38% of full sunlight by hardwood shade. When Douglas-fir was thus shaded by hardwoods, photosynthesis was light-limited. Summer (July through September) soil water potentials (30-cm depth) averaged -0.64 MPa when hardwoods were present and -0.23 MPa when they were absent. In the hardwood stand, photosynthesis of associated Douglas-fir was reduced because of the reduced availibility of soil water and the higher air temperatures and lower relative humidities. At plant water potentials of -2.3 for tanoak, -2.5 for Douglas-fir,and -3.4 MPa for Pacific madrone, stomata neared complete closure. Among the 3 species, seasonal rates of photosynthesis were not greatly varied, but specific water-use patterns were apparent. Tanoak was most able to minimize water stress, followed by Douglas-fir and Pacific madrone.

178. Helgerson, O.T. 1981. Nitrogen fixation by scotch broom (*Cytisus scoparius* L.) and red alder (*Alnus rubra* Bong.) planted under precommercially thinned Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Ph.D. thesis. Oregon State University, Corvallis, Oregon. 88 p.

Through the season, plant moisture stress affected nitrogen fixation more than did soil temperature. Available light or Douglas-fir basal-area cover did not appear to be related to N fixation. On a per-plant basis, scotch broom and red alder were nearly equal in N fixation per unit nodule weight, but over the season, broom averaged significantly greater rates. In late February, nitrogenase activity was strong for broom but sporadically weak for red alder and absent for snowbrush; broom fixation may be much less controlled by dormancy. Red alder plugs have higher survival, potentially greater growth and fixation, and lower weed potential, and are easier to plant; they thus offer better potential for N fixation.

179. Helgerson, O.T., J.C. Gordon, and D.A. Perry. 1984. N_2 fixation by red alder (*Alnus rubra*) and scotch broom (*Cytisus scoparius*) planted under precommercially thinned Douglas-fir (*Pseudotsuga menziesii*). Plant and Soil 78:221-233.

For red alder, nodule activities averaged 18.78 µmol C_2H_4 nodule/dry weight (dw)/h; for scotch broom, activities averaged 59.95 µmol C_2H_4 nodule/dw/h. Nodule activity and percent leaf nitrogen were not strongly correlated with the dw of other plant parts, but plant activity and total N were correlated. Over the growing season for both species and mid season for red alder alone, plant and nodule activities were not associated with temperature, moisture stress, precipitation, or percent light. There was a strong correlation among nodule dw, leaf dw, plant size, and total leaf N for red alder on the same site after 5 to 6 growing seasons; trees on that site ranged from 30 to 332 cm in height. To predict the effect of adding a plant that fixes N to a population of trees that do not fix N, logistic equations may be modified.

180. Kabzems, R.D., and K. Klinka. 1987. Initial quantitative characterization of soil nutrient regimes. II. Relationships among soils, vegetation, and site index. Canadian Journal of Forest Research 17:1565-1571.

On Vancouver Island, variations in understory vegetation and foliar properties in Douglas-fir ecosystems were highly correlated with the soil properties that best characterized soil nutrient regimes of the ecosystems, such as mineralizable N, total N, and exchangeable Ca and Mg. Soil nutrient availability increases were correlated with increased concentration of foliar N in the foliage of the current year. Increased soil nutrient availability (particularly N, Mg, and Ca) was consistently correlated with decreased foliar Mn and Al. In comparisons of sites with equivalent soil moisture regimes, the Douglas-fir site index was significantly greater when quantities of most nutrients (particularly N, Mg, and Ca) were also greater.

181. Kelliher, F.M. 1985. Salal understory removal effects on the soil water regime and tree transpiration rates in a Douglas-fir forest. Ph.D. thesis. University of British Columbia, Vancouver, B.C.

Where salal was present in a 31-yr-old Douglas-fir stand, total evapotranspiration was only slightly higher than where salal had been removed. In cut subplots, salal transpiration was greater than forest floor evaporation; where salal had been removed, Douglas-fir transpiration was higher. Although soil water increased only slightly, soil water potential was significantly higher where salal had been removed. Higher Douglas-fir predawn twig xylem water potentials corresponded to low values of soil water content. Tree diameter growth was significantly greater where salal had been removed than where it remained.

182. Kim, D.Y. 1987. Seasonal estimates of nitrogen fixation by *Alnus rubra* and *Ceanothus* species in western Oregon forest ecosystems. M.S. thesis. Oregon State University, Corvallis, Oregon. 71 p.

At Alsea, OSU field laboratory, and Cascade Head, annual nitrogen fixation was 22.8, 17.5, and 50.1 kg/ha/yr, respectively. At 2 and 58 yr, red alder could potentially add substantial N to the ecosystem. Deerbrush and varnishleaf ceanothus showed similar N-fixing activity at 5 to 6 yr. Snowbrush had a different seasonal pattern at 11 yr. For varnishleaf ceanothus, deerbrush, and snowbrush, annual N fixation was 8.3, 0.3, and 69.4 kg/ha/yr, respectively. At 11 yr, snowbrush added much N to the ecosystem.

183. Luken, J.O., and R.W. Fonda. 1983. Nitrogen accumulation in a chronosequence of red alder communities along the Hoh River, Olympic National Park, Washington. Canadian Journal of Forest Research 13:1228-1237.

The mean nitrogen level of bare sandbars deposited by the Hoh River was 783 kg/ha. The total community N level increased to 4659 kg/ha in 65-yr-old red alder stands. The trees themselves held 942 kg/ha and the soils held 3594 kg/ha N in the upper 45 cm. From 14 to 65 yr, the N content of the soil, alder wood, bark and branches, grasses, total aboveground biomass, total belowground biomass, and sticks less than 1 cm diameter all increased significantly. Red alder is important in linking the nutrient inventory between bare sandbars and western hemlock and Sitka spruce climax forests.

184. Margolis, H.A., and R.H. Waring. 1986. Carbon and nitrogen allocation patterns of Douglas-fir seedlings fertilized with nitrogen in autumn. II. Field performance. Canadian Journal of Forest Research 16:903-909.

Budbreak was earlier and shoot growth, relative growth rates, net assimilation rates, and leaf area indices were greater for fertilized than for unfertilized Douglas-fir seedlings. In both fertilized and unfertilized seedlings, grass significantly increased predawn moisture stress by early August. By September 3, however, unfertilized seedlings were significantly more stressed than fertilized seedlings growing with grass. Free amino acids and total N concentration were not significantly affected by fertilizer at the end of the growing season, but both N and carbohydrate chemistry were affected by competition from grass.

185. McDonald, M.A. 1990. Competition for nutrients and chemical interference by salal (*Gaultheria shallon* Pursh.). P. 16-18 in Vegetation Management: An Integrated Approach, Proceedings of the Fourth Annual Vegetation Management Workshop. E. Hamilton, ed. British Columbia Ministry of Forests, and Forestry Canada, Victoria, B.C. FRDA Report 109.

In coastal British Columbia, salal appears to be an effective nutrient sink in clearcuts from old-growth cedar and hemlock stands. Salal appears to affect the humification processes by immobilizing nutrients. In areas awaiting natural regeneration, fire prevention and supplemental fertilization may enhance reforestation.

186. Messier, C. 1991. Factors limiting early conifer growth in salal-dominated cutovers on northern Vancouver Island, British Columbia. Ph.D. thesis. University of British Columbia, Vancouver, B.C. 178 p.

Conifers, especially Sitka spruce on cutovers, may suffer nutritional stress and grow poorly when (1) forest floor fertility is inherently low because of previous old-growth forests, (2) salal competes and immobilizes nutrients in salal biomass, and (3) site fertility decreases after the initial nutrient flush on a logged and burned site.

187. Messier, C., and J.P. Kimmins. 1990. Nutritional stress in *Picea sitchensis* plantations in coastal British Columbia: the effects of *Gaultheria shallon* and declining site fertility. Water, Air and Soil Pollution 54:257-267.

In coastal British Columbia, Sitka spruce plantations growing with salal had nutritional stress (primarily nitrogen deficiency). Up to 10 yr after clearcutting and slashburning in a chronosequence of sites, there was no direct evidence of allelopathic contribution to the N stress. The stress may be partially explained by the rapid accumulation of fine roots and

rhizomes of salal and the nutrients contained therein. Soil fertility was lower 8 to 10 yr after clearcutting and slashburning than 2 to 4 yr after, which probably caused further nutritional stress in Sitka spruce. Competition from salal and the immobilization of nutrients in salal biomass, as well as declining site fertility after the post-slashburn nutrient flush, contribute to nutritional stress in Sitka spruce plantations. Site nutrient management as well as vegetation management is necessary to sustain good growth on such plantations.

188. Miller, R.E., and M.D. Murray. 1979. Fertilizer versus red alder for adding nitrogen to Douglas-fir forests of the Pacific Northwest. P. 356-373 *in* Symbiotic Nitrogen Fixation in the Management of Temperate Forests. J.C. Gordon, C.T. Wheeler, and D.A. Perry, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Several crop rotation and mixed-stand options using red alder were compared with repeated applications of urea. Red alder may be a practical silvicultural alternative to urea fertilizer. Specific research studies are suggested to clarify or improve the feasibility of using nitrogen-fixing plants to increase available N in northwest forests.

189. Minore, D. 1985. Effects of madrone, chinkapin and tanoak sprouts on light intensity, soil moisture, and soil temperature. Canadian Journal of Forest Research 16:654-658.

Beneath clumps of Pacific madrone, light intensity was higher than beneath tanoak or chinquapin. During the cool moist summer of 1983, soil moisture was higher and soil temperature was lower under the clumps that outside them. During the warm dry summer of 1985, soil temperature remained lower, but moisture conditions beneath the clumps were similar to those outside the clumps after the prolonged 1985 drought.

190. Newton, M. 1964. The influence of herbaceous vegetation on coniferous seedling habitat in old field plantations. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 114 p.

Competition from heavy stands of herbaceous vegetation has been blamed for plantation failures on abandoned pasturelands and old clearcuts. However, quantitative data on herbaceous competition was unavailable until the development of selective chemicals, which enabled the creation and study of various vegetation conditions. The quantity of vegetation directly influenced the rate of moisture depletion. On devegetated plots, soil surface evaporation accounted for moisture loss that only affected tension in the surface 6 in.; below 6 in., moisture was abundant within the root zones of planted seedlings. By June 23, available moisture in the surface 36 in. was completely depleted on vegetated plots; throughout the soil profile, depletion continued at equal rates. Mathematical models were developed to predict available moisture on the basis of vegetation, drainage, and soil depth, and moisture depletion rates on the basis of vegetation, soil conditions, and climate. When vegetation is properly monitored and controlled with chemicals when necessary, enough moisture may be conserved to prevent drought conditions for at least 1 season.

191. Pabst, R.J., J.C. Tappeiner II, and M. Newton. 1990. Varying densities of Pacific madrone in a young stand in Oregon alter soil water potential, plant moisture stress, and growth of Douglas-fir. Forest Ecology and Management 37:267-283.

When shrubs and herbs were controlled and Pacific madrone was absent (treatment N), soil water potential at 0- to 30-cm depth was significantly higher than in all other treatments. When shrubs and herbs were predominant and Pacific madrone was absent (U), soil water potential averaged 1.5 MPa (permanent wilting point) in both years of the study between June and July; that level was never reached in the other treatments. With shrubs and herbs controlled and madrone at high density (H), soil water conditions were also relatively severe. In treatment N, Douglas-fir predawn moisture stress was significantly lower than in all other treatments. Seasonal moisture stress relief of Douglas-fir was greatest in treatment N and was significantly related to madrone leaf area index. Seasonal moisture stress relief and leaf area index were also significantly correlated. For Douglas-fir and madrone, linear relationships were highly significant between both predawn and midday plant moisture stress and soil water potential. Maximum growth of Douglas-fir occurred when competing

vegetation was controlled and madrone was absent (N). There was no significant difference between treatments N and U in the average diameter growth of Douglas-fir, but growth was greater in treatment N. Diameter growth was lowest in treatment H. Seasonal moisture stress relief, madrone leaf area index, and seasonal tension relief influenced the growth of Douglas-fir diameter, stem basal area, and stem volume.

192. Perry, D.A., C. Choquette, and P. Schroeder. 1987. Nitrogen dynamics in conifer-dominated forests with and without hardwoods. Canadian Journal of Forest Research 17:1434-1441.

Thinned stands with and without hardwoods were stocked with the same number of conifers. When hardwoods were absent, N levels in mineral soil averaged 520 kg/ha more than when hardwoods were present. During 7-day incubations, stands without hardwoods also had 20% more N mineralized from soil and lower ratios of C:N in soil. These variables did not differ between thinned and unthinned mixed stands. Levels of N in soil were not correlated with the number of hardwoods removed. There were no differences between mixed and pure stand in either the weight of forest floor or its rate of N mineralization. The quantity of N returned in leaf litter was about 10 kg/ha/yr more in stands without hardwoods. In mixed stands, soil N mineralization was positively correlated with forest floor mineralization, but not with sandtrap accretion. In pure conifer stands, the opposite was true.

193. Petersen, T.D. 1980. First-year response of Douglas-fir after release from snowbrush ceanothus. M.S. thesis. Oregon State University, Corvallis, Oregon. 49 p.

In the western Cascade Range, Douglas-fir yield may improve if competition from snowbrush is eliminated. During the summer drought, soil moisture conservation depended upon the degree of vegetation control. When competing vegetation was completely controlled, soil water potential remained near field capacity throughout summer. In contrast, when competing vegetation was only partially controlled, soil moisture was largely depleted to a depth of 40 cm; in undisturbed stands, moisture was depleted to a depth of at least 1 m. The depletion of the lower profile soil water was closely followed by the seasonal water stress of Douglas-fir. In younger stands with low stem biomass, the availability of light greatly increased after manual release. In older stands, there was no significant increase in light beneath the dead canopy. In the 1st season after treatment, stress from the full and sudden exposure to light reduced Douglas-fir height growth. After other treatments, there was no increase in height growth. Based on these environmental and growth responses, it is hypothesized that the more favorable water and light environments after release will promote increased Douglas-fir growth in the future.

194. Preest, D.S. 1973. Summer soil moisture dynamics in a young Douglas-fir plantation as influenced by three herbaceous weed communities. M.S. thesis. Oregon State University, Corvallis, Oregon. 93 p.

When chemicals were used to control grasses in Douglas-fir plantations, those sites became predisposed to heavy forb and forb-annual grass infestations in subsequent years. Early in the season in the Oregon Coast Range, bentgrass made heavy demands in the upper profile soil moisture, but only moderate demands in the lower profile. This pattern was consistent with its characteristics of aestivating and rooting. Early-season demands by moderate to dense pure forbs on the upper profile were relatively light, but were heavy later in the season at all levels in the profile. The most demanding was the forb/annual grass mixture, which caused heavy upper-profile moisture withdrawal early in the season coupled with sustained lower-profile moisture depletion. This pattern was again consistent with the phenological and rooting habits of the plants.

Much water was eventually lost through increased surface evaporation and unsaturated flow; because of weed control, it was not transpired. Although with weed control only a small amount of the moisture saved from transpirational loss was made available to trees, that water was important in relieving tree moisture stress. It may be desirable and perhaps economically justifiable to partially or completely control herbaceous weeds in young conifer plantations.

195. Price, D.T., T.A. Black, and F.M. Kelliher. 1986. Effects of salal understory removal on photosynthetic rate and stomatal conductance of young Douglas-fir trees. Canadian Journal of Forest Research 16:90-97.

Photosynthesis rates significantly increased both diurnally and seasonally in 32-yr-old Douglas-fir trees when the understory was removed. Stomatal conductance did not generally limit photosynthesis unless vapor pressure deficit was high and photon flux density was saturating. When salal was removed, tree growth responded to the high soil water potential, which enabled increases in both photosynthetic capacity and stomatal conductance.

196. Rhoades, C.C., and D. Binkley. 1992. Spatial extent of impact of red alder on soil chemistry of adjacent conifer stands. Canadian Journal of Forest Research 22:1434-1437.

The availability of N increased for about 8 to 12 m downslope from a red alder-conifer stand on a relatively infertile site, but no effect was apparent upslope. Soil pH in a conifer stand was depressed for about 5 m from a red alder-conifer stand on a fertile site, but there was no trend in N availability. Red alder appeared to affect soil chemistry only to a distance of less than half the height of the trees.

197. Robinson, M.C. 1964. Temperature microenvironments associated with early stages in plant succession on Douglas-fir clear-cuts in the Oregon Coast Range. M.S. thesis, Oregon State University, Corvallis, Oregon. 59 p.

In the 2nd year after clearcutting and burning a Douglas-fir site, wood groundsel characteristically dominated the early stages of succession, followed by bull thistle in the 3rd year, and velvetgrass and deervetch for the following years. The physical form of these species affected air temperature 1.5 in. above the ground. Deervetch is characterized by a dense canopy of leaves 1 or 2 ft above the ground, which reduced maximum air temperatures by about 7 degrees compared with bare ground. Velvetgrass has no leaf canopy but forms a dense mat at the soil surface, which increased maximum air temperature by 5 degrees. Groundsel and bull thistle similarly decreased air temperatures by about 5 degrees. Under vegetation, soil temperatures at a depth of 3 in. were always cooler than under bare ground. The plants appeared to act as a heat insulating layer; differences in temperature seemed to be correlated with the quantity of plant material. During the early stages of plant succession, bull thistle and wood groundsel created a changeable temperature environment over the clearcut. During the later stages of succession (velvetgrass and deervetch), temperatures were relatively stable. Douglas-fir seedlings should survive best when planted within 3 yr of clearcutting.

198. Rose, S.L., and C.T. Youngberg. 1981. Tripartite associations in snowbrush (*Ceanothus velutinus*): effect of vesicular-arbuscular mycorrhizae on growth, nodulation, and nitrogen fixation. Canadian Journal of Botany 59:34-39.

Nitrogen-fixing nonleguminous (actinorrhizal) snowbrush seedlings and 2 microorganisms, a vesicular-arbuscular (VA) mycorrhizal fungus and a filamentous actinomycete capable of inducing nodule formation, established symbiotic associations. The VA fungus was both inter- and intra-cellular within the root tissue and was found within the nodules; the actinomycete was in nodules where atmospheric dinitrogen is fixed and made available to the host plant. The 2 symbiotic microorganisms made N and P available to the host plant. The possibility of a direct interaction between the endophytes in the symbioses was investigated. Total dry weight of shoots and roots, number of nodules, weight of nodular tissue, higher levels of N, Ca, and P, and nitrogenase activity (as measured by ethylene reduction) increased in dually colonized plants.

199. Scott, W. 1969. Effect of snowbrush on the establishment and growth of Douglas-fir seedlings. M.S. thesis. Oregon State University, Corvallis, Oregon. 128 p.

Planted Douglas-fir seedlings survived and grew better under snowbrush than in the open. The brush cover greatly reduced browsing damage. The top 6 in. of soil under snowbrush contained more moisture throughout the growing season than did soil in the open. Douglas-fir seedlings growing in association with snowbrush had greater concentrations of N, Ca, Mg, and K in needles than did those growing in the open. Snowbrush not only fixed N, but also helped maintain more cations in the surface soil through recycling in the litter. In the western Cascade Range, snowbrush appears instrumental in creating both a microenvironment and a nutrient regime that are more favorable for newly established Douglas-fir seedlings.

200. Tarrant, R.F. 1972. The role of alder in improving soil fertility and growth of associated trees. P. 17-34 *in* Managing Young Forests in the Douglas-fir Region. Volume 3. A.B. Berg, ed. School of Forestry, Oregon State University, Corvallis, Oregon.

Red alder appears to positively affect properties of forest soil and increase the vigor and growth of associated vegetation. Because red alder fixes N and improves soil fertility, foresters should consider it a potentially valuable species, rather than an aggressive weed.

201. Tarrant, R.F., K.C. Lu, W.B. Bollen, and J.F. Franklin. 1969. Nitrogen enrichment of two forest ecosystems by red alder. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW-76. 8 p.

A conifer stand of Douglas-fir, western hemlock, and Sitka spruce was compared with a 40-yr-old natural mixed stand of red alder and conifers and a pure stand of red alder. The conifer stand had 490 trees and 4232 lb/ac litterfall, the mixed stand had 860 trees and 5930 lb/ac litterfall, and the red alder stand had 381 trees and 4490 lb/ac litterfall. In each stand, the litter weight varied seasonally and annually. The annual variation was probably caused by changes in weather from year to year. The percent of N in litterfall varied seasonally and annually in all stands and the interaction between season and year was highly significant. Over 3 yr, the average percent of N in the litterfall of the mixed stand was more than double and in pure alder stands was nearly triple the N in the pure conifer stand. In the annual litterfall, the average weight of N was 104, 100, and 32 lb/ac, respectively, for the mixed, alder, and conifer stands. In the mixed stand, the net annual addition of alder-fixed N returned in litter was estimated at 72 lb/ac; in the pure red alder stand, it was 68 lb/ac.

202. Tarrant, R.F., and R.E. Miller. 1963. Accumulation of organic matter and soil nitrogen beneath a plantation of red alder and Douglas-fir. Soil Science Society of America Proceedings 27:231-234.

The amount of N in the forest floor and upper 24 in. of mineral soil was significantly greater in a mixed plantation of red alder and Douglas-fir than in a plantation of pure Douglas-fir. In the upper 12 in. of mineral soil, the organic matter content was also greater and at 0 to 3 in., bulk density was significantly lower. The C-N ratio was lower beneath the alder-fir stand, for both the forest floor and at 0 to 3 in. To a depth of 36 in. beneath the alder-fir plantation, the amount of N was 938 lb/ac greater. Consequently, beneath the mixed stand, there was an average of 36 lb/ac more of annual N accumulation than under the pure conifer stand.

203. Tripp, L.N., D.F. Bezdicek, and P.E. Heilman. 1979. Seasonal and diurnal patterns and rates of nitrogen fixation by young red alder. Forest Science 25:371-380.

In 2- and 3-yr-old red alder, dinitrogen fix-ation occurred during the 7 mo corresponding to the growing season, with maximum fixation rates in May and June. The highest rates occurred at midday and were 4 to 6 times greater than rates at night. For the growing season, total N fixation averaged 7.7 g/tree, which was about 70% of the total N accumulated during the growing season by the plant. Estimated annual N fixation was at 62 kg/ha at a stand density of 8000 trees/ha.

204. Turner, J., J.N. Long, and A. Backiel. 1978. Under-story nutrient content in an age sequence of Douglas-fir stands. Annals of Botany 42:1045-1055.

Nutrient concentrations were significantly different for understory species in Douglas-fir of 9 to 95 yr. Mean concentrations of some nutrients appeared to be associated with stand maturity; ash, K, and Mg declined, P and Mn increased, and N and Ca reached a maximum, then declined, when stands were 20 to 30 yr. The nutrient content of the stand understory components are presented and discussed.

205. Weetman, G.F., R. Fournier, J. Barker, and E. Schnorbus-Panozzo. 1989. Foliar analysis and response of fertilized chlorotic western hemlock and western redcedar reproduction on salal-dominated cedar-hemlock cutovers on Vancouver Island. Canadian Journal of Forest Research 19:1512-1520.

The response of western hemlock to N and P was identified with foliar vector analysis and confirmed by subsequent 3-yr height growth. When salal with removed, western redcedar increased N uptake. Although western redcedar also responded to the addition of N and P, vector analysis was not feasible because growth was indeterminate. The primary cause of inadequate N and P nutrition may be competition or allelopathy from salal.

206. Wollum, A.G., II, C.T. Youngberg, and F.W. Chichester. 1968. Relation of previous timber stand age to nodulation of *Ceanothus velutinus*. Forest Science 14:114-118.

As the age of the previous stand increased, there was an exponential decline in the nodulation potential of soils supporting snowbrush. Two snowbrush ecotypes were indicated by a greenhouse study:one originated in association with Douglas-fir and one originated in association with ponderosa pine. The nodulation of snowbrush was not caused by a seed-borne organism.

207. Youngberg, C.T., A.G. Wollum, and W. Scott. 1979. *Ceanothus* in Douglas-fir clearcuts: nitrogen accretion and impact on regeneration. P. 224-233 *in* Symbiotic Nitrogen Fixation in the Management of Temperate Forests. J.C. Gordon, C.T. Wheeler, and D.A. Perry, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Fifteen years after an old-growth stand of Douglas-fir was logged and burned, aboveground snowbrush biomass was 62,000 kg/ha. Accretion of N in snowbrush biomass, litter, and soil was 1261 kg/ha. Snowbrush ameliorated surface soil temperatures and soil moisture in the seedling root zone. Under snowbrush cover, milacre stocking of Douglas-fir seedlings was 48% greater than in the open, and both annual height growth and total height were also greater. When grown under snowbrush, seedlings did not experience N stress during the growing season and had higher foliar concentrations of N than when grown in the open.

208. Zavitkovski, J. 1966. Snowbrush, *Ceanothus velutinus* Dougl., its ecology and role in forest regeneration in the Oregon Cascades. Ph.D. thesis, Oregon State University, Corvallis, Oregon. 102 p.

After an absence of 300 to 500 yr on a site, snowbrush may occur. Seed that accumulated in the duff and upper mineral soil layer during the brief lifetime of the snowbrush stands may be stimulated by fire and germinate after winter stratification. Snowbrush has occupied extensive areas that were logged and burned. Snowbrush may benefit or harm managed forests. Its desirability generally seems to be inversely proportional to the fertility of the soil. Snowbrush may benefit concurrently grown coniferous species but only after the first 8 yr. Planted conifers have significantly higher survival on freshly burned clearcuts than under live or dead snowbrush, or in snowbrush stand openings.

209. Zavitkovski, J., and M. Newton. 1968. Ecological importance of snowbrush (*Ceanothus velutinus*) in the Oregon Cascades. Ecology 49:1134-1145.

In the upper 2 ft of soil, total N was higher under snowbrush than in the open, but the N loss from open areas rather than N fixation may have caused the difference. Under snowbrush, total N in the upper 15-cm soil layer did not differ from that under nonfixing shrub species. Various species of shrubs may increase total N in soil under their canopies, even if they do so only by accumulation from sites that lack vegetation. The biomass of mature snowbrush stands may have more N than that of other shrubs; in this study, annual N fixation ranged from zero to about 20 kg/ha. Snowbrush did not add significant N to the soil through fixation in bioassays with Douglas-fir seeds and hemlock seedlings. Snowbrush did contribute large amounts of N-rich litter to the formation of a new organic layer, however.

B. Influences on Stand Development

210. Allen, H.H. 1969. The inter-relationship of salmonberry and Douglas-fir in cutover areas. M.S. thesis. Oregon State University, Corvallis, Oregon. 56 p.

The height growth of salmonberry shrubs and the initial size of the opening largely determine encroachment on Douglas-fir. Salmonberry suppresses the growth of Douglas-fir seedlings. Rabbits frequently damage seedlings that are dominated by salmonberry or even in close proximity to it.

211. Berntsen, C.M. 1961. Growth and development of red alder compared with conifers in 30-year-old stands. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper 38. 20 p.

The volume of a 29-yr-old stand of pure conifer equaled that of a 32-yr-old, unthinned stand of pure red alder and was greater than those of thinned alder and unthinned mixed stands of alder and conifers. At age 31, yield of the unthinned stand of red alder was about 13% more than that of the thinned stand. At age 29, yield of the unthinned, mixed stand was lower than all the other experimental stands.

212. Binkley, D. 1984. Douglas-fir stem growth per unit of leaf area increased by interplanted Sitka alder and red alder. Forest Science 30:259-263.

The effect of red alder on the ratio between stem growth and leaf area of Douglas-fir in a 23-yr-old plantation depended on the method used to calculate it. When 5-yr stem growth (biomass)/leaf area (based on leaf area:sapwood area) was used, Sitka alder increased it 40% and red alder, 50%. Greater net photosynthetic rates and a shift in photosynthate allocation within trees probably caused the increase in stem growth per unit leaf area.

213. Binkley, D. 1984. Importance of size-density relationships in mixed stands of Douglas-fir and red alder. Forest Ecology and Management 9:81-85.

Mixed stands of red alder and Douglas-fir had higher mortality rates on fertile sites than did stands of pure conifer. The stands of pure conifer were well below the maximum tree size and density relationship on infertile sites compared with both fertile sites and mixed stands, however, which suggests that alder fixed N from under-utilized site resources.

214. Brand, D.G. 1985. A competition index for predicting the vigour of planted Douglas-fir in southwestern British Columbia. Canadian Journal of Forest Research 16:23-29.

Data from 124 planted, 1- to 5-yr-old Douglas-fir trees were used to derive an index to quantify competition from brush in coastal plantations. The competition index included brush proximity, relative height, and percent ground cover. It could be used to predict changes in tree vigor measured as a relative production rate, and it appeared to act as a measure of light interception around the tree crown. Tree vigor appeared to be a function of the competition index ($r^2 = 0.71$) and the age of the tree (from planting). Measures of growth vigor that were based on foliage were more strongly related to the index than were measures based on basal area or height. The index may be used to assess problems of interspecific competition in young plantations of Douglas-fir.

215. Brand, D.G. 1986. Competition-induced changes in developmental features of planted Douglas-fir in southwestern British Columbia. Canadian Journal of Forest Research 16:191-196.

In 1- to 5-yr-old Douglas-fir, the specific foliage leaf area, the height-to-basal area allometric relationship, and nodal-shoot bud production were the developmental characteristics that could best be used to assess competition stress. Leaf internode length and foliar nitrogen status were less well correlated with the competition index. The effects of brush competition on planted trees are expressed as developmental acclimation to lower light intensity. The effects of changes in availability of nutrients or moisture was less evident in developmental expression, but reduced demand or secondary brush canopy effects may have confounded that expression.

216. Brodie, J.D., and J.D. Walstad. 1987. Douglas-fir growth and yield response to vegetation management. P. 273-294 in Forest Vegetation Management for Conifer Production. J.D. Walstad and P.J. Kuch, eds. John Wiley & Sons, New York.

Several empirical case studies have illustrated the effects of competing vegetation on the growth and yield of Douglas-fir. Competition from weeds reduces stocking, growth, or both. The stage of conifer development and the type and severity of competition determine the extent of the reductions. For example, Douglas-fir seedlings were virtually eliminated by a dense thicket of red alder, but the growth of well-established saplings was either unaffected or affected only moderately by a sparse cover of ceanothus sprouts. Stand development under different regimes of management can be projected with simulation models. Stocking levels and growth rate can be adjusted to stand development under different management regimes by adjusting stocking level to account for the effects of competition from other vegetation.

217. Carlton, G.C. 1988. The structure and dynamics of red alder communities in the central Coast Range of western Oregon. M.S. thesis. Oregon State University, Corvallis, Oregon. 173 p.

According to conventional succession theory, the relatively short-lived pioneer species, red alder, should relinquish sites to longer-lived conifers such as Douglas-fir. However, on sites where red alder is dominant, studies have found very little tree regeneration. Therefore, when red alder senesces, species of shrubs, such as salmonberry or vine maple, may become dominant. For red alder to successfully colonize sites, disturbance was important, but the structure or productivity of subsequent stands did not depend on the type of disturbance. Stand structure was more dependent on site conditions such as physiographic position, elevation, and slope than on agents of disturbance. Under intact canopies or under the discontinuous canopies of red alder in senescence, there was little tree regeneration. Tree regeneration in older stands was apparently inhibited by abundant understory vegetation, which competed for light and other resources and directly affected regeneration by depositing litter on the forest floor. Communities dominated by salmonberry or vine maple appeared to be the most likely succession stage on most sites. On some sites, however, a discontinuous canopy of western hemlock and western redcedar saplings might eventually form.

218. Chan, S.S. 1984. Competitive effects of overtopping vegetation on Douglas-fir morphology in the Oregon Coast Range. M.S. thesis. Oregon State University, Corvallis, Oregon. 49 p.

As levels of overtopping plant competition increased, Douglas-fir saplings were generally smaller. The strongest indicator of competition from overtopping vegetation was basal stem diameter, which was most negatively affected. Tree height had a similar but weaker relationship. Sapling height and basal stem diameter for the current year (N + 1) were strongly determined by sapling size in the previous year (N) and degree of overtopping vegetation. Leader growth predictions in year N + 1 had similar but more moderate relationships. The exact mechanisms of competition were not identified, although strong empirical relationships were found. Overtopping vegetation appears to negatively affect the size of Douglas-fir during the current year, then continues to affect size in subsequent years through compounding. Competition from overtopping brush must be controlled in the early years of reforestation.

219. Chan, S.S., and J.D. Walstad. 1987. Correlations between overtopping vegetation and development of Douglas-fir saplings in the Oregon Coast Range. Western Journal of Applied Forestry 2:117-119.

Sapling growth (as indicated by size) generally decreased as the amount of overtopping brush increased. Growth of basal stem diameter was most reduced, but growth was also reduced for tree height and other morphological features.

220. Cole, E.C. 1984. Fifth-year growth responses of Douglas-fir to crowding and other competition. M.S. thesis. Oregon State University, Corvallis, Oregon. 321 p.

Competition from red alder and grass, as well as other Douglas-fir, inhibited growth of Douglas-fir. On a plantation, competition from

grass was only severe during the initial years, whereas competition from red alder became more pronounced over time. Density, competitor type, site, and the interactions among them determined growth. Leaf weight, stand density, and competitor type can be used to predict the leaf area of individual Douglas-fir under competition. The ratio of leaf area to leaf weight increased as shade needle formation responded to density and competitor type. The most vigorous trees did not have the highest growth efficiency (stemwood volume production/unit of leaf area). High productivity was correlated with high leaf-area index on a per-hectare basis, but on a per-tree basis, the relation was reversed.

221. Cole, E.C., and M. Newton. 1986. Nutrient, moisture, and light relations in 5-year-old Douglas-fir plantations under variable competition. Canadian Journal of Forest Research 16:727-732.

There were significant differences between sites in foliar nitrogen concentrations in Douglas-fir and total and available soil N, but differences were not significant between competition treatments. Douglas-fir grown with grass had significantly higher levels of foliar phosphorus. At high densities, both P and N were lower. The lowest predawn moisture stress occurred under Douglas-fir growing alone at low densities, but stresses varied with site, competitor, and density. The lowest values for canopy light penetration occurred under red alder, and varied with competitor, density, and height above ground. Red alder reduced the amount of light and moisture available and grass primarily competed for moisture. Levels of N in soil or in Douglas-fir foliage did not increase on any site or at any density with nodulated red alder.

222. Cole, E.C., and M. Newton. 1987. Fifth-year response of Douglas-fir to crowding and nonconiferous competition. Canadian Journal of Forest Research 17:181-186.

The aboveground dry weight per Douglas-fir tree decreased with crowding and competition from grass and red alder. When tree densities were higher, dry weight/ha was higher, although as the larger trees at low densities form fully stocked stands, dry weight was expected to increase. Grass affected growth of Douglas-fir most on the driest site. Red alder decreased the growth of Douglas-fir on all sites, but most significantly on the coastal site, where the most limiting factor was light and the least limiting factor was moisture. Low stocking levels and control of competing vegetation should produce the largest individual trees.

223. Cole, E.C., M. Newton, and S.M. Zedaker. 1983. Intra- and interspecific competition in Douglas-fir plantations in the Oregon Coast Range. Proceedings, Western Society of Weed Science 36:72-76.

In a 5-yr study, the density of Douglas-fir stands had a pronounced effect on average height and diameter of the trees, whereas grass and red alder had a lesser effect. The decrease in diameter at 15 cm above ground ranged from negligible to 10.4 mm because of grass. Height growth decreased by 0 to 0.63 m during 5 yr because of red alder and grass. After a year of total weed control, the effect of grass was much less than would be anticipated for established grass, but growth impact was still measurable even under environments where moisture is generally not regarded as critical for established trees.

224. Cooke, P.T. 1987. The role of density and proportion in allometric equations of Douglas-fir and red alder seedlings. M.S. thesis. Oregon State University, Corvallis, Oregon. 46 p.

Stem diameter, total height, and crown width of 3-yr-old Douglas-fir and red alder were the best predictors of biomass components. For predictions of Douglas-fir leaf biomass and total biomass, density was a significant variable. However, density was excluded from the model because, unlike normal yield-density relationships, it was positively correlated with biomass. For predictions of Douglas-fir root biomass, a significant variable was percent cover of shrub and herbaceous species on the plot. The total biomass of red alder was correlated with proportion, which indicated that root biomass was higher when sample trees were surrounded by more alder than Douglas-fir. The percent cover of shrub and herbaceous species was generally the most significant spatial variable predicting the biomass of Douglas-fir. For predicting the biomass of red alder, the most significant spatial variable was the distance to the nearest tree.

225. Dunlap, J.M., and J.A. Helms. 1983. First year growth of planted Douglas-fir and white fir seedlings under different shelterwood regimes in California. Forest Ecology and Management 5:255-268.

In 3 shelterwoods with residual basal areas of 10, 15, and 20 m^2/ha, the survival of Douglas-fir was greater than 93%. As the density of the overstory increased, white fir survival ranged from 63 to 85%. For both species, height growth was about 2.3 to 3.1 cm for the control and under the least-dense shelterwood, respectively. In treatments 10 and 15, stem diameter growth (1.3 mm) was significantly greater than in treatments 20 and the control (0.3 mm). As residual basal area in shelterwoods decreased, shoot:root ratios and biomass tended to increase in Douglas-fir and decrease in white fir, although biomass production was similar for both. In the uncut stand, plant moisture stress for Douglas-fir and white fir reached -19 and -22 bar, respectively, and seedling growth was lowest. Container-grown 1st-yr Douglas-fir can successfully survive and grow in a 10 m^2/ha shelterwood; bareroot white fir prefers a density of 15 m^2/ha. Under shelterwoods of up to 20 m^2/ha, there appears to be no delay in the initiation of shoot growth.

226. Emmingham, W.H., M. Bondi, and D.E. Hibbs. 1989. Underplanting western hemlock in a red alder thinning: early survival, growth, and damage. New Forests 3:31-43.

After a 14-yr-old stand of red alder was thinned, seedling survival for western hemlock wildlings averaged 78 and 52%, respectively, for the 1st and 5th growing seasons. Under various thinning regimes, average 5th yr height growth of surviving seedlings ranged from 38 to 49 cm, but in the unthinned stand it was only 9 cm. Growth and survival were reduced when wildlife browsed seedlings or when seedlings were pinned by falling debris.

227. Hansen, A.J., S.L. Garman, P. Lee, and E. Horvath. 1993. Do edge effects influence tree growth rates in Douglas-fir plantations? Northwest Science 67:112-116.

Within forest fragments, microclimate, forest dynamics, and other ecological properties are influenced by patch size and edge structure. The effects of such "edges" on young plantations embedded in a matrix of older forest are largely unknown. When the effects of tree density were controlled for, the distance of trees from the plantation edge significantly affected height and dbh of Douglas-fir. Trees 20 m from the edge of the plantation were smaller than all the rest. This negative effect should be considered in plantation design, especially when small "gap" cuts are considered.

228. Harrington, T.B. 1989. Stand development and individual tree morphology and physiology of young Douglas-fir (*Pseudotsuga menziesii*) in association with tanoak (*Lithocarpus densiflorus*). Ph.D. thesis. Oregon State University, Corvallis, Oregon. 198 p.

Competition from tanoak decreased the quantity and size of buds, internodes, and needles for shoots of Douglas-fir, thereby also reducing growth potential in future years. When competition reduced numbers of internodes, potential shoot growth was reduced; when basal area growth was reduced, stem circumference and diameter growth were lower. Douglas-fir shaded by tanoak had photosynthesis rates that were light limited throughout the year. In areas where tanoak was dominant, both shaded and unshaded Douglas-fir had elevated leaf temperatures, lower relative humidities, and less available soil water during the growing season, which limited photosynthesis rates.

229. Harrington, T.B., and J.C. Tappeiner II. 1991. Competition affects shoot morphology, growth duration, and relative growth rates of Douglas-fir saplings. Canadian Journal of Forest Research 21:474-481.

For Douglas-fir shoots, competition reduced the number and size of buds, length of shoots and needles, number and length of internodes, and biomass of foliage and wood. Reductions in the length and, especially, the number of internodes, were responsible for differences in the length and biomass of Douglas-fir shoots. In Douglas-fir, competition from previous years, as manifested in bud size and stem circumference, explained 65 and 92% of the variation in the growth of shoots and stem basal area, respectively, in the following year. During 2 growing seasons, both the rates and the duration of basal area growth were limited by competition; competition reduced only the rate of height growth, however.

230. Harrington, T.B., J.C. Tappeiner II, and T.F. Hughes. 1991. Predicting average growth and size distributions of Douglas-fir saplings competing with sprout clumps of tanoak or Pacific madrone. New Forests 5:109-130.

For Douglas-fir, 53, 66, and 90% of the variation in the average annual increment of cover, height, and diameter-squared, respectively, can be explained with biologically based nonlinear equations for average growth and size distributions. For hardwood and understory vegetation, annual increment equations explained only 10 to 12% of the variation because of the variability of the parameters. For the same initial levels of cover, model simulations demonstrated that tanoak cover both grew and limited Douglas-fir growth more than did Pacific madrone. Douglas-fir growth increased when understory was suppressed only in the absence of hardwood cover.

231. Harrington, T.B., J.C. Tappeiner II, T.F. Hughes, and A.S. Hester. 1991. Planning with PSME: a growth model for young Douglas-fir and hardwood stands in southwestern Oregon. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Special Publication 21. 14 p.

Plantation Simulator-Mixed Evergreen (PSME) is a computerized growth model for predicting development of Douglas-fir plantations in southwestern Oregon under specific levels of competition from tanoak, Pacific madrone, chinkapin, and from herb + shrub vegetation. It uses values for cover of competing vegetation, average size of Douglas-fir seedlings at stand age 3 yr, and preharvest stand information on hardwood basal area and stem density to provide tabular and graphic output of the development of the Douglas-fir, hardwood, and herb + shrub components through stand age 10. It also predicts frequency distributions of Douglas-fir height and stem diameter at 10 yr. PSME can be run on any IBM-compatible microcomputer (hard disk not necessary) with a copy of a BASIC interpreter, such as GW-BASIC. This user's manual provides software for PSME, information on model installation and application, and techniques for collecting input data.

232. Henderson, J.A. 1970. Biomass and composition of the understory vegetation in some *Alnus rubra* stands in western Oregon. M.S. thesis, Oregon State University, Corvallis, Oregon. 64 p.

In red alder stands of 2 to 64 yr in age, biomass varied from 1234 kg/ha at 2 yr to 7700 kg/ha in one of the older stands. For the first 64 yr, annual net productivity was estimated at 97 kg/ha/yr. Understory biomass comprised only up to 2.5% of the overstory biomass. As age of the overstory increased, composition varied considerably. The process of succession from a grass-herb to a shrub-fern dominated understory was quantified. Without a suitable source of conifer seed, brush fields of salmonberry may dominate lands once dominated by red alder.

233. Hobbs, S.D., and P.W. Owston. 1985. Plant competition associated with Douglas-fir shelterwood management in southwest Oregon. P. 17-21 *in* Proceedings of a Workshop on the Shelterwood Management System. J.W. Mann, and S.D. Tesch, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Shelterwood prescriptions are based on the assumption that overstory shade ameliorates understory microclimate, thus improving the performance of underplanted seedlings. However, competition for available soil moisture from overstory and understory vegetation, as well as decreased light, may negate the beneficial effects of lower soil temperatures. The development of understory competitors may be related to the amount of overstory cover. The importance of minimizing competition in shelterwood systems in the 2 to 4 yr after underplanting is discussed.

234. Horowitz, H. 1982. Conifer-shrub growth interactions on proposed brush control sites in the western Oregon Cascades. Ph.D. thesis. University of Oregon, Eugene, Oregon. 282 p.

There was no correlation between the stocking or growth of crop trees and variations in density of brush. Mean height and leader growth were slightly higher for conifers at the edge of patches than for conifers inside or outside patches. Most crop trees dominated brush. Mean growth of the few overtopped trees was much below average. On all but the sprayed sites, mean leader growth increased annually for 3 yr; in the 1st yr after treatment, the sprayed sites showed a slight negative response. This discussion includes an overview of snowbrush management in Douglas-fir plantations and an evaluation of the potential benefits of treatment.

235. Howard, K.M. 1979. The influence of seral Coast Range vegetation on the growth habit of juvenile Douglas-fir. M.S. thesis. Oregon State University, Corvallis, Oregon. 208 p.

Six Douglas-fir stock types were grown with typical seral Coast Range vegetation. Juvenile seedling growth was analyzed to determine the influences of competition and to compare characteristics and growth patterns among stock types. Variations in the seedling growth over 7 yr with vegetation groups were consistently associated with the initial height of the seedling, rather than with stock type. On cutovers at 6 and 7 yr, site vegetation explained only a small amount of the variation in current growth. The effects of competing vegetation on tree seedlings appear to be cumulative, however. The present status of tree seedlings was highly correlated with competitive stress from previous years. Seral vegetation that overtops tree seedlings, such as tall hardwoods and sprouts that reduce available light, has more influence on seedlings than does vegetation such as low shrubs and herbs, which encroach on them from the sides or from below. In coastal mesic to moist brushy areas, the advantages of larger stock types were still obvious after 7 yr, even though there were no significant differences in seedling growth between stock types, vegetation groups, or sites during that time. Larger seedlings were able to establish as much as 3 yr before smaller seedlings and had survival rates that were higher than those of smaller seedlings. Larger stock types maintained their initial height advantage and, at 7 yr, were less susceptible to animal damage and to adverse site influences than were smaller stock types.

236. Howard, K.M., and M. Newton. 1984. Overtopping by successional Coast Range vegetation slows Douglas-fir seedlings. Journal of Forestry 82:178-180.

Growth of Douglas-fir seedlings 5 and 7 yr after planting was not affected by plants that formed ground cover or encroached from the side. Seedlings that were overtopped, however, grew more slowly and were smaller than seedlings not shaded by other vegetation. Where woody competitors and bracken abound, large transplants should be used and overtopping vegetation should be controlled.

237. Hughes, T.F., J.C. Tappeiner II, and M. Newton. 1990. Relationship of Pacific madrone sprout growth to productivity of Douglas-fir seedlings and understory vegetation. Western Journal of Applied Forestry 5:20-24.

Total aboveground biomass of 9-yr-old Pacific madrone sprouts ranged from 8390 to 25,630 kg/ha and the average leaf area index (LAI) ranged from 1.0 to 3.5 m^2/m^2, respectively, on high and low density plots 5 yr after density treatments. There was an inverse relationship between diameter of 9-yr-old Douglas-fir and LAI of madrone; diameter ranged from 27 mm on the high-density plots to 54 mm where madrone was absent. Growth of Douglas-fir was significantly faster in the absence of madrone than in other treatments. There was an inverse relationship between the density of shrubs, forbs, and grasses and the LAI of madrone, which suggests that during secondary succession, understory species are quickly excluded from young stands of madrone. Equations were developed to relate 5-yr growth of 9-yr-old Douglas-fir to measures of seedling size and madrone density made when the plantation was 5 yr old.

238. Jaramillo, A.E. 1988. Growth of Douglas-fir in southwestern Oregon after removal of competing vegetation. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Note PNW-RN-470. 10 p.

In plots that had been totally cleared of non-conifer vegetation, young Douglas-fir trees were larger after 3 growing seasons than trees in plots that had been partially cleared or not cleared at all. There were significant differences in height and diameter between treatments, and differences in diameter were highly significant on another unit.

239. Klinka, K., R.E. Carter, M.C. Feller, and Q. Wang. 1989. Relations between site index, salal, plant communities, and sites in coastal

Douglas-fir ecosystems. Northwest Science 63:19-27.

Salal has been thought to adversely affect the growth of trees and is often considered an undesirable forest plant. Salal cover did not cause significant differences in the foliar nutrients of Douglas-fir. Regression analyses showed that the relationship between site index and salal cover was poor, which suggests that salal cover had no major adverse effect on the height growth of the Douglas-fir. Site index was better predicted by soil moisture or nutrient regime variables than by vegetation variables not involving salal cover. Tree growth may not necessarily be significantly influenced by salal in coastal Douglas-fir ecosystems.

240. Knowe, S.A. 1994. Effect of competition control treatments on height-age and height-diameter relationships in young Douglas-fir plantations. Forest Ecology and Management 67:101-111.

On 6 sites in the Coast Ranges, there were significant differences in height growth patterns of dominant Douglas-fir trees between sites with total competing vegetation control and either operational release or no treatment. In the total vegetation control treatment, the resulting height-age function depicted growth patterns that were exponential; in the operational release treatment and no treatment, patterns were nearly linear. Quadratic mean diameter prediction and dominant height growth functions were compatible with the height-diameter function. The total vegetation control and the operational release and untreated control treatments were associated with height-diameter curve shapes that differed. Under interspecific competition, Douglas-fir trees (especially those with smaller diameters) were slightly taller. Diameter distribution or stand table projection models developed by using height-age and height-diameter functions may be used to predict dynamics and stand structure in young plantations of Douglas-fir.

241. Knowe, S.A. 1994. Incorporating the effects of interspecific competition and vegetation management treatments in stand table projection models for Douglas-fir saplings. Forest Ecology and Management 67:87-99.

Individual-tree and stand-level models were the basis for a stand table projection system developed for young plantations of Douglas-fir in the Coast Range and Siskiyou Mountains. Relative tree size, defined as the ratio of individual-tree diameter (at 15 or 30 cm above ground level) to quadratic mean diameter, in a projection equation indicated that when competing vegetation was completely controlled, diameters of Douglas-fir in the Coast Ranges became more uniform over time. In the Siskiyou study, quadratic mean diameter was projected with an additional equation, which included the effect of vegetation management treatments expressed as an interaction between intensity (proportion of cover removed by treatments) and dominant height at time of treatment relative to current dominant height of Douglas-fir. For projection periods of 1 and 2 yr, the stand table projection system performed similarly to a system for predicting diameter distributions, which was based on a Weibull distribution function. As the projection period increased to 5 yr, however, the difference between projected and predicted diameter distributions became more pronounced.

242. Knowe, S.A., B.D. Carrier, and A. Dobkowski. 1995. Effects of bigleaf maple sprout clumps on diameter and height growth of Douglas-fir. Western Journal of Applied Forestry 10:5-11.

The effects of bigleaf maple competition on diameter and height growth of 7-yr-old Douglas-fir were examined. The size of Douglas-fir at plantation age 7 and the distance from the stump and crown diameter of the bigleaf maple clump were used to develop growth models for the period from 7 to 11 yr in plantations in Oregon and Washington. Clumps of bigleaf maple 5.7 to 14.6 m from planted Douglas-firs appeared to decrease the dbh and height growth of Douglas-fir; that decrease became greater as the size of the clump increased. These models may be used in determining vegetation management prescriptions on sites with bigleaf maple sprout clumps.

243. Knowe, S.A., T.B. Harrington, and R.G. Shula. 1992. Incorporating the effects of interspecific competition and vegetation management treatments in diameter distribution models for Douglas-fir saplings. Canadian Journal of Forest Research 22:1255-1262.

The effect of competing vegetation in 2- to 8-yr-old plantations of Douglas-fir was incorporated into a diameter distribution prediction method. In the Siskiyou Mountains, quadratic mean diameter and all 4 percentiles of the diameter distribution were affected by cover and total vegetation control; the 0 and 25th percentiles were affected by the intensity of the vegetation treatments; and mean diameter was affected by the interaction between intensity and timing of treatment. In the Coast Ranges, cover of woody vegetation affected only quadratic mean diameter, whereas total vegetation control affected quadratic mean diameter and the 25th percentile. As cover increased, particularly in the Siskiyou Mountains, the predicted distributions showed decreasing variance. As cover increased in the Coast Ranges, the coefficient of variation increased, which indicates that average size affected the variance of stem diameters. Plots with total vegetation control on xeric sites in the Siskiyou Mountains had high variability in diameter, suggesting the expression of microsite variation may be inhibited by interspecific competition.

244. Messier, C., J.P. Kimmins, F.L. Bunnell, and R.K. McCann. 1990. Understanding salal as a competitor. P. 40-42 *in* Vegetation Management: an Integrated Approach. Proceedings of the 4th Annual Vegetation Management Workshop. E. Hamilton, ed. British Columbia Ministry of Forests, and Forestry Canada, Victoria, B.C. FRDA Report 109.

After it is cut, salal reestablishes itself rapidly from rhizomes, and its roots quickly and fully occupy the environment below ground. Competition from salal appears to affect Sitka spruce and western hemlock more than western redcedar and Douglas-fir. After tree crown closure on moist sites, the impact of salal should decline sharply. The impact may last longer on dry sites; therefore, thinning practices should be carefully considered. Slow growth of conifers may reflect poor- to medium-nutrient conditions as much as or more than the presence of salal because salal is most abundant on such sites.

245. Miller, R.E., and M.D. Murray. 1978. The effects of red alder on growth of Douglas-fir. P. 283-306 in Utilization and Management of Alder. D.G. Briggs, D.S. DeBell, and W.A. Atkinson, eds. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-70.

In a 4-yr-old Douglas-fir plantation in southwestern Washington, tree growth was limited by insufficient available nitrogen. Height and diameter of the dominant Douglas-fir increased in association with red alder. At about 30 yr from seed, when the Douglas-fir emerged through the alder canopy, diameter growth began to improve. At 48 yr, the volume per acre of Douglas-fir in the mixed stand averaged about 3100 ft^3 compared to 2900 ft^3 in the pure stand. The volume of red alder was about 2500 ft^3. When red alder is maintained in Douglas-fir stands, merchantable yields on N-deficient sites can increase. About 20 to 40 uniformly distributed red alder per acre should provide adequate N while not seriously reducing Douglas-fir growing stock.

246. Murray, M.D., and R.E. Miller. 1986. Early survival and growth of planted Douglas-fir with red alder in four mixed regimes. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Paper PNW-366. 13 p.

When nonlocal red alder was used to reduce aboveground competition with Douglas-fir, no apparent advantage was gained. When Douglas-fir was released from volunteer alder at age 7 instead of age 3, Douglas-fir density did not decrease and there was no reduction in average height and dbh through plantation age 10. Silviculturists can delay alder control on most sites of average or below-average quality for 6 to 8 yr after planting Douglas-fir when fewer than 500 volunteer alder per acre are established.

247. Newton, M., and E.C. Cole. 1991. Root development in planted Douglas-fir under varying competitive stress. Canadian Journal of Forest Research 21:25-31.

For each competition treatment (weed-free intraspecific competition, grass cover seeded after 1 yr of seedling growth, and red alder interplanted 1:1 among the Douglas-fir), standing aboveground:belowground biomass ratios were the same at age 5 yr. The average shoot: root ratios were about 4:1, except in severely suppressed trees, where they dropped toward 1:1 in trees near death. Planting-induced root deformities, such as J- or L-rooting, did not affect shoot:root ratio or tree size. Future growth and stability were not jeopardized and all root systems had been fully compensated for planting deformities after 5 yr.

248. Newton, M., B.A. El Hassan, and J. Zavitkovski. 1968. Role of red alder in western Oregon forest succession. P. 73-84 *in* Biology of Alder. J.M. Trappe, J.F. Franklin, R.F. Tarrant, and G.M. Hansen, eds. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

The influence of red alder on long-term forest succession was studied. Juvenile growth of red alder appears responsible for the failure of other species, particularly conifers, to maintain positions of dominance. A delay of 4 to 9 yr before alder is established may help Douglas-fir succeed, as will spacing to ensure that Douglas-fir is 8 to 10 yr old before encroachment by alder. Salmonberry, vine maple, and hazelnut, in that order, commonly succeed alder. Eventually, western hemlock may follow, but Douglas-fir is virtually absent except where it develops in openings within the alder stand concurrently with the alder.

249. Newton, M., and D.S. Preest. 1988. Growth and water relations of Douglas fir (*Pseudotsuga menziesii*) seedlings under different weed control regimes. Weed Science 36:653-662.

During the 3 yr after planting, Douglas-fir growth was greatest when weeds were controlled in the season seedlings were transplanted. When weeds were controlled during the 2nd and 3rd yr after transplanting, growth increments were smaller. The benefits of early weed control continued through the 5th yr, indicating that later growth was strongly influenced by conditions during establishment. Tree seedlings on plots with no herbaceous vegetation experienced less water stress and had more available soil water than did those with competing vegetation. When seedlings were watered during the 3rd yr, stem diameter increased, but there was no additional effect thereafter. Five years after transplanting, stem volume increases in the average seedling were linearly related to xylem potential differences during the first 3 growing seasons and to the xylem potential at which photosynthesis ceased, which was -2 MPa.

250. Newton, M., D.S. Preest, and D.E. White. 1987. Effect of relieving moisture stress with extended weed control in Douglas-fir. Proceedings, Western Society of Weed Science 41:129-130.

Moisture stress in trees was relieved when weeds were controlled, which increased the hours each year when stress and photosynthesis were compatible. Photosynthesis tends to shut down in Douglas-fir when moisture stress is about -2.0 MPa. The number of MPa-hr above -2.0 MPa during the 3 yr after planting accounted for 77% of the variation in 5th-yr biomass. Douglas-fir needs about 1700 MPa-hr above -2.0 to survive; additional moisture will significantly contribute to growth.

251. Newton, M., and D.E. White. 1983. Effect of salmonberry on growth of planted conifers. Proceedings, Western Society of Weed Science 36:59-64.

For all conifer species and stock classes tested, mortality increased with each year of delay in planting beyond the 2nd. Sitka spruce best tolerated partial suppression, followed by Douglas-fir, then western hemlock. Larger trees could tolerate suppression better than could smaller trees, but even 90-cm tall planting stock had high death rates in 4-yr-old brush and had major growth losses when delayed 2 yr. When salmonberry was removed before it overtopped seedlings, all planting stock types performed well. In this study, all overtopping wmas detrimental.

252. Petersen, T.D., and M. Newton. 1983. Growth of Douglas-fir following release from snowbrush and forbs in the Oregon Cascades. Proceedings, Western Society of Weed Science 36:58-59.

In Douglas-fir plantations of the central Cascade Range, snowbrush, fireweed, trailing blackberry, and bracken fern suppressed conifer growth. Douglas-fir stem volume increases were greatest after 4 yr when herbicides were used to control all competing vegetation during 1 growing season. Snowbrush appears to compete with Douglas-fir by depleting moisture in the soil. Although forbs suppress the growth of Douglas-fir, the mechanism of competition is less evident. Perhaps because forbs may compete for nutrients or inhibit conifer growth allelopathically rather than by simply competing for water, Douglas-fir grows better when forbs are absent. Douglas-fir should be released at an early age to achieve the maximum reduction in rotation time. The potential benefits of release from shrubs can be negated by forbs; therefore, to promote the maximum growth of Douglas-fir, forbs should be controlled concurrently with shrubs.

253. **Petersen, T.D., M. Newton, and S.M. Zedaker. 1988. Influence of *Ceanothus velutinus* and associated forbs on the water stress and stemwood production of Douglas-fir. Forest Science 34:333-343.**

Where snowbrush was growing with forbs 1 yr after treatment, soil water potential during late summer was less than -1.5 MPa at depths of 10, 40, and 100 cm. When shrubs and forbs were absent, soil water potential was near field capacity at 100 cm throughout the 1979 growing season. During later summer, the predawn stem water potential of Douglas-fir with snowbrush and forbs was significantly lower than for either trees without competitors (complete treatment) or trees with forbs (partial treatment) in the four 5-yr-old stands and in 2 of the 10-yr-old stands. By 1986, when competitors were absent, the stems of Douglas-fir were 2 to 6 cm larger in basal diameter and 1 to 2 m taller. Snowbrush and forbs affected the stem size of 5-yr-old trees more than that of 10-yr-old trees. Growth and water stress were correlated, suggesting that competition for soil water among species during summer drought can limit the production of Douglas-fir stemwood.

254. **Preest, D.S. 1975. Effects of herbaceous weed control on young Douglas-fir moisture stress and growth. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 111 p.**

On hot, clear summer days, the major changes in transpiration resistance in young Douglas-fir appear to depend on several environmental variables. Light appears to control the main early morning and later afternoon opening and closing reactions of the stomates; high leaf temperatures stimulate a partial mid-morning closure. Factors such as pre-dawn TMS, vapor pressure deficit, and total available soil moisture greatly influence sensitivity to those signals and the timing of responses. Within the constraints imposed by the major changes in leaf resistance, the relative and absolute maxima and minima of the TMS curves and the gradients were determined by these latter parameters.

255. **Preest, D.S. 1977. Long-term growth responses of Douglas-fir to weed control. New Zealand Journal of Forest Science 7:329-332.**

In the warm, dry-summer climate of Oregon, competition from grasses and other herbaceous weeds heavily influenced survival and growth of young Douglas-fir transplants. Weed control produced ephemeral increases in available soil moisture, which reduced tree moisture stress in the summer. Although growth increased immediately, it was also positively affected for several years following, which hastened the onset of exponential growth, thereby shortening crop rotation.

256. **Ruth, R.H. 1956. Plantation survival and growth in two brush-threat areas in coastal Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper 17. 14 p.**

The major competitors were salmonberry and associated shrubs; after the 2nd growing season, red alder became increasingly important. Brush, alder, and willow dominated 50% of the site by the spring of 1954, and only 37% of the planted Douglas-fir trees were considered established in the Douglas-fir type. Only 25% of the Douglas-fir planted in the Sitka spruce-western hemlock type were established 5 yr later, and half of those were naturals. Brush, alder, and herbs dominated approximately 64% of the site.

257. **Ruth, R.H. 1957. Ten-year history of an Oregon coastal plantation. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper 21. 15 p.**

Douglas-fir survived better and grew faster than either Sitka spruce or Port-Orford-cedar. The plantation was more successful on the southeast than northwest slope. Shading of planted trees increased during the first 3 yr, then decreased for trees that overtopped competing vegetation. Overtopped trees consistently had greater annual mortality. The study area would have had even greater success had it been replanted immediately after the 1936 fire, because planted trees would have had a head start on competing vegetation and been less subject to overtopping.

258. Shainsky, L.J. 1988. Competitive interactions between Douglas-fir and red alder seedlings: growth analysis, resource use, and physiology. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 221 p.

Quantifiable changes in tree performance can be produced through manipulation of species densities. Complex interactions between species identity, density, size, and time determine tree size. Differences in growth rates, resource acquisition, and physiological tolerance to stress are linked to competitive ability. Red alder showed consistently greater growth potential, lower water stress, and the ability to consume more resources than Douglas-fir. Red alder was able to sequester light resources, which may enable it to assimilate carbon to produce roots for consumption of moisture. Individual red alder trees that could not maintain growth rates equal to that of the main canopy died; Douglas-fir grew slowly under a dense overstory but survived. Red alder had more growth loss because of the proximity of neighbors and was more sensitive to water stress, which suggests that red alder may be more sensitive to competitive stresses than Douglas-fir. Red alder maintained relatively lower levels of physiological stress and continued to suppress Douglas-fir by controlling the limiting resources.

259. Shainsky, L.J., M. Newton, and S.R. Radosevich. 1992. Effects of intra- and inter-specific competition on root and shoot biomass of young Douglas-fir and red alder. Canadian Journal of Forest Research 22:101-110.

The density of red alder after 4 growing seasons had more influence on the root and shoot biomass of both alder and Douglas-fir than did the density of Douglas-fir. Root biomass of Douglas-fir was most reduced when the density of alder was increased from 0 to 1 tree per m^2. All components of biomass were influenced by the interaction between Douglas-fir density and red alder density. The effects of Douglas-fir density were inconsistently significant across alder densities. Root and shoot biomass per tree were reduced while density increased in each species, but competition did not affect allocation of biomass to roots and shoots. Competition did not affect the allometric equations relating biomass to stem diameter and stem volume index. Concentrations of N and P in Douglas-fir foliage in the understory are reported.

260. Shainsky, L.J., and S.R. Radosevich. 1991. Analysis of yield-density relationships in experimental stands of Douglas-fir and red alder seedlings. Forest Science 37:574-592.

Red alder density affected individual tree stem volume of both alder and Douglas-fir twice as much as Douglas-fir density. There was a multiplicative effect on mean tree stem volume from the densities of the 2 species. Red alder and Douglas-fir densities had interdependent effects on tree size. Alder density had varied effects on stem volume and decreased as Douglas-fir density increased. As alder density varied, the effects of Douglas-fir density on stem volume varied. The densities of the 2 species were interdependent and produced an unusual pattern in which the individual stem volume of Douglas-fir increased as its density increased at high densities of alder.

261. Shainsky, L.J., and S.R. Radosevich. 1992. Mechanisms of competition between Douglas-fir and red alder seedlings. Ecology 73:30-45.

Red alder overtopped Douglas-fir and was the dominant competitor. The effects of density on the leaf area of each species mediated competition for light. As alder leaf area increased, it decreased the amount of light reaching understory Douglas-fir. As Douglas-fir leaf area increased, however, the amount of light available to understory conifers increased because Douglas-fir decreased the leaf area of alder. As the density of both species increased, available soil moisture decreased, causing negative leaf water potentials. As plant water stress increased, growth rates declined concurrently. A conceptual model was designed with response variables to show the regulation of growth through the interactions between resource limitations and physiological functions as regulated by density of species.

262.Tappeiner, J.C. 1986. Tanoak and madrone effects on Douglas-fir regeneration: abstract of preliminary results. P. 91-97 *in* Proceedings, Seventh Forest Vegetation Management Conference, Eureka, California.

The density of the hardwood sprout clumps was regulated so that leaf area index (LAI) was approximately 1.0, 0.5, 0.25, and 0.0 times that of the dense plots; within 5 yr of regulating, the hardwood LAI reached about 75% of the maximum in the dense plots. The higher densities affected the diameter growth of Douglas-fir within 2 yr; the effect increased at 3 yr. A good indicator of competition may be bud development, as there were significantly more buds on the main stems of Douglas-fir with low or no competition from hardwoods than on those with competition.

263.Tappeiner, J.C., II, T.F. Hughes, and S.D. Tesch. 1987. Bud production of Douglas-fir (*Pseudotsuga menziesii*) seedlings: response to shrub and hardwood competition. Canadian Journal of Forest Research 17:1300-1304.

There was a significant increase in bud production on the leaders of Douglas-fir seedlings during the 1st growing season after a reduction in shrub and hardwood cover. Buds responded more to levels of competition than did leader length or growth in stem diameter, which usually had no significant differences until the 2nd growing season after treatment. A good indicator of seedling vigor is bud number on the leader. There was a positive correlation between the number of buds produced on the leader during the 1st growing season after treatment and leader, stem diameter, and stem cross-sectional area growth in the 2nd and 3rd yr after treatment.

264.Tarrant, R.F. 1961. Stand development and soil fertility in a Douglas-fir-red alder plantation. Forest Science 7:238-246.

A 27-yr-old plantation of red alder and Douglas-fir had more than twice the volume of a pure Douglas-fir plantation without adverse effects on stem size and with an adequate Douglas-fir stocking level. During ages 20 through 27, diameter and height growth in dominant Douglas-fir were faster, form class and upper crowns were better, and the amount of total nitrogen in soil and foliage was greater. In Douglas-fir dominants of more than 20 yr, red alder evidently contributed to increased growth.

265.Tesch, S.D., and S.D. Hobbs. 1986. Sprouting brush is tough competition for planted Douglas-fir seedlings in southwest Oregon. P. 81-84 *in* Proceedings, Seventh Forest Vegetation Management Conference, Eureka, California.

Douglas-fir seedling root and shoot growth were enhanced when canyon live oak and greenleaf manzanita sprouts were completely controlled. A treatment that removed aboveground competition from a harsh, rocky site, but left brush root systems alive, led to substantially smaller seedlings, as sprouts developed rapidly. When seedlings were planted among 3-yr-old sprouts, additional growth reductions were observed. These brush species can sprout rapidly; therefore, reforestation practices that allow sprouts to develop without control may result in longer rotations.

266.Tesch, S.D., and S.D. Hobbs. 1989. Impact of shrub sprout competition on Douglas-fir seedling development. Western Journal of Applied Forestry 4:89-92.

There were no significant differences after 3 yr in survival of Douglas-fir among levels of competition consisting of 0.25-m-tall dead sprouts, mature shrubs slashed just before planting, and 1-m-tall sprouts of greenleaf manzanita and canyon live oak. Percent cover of competing shrubs and conifer root and shoot biomass were negatively correlated, however. Shoot biomass increased 103 times over dry weight at planting and root biomass increased 25 times under the least competition, but in other treatments dry weights increased less than 5 times. After shrub removal, there was no significant increase in growth of Douglas-fir seedlings when vigorous sprouting occurred during the 1st year. In the minimum-competition plots, however, competitor cover was less than 15% and conifer biomass had increased exponentially after 3 yr.

267.Tesch, S.D., E.J. Korpela, and S.D. Hobbs. 1993. Effects of sclerophyllous shrub competition on root and shoot development and biomass partitioning of Douglas-fir seed-

lings. Canadian Journal of Forest Research 23:1415-1426.

Stumps of mature shrubs slashed just before planting (C2) sprouted quickly and 0.5-m-tall sprouts of shrubs (C3) grew vigorously, thereby competing with planted Douglas-fir seedlings. Seedlings planted among dead shrub sprouts (C1) initially grew without competition. As competition increased, above- and belowground growth were substantially reduced. C1 seedlings had root and shoot biomass of approximately 9 to 10 and 22 to 25 times larger, respectively, than that of C2 and C3 seedlings. Root biomass of seedlings in all 3 treatments increased relatively more during the 1st growing season than did shoot biomass. During subsequent seasons, that growth pattern was reversed; shoot biomass grew more over 5 yr than did root biomass. Over time, both shoot:root and height:diameter ratios increased in C2 and C3 seedlings. In C1 seedlings, however, the shoot: root ratio increased and the height:diameter ratio decreased. There was no significant difference in biomass allocation to shoot and root shown by allometric regression analyses among treatments over time.

268. Wagner, R.G. 1989. Interspecific competition in young Douglas-fir plantations of the Oregon Coast Range. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 200 p.

The importance of interspecific competition was evaluated by using preliminary models that described the relationship between the size of 4- to 9-yr-old Douglas-fir saplings and surrounding nonconiferous woody vegetation. The influence of the abundance, height, distance, azimuth, and spatial arrangement of woody neighbors was evaluated with a gradient of woody and herbaceous vegetation. There was a negative correlation between the height and stem diameter growth of planted Douglas-fir and all neighborhood measures of interspecific competition. The best of 7 tested measures of neighbor abundance was visual estimate of cover for woody species. The models were better when height of the cover relative to the tree was included. Woody neighbors that overtopped Douglas-fir were the primary influence on height growth, whereas all neighbors influenced stem diameter growth. Herbaceous vegetation was less competitive than woody vegetation. Competitive influences were 1-sided or asymmetric on height growth of Douglas-fir and 2-sided or symmetric on stem diameter growth. There were negative correlations between availability of light and soil water in the seedling environment and abundance of neighbors, which was consistent with the best measures of interspecific competition used to predict growth of Douglas-fir. Competition from woody and herbaceous vegetation did not influence seedling survival.

269. Wagner, R.G. 1992. Neighborhood approaches for assessing weed impacts in young forests. Proceedings, First International Weed Control Congress 2:535-539.

Potential mechanisms involved in competitive interaction were examined and predictive computer models were developed on the basis of the importance of abundance, height, distance, azimuth, and spatial arrangement of woody plants surrounding young trees.

270. Wagner, R.G., D. Opalach, B.D. Maxwell, J.H. Dukes, Jr., and S.R. Radosevich. 1989. Interspecific competition index project system (ICIPS) for young Douglas-fir stands on the Siuslaw National Forest: report #2. College of Forestry, Oregon State University, Corvallis, Oregon. 77 p.

The interspecific competition index project system (ICIPS) projects the height and cover dynamics of salmonberry, red alder, thimbleberry, and vine maple, the 4 most abundant woody species on the Siuslaw National Forest. An interspecific competition index based on the total cover contributed by each nonconifer species can be calculated from these projections for any year within the first 20 yr of plantation development.

271. Wagner, R.G., and S.R. Radosevich. 1987. Interspecific competition indices for vegetation management decisions in young Douglas-fir stands on the Siuslaw National Forest: report #1. College of Forestry, Oregon State University, Corvallis, Oregon. 108 p.

A set of preliminary regression equations describe the relation of tree age, interspecific competition, 1st-yr height, animal damage, prescribed burning, slope aspect, and slope angle to the height, stem diameter, stem volume, and crown volume of individual Douglas-fir trees. Twenty-three indices of interspecific

competition, calculated from extensive and intensive vegetation measurements around individual trees, were evaluated. Nearly all indices were negatively correlated with tree size, but the most precise estimate of the effects of interspecific competition was a visual estimate of woody vegetation cover that was equal to or taller than 66% of tree height. Woody vegetation cover that was equal to or taller than 125% of tree height was the most precise index for predicting total tree height. The competition index also interacted significantly with tree age, indicating that the negative effect of woody vegetation on tree size increased with time.

272. **Wagner, R.G., and S.R. Radosevich. 1991. Interspecific competition and other factors influencing the performance of Douglas-fir saplings in the Oregon Coast Range. Canadian Journal of Forest Research 21:829-835.**

Burned and unburned sites were retrospectively analyzed and regression models were developed that described total height, stem diameter, stem volume index, and crown volume index of individual 4- to 9-yr-old saplings of Douglas-fir. Age, interspecific competition index, height, animal damage, use of prescribed burning, and slope angle and azimuth were the variables in the model. In 1 set of equations, the models integrated environmental and morphological factors that can influence the performance of Douglas-fir saplings, and accounted for 64 to 73% of the variation in individual tree size. Tree size was negatively correlated with interspecific competition and amount of animal damage. Tree size was positively correlated with tree age, 1st-yr height, and the use of prescribed burning. Trees were largest on steep southeast slopes when factors were held constant. Tree age, competing vegetation, animal damage, and initial seedling size had a dominant influence on Douglas-fir sapling performance; prescribed burning and topography were of relatively minor importance.

273. **Wagner, R.G., and S.R. Radosevich. 1991. Neighborhood predictors of interspecific competition in young Douglas-fir plantations. Canadian Journal of Forest Research 21:821-828.**

The effect of interspecific competition on the height and stem diameter of 4- to 9-yr-old Douglas-fir saplings were described in neighborhood models developed from site preparation experiments in the Oregon Coast Range. The study examined the influence of abundance measures, height, distance, and spatial arrangement of nonconiferous woody plants surrounding individual saplings. Total percentage cover for all woody species within a 2.1-m radius was the best interspecific competition index for predicting Douglas-fir height and stem diameter. The cover of woody species that equaled or exceeded the height of the tree was the best predictor of tree height. The cover of woody species that equaled or exceeded half the height of the tree was the best predictor of stem diameter. Stem diameter of Douglas-fir was more sensitive to neighboring woody plants than was height.

274. **White, D.E. 1986. Effects of whiteleaf manzanita on Douglas-fir and ponderosa pine: water use strategies and growth. P. 86-90 in Proceedings, Seventh Forest Vegetation Management Conference, Eureka, California.**

Plots with little or no whiteleaf manzanita had the best conifer growth. In a 4-yr-old plantation, more than 20% manzanita canopy cover decreased diameter and height growth. Competition from grass and forbs most severely limited the growth of Douglas-fir and ponderosa pine.

275. **White, D.E. 1987. Competitive interactions between Douglas-fir or ponderosa pine and whiteleaf manzanita. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 148 p.**

In southwestern Oregon, the growth of juvenile Douglas-fir, ponderosa pine, and whiteleaf manzanita varied with the presence of herbaceous cover and the density of co-developing manzanita. For each species, xylem pressure potential and stomatal conductance responded to the depletion of soil water from competition, although rates varied among species. There was usually a 2-yr lag between stress and observed response for the best correlations with growth; stem volume in 1985 was most highly correlated with canopy cover of manzanita in 1983.

At age 3, intraspecific competition began between individual manzanita seedlings, and by age 5 it became more accentuated, reducing growth. When herbaceous plants were present, growth was always least. There was a negative correlation between soil moisture depletion and amount of seedling growth. At the highest densities, the community parameters of leaf area index, stand biomass, and stand basal area increased most rapidly, which suggests that full site occupancy did not occur by age 5. Manzanita shrubs only slightly influenced Douglas-fir and ponderosa pine at age 3, but progressively increased through the 5th yr. Conifers with the smallest stem volumes were those growing with both manzanita and herbaceous competition; stem volumes were smaller for conifers kept herb-free during the 1st and 2nd yr of the study than for those kept herb-free for all 3 yr. Water use strategies differed among species. Xylem pressure potential and stomatal conductance levels were high in manzanita. Xylem pressure potential was intermediate in Douglas-fir and low in ponderosa pine; stomatal conductance was similar in both species. Ponderosa pine may have had access to soil water that neither Douglas-fir nor manzanita could exploit.

276. White, D.E., T. Harrington, and T. Hughes. 1986. Effects of herbs and brush on growth of young conifers. P. 41-45 *in* Forest Pest Management in Southwest Oregon: Proceedings of a Workshop. O.T. Helgerson, ed. Oregon State University, Corvallis, Oregon.

The stem volume of 4-yr-old Douglas-fir was reduced by 30 to 70% by tanoak with LAI from 2.9 down to 1 m^2/m^2. Douglas-fir was reduced by almost 10% by Pacific madrone at 650 to 1560 clumps per acre and its diameter was reduced by 33%. Height of Douglas-fir was significantly reduced by whiteleaf manzanita at 5445 to 10,890 plants per acre with a canopy cover of 25 to 40%.

277. White, D.E., and M. Newton. 1989. Competitive interactions of whiteleaf manzanita, herbs, Douglas-fir, and ponderosa pine in southwest Oregon. Canadian Journal of Forest Research 19:232-238.

By the 3rd yr of a study, basal diameter of individual shrubs, leaf area, biomass, and canopy volume were reduced by intraspecific competition in manzanita. At the highest density in the manzanita stand, however, those variables increased. For 5-yr-old Douglas-fir and ponderosa pine, stem volume decreased in relation to density of manzanita, biomass, leaf area index, and canopy cover. Growth of both manzanita and conifers was reduced by herbaceous vegetation.

278. Winjum, J.K. 1968. Studies on the competitive performance of outplanted 2+0 Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) through the first growing season. Ph.D. thesis. University of Michigan, Ann Arbor, Michigan. 118 p.

Douglas-fir seedlings were more severely affected by competition from red alder than from salal; red alder competed primarily for soil moisture and macronutrients, but not for light. Competition from salal for any of the 3 environmental factors did not appear to be limiting to Douglas-fir. Seedling growth was influenced by competition, but seedling survival appeared to be unaffected during the 1st yr after outplanting.

279. Zavitkovski, J., and M. Newton. 1967. The role of snowbrush (*Ceanothus velutinus* Dougl.) and red alder (*Alnus rubra* Bong.) in forest regeneration in the Pacific Northwest. P. 429-440 *in* 14th World Congress Proceedings, Part II (Section 21), International Union of Forest Research Organizations, Munich, Germany.

Because of their litter production, both snowbrush ceanothus and red alder are important pioneer species and soil builders on infertile soils in the early stages of succession, but their roles as nurse crops are of doubtful value. Alder and snowbrush have a more harmful than beneficial net effect on conifers. The development of natural or planted conifer seedlings may be retarded by 5 to 15 yr and their survival may also be decreased by snowbrush. Red alder has an even greater suppressive potential; under heavy stands, tolerant species may survive.

280. Zavitkovski, J., M. Newton, and B. El-Hassan. 1969. Effects of snowbrush on growth of some conifers. Journal of Forestry 67:242-246.

When Douglas-fir seedlings were planted in stands of snowbrush ceanothus aged to 15 yr, survival and development were significantly better than those of ponderosa pine, western hemlock, and noble fir. All 4 species could best dominate the site when snowbrush was age 0; as snowbrush aged, the ability of conifers to dominate the site decreased. In about 10 yr, snowbrush fully occupied the site, after which conifers were severely suppressed. Height growth was reduced by half when 6 naturally developing species of conifer were suppressed by snowbrush. On western slopes of the Oregon Cascade Range, snowbrush is more detrimental than beneficial to conifer regeneration.

281. Zedaker, S.M. 1981. Growth and development of young Douglas-fir in relation to intra- and inter-specific competition. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 175 p.

Competition with red alder and grass inhibited the growth of Douglas-fir. There were significant interactions between the type of competitor (Douglas-fir alone, grass, or red alder) and the site. The site-competitor-density interactions were indicated by differences in soil moisture depletion and plant moisture stress. Area per tree and tree growth were correlated; an upper asymptote was reached within the range studied. In the range of sites studied, moisture did not appear to be a limiting factor for growth of Douglas-fir after 1st-yr irrigation and when there were no competitors. There was a positive correlation between space available and foliage, root, and total biomass per tree.

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282. Bancroft, B., G. Butt, and J.D. Lousier. 1990. Red alder seed tree control in coastal British Columbia: a review. British Columbia Ministry of Forests, and Forestry Canada, Victoria, B.C. FRDA Report 159. 57 p.

In coastal British Columbia, competition from red alder is a serious concern in conifer crop reforestation, stand tending, stand conversion, and site rehabilitation programs. The problem may be ameliorated if the source of red alder seed was eliminated, but the effectiveness of that method as a silvicultural tool has not been established.

283. Beckner, D.G. 1993. Hand removal of snowbrush in conifer plantations of the Cascade Range. P. 106-111 *in* Forest Vegetation Management Without Herbicides. T.B. Harrington and L.A. Parendes, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

As many as 2300 snowbrush ceanothous plants per worker-day can be handpulled in the Willamette National Forest. In 3- to 4-yr-old stands, handpulling is an effective release method because it selectively removes competing vegetation but does not directly impact non-target species. On older brushfields, however, where snowbrush is large and deeply rooted, handpulling is not feasible. If a conifer stand is established and grows rapidly, it may not need to be released from snowbrush. Release objectives may be achieved without complete removal of snowbrush. With current methods of release, all snowbrush plants are handpulled within a 4-ft radius of 300 conifer trees per ac. Logging methods with the minimal soil disturbance and shelterwoods will reduce the intensity of competition from snowbrush. If light levels and soil temperatures in the post-harvest stand are similar to those in undisturbed forest, scarification of snowbrush seed and its subsequent germination will be lower. Fewer snowbrush seeds will be released from dormancy during low-intensity spring fires. The most effective time to handpull snowbrush is the 4th growing season after harvest. Ideally, plants should be 1 to 2 ft tall, but plants as tall as 4 ft may be pulled. When soil moisture is near field capacity in the spring and early summer and soil crumbles easily, complete removal of plants is most successful.

284. Belz, D., and T.E. Nishimura. 1989. Effect of imazapyr, 2,4-D and metsulfuron methyl on conifer tolerance. Proceedings, Western Society of Weed Science 42:98-104.

Tolerance to imazapyr and combinations of either 2,4-D or metsulfuron varied among Douglas-fir, ponderosa pine, western hemlock, and Pacific silver fir. Ponderosa pine was generally most tolerant, followed by Douglas-fir, Pacific silver fir, and western hemlock. Plant injury caused by those chemicals was more related to timing than to rate. Applications made when growth had initiated and after elongation caused considerable injury and reduced heights and diameters. Applications made before planting and after bud set caused some injury and reduced growth.

285. Bickford, M., and R.K. Hermann. 1967. Herbicide aids survival of Douglas-fir seedlings planted on dry sites in Oregon; root wrapping has little effect. Tree Planters' Notes 18(4):5-8.

Survival was significantly affected by lifting date, atrazine rate, and the position of the planting site on the slope. Although the packing method alone did not affect survival, it had significant interactions with atrazine rate and lifting date.

286. Bickford, M.L., J. Zavitkovski, and M. Newton. 1965. Atrazine improves survival of Douglas-fir seedlings and ponderosa pine seed spots. Research Progress Report, Western Weed Control Conference 1965:48-49.

On plots where 1.67 lb/ac of atrazine was applied, survival doubled at the end of the 1st growing season; on plots where 3.33 lb/ac was applied, survival increased to nearly 5 times that of untreated plots. In the plots treated with chemicals, root and top growth clearly increased.

287. Campbell, D.L., and J. Evans. 1978. Establishing native forbs to reduce black-tailed deer browsing damage to Douglas-fir. P. 145-151 *in* Proceedings, Eighth Vertebrate Pest Conference, University of California, Davis, California.

In the Pacific Northwest, plastic mesh cylinders around individual seedlings and animal repellents applied to foliage are the principal methods used to discourage black-tailed deer from browsing Douglas-fir seedlings. When highly palatable native forbs were quickly established, summer browsing on planted seedlings was reduced such that deer no longer were limiting to regeneration of Douglas-fir. The establishment of native forbs should have wide utility because it is a sound ecological approach to deer-caused reforestation problems and it integrates objectives of both forest and wildlife management by regenerating conifers and enhancing wildlife habitat.

288. Chen, J.J. 1974. Economic analysis of the cost of chemical brush control in western Oregon. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 92 p.

Chemical brush control had low (4 to 6%) rates of return compared with the market rate, even in the most productive Siuslaw area for site class I land. For better sites, the return curves are generally above those of lower site classes. The return rates were most governed by productivity of forest land and stumpage price in this study. The return was lower from chemical brush control as rotation length increased. Chemical brush control may be more effective with intensive management practices such as fertilization and thinning, which reduce rotations.

289. Coates, K.D., M.J. Douglas, J.W. Schwab, and W.A. Bererud. 1993. Grass and legume seeding on a scarified coastal alluvial site in northwestern British Columbia: response of native non-crop vegetation and planted Sitka spruce (*Picea sitchensis* (Bong.) Carr.) seedlings. New Forests 7:193-211.

On blade-scarified alluvial sites, seeding combinations of legumes, bunchgrasses, or sodforming grasses affected the reestablishment of 4 selected native competitors in various ways. Although no combination effectively controlled all 4 competitors, individual species and combinations of species could be controlled. Either bunch- or sodforming grasses can be seeded on scarified sites to reduce reestablishment of thimbleberry. Red elderberry and salmonberry can be effectively controlled with blade scarification alone and without seeding. The abundance and growth of red alder can be reduced by seeding legumes. Sitka spruce had varied early survival and growth that appeared to depend on seeding treatment. Where Sitka spruce is planted, sodforming grasses should not be used to control vegetation as they were more serious competitors than native plants. The most critical determinant of the long-term success of Sitka spruce appeared to be the abundance of red alder.

290. Cole, E.C., and M. Newton. 1988. Evaluation of 2,4-D and sulfometuron for shrub and herbaceous weed control. Abstracts, Weed Science Society of America 28:34-35.

The species of herbs and shrubs evaluated were best controlled with mixtures of 2,4-D and sulfometuron.

291. Cole, E.C., and M. Newton. 1988. Evaluation of herbicides for herbaceous weed control in young conifer plantations in coastal Oregon. Research Report, Western Society of Weed Science 1988:86-88.

Treatments for shrubs and ferns were not significantly different. There were minimal quantities of ferns and shrubs on all plots, including the controls. There were significant differences among treatments and the control plots (29% cover) for forb cover. Clopyralid, sulfometuron, and 2,4-D ester produced forb cover of less than 4%; forb cover ranged from 6 to 15% in the other treatments. All treatments significantly reduced grass cover except the 2,4-D ester and clopyralid treatments, which had grass cover of 70 to 78%, compared with 63% for the control plots. There were no significant differences among the effective treatments, which had grass cover of less than 14%.

292. Cole, E.C., and M. Newton. 1989. Seasonal efficacy comparison of two glyphosate formulations. Proceedings, Western Society of Weed Science 42:136-142.

Although 13% of the glyphosate formulation traditionally used in forestry contains a surfactant, there will be no surfactants in the formulation to be used in the future. All high rate treatments on bracken fern (except for applications during October) had significant differences in cover reduction as compared with the untreated controls. Cover decreased significantly as the rate of application increased. There were no differences in efficacy found between glyphosate formulations.

293. Cole, E.C., and M. Newton. 1989. Using herbicides to delay vegetation development on burns. Research Progress Report, Western Society of Weed Science 1989:122-123.

Noncrop species can rapidly revegetate burned areas; if the development of vegetation could be delayed, planted seedlings would have a better environment for survival and growth. There were significant differences in vegetation cover between the untreated control and all treatments, but there were no significant differences among treatments. Cover was lowest (7 to 9%) on the imazapyr treatment and was 23 to 30% on the remaining treatments. Conifer injury was significant on all treatments and on the untreated control, and some trees died. The hot, dry summer conditions on the site caused some injury. Plots with the lowest amount of cover (imazapyr) had the best survival and the least injury.

294. Cole, E.C., and M. Newton. 1990. Efficacy of different herbicides on bigleaf maple sprout clumps. Proceedings, Western Society of Weed Science 43:37-43.

Applications of triclopyr ester at concentrations greater than 20% in both active (June) and dormant (April) seasons resulted in less than 10% crown recovery of bigleaf maple. When fluroxypyr was applied at high concentrations (greater than 24%) in June and imazapyr was applied as a summer foliar spray, crown recovery was less than 11%. Applications of either fluroxypyr or triclopyr ester at 1.5 g a.i./ft of clump diameter will provide excellent control of maple stems.

295. Cole, E.C., and M. Newton. 1991. Efficacy of cut stump treatments for controlling bigleaf maple. Proceedings, Western Society of Weed Science 44:50-53.

Picloram plus triclopyr amine applied to 40- to 50-ft tall bigleaf maple trees in April resulted in no sprouting after 1 yr. Among other treatments, sprouting was highly variable.

296. Cole, E.C., M. Newton, and M. Gourley. 1989. Herbaceous weed control in young conifer plantations. Research Progress Report, Western Society of Weed Science 1989:66-67.

The average total cover was less than 40% and was significantly different from the untreated control in all but 1 of the herbicide treatments (glyphosate at 0.8 kg in April). That glyphosate treatment averaged 57% total cover and control plots averaged 90%. The lowest total cover (12 and 10% with April and May treatments, respectively) was provided by atrazine plus glyphosate. Treatments applied in May were generally significantly better at reducing total cover than were treatments applied in April. Most of the treatments injured Douglas-fir seedlings to some degree. Douglas-fir seedlings were severely injured or killed only on plots treated with 2,4-D or glyphosate. For the conditions of this study, sulfometuron, hexazinone, or atrazine plus 2,4-D in April were acceptable choices.

297. Cole, E.C., M. Newton, and D.E. White. 1986. Response of northwestern hardwoods, shrubs, and Douglas-fir to Arsenal® and Escort®. Proceedings, Western Society of Weed Science 39:93-101.

When applied in late summer, Arsenal® controlled bigleaf maple sprout clumps most completely and consistently. Early summer applications controlled sclerophyll brush communities better than mid-summer treatments. High rates of Arsenal® were ineffective on blackberry, but controlled red alder and salmonberry well. The crown volume on bigleaf maple was reduced by Escort®, but it appeared likely to recover. Escort® treatments on sclerophyll brush were more effective in June than in July. Escort® was not effective on alder but killed blackberries and salmonberry. Both chemicals severely injured Douglas-fir so would not be suitable for conifer release, but could be used for site preparation.

298. Cole, E.C., M. Newton, and D.E. White. 1987. Evaluation of herbicides for early season conifer release. Proceedings, Western Society of Weed Science 40:119-128.

Weed species may be treated with herbicides early in the season, when associated conifers are less susceptible to injury. In the Coast Range, red alder was best controlled with 2,4-D at 3 lb/ac, triclopyr ester at 0.75 or 1.5 lb/ac, imazapyr at 0.75 lb/ac, and fluroxypyr at 1.0 lb/ac. Salmonberry was best controlled with sulfometuron methyl at 4 oz/ac and metsulfuron methyl above 0.5 oz/ac. Sulfometuron methyl at 4 oz/ac, granular hexazinone at 1.5 or 3.0 lb/ac, and granular hexazinone with nitrogen at 3.0 lb/ac effectively controlled thimbleberry. Granular hexazinone+sulfometuron methyl, triclopyr ester at 1.5 lb/ac, and sulfometuron methyl at 4 oz/ac produced terminal leader dieback of planted Douglas-fir. Needle necrosis and stunting were caused by imazapyr, sulfometuron methyl, triclopyr, and fluroxypyr. Snowbrush ceanothus was controlled on an eastern Cascade Range site with 2,4-D at 1 and 2 lb/ac, triclopyr ester at 1 lb/ac, and metsulfuron methyl at 1 oz/ac. Control of greenleaf manzanita was achieved with 2,4-D at 2 lb/ac, fluroxypyr at 1 lb/ac, and 2,4-D+clopyralid at 2+0.5 lb/ac. Treatment with 2,4-D caused dieback of ponderosa pine; minor terminal dieback and needle necrosis were caused by sulfometuron methyl, metsulfuron methyl, triclopyr, picloram, and clopyralid.

299. Cole, E.C., M. Newton, and D.E. White. 1988. Efficacy of imazapyr and metsulfuron methyl for site preparation and conifer release in the Oregon Coast Range. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Note 81. 7 p.

Red alder and bigleaf maple were highly affected by imazapyr, but salmonberry and both species of blackberry were less affected. Metsulfuron methyl was very effective on salmonberry and blackberry species but was ineffective on red alder and bigleaf maple. Both chemicals severely injured Douglas-fir seedlings, however, especially when applied during the growing season. These chemicals are limited for broadcast release in Douglas-fir, but may be useful for site preparation.

300. Conard, S.G., and W.H. Emmingham. 1984. Herbicides for brush and fern control on forest sites in western Oregon and Washington. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Special Publication 8. 8 p.

Herbicide treatment recommendations are made for controlling bracken fern and swordfern, as well as various hardwood and shrub species in coastal forests. Species responses, by severity of injury, to several herbicides and herbicide combinations are diagrammed. Guidelines provide detailed descriptions of the herbicide spray mixtures and comments on the registration status, timing, rates, efficacy, and selectivity of various treatments.

301. Conard, S.G., and W.H. Emmingham. 1984. Herbicides for grass and herbaceous weed control in Oregon and Washington. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Special Publication 7. 8 p.

Herbicide treatment recommendations are made for controlling grasses, herbs, forbs, and blackberries. Species responses, by severity of injury, to several herbicides and herbicide combinations are diagrammed. Guidelines provide detailed descriptions of the herbicide spray mixtures and comments on the registration status and efficacy of various treatments.

302. Conard, S.G., and W.H. Emmingham. 1984. Herbicides for clump and stem treatments of trees and shrubs in Oregon and Washington. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Special Publication 9. 8 p.

Herbicide treatment recommendations are made for controlling weed trees and shrubs, such as red alder, bigleaf maple, black oak, canyon live oak, cherry, chinquapin, hazelnut, Pacific madrone, manzanita, black cottonwood, tanoak, vine maple, and willow. Species' responses, by severity of injury, to several herbicides and herbicide combinations are diagrammed. Guidelines provide detailed descriptions of the herbicide spray mixtures and comments on the registration status, timing, rates, efficacy, and selectivity of various treatments.

303. D'Anjou, B. 1990. Growth response of several vegetation species to herbicides and manual cutting treatments in the Vancouver Forest Region. British Columbia Ministry of Forests, and Forestry Canada, Victoria, B.C. FRDA Report 135. 8 p.

The growth response of thimbleberry, hazelnut, ocean spray, salmonberry, elderberry, swordfern,

red-osier dogwood, black twinberry, bigleaf maple, birch, red alder, and black cottonwood are summarized from 1 to 5 growing seasons after treatments. Treatments included the chemicals glyphosate, hexazinone, triclopyr ester, sulfometuron methyl, and metsulfuron methyl, as well as manual cutting at various times throughout the growing season.

304. D'Anjou, B. 1990. Control of salal. P. 25-26 *in* Vegetation Management: an Integrated Approach. Proceedings of the Fourth Annual Vegetation Management Workshop. E. Hamilton, ed. British Columbia Ministry of Forests, and Forestry Canada, Victoria, B.C. FRDA Report 109.

Over 3 yr, growth response showed that long-term control of salal cannot be achieved with spot scarification treatments. Salal recovery occurs as roots grow into the treated areas from established root systems of salal in surrounding areas. Salal can be controlled longer with blade scarification, but that method is considered inappropriate because it degrades sites. Garlon® in repeated applications provided the highest level of control, but it may be more practical to use a single application.

305. DeBell, D.S., and T.C. Turpin. 1989. Control of red alder by cutting. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Paper PNW-RP-414. 10 p.

When alder stumps were cut in June or July, at least 95% died by the end of the next growing season. Stumps cut in May, August, and September had mortality rates of 88, 70, and 22%, respectively. Survival and sprout height were higher for stumps of 4-yr-old alder trees than for 6- to 10-yr-old trees. Angle of cutting and height did not generally influence sprouting. Cutting guidelines developed from these results can be used to control red alder effectively.

306. DeMeo, T. 1987. Relationships of tree growth to nitrogen and water availability in a sheep-tree-pasture system in Douglas County, Oregon: field study and shadehouse simulation. M.S. thesis. Oregon State University, Corvallis, Oregon. 104 p.

Near Roseburg, Oregon, growth of trees in a 2-yr-old agroforestry planting was compared in sheep-grazed, forb-dominated, and grass-dominated pastures and in bareground treatments. Both height and diameter growth of trees were significantly greater on the bareground treatment. Absolute growth of KMX pine was always superior to that of Douglas-fir, although both species grew at relatively the same rates. There were no significant differences in predawn tree xylem potential among pasture treatments, but during summer drought KMX pine values differed significantly (less stress) from those of Douglas-fir. Growth of KMX pine appeared to be limited by moisture, rather than by nitrogen. On similar sites, N from animal wastes is unlikely to induce a foliar response in tree plantations during the establishment phase (0 to 3 yr).

Douglas-fir, KMX pine, and Tingiringi gum were grown in pots with varied proportions of perennial ryegrass and subterranean clover in open shadehouses. To simulate animal grazing and return of waste N, forage was clipped monthly for 1 growing season; after each clipping, 80% of N removed was returned as urea. For controls, trees were grown without forage, and some forage treatments were clipped but had no added urea. Diameter, growth, and total biomass were significantly greater in KMX pine than in the other species, and gum had the greatest height growth. Trees with grass or mixed clover-grass competition grew less than trees with clover only or no vegetation. High grass depressed tree growth and fertilization had no effect. Over time, trees without competing vegetation lost the most water.

In grass-clover mixtures, ryegrass had consistently greater biomass production, which nearly doubled with fertilization; clover was unaffected. Forage growth was lowest in association with KMX pine, followed by gum and Douglas-fir.

307. Dimock, E.J., II. 1981. Herbicide and conifer options for reforesting upper slopes in the Cascade Range. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW-292. 14 p.

After 3 yr, survival of 4 species of conifer was substantially and consistently improved when glyphosate or a mixture of atrazine and dalapon were used on upper-slope forest sites dominated by sedge and beargrass.

308. **Dimock, E.J., II, T.F. Beebe, and E.B. Collard. 1983. Planting-site preparation with herbicides to aid conifer reforestation. Weed Science 31:215-221.**

Sites in Washington and Oregon were treated once with 1 of 7 herbicides and 2 combinations of herbicides to control perennial grasses and forbs either before or after the planting of 2-yr-old ponderosa pine and Douglas-fir seedlings. In both states, the most effective and lasting herbaceous weed control was hexazinone applied at 2.2 kg/ha. Dalapon and atrazine in combination applied at 9.0 + 4.5 kg/ha was similarly effective. Over 6 yr, both conifer species responded with exponential growth increases. Treatment with hexazinone increased tree height by 58 and 70%, stem diameter by 70 and 69%, and stem-volume yield by 387 and 650%, in ponderosa pine and Douglas-fir, respectively, compared with untreated checks. With the dalapon and atrazine treatment, corresponding gains were 73 and 54% in height, 63 and 46% in diameter, and 421 and 349% in volume, respectively, for ponderosa pine and Douglas-fir.

309. **Dimock, E.J., II, E. Bell, and R.M. Randall. 1976. Converting brush and hardwoods to conifers on high sites in western Washington and Oregon — progress, policy, success and costs. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW-213. 16 p.**

Opportunities, techniques, success, and cost of brushland reclamation efforts over almost 20 yr were evaluated. Multiple-spray conversions were consistently less successful and less economical on a per-established-conifer basis than were slash-and-burn and spray-and-burn approaches.

310. **Dimock, E.J., II, and E.B. Collard. 1981. Postplanting sprays of dalapon and atrazine to aid conifer establishment. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW-280. 16 p.**

Competition to newly planted ponderosa pine and Douglas-fir seedlings from perennial grasses and forbs was controlled with a mixture of dalapon and atrazine at 8 and 4 lb/ac, respectively, or with dalapon or atrazine alone. In 1975, herbicides were spot sprayed around individual seedlings in 4 studies in Oregon. Herbicides were broadcast sprayed in 2 studies in Washington and Oregon in 1976. Grass and forbs were consistently controlled better with the mixture than with either herbicide alone. Grass and forb cover were reduced by 80 to 82% and 48 to 58%, respectively, in the 1st yr and control persisted for 2 to 4 yr. The different treatments affected survival and height growth in various ways.

311. **Doescher, P.S., and M. Alejandro. 1985. Cattle and establishment of conifer seedlings: preliminary findings for southwest Oregon. P. 7-10 *in* Research in Rangeland Management: 1985 Progress Report. Agricultural Experiment Station, Oregon State University, Corvallis, Oregon. Special Report 743.**

Controlled grazing can be used to reduce competition to trees and increase the availability of soil moisture and nutrients for growth.

312. **Doescher, P.S., S.D. Tesch, and W.E. Drewlen. 1989. Water relations and growth of conifer seedlings during three years of cattle grazing on a southwest Oregon plantation. Northwest Science 63:232-240.**

Among 3 levels of competition, there was little difference in water stress for ponderosa pine. Douglas-fir seedlings showed significantly greater water stress on ungrazed plots earlier in the season than on cattle-grazed and no-competition plots. Both ponderosa pine and Douglas-fir had significantly lower water stress and significantly greater stomatal conductance on grazed plots than on ungrazed plots early in the growing season of 1986. Improved water relations on the grazed area appeared to increase growth and vigor of conifer seedlings. Seedling volume of both ponderosa pine and Douglas-fir was significantly greater on the grazed plots than on the ungrazed plots after 3 yr.

313. **Dorworth, C.E. 1990. Mycoherbicides for forest weed biocontrol — the P.F.C. enhancement process. P. 116-119 *in* Alternatives to the Chemical Control of Weeds. C. Bassett, L.J. Whitehouse, and J.A. Zabkiewicz, eds. New Zealand Ministry of Forestry, Forest Research Institute, Rotorua, New Zealand.**

FRI Bulletin 155.

Mycoherbicides were tested with acceptable chemicals and techniques in British Columbia to improve the efficiency of weed biocontrol operations in the forest. The goal of the study was to limit weed growth or to kill weeds only in the area immediately surrounding crop plants, rather than over a widespread area, such that weeds became either benign or beneficial within the plant community. The generation of cost-effective mycoherbicides was emphasized. Mycoherbicides that could be alternatives to chemical herbicides were most urgently required. *Melanconis* spp., *Hypoxylon mammatum*, and *Nectria ditissima* were promising mycoherbicides for red alder. *Phyllosticta pyrolae*, *Cylindrocarpon* spp., and *Chondrostereum purpureum*, respectively, showed promise for salal, thimbleberry, and a variety of hardwoods.

314. Fiddler, G.O., and P.M. McDonald. 1987. Alternative treatments for releasing conifer seedlings: a study update. P. 64-69 *in* Proceedings, Eighth Forest Vegetation Management Conference, Sacramento, California. Forest Vegetation Management Conference, Redding, California.

A radius of at least 5 ft is required for release of conifers in northern California. The best indicator of release is diameter growth. Some chemicals are effective; to effectively control shrubs, mechanical treatments require additional treatments. Manual treatments are effective but costly.

315. Figueroa, P.F. 1988. First-year results of a herbicide screening trial in a newly established red alder plantation with 1+0 bare-root and plug seedling stock. Proceedings, Western Society of Weed Science 41:108-124.

For control of grasses, sedges, forbs, and shrubs in the 1st yr, the most effective herbicides were hexazinone, imazapyr, atrazine + dalapon + 2,4-D + triclopyr, sulfometuron, metsulfuron methyl, and glyphosate in combination with 2,4-D or atrazine. The vegetation community was least affected by sethoxydim, clopyralid, and pronamide. Herbicide treatments appeared to affect red alder plug seedlings more than bareroot seedlings, but the relative ranking of toxicity and growth improvement were similar. Red alder seedlings treated with glyphosate + 2,4-D or atrazine, atrazine + dalapon + 2,4-D + triclopyr and hexazinone (2 lb/ac) had the highest survival, vigor, and height; sulfometuron, metsulfuron methyl, hexazinone (3 lb/ac), and imazapyr were the most toxic to red alder seedlings.

316. Figueroa, P.F. 1989. Bigleaf maple control: triclopyr thin-line and spot-foliar application treatments using imazapyr, metsulfuron, and glyphosate. Proceedings, Western Society of Weed Science 42:104-119.

When metsulfuron and glyphosate were applied in June as spot-foliar treatments, they were not effective for control of bigleaf maple. To obtain maximum control as a spot-foliar treatment, full-crown application of imazapyr is needed. Bigleaf maple can be controlled with triclopyr at application rates of 2 ml per m^2 of crown area, provided all stems are banded. If delivery rates average 59 ml per clump, triclopyr solution rates to 45% concentration are theoretically possible.

317. Figueroa, P.F. 1991. Ground-applied herbicide methods for red alder control: herbicide efficacy, labor costs, and treatment method efficiency. Proceedings, Western Society of Weed Science 44:53-68.

Methods of treatment tested included: cut-surface, low-volume basal, thinline, stream-line, hack-and-squirt, and capsule injection. Costs of herbicide and labor were directly related to the density of stems treated. For 500 red alder stems per acre, treatment costs ranged from $22 to $60; for 1500 stems per acre, costs were from $75 to $180 per acre, based on $15 per hr contractor costs and average 1990 herbicide prices. Where conventional helicopter application may not be possible, ground application treatments can be used.

318. Figueroa, P.F., and V.F. Carrithers. 1993. Bigleaf maple control: thinline basal applications using triclopyr and triclopyr plus picloram. Proceedings, Western Society of Weed Science 46:24-30.

The minimum threshold level of triclopyr (in a thinline basal application) needed to control bigleaf maple stump sprouts was determined. The timing of applications ranged from the beginning to the end of winter dormancy. A diluted pre-mix of triclopyr and picloram was included as an additional treatment. When concentrations of herbicides were averaged by timing, survival of bigleaf maple was higher with December than with February or April applications of triclopyr. During the 2nd yr, the triclopyr + picloram treatment alone had no resprouting; bigleaf maple on all other treatments resprouted.

319. Figueroa, P.F., and V.F. Carrithers. 1994. Triclopyr for control of bigleaf maple: basal thinline applications in December, February, and April. Proceedings, Western Society of Weed Science 47:38-43.

Triclopyr (formulated as the butoxyethyl ester) was applied as a basal thinline application to bigleaf maple stump sprouts to determine the minimum threshold of herbicide needed for control (LD_{90}). A diluted pre-mix of triclopyr + picloram also was evaluated; it was applied only in February. Survival of 1st-yr bigleaf maple was higher when triclopyr was applied in December than in February or April. Differences in survival among applications decreased during the 2nd and 3rd yr. During the 2nd yr, bigleaf maple resprouted on all treatments except triclopyr + picloram.

320. Figueroa, P.F., R.C. Heald, and S.R. Radosevich. 1990. Sensitivity of actively growing Douglas-fir to selected herbicide formulations. Proceedings, Western Society of Weed Science 43:45-53.

Douglas-fir survival and growth may be significantly reduced if aerial foliar herbicide treatments with 2,4-D or triclopyr (separately or in combinations) are applied during periods of active conifer growth. Herbicide treatment damaged all sprayed trees in Washington test plots. No trees died after 5 yr, but reductions in tree vigor, basal caliper, diameter, and volume growth were still evident. After 6 yr, all treatments in a California study caused reductions in survival of Douglas-fir. Both 2,4-D and triclopyr should be applied when conifers are dormant. As trees begin active growth, lower rates of herbicides have less impact.

321. Figueroa, P.F., and T.E. Nishimura. 1992. Bigleaf maple control: basal thinline applications using imazapyr liquids and ground applications of imazapyr granules. Proceedings, Western Society of Weed Science 45:65-72.

For control of bigleaf maple, the threshold level of imazapyr applied with the basal bark thin line method was determined. A ready-to-use formulation of imazapyr and a granule of imazapyr applied directly on the uphill side of the cut stump in a single spot also were tested. After 2 yr, all bigleaf maple died when a concentrate of imazapyr above 30% solution in Mor-act® was used. Ready-to-use imazapyr effectively controlled bigleaf maple when applied during the dormant season. Granules also were effective, when applied at rates below 4.8 oz per clump; however, during the 2nd yr, crown volume reduction decreased and control was less effective.

322. Figueroa, P.F., and T.E. Nishimura. 1994. Imazapyr for control of bigleaf maple: basal thinline and ground applied granules. Proceedings, Western Society of Weed Science 47:43-49.

Imazapyr was applied by the thinline method to define the lowest threshold for control of bigleaf maple. Imazapyr RTU formulation and 5% G treatments were also compared. Four years after treatment, survival of bigleaf maple ranged from 0 to 60%. After 3 yr, there was a rate differentiation by concentration for imazapyr EC. Total mortality was maintained with concentrations above 30%; mortality decreased as concentration level decreased. All bigleaf maple died when imazapyr RTU was used.

323. Finnis, J.M. 1967. The effect of Tordon on vine maple. Down to Earth 224:22-23.

A backpack mistblower was used to apply 3 rates of 2 formulations of Tordon®. Two years after treatment, 95% of the sprayed vine maple clumps were either effectively eliminated as competitors or dead. All tested Tordon® treatments effectively controlled vine maple.

324. Fischer, V.F., and V.F. Carrithers. 1992. Tolerance of one and two year old Douglas-fir seedlings to triclopyr applications. Proceedings, Western Society of Weed Science 45:73-75.

Douglas-fir tolerance to triclopyr formulations was tested on seedlings during the first 2 yr after transplanting. Rates of triclopyr amine up to 1.5 lb/ac did not significantly damage 1-yr-old trees. At 1 lb/ac, triclopyr ester with a water carrier did not injure trees, but terminal buds were injured after all applications of 1.5 lb/ac.

325. Gourley, M., M. Vomocil, and M. Newton. 1990. Forest weeding reduces the effect of deer-browsing on Douglas-fir. Forest Ecology and Management 36:177-185.

On 4 cutover sites in the Oregon Coast Range, 3-yr-old bareroot Douglas-fir transplants were established where deer were expected to browse. To protect against browsing, 5 physical treatments and 1 chemical treatment were applied. Directed applications of glyphosate were used to test each treatment with and without complete weed control. After 5 yr, there were no growth advantages gained from treatments; some treatments even caused growth losses. Growth was consistently improved by weed control, however, with or without additional protective measures. Regardless of browsing, weeded trees had twice the average biomass of unweeded trees by the 5th yr. On the treatment without either weeds or barriers against browsing, average tree size was largest. On the poorest site, the advantages of weeding were greatest. Losses from moderate browsing could be largely prevented with weed control and the use of large transplants.

326. Gratkowski, H. 1959. Effects of herbicides on some important brush species in southwestern Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper 31. 33 p.

To control most species of brush, the most effective herbicides were low-volatile esters of 2,4-D and 2,4,5-T. Low concentrations of 2,4-D in water readily killed the highly susceptible hairy manzanita, hoary manzanita, Howell manzanita, and deerbrush. The herbicide did not completely kill greenleaf manzanita, snowbrush, varnishleaf ceanothus, and mountain whitethorn, most of which resprouted the following year. Parts of the stems and branches of chinkapin, giant chinkapin, scrub tanoak, Saskatoon serviceberry, and canyon live oak died back, but none of the plants were killed.

327. Gratkowski, H. 1975. Silvicultural use of herbicides in Pacific Northwest forests. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-37. 44 p.

Includes detailed discussion of 1) herbicide selection, 2) rate per acre, 3) carriers, 4) volume of spray per acre, and 5) seasons for aerial application. Standard treatments for many common silvicultural problems with site preparation and release are included in appendixes.

328. Gratkowski, H., D. Hopkins, and P. Lauterbach. 1973. Rehabilitation of forest land: the Pacific Coast and northern Rocky Mountain region. Journal of Forestry 71:138-143.

In the Oregon and Washington Coast ranges and in the Washington Cascade foothills, red alder, bigleaf maple, and shrubs such as salmonberry, western thimbleberry, and vine maple occupy about 2.4 million acres of highly productive land. Tough evergreen shrubs and weed trees hold almost 1 million additional acres in the highly productive redwood/Douglas-fir type in southwestern Oregon and northern California. To restore these lands to productivity, mechanical eradication, prescribed burning, and chemical application are used in site preparation. Foresters should restrict reclamation efforts to conditions and sites on which practicable and economical methods may be used until research provides better methods.

329. Gratkowski, H., R. Jaszkowski, and L. Armstrong. 1979. Survival of Douglas-fir seedlings sprayed with atrazine, terbacil, and 2,4-D. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW-256. 8 p.

On 3 summer-dry sites in southwestern Oregon, survival of Douglas-fir seedlings increased in new plantations when atrazine was applied as a broadcast spray to control grass. Atrazine was more effective than terbacil and 2,4-D. Along the southwestern coast of Oregon, conifer survival was excellent on 4 typical sites in or near the fog belt.

330. Gratkowski, H., and P. Lauterbach. 1974. Releasing Douglas-fir from varnishleaf ceanothus. Journal of Forestry 72:150-152.

Young Douglas-fir are often found in well-stocked stands beneath dense overstories of varnishleaf ceanothus. Competition for soil moisture and shade from the shrubs can retard the growth of conifers. Douglas-fir released from ceanothus competition had growth that was 1.7 to 2.5 times that of trees under unsprayed ceanothus. Basal spraying of varnishleaf ceanothus produced similar but less dramatic responses on small plots. As soon as Douglas-fir are well established, a herbicidal treatment is suggested to release the trees from varnishleaf ceanothus.

331. Gratkowski, H.J., R.E. Stewart, and H.G. Weatherly. 1978. Triclopyr and Krenite herbicides show promise for use in Pacific Northwest forests. Down to Earth 34(3):28-31.

In areas with both evergreen and deciduous shrubs, either ester or amine formations of triclopyr were effective for site preparation. Krenite herbicide was ineffective on evergreen shrubs, but very effective on deciduous species. The best choice for releasing young conifers from mixed stands of deciduous brush and evergreens was phenoxy herbicides.

332. Green, R.N. 1990. Douglas-fir response to salal control. P. 27-28 *in* Vegetation Management: An Integrated Approach. Proceedings of the Fourth Annual Vegetation Management Workshop. E. Hamilton, ed. British Columbia Ministry of Forests, and Forestry Canada, Victoria, B.C. FRDA Report 109.

Compared with untreated controls or treatments that scalp or disturb the forest floor, losses of soil water may be substantially reduced when salal leaf area is removed with Garlon®. Compared with controls, 3rd-yr height of Douglas-fir showed 60% improvement.

333. Hall, F.C., D.W. Hedrick, and R.F. Keniston. 1959. Grazing and Douglas-fir establishment in the Oregon white oak type. Journal of Forestry 57:98-103.

Douglas-fir can be successfully established under stands of Oregon white oak, and carefully managed sheep grazing can be compatible with the establishment of Douglas-fir. The crown cover of the oak, the composition of forage species, and the management of livestock all influence animal production per acre. To avoid damage to the Douglas-fir, the use of palatable plants must be properly timed and carefully managed.

334. Harrington, C.A. 1984. Factors influencing initial sprouting of red alder. Canadian Journal of Forest Research 14:357-361.

Stumps cut in January at 30 cm or higher had the greatest survival and stumps cut during July and September at 0 to 10 cm had the lowest. Very young stands had the most vigorous and consistent sprouting. In the oldest stands, few stumps sprouted and the sprouts were shorter. Stumps with a level surface were least likely to sprout and had the greatest mortality. When the cut surface of stumps faced south or west, stumps were most likely to sprout and had the lowest mortality. To achieve various management objectives, specific felling practices can be used.

335. Harrington, T.B. 1985. Douglas-fir treatment means by site for the CRAFTS Coast Range Competition Release Study: three years following treatment application. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. CRAFTS Technical Report. 7 p.

There were no significant differences among treatments for survival, 3rd-yr height, or height growth. However, 3rd-yr diameter and diameter growth were greater in the complete removal treatment. Preliminary regression analyses suggested that the effect of brush cover on diameter growth increased in importance over time, and the effects of pretreatment diameter and herb cover decreased.

336. Harrington, T.B., and R.G. Wagner. 1986. Three years of Douglas-fir growth and survival following six competition release treatments in the Oregon and Washington Coast Range. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. CRAFTS Technical Report. 14 p.

Plots were established at 6 sites, from Forks, Washington, to Coos Bay, Oregon, in 1981 and 1982. All plots contained 2- or 3-yr-old Douglas-fir that had been overtopped by various shrub species, especially salmonberry and thimbleberry. Each study area received 5 treatments: 1) no treatment; 2) manual cutting; 3) Garlon® during early or late dormancy; 4) Roundup®; and 5) complete removal of all vegetation through periodic applications of

Roundup®, Garlon®, and Velpar®. Diameter increment of Douglas-fir significantly increased when all competing vegetation was removed. None of the operational release treatments significantly increased Douglas-fir height or stem diameter growth compared with the untreated control.

337. Hedrick, D.W., and R.F. Keniston. 1966. Grazing and Douglas-fir growth in the Oregon white-oak type. Journal of Forestry 64:735-738.

In an Oregon white oak foothill area, planted Douglas-fir seedlings in plots where sheep grazed for a short period in the spring grew faster than seedlings in ungrazed plots. Soil moisture was measured on all plots through the growing season. Douglas-fir height growth was significantly greater on the grazed plots after 3 yr and continued to be so for 4 yr of additional grazing and for 3 yr after grazing ended. As sheep removed much palatable herbage, soil moisture became more abundant. Seedlings grew faster on the clearcut plot, followed by the thinned plot, then the plot with the full oak canopy. The average height of Douglas-fir was 25 in. greater (27%) on the grazed than on the ungrazed plots 10 yr after grazing began.

338. Helgerson, O.T. 1990. Response of underplanted Douglas-fir to herbicide injection of sclerophyll hardwoods in southwest Oregon. Western Journal of Applied Forestry 5:86-89.

In southwest Oregon, low-value sclerophyll forests typically composed of tanoak, Pacific madrone, and chinkapin may be underplanted with commercially valuable Douglas-fir. Container-grown plug and nursery-grown bareroot Douglas-fir seedlings were planted on plots in which triclopyr amine had been injected into all hardwood stems. Although injection killed 60% of the hardwood cover on those plots, ground cover was significantly greater after 7 yr because of sprouting. Daytime moisture stress was greater for seedlings planted beneath treated hardwoods but predawn moisture stress was lower. Survival was better for plugs than for bareroots; survival was not significantly better for seedlings on treated plots until 2 yr after planting. Height, diameter, and volume growth rates of Douglas-fir seedlings increased when competitors were injected with herbicides.

339. Hermann, R.K. 1964. Paper mulch for reforestation in southwestern Oregon. Journal of Forestry 62:98-101.

A common cause of death for newly planted seedlings is the rapid exhaustion of available soil moisture, particularly where herbaceous vegetation is abundant. In western Oregon, 2 + 0 Douglas-fir seedlings were mulched with paper to examine the effect on 1st-yr survival. To represent 3 different climatic and topographic conditions, 9 sites were each planted with 250 seedlings with and without mulch. Mulch significantly increased seedling survival as much as 5 times that of seedlings without mulch. The amount of precipitation and the time of mulch application, but not steepness of site, appeared to be related to the degree of success with mulch.

340. Hibbs, D.E., and C.G. Landgren. 1987. Thin-line treatment of red alder. Western Journal of Applied Forestry 2:130-131.

Red alder with a basal diameter of less than 2 cm can be controlled by the thin-line method of herbicide treatment. Triclopyr and 2,4-D were equally effective for killing small alder trees. When the 2 herbicides were combined, they were slightly less effective than either herbicide alone for killing larger stems. The timing of application may also affect effectiveness. The rate necessary for control ranged from 2.4 to 4.6 ml per stem, although as little as 0.4 ml of herbicide (with a 15% dilution) per stem could actually be used.

341. Hobbs, S.D. 1986. A reexamination of slashing as a manual method of sclerophyll brush control. P. 71-80 *in* Proceedings, Seventh Forest Vegetation Management Conference, Eureka, California. Forest Vegetation Management Conference, Redding, California.

Vegetation management programs have been adversely affected by increasing restrictions on the use of herbicides. Because of its high costs and poor efficacy, manual control or slashing of brush had been largely discarded as a treatment option. As cost-effective herbicides have become less available, however, interest in manual control has been renewed. Preliminary results on one study site showed that, after 4 yr, grubbing and slashing did not significantly increase the growth of ponderosa pine or Douglas-fir. There was a correlation between changes in concentrations of carbohydrates and xylem pressure potential and specific phenologic events, such as budbreak and budset, in sprouts and Douglas-fir seedlings in southwestern Oregon, which enabled foresters to recognize appropriate times for slashing.

342. Hobbs, S.D., and K.A. Wearstler, Jr. 1985. Effects of cutting sclerophyll brush on sprout development and Douglas-fir growth. Forest Ecology and Management 13:69-81.

Within 3 wk of slashing, sclerophyll brush species (canyon live oak and greenleaf manzanita) sprouted vigorously. That response was greatest in areas where brush had been totally removed; during the 1st yr, 861,513 sprout stems/ha developed. Douglas-fir had less negative soil water and predawn xylem pressure potentials in areas of total removal than in areas of partial removal or no treatment (controls). In areas of total and partial brush removal, relative growth rates of Douglas-fir saplings temporarily increased, but did not differ significantly from untreated areas 3 yr after treatment. Because sclerophyll brush recovers rapidly by sprouting, slashing to release Douglas-fir is not recommended.

343. Hooven, E.F., and H.C. Black. 1978. Prescribed burning aids reforestation of Oregon Coast Range brushlands. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Paper 38. 14 p.

Brown-and-burn has several advantages as a site preparation technique for forest managers wanting to reforest western Oregon brushlands. Chemically treating and burning undesirable vegetation removes fire hazards, simplifies either aerial seeding or planting, and removes plant competition so the seedlings receive more light and soil moisture. The removal of cover also causes a sharp, immediate decline in populations of small mammals that feed on seeds and seedlings. Observations several years after fire show that brown-and-burn is an excellent tool for site preparation. However, because vegetation recovers rapidly in western Oregon, additional applications of herbicide should be considered, especially if the original brush did not completely burn.

344. Hoyer, G.E., and D. Belz. 1984. Stump sprouting related to time of cutting red alder. Washington Department of Natural Resources, Olympia, Washington. DNR Report 45. 17 p.

Time of day and phase of the moon did not influence the sprouting of red alder. When trees were cut in late April and May, conifers received 0 to 1 yr of release; when trees were cut in June, conifers received 2 yr; and when trees were cut in July through mid-August, conifers received 3 yr or sometimes permanent release. From mid August through December, conifers received 2 to 3 yr of release.

345. Iverson, R.D. 1976. The efficacy of various coniferous stock types planted on brush sites in the Oregon Coast Range. M.S. thesis. Oregon State University, Corvallis, Oregon. 112 p.

Nursery stock survived considerably better than did wildlings at 1 site; overall, survival was higher on the burned site than on the brush site. On both sites, the stock types generally had the same pattern of survival. Both survival and growth appeared to be related to the initial height of the seedling; larger seedlings are capable of better survival because they are less vulnerable to adverse site factors. Size governs growth of seedlings almost independently of stock type. The effect of size is particularly crucial for seedlings in areas of soil movement or in heavy brush.

346. Kastner, W., and R. Monthey. 1989. Effects of using grass-legume seeding mixtures for vegetation management in three Oregon coastal clearcuts. USDI, Bureau of Land Management. Technology Transfer Bulletin. 15 p.

During the first 3 yr of a stand, the occurrence and cover of salmonberry and thimbleberry may be substantially reduced by seeding with a mixture of grasses and legumes. Height growth of salmonberry, thimbleberry, and Douglas-fir seedlings is generally reduced by seeding. Grass cover should be greater than 30% to effectively reduce salmonberry cover. Seeding did not significantly influence survival of Douglas-fir seedlings. Seeding did not influence animal damage for the first 2 yr, but may potentially attract many big game animals into seeded areas, which may result in damage from browsing. Seeding did not appear to reduce habitat quality for mountain beaver because swordfern cover was not consistently lower in the seeded areas. In the seeded areas, Douglas-fir seedlings had no damage from meadow mice after 5 yr. Seeding reduced erosion of the surface soil and should increase the organic matter incorporated into the soil through the proliferation of grass roots.

347. Kastner, W.W., Jr., and R.W. Monthey. 1993. Grass and legume seeding in forest vegetation management: a case study in the Oregon Coast Range. P. 73-82 *in* Forest Vegetation Management Without Herbicides. T.B. Harrington and L.A. Parendes, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

For the first 3 yr, salmonberry cover was lower in seeded and fertilized areas. After 5 yr, thimbleberry cover was lower in the seeded areas. During the 2nd yr, Douglas-fir height growth was notably lower in the seeded areas, but by the 3rd yr height growth and total height in the control and seeded areas were nearly equal. In the seeded areas after 5 growing seasons, however, Douglas-fir height averaged 19% less than in the controls. Seeding did not significantly affect survival of Douglas-fir. For the first 3 yr, browsing by big game did not appear to be significantly related to seeding. In the seeded areas, no vole damage was observed on Douglas-fir after 5 yr. Swordfern cover was not consistently lower in the seeded areas; therefore, mountain beaver habitat quality did not appear to decrease.

348. Kelpsas, B., and M. Newton. 1978. A comparison of chemical, fire and mechanical removal of brush in the Oregon Coast Range. Abstracts, Weed Science Society of America 1978:40.

Vegetation more than 1.5 m tall was reduced by bulldozing, raking, herbicides, and burning to produce abundant plantable spots in alder-dominated brush with a thick understory of coastal shrub species. A dense herbaceous cover, especially of grasses, grew after soil disturbance. The most cost-effective method for reforestation was herbicides used alone.

349. Kelpsas, B.R. 1978. Comparative effects of chemical, fire and machine site preparation in an Oregon coastal brushfield. M.S. thesis. Oregon State University, Corvallis, Oregon. 97 p.

In a dense overstory of red alder and a thick understory of deciduous brush, competitive woody cover was successfully reduced by tractor scarification, aerial application of 2,4,5-T and picloram followed by broadcast burning or tractor crushing, and aerial application of glyphosate. After site preparation treatment, canopies supporting 50 to 100% cover were typically reduced to near-zero levels, although the treatments eliminated few plant species, either woody or herbaceous. One season after logging and site preparation, species from the original brushfield community were present, although the relative dominance decreased as the abundance of a few invading and residual species increased. Among treatments, plant response was not equal; few woody plants were undamaged and many were removed completely in the scarified area. In the herbicide-burn-crush combinations, shrubs generally were top-killed, but often produced basal sprouts. After application of glyphosate, deciduous woody plants that had not been mechanically injured died or had no basal sprouting and showed signs of injury. In all areas, however, viable woody root systems were still present. All 4 treatments created abundant and well-distributed planting environments. Planting was easiest in the scarified area.

350. Kelpsas, B.R. 1987. Seasonal impacts of fluroxypyr and triclopyr on conifers and shrubs. Proceedings, Western Society of Weed Science 40:128-129.

Medium and high rates of fluroxypyr severely damaged Douglas-fir when applied during the dormant season. When applied just before bud burst in the early foliar season, Douglas-fir tolerated low and medium rates with only minor shoot deformation. Regardless of timing, triclopyr caused little injury. Fluroxypyr at 2.24 kg/ha effectively controlled red alder only during dormancy. During the dormant and early foliar timings, triclopyr generally provided good control of alder, but late foliar treatment reduced efficacy. At all timings and rates, fluroxypyr and triclopyr were less effective on salmonberry.

351. Kelpsas, B.R., and M. Newton. 1982. Plant community changes and conifer stock type

performance following brushland conversion. Proceedings, Western Society of Weed Science 35:49-50.

In the Coast Range of Oregon, the effects of 4 methods of site preparation on plant communities and planted seedlings in a deciduous brushfield were compared. The methods of site preparation were 1) scarification by bulldozer; 2) aerial application of glyphosate; 3) aerial application of 2,4,5-T and picloram, followed by broadcast burning; and 4) aerial application of 2,4,5-T followed by crushing by bulldozer. Survival and height growth of 6 stock type-species combinations (Douglas-fir, Sitka spruce, western hemlock, and grand fir) were recorded for 4 yr. Canopies of both trees and shrubs were reduced to near-zero values with all treatments. The distribution of shrub and tree cover 5 yr after treatment had not yet reached pretreatment levels.

352.Kintop, C.L. 1993. Paper mulches for herbaceous weed control in conifer plantations of the Roseburg BLM district. P. 99-105 *in* Forest Vegetation Management Without Herbicides. T.B. Harrington, and L.A. Parendes, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Procedures for the application of mulches to manage vegetation in the Roseburg BLM district are described.

353.Klingler, G.E. 1986. Effects of grass legume competition on shrub and hardwood invasion in newly harvested clearcuts. M.F. thesis. University of Washington, Seattle, Washington. 41 p.

Little or no woody vegetation grew in clearcuts where grasses had been seeded to shade planted conifers. The invasion of thimbleberry and red alder could be delayed for 5 yr if, soon after burning and before planting, the site was seeded with 4 different grass, legume, and fertilizer mixes. In most cases, the survival and growth of Douglas-fir was reduced but was not harmed. A particular grass species was primarily associated with the growth losses that did occur.

354.Knapp, W.H., T.C. Turpin, and J.H. Beuter. 1984. Vegetation control for Douglas-fir regeneration on the Siuslaw National Forest: a decision analysis. Journal of Forestry 82:168-173.

In the western Oregon Siuslaw National Forest, records from 324 plantations before and after planting were used in the development of stocking outcomes from vegetation control methods. According to a decision-tree analysis, without site preparation or release, the mean annual increment and present net worth of the forest as a whole would be 63% and 35%, respectively, of what would be expected if all available means of chemical and manual vegetation control were used.

355.Lauterbach, P., and L.E. Warren. 1982. Control of resprouting hardwood clumps with applications of triclopyr ester by hovering helicopter. Proceedings, Western Society of Weed Science 35:36-38.

An invert emulsion of triclopyr applied from a hovering helicopter has been efficacious and is economically feasible for controlling sprouted clumps of dormant bigleaf maple.

356.Leininger, W.C. 1984. Silvicultural impacts of sheep grazing in Oregon's Coast Range. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 211 p.

In plantations of Douglas-fir, sheep browsing was highest after bud opening in May. The sheep ate 28% of the current year's growth, averaged over 2 yr of grazing. When seedlings outgrew the reach of the sheep, browsing of growing points ceased. Sheep trampled less than 3% of the trees. Sheep damaged the growth of 2-yr-old Douglas-fir, but appeared to increase the growth of 4- to 6-yr-old trees, perhaps because sheep excreta increased nitrogen. The annual diet of the sheep was composed of 40% graminoids, 40% forbs, and 3% Douglas-fir in young plantations; in older plantations, graminoids were 70% and forbs were 16%. Sheep weight gains were typical of seasonal trends for sheep in western Oregon on non-irrigated hill pastures.

357.Leininger, W.C., and S.H. Sharrow. 1987. Seasonal diets of herded sheep grazing Douglas-fir plantations. Journal of Range Management 40:551-555.

Diets of sheep varied in vegetational composition by year, season, and plantation age. On older plantations, sheep diets contained nearly equal (40%) amounts of graminoids and forbs when averaged over the 2 yr of grazing. In young, grass-seeded plantations, however, sheep diets averaged 70% graminoids and only 16% forbs. In both age classes of plantations, ferns comprised only 2% of sheep diets. In old and young plantations, browse averaged 15 and 12%, respectively, of sheep diets. Sheep found Douglas-fir most palatable in spring soon after bud break, but Douglas-fir never comprised more than 3% of sheep diets and was generally avoided. During summer and late summer, sheep most prefer brush species to Douglas-fir and can be effectively used to control target brush species.

358. Loucks, D.M., and T.B. Harrington. 1991. Herbaceous vegetation in forests of the western United States: an annotated bibliography. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. 104 p.

This publication includes citations and abstracts for 325 articles on herbaceous vegetation in forests of the western United States and a review of literature since 1970. Most of the articles cited pertain to management of conifer stands, especially ponderosa pine and Douglas-fir, in the Rocky Mountains and Pacific Northwest. Topics include the effects of herbaceous plants on development of forest stands and soil processes, and the management of herbaceous plants to increase production of timber and animal forage.

359. McDonald, P.M. 1986. Grasses in young conifer plantations — hindrance and help. Northwest Science 60:271-278.

Conifer establishment may be hindered in plantations by grasses, which preempt resources, exclude natural seedlings through allelopathy, attract insects and animals, and increase fire hazards. In conifer plantations less than 5 yr old, grasses generally are not desirable, but in older plantations grasses can benefit conifers by excluding more competitive vegetation. Grasses can exclude deeper-rooted shrubs on good sites with deep soils. On shallow soils and poor sites, however, grasses do not benefit conifers, and grasses and shrubs often compete throughout the soil profile.

360. McDonald, P.M., and G.O. Fiddler. 1986. Release of Douglas-fir seedlings: growth and treatments costs. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Paper PSW-182. 9 p.

In northern California, several manual and chemical techniques were used to release a 3-yr-old plantation on the Klamath National Forest from deerbrush. Shrubs and herbaceous seedlings were grubbed in 2-, 4-, and 6-ft radii around Douglas-fir seedlings; 2, 4-D was applied as a direct spray in a 3-ft radius around seedlings and throughout an area of 0.14 ac. Each treatment was applied twice at an interval of 2 yr. There were significant differences between stem caliper of Douglas-fir (12 in. above mean ground line) in the 0.14-ac treatment area and the untreated control after 4 yr. Douglas-fir seedling survival and stem caliper also differed significantly.

361. McDonald, P.M., G.O. Fiddler, and W.H. Smith. 1989. Mulches and manual release fail to enhance Douglas-fir seedling survival and growth. P. 140-153 *in* Proceedings, 10th Forest Vegetation Management Conference, Eureka, California.

There were no significant differences in stem diameter and height of Douglas-fir seedlings 4 yr after 5- and 10-ft squares of Terra Mat "E" polyester felt were installed or where trees were manually released at age 2 and again at age 3. Tanoak sprouts grew vigorously on the edge of the mulches, soil moisture levels were lower beneath the mulches, and tanoak sprouts regrew, which may account for these results.

362. McDonald, P.M., and O.T. Helgerson. 1990. Mulches aid in regenerating California and Oregon forests: past, present, and future. USDA Forest Service, Pacific Southwest Research Station, Berkeley, California. General Technical Report PSW-123. 19 p.

In the late 1950s, mulches began to be used as a tool for reforestation in Oregon and California. Mulches such as sheets of plastic, newspaper, and plywood; bark, sawdust, sand, and straw in various thicknesses; sprayed-on petroleum resin; and even large plastic buckets were tried but were mostly ineffective, costly,

or both. Early mulches were small and made from short-lived materials that aided the survival but not the growth of conifer seedlings. Later mulches were larger and made mostly of longer-lived sheet materials such as reinforced paper, polyester, polypropylene, or combinations of polyester and polypropylene. Larger, (10 by 10 ft) durable mulches have recently been used to enhance both survival and growth of seedlings and to control competing plants that have stiffer stems.

363.**McHenry, W.B., B.L. Willoughby, D.R. Anderson, J.A. Roncoroni, N.L. Smith, and R. Standiford. 1988. Comparison of a paper weed smothering mat with atrazine and hexazinone for the control of seedling deerbrush ceanothus, *Ceanothus integerrimus*. P. 151-156 *in* Proceedings, Ninth Forest Vegetation Management Conference, Redding, California.**

The performance of hortopaper weed mats was comparable to that of herbicides for reducing deerbrush seedling establishment and improving conifer survival for 3 yr. The mats were statistically superior to untreated controls in terms of reducing deerbrush seedlings; however, the 16-ft^2 competition reduction zone (centered on the conifer) was inadequate to maximize site resource allocation for conifers. The economics of mats for industrial timber products appears tenuous, but the mats may be economically feasible for Christmas tree growers and owners of small-acreage forests, as well as for sites where herbicides must not be used.

364.**Minore, D. 1986. Effects of site preparation on seedling growth: a preliminary comparison of broadcast burning and pile burning. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Note PNW-RN-452. 12 p.**

Although site preparation is often necessary to obtain adequate forest regeneration, subsequent growth may be reduced by inappropriate treatment. In southwestern Oregon, plantations that had been broadcast burned or piled and burned were studied to determine whether method of burning affected Douglas-fir growth. On broadcast-burned sites, 5-yr-old seedlings had nearly equal measured and potential heights, but on most of the piled-and-burned plantations, measured heights were less than potential heights. Piling and burning probably damages site quality.

365.**Minore, D., and H.G. Weatherly. 1988. Yarding-method and slash-treatment effects of compaction, humus, and variation in plantation soils. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Note PNW-RN-476. 6 p.**

In southwestern Oregon, soil penetration resistance and soil-humus frequency on 86 progeny-test plantations were measured to determine the effects of yarding method and slash treatment on soil compaction and humus, and a disturbance index was calculated for each plantation. Tractor-yarded, machine-piled plantations had compaction and humus loss that was more severe than on cable-yarded, broadcast-burned plantations. Compaction and humus loss were not significantly greater on plantations with machine piling and burning than on broadcast burned, tractor-yarded plantations. Soil compaction within plantations varied more on tractor-yarded plantations that were broadcast burned than on tractor-yarded plantations that were not burned but had stumps removed.

366.**Minore, D., and H.G. Weatherly. 1990. Effects of site preparation on Douglas-fir seedling growth and survival. Western Journal of Applied Forestry 5:49-51.**

Survival and growth of Douglas-fir were compared among 5 yarding-slash treatment combinations on 149 progeny-test plantations in western Oregon. Heights, potential heights, and survival percentages of seedlings were measured, as well as soil-penetration resistances and the occurrence of visible soil humus. Mechanical site preparation did not improve seedling survival. During the first 5 yr on the compacted, low-humus soils associated with off-site slash piling, seedlings did not grow as tall as on similar sites where slash had been broadcast burned. Height growth of seedlings did not benefit from tilling (disking or ripping).

367.**Newton, M. 1967. Control of grasses and other vegetation in plantations. P. 141-147 *in* Symposium Proceedings: Herbicides and Vegetation Management in Forests, Ranges, and Noncrop Lands. M. Newton, ed. Oregon State University, Corvallis, Oregon.**

The most common weeding technique on forest plantations is scalping around planted seedlings, but furrowing, scarification, and cultivation are also commonly practiced. Selective chemical treatments have been developed that control weeds without injuring seedlings or disturbing the soil. Several herbicides control weeds in conifer plantations without injuring conifers planted either before or after spraying. The broadcast application of atrazine over conifer plantations in the Pacific Northwest has probably been the most important practice developed in this regard. Methods of application, dosage rates, and effects of atrazine on plantations are reviewed.

368. Newton, M. 1969. Herbicide interaction in reforestation grass sprays. Research Progress Report, Western Society of Weed Science 1969:23-30.

In 2-yr-old plantings of Douglas-fir, grasses were controlled with atrazine at rates as low as 2 lb/ac. To control broad-leaved weeds, including false dandelion, however, the addition of 2,4-D at 0.5 lb/ac was required. Cacodylic acid appeared to act synergistically with atrazine to increase the speed of plant response, but the addition of a wetter provided no advantage. Atrazine + 2,4-D + cacodylic acid in combination was particularly effective and did not harm conifers when sprayed either before or after planting.

369. Newton, M. 1978. Herbicides in alder management and control. P. 223-230 *in* Utilization and Management of Alder. D.G. Briggs, D.S. DeBell, and W.A. Atkinson, eds. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-70.

Red alder/shrub communities can be converted to conifers through use of herbicides. Herbicides also can be used to release conifers and probably to prepare sites for alder production. Young stands of alder can be thinned and culled with selective injections of triclopyr, 2,4-D amine, and cacodylic acid. Before bud burst, alder and associated species can be controlled with 2,4,5-T; in late summer they can be controlled with 2,4-D + 2,4,5-T. The brown-and-burn procedure is expensive initially but is most successful for converting brushfields. Phenoxys (2,4-D and 2,4,5-T) alone often require multiple treatments for site preparation. If large seedlings are used and treated stems larger than 3-in. in diameter are felled, Krenite®, picloram, phenoxy mixtures, and glyphosate can be effective.

370. Newton, M. 1981. Chemical management of herbs and sclerophyll brush. P. 50-65 *in* Reforestation of Skeletal Soils. Proceedings of a Workshop. S.D. Hobbs and O.T. Helgerson, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Competing vegetation negatively affects the growth of conifers in plantations, especially in early years. To most effectively improve growth, release treatments should be applied before competition becomes severe. Some chemicals may injure conifers, but conifers recover within 2 yr except when treated with picloram. With appropriate site preparation, however, the need for release can be reduced or eliminated. Two extensive tables show the properties of herbicides commonly used in southwestern Oregon and the herbicides to select for various types of vegetation. Dalapon, atrazine, 2,4-D, and hexazinone are recommended for site preparation where grasses and forbs are present; hexazinone, pronamide, and simazine are recommended for release. For ferns, dicamba is recommended for site preparation, and glyphosate and asulam are recommended for both site preparation and release.

371. Newton, M. 1984. Vegetation management in plantations of the Pacific Northwest. P. 250-257 *in* Forest Resources Management - The Influence of Policy and Law. Proceedings, 1984. Society of American Foresters National Convention, Quebec, Canada. Society of American Foresters, Bethesda, Maryland.

In the Pacific Northwest, vegetation is managed deliberately on most cutover lands. For most of the acreage, herbicides and fire are used, although hand and machine methods may occasionally be used. Herbicides can be used selectively and specifically, with low impact. Weed control in the first few years contributes to major gains in growth of conifers. Vegetation management tools in silviculture may also be used for improving other resource values.

372. Newton, M. 1989. Test of western hemlock wildlings in brushfield reclamation. Forest Research Laboratory, Oregon State Univer-

sity, Corvallis, Oregon. Research Paper 39. 23 p.

Two methods of site preparation were compared in an area dominated by red alder in Oregon. One site was completely cleared by poisoning vegetation, then crushing and burning it. The other site was partially cleared by using herbicides only. Western hemlock wildlings, 3- to 6-yr-old and 8 to 60 in. in height, were transplanted and monitored for 4 yr. Survival, damage, and height growth were compared at the 2 sites and also with data for Douglas-fir seedling planted nearby. Wildlings were shown to be low-cost transplants, with good potential for growth on sites only partially cleared. Total clearing was counterproductive when seedlings taller than 24 in. were used.

373. Newton, M., and E.C. Cole. 1989. Where does sulfometuron fit in Pacific Northwest silviculture. Proceedings, Western Society of Weed Science 42:121-128.

Treatments with sulfometuron, alone and in combination with hexazinone and with atrazine plus glyphosate at several rates, were compared. All treatments significantly reduced plant cover for all sites considered together, compared with untreated controls. All chemical treatments reduced forbs, grass, shrubs, and trailing blackberry, but not ferns. The effect of sulfometuron on forbs and trailing blackberries significantly increased with the addition of 2,4-D. Sensitivities of individual species groups varied greatly. After treatment, the highly resistant pearly everlasting, bedstraw, fireweed, and false hellebore appeared. Sulfometuron with or without 2,4-D nearly eradicated figwort and foxglove. Sulfometuron reduced thistles; when 2,4-D was added, thistles were nearly eradicated. Swordfern cover did not differ significantly among treatments, but plants treated with sulfometuron appeared lower in vigor and were expected to decline the following year.

374. Newton, M., E.C. Cole, and D.E. White. 1985. First year evaluation of Arsenal® and Escort® herbicides in the Oregon Coast Range. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. CRAFTS Progress Report. 7 p.

Two rates of Arsenal® caused nearly 100% defoliation of 2-yr-old clumps of bigleaf maple. Most clumps treated with Escort® had some crown reduction, but the lower portions of the crown recovered and exhibited little sign of injury. All treatments of Escort® injured Douglas-fir at the time of application.

375. Newton, M., E.C. Cole, and D.E. White. 1986. What influences control of coastal deciduous brush with glyphosate? Proceedings, Western Society of Weed Science 39:86-92.

The efficacy of glyphosate and the factors that influence its effects on 6 woody species were investigated in 2 experiments in the Oregon Coast Range. Five of the species that were present 3-1/2 yr after harvest of a forest of alder, spruce, and hemlock (with understory of salmonberry and elderberry and a considerable seed bank of Himalaya and evergreen blackberry) were investigated. Red alder was dominant on the site. On another site, a clearcut had been replanted with 3-yr-old Douglas-fir. After 2 yr, bigleaf maple sprout clumps were examined. On both sites and for all species, glyphosate was most effective in volumes of 10 gpa or more. Plants were most sensitive to glyphosate in August, except alder, which was most sensitive in July. For maple clumps, coverage was especially important.

376. Newton, M., E.C. Cole, and D.E. White. 1993. Tall planting stock for enhanced growth and domination of brush in the Douglas-fir region. New Forests 7:107-121.

There were strong positive relationships between initial height and long-term (10 to 14 yr) growth of container, 2+0 bareroot, and 3-yr-old Douglas-fir transplants under a range of site conditions and where brush development was highly probable. On sites logged 0 and 4 yr previously, Douglas-fir, western hemlock, and Sitka spruce seedlings were planted in salmonberry. Six mo after planting, half the seedlings were released with glyphosate. Bareroot seedlings of hemlock and Douglas-fir grew well if planted in a fresh burns, despite rapid regrowth of salmonberry, but 4-yr-old salmonberry killed virtually all seedlings less than 60 cm tall except Sitka spruce if not released. In 4-yr-old salmonberry, release improved height growth of survivors by 51%, diameter growth by 72%, and volume growth by 325% at age 12. The probability of being overtopped by brush decreased in all comparisons as initial stock height increased; there also was an inverse relationship between the effect of suppression on growth and initial height.

377. **Newton, M., and W.S. Overton. 1973. Direct and indirect effects of atrazine, 2,4-D and dalapon mixtures on conifers. Weed Science 21:269-275.**

When used alone for weed control, dalapon injured Douglas-fir and grand fir, but when combined with atrazine and 2,4-D at rates up to 3.36 and 4.48 kg/ha, respectively, it was safe and even beneficial. At rates up to 3 times those adequate for control of grasses, harmful effects of dalapon were marked.

378. **Newton, M., C. Roberts, and B.R. Kelpsas. 1978. Ecological effects of fire, bulldozers, glyphosate and phenoxy herbicides in reforested Oregon brushfields. Abstracts, Weed Science Society of America 1978:41.**

This report summarizes the effects of site preparation (burning, bulldozing, and herbicides) on species composition. When the soil surface is physically disturbed, it is rapidly recolonized by forbs and woody species and the delay in the recovery of primary production is less than for other methods. Short-lived forb communities appear after burning. Woody species sprout when phenoxy herbicides are applied in the dormant season; when applied in the summer, they reduce most broadleaved species. Glyphosate kills all deciduous plants when applied in September at moderate rates. In all cases, within several years perennial plants with surviving root systems formed the dominant cover. Plant succession was greatly influenced by the planting of conifers on sites that had been treated to control sprouting.

379. **Newton, M., D.E. White, K.M. Howard, and G. Cline. 1982. Can we control brush by helicopter spraying before timber harvest? Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Note 70. 6 p.**

Moderate rates of fosamine ammonium or glyphosate in aerial application were not adequate to control understory brush before mature Douglas-fir stands were harvested or to reduce the vigor of sprouting after harvest. Injuries caused by herbicides were those associated with low rates of application, which suggests that too much herbicide was intercepted by the overstory canopy and not enough reached the brush in the understory. Site preparation after logging had a more pronounced effect on curbing future dominance by brush than did herbicide treatment. Spraying and logging, alone or in combination, did not change shrub species composition. To control understory brush with herbicides before harvest, aerial application may need to occur at higher rates or ground equipment may be needed where coniferous overstories are dense.

380. **Newton, M., D.E. White, and B.R. Kelpsas. 1982. Growth response of Douglas-fir after herbicide application and hand clearing. Proceedings, Western Society of Weed Science 35:48-49.**

The growth response of Douglas-fir was compared after trees were manually released, treated with herbicides, or left untreated. Conifers ranged from dominant to suppressed in brush that ranged from 15 to 25 yr in age. Treatments caused either no injuries (control and triclopyr ester in October), minor injuries (2,4-D and triclopyr ester in August), or severe injuries (picloram and hand release) to conifers. In the plot that was manually released, trees probably grew poorly because of the sudden exposure to solar radiation in conjunction with belowground competition from sprouting shrubs.

381. **Nolte, D.L., J.P. Farley, D.L. Campbell, G.M. Epple, and J.R. Mason. 1993. Potential repellents to prevent mountain beaver damage. Crop Protection 12:624-626.**

Mink and coyote urines were the most effective repellents of mountain beavers and were the only treatments that significantly reduced the amount of damage to Douglas-fir. Mink urine, coyote urine, o-aminoacetophenone, and denatonium benzoate reduced clipping of salal.

382. **Norris, L.A., M.L. Montgomery, L.E. Warren, and W.D. Mosher. 1982. Brush control with herbicides on hill pasture sites in southern Oregon. Journal of Range Management 35:75-80.**

Mixtures of either 2,4-D and picloram at ratios of 4:1 and 2:1 or silvex, alone or with 2,4-D at a ratio of 1:1 were sprayed on 2 sites that had been invaded by poison oak, California black oak, maples, roses, manzanita, ceanothus, and Pacific madrone. Many shrubs were 50 to 100% controlled up to 38 mo after treatment with silvex alone or with 2,4-D at 3.4 kg/ha. Shrubs were 70 to 100% controlled with 2,4-D and picloram; the 4:1 ratio gave the best results. Douglas-fir seedlings showed no toxic symptoms 5 mo after being planted on a site that had been treated with 2,4-D and picloram at the 4:1 ratio 21 mo previously.

383. Obermeyer, E.L. 1993. Manual cutting of competing vegetation in conifer plantations of the Siuslaw National Forest. P. 123-127 *in* Forest Vegetation Management Without Herbicides. T.B. Harrington and L.A. Parendes, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Techniques developed for the control of woody vegetation since the 1984 ban on herbicides are described and evaluated.

384. O'Dea, M., E. Cole, and M. Newton. 1994. The effects of herbaceous and shrub competition on Douglas-fir seedlings. Proceedings, Western Society of Weed Science 47:29-34.

The growth of seedlings under various release schedules was evaluated. Seedlings were released a) only during the 1st growing season, b) only during the 2nd growing season, and c) during the 1st and 2nd growing seasons. Growth of seedlings was also evaluated d) without any release treatment (control), e) within a conventional forestry treatment of 1 broadcast release after plantation establishment, f) when surrounding vegetation was controlled with a directed spray, and g) when the site was kept continuously weed-free.

Treatment c was consistently the best operational treatment over all sites, despite inherent differences in sites and in amounts of animal damage. Only treatment g had seedling growth greater than that in treatment c. Within the best treatments, the volume of seedlings was consistently 3 or more times greater than those within the poorest treatments. Regardless of the location of seedlings or the intensity of animal browsing on seedlings, growth was enhanced by 2 or more yr of weeding.

385. Pendl, F., and B. D'Anjou. 1990. Effect of manual treatment timing on red alder regrowth and conifer response. British Columbia Ministry of Forests, and Forestry Canada, Victoria, B.C. FRDA Report 112. 21 p.

After cutting treatments at 5 different times, red alder survival during the first 2 growing seasons was lower when stems had been cut later in the season. In all control and treatment plots, the effects of the treatments were masked during subsequent years by high mortality, possibly caused by moisture stress and the disease *Melancomium*. Over the 5 yr of measurement, cutting produced a significant reduction in alder height, but there was no significant effect on the number of sprouts from surviving stumps. The height of Douglas-fir was significantly lower in control plots 3 yr after treatment, where alder continued to overtop more than 90% of the Douglas-fir saplings, although it had been cut in 1980. There were no significant differences in stem diameter or survival of Douglas-fir after 5 yr.

386. Petersen, T.D., and M. Newton. 1985. Growth of Douglas-fir following control of snowbrush and herbaceous vegetation in Oregon. Down to Earth 41(1):21-25.

After release from snowbrush and forbs, the relative increase in Douglas-fir growth depended upon the control of competing vegetation, the age of Douglas-fir when released, and the method of release. In 2 age classes after 5 yr, stem diameters and volumes were greatest where snowbrush and herbaceous vegetation were controlled. Vegetation other than snowbrush also suppressed growth of conifers, as reflected in stem height after 5 yr. Without concurrent control of fireweed, blackberry, and bracken fern, control of snowbrush alone did not significantly improve height growth of Douglas-fir in 10-yr-old plantations. Conifers should be released from both shrubs and herbaceous weeds from the time of planting so that they have free-to-grow conditions.

387. Phelps, N. 1979. Sheep grazing on certain harvest units of Beckler River drainage of western Washington. M.S. thesis, Washington State University, Pullman, Washington. 76 p.

On clearcut units in the western Cascade Range, vegetation production and sheep utilization samples were collected from a band of 800 dry ewes during a grazing trial in the summer of 1978. On 10- to 15-yr-old clearcut units, fireweed comprised 70 to 80% of the total production. The next largest proportions of available vegetation were composed of *Vaccinum* spp. and *Rubus* spp. Herbaceous and shrubby species, including fireweed, represented the great bulk of sheep diets. Sheep did not eat conifers unless held on an area for a long time.

388. Powell, R.L. 1993. Prescribed fire for conifer regeneration in the Oregon Coast Range. P. 33-38 *in* Forest Vegetation Management Without Herbicides. T.B. Harrington and L.A. Parendes, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

The benefits of burning include hazard reduction, animal habitat modification, vegetation control, planting site improvement, and reduction in worker injuries with subsequent reduction in worker's compensation insurance rates. Expected gains from burning are increasing the number of trees planted by 50 to 75 trees per acre, increasing the plantable area by 15%, reducing the rotation age by 2 to 4 yr, increasing wood volume at harvest by 4 to 5 MBF, and increasing net present value by $200 to 240/acre.

389. Radosevich, S.R., P.C. Passof, and O.A. Leonard. 1976. Douglas-fir release from tanoak and Pacific madrone competition. Weed Science 24:144-145.

Picloram, 2,4-D, and 2,4,5-T applied to cut surfaces of tanoak and Pacific madrone overstories provided acceptable control for 10 yr. When tanoak and Pacific madrone were controlled, Douglas-fir stems increased substantially.

390. Reynolds, P.E., K. King, R. Whitehead, and T.S. MacKay. 1986. One-year results for a coastal British Columbia glyphosate conifer release trial. Proceedings, Western Society of Weed Science 39:107-117.

Salmonberry was controlled by a single spray of 2 kg/ha of glyphosate, but control of red alder varied from 0 to 100%. Glyphosate did not control salal. On upper slopes, control of many species was greater than in the watershed valley bottom. Western hemlock and western redcedar had minor injuries but recovered after 1 yr; Sitka spruce, Douglas-fir, Pacific silver fir, and grand fir were not injured. After herbicide treatment, some crop trees increased in height.

391. Richmond, R.M. 1983. Problems and opportunities of forestland grazing in the Pacific Northwest. P. 71-73 *in* Forestland Grazing. B.F. Roche, Jr. and D.M. Baumgartner, eds. Washington State University, Pullman, Washington.

In Douglas-fir plantations near Alsea, Oregon, grazing was investigated as a means of vegetation control after clearcutting. Test clearcut areas had dominant vine maple/swordfern communities. A flock of 600 ewes with lambs was used from 1980 to 1981 and 900 dry ewes were used in 1982. The sheep moved from clearcut to clearcut as a single flock from mid-May to late August and used approximately 6 ac per day. The results included reduction of brush competition to Douglas-fir without significant damage to seedlings; stimulation of regrowth in grazed plants, which improved forage quality for big game; and control of tansy ragwort.

392. Robocker, W.C. 1971. Herbicidal suppression of bracken and effects of forage production. Weed Science 19:538-541.

Nineteen herbicides were tested in various formulations for pre- and postemergence control of western bracken. Fall applications of granular dichlobenil at 6.7 and 10.1 kg/ha, picloram at 2.2 kg/ha, and dicamba at 4.5 to 9.0 kg/ha provided 1 yr of excellent suppression. After 1 yr of suppression by dichlobenil, bracken recovered rapidly but other herbaceous species died. During the 2nd growing season after picloram and dicamba were used, bracken recovered considerably, although morphological effects were noticeable for 2 to 3 yr, particularly from dicamba. Grasses apparently were not harmed by picloram. Dicamba caused some injury to orchardgrass.

393. Ruth, R.H. 1976. Harvest cutting and regeneration in young-growth western hemlock. P. 41-74 *in* Managing Young Forests in the Douglas-fir Region. Volume 5. A.B. Berg, ed. School of Forestry, Oregon State University, Corvallis, Oregon.

After most of the standard methods of harvest (clearcut, seed tree, shelterwood, and selection) western hemlock may be naturally regenerated. Because hemlock is a slow starter, however, young seedlings may easily be overtopped by competing vegetation such as salmonberry, thimbleberry, and red alder, particularly in wet areas. Before logging, areas threatened by brush should be identified so that operations may be designed to facilitate control work. Logs may be dragged through brush patches during yarding, brush may be burned, or tractor scarification or herbicides may also be used. To control alder and favor hemlock, the overstory may be left as a shelterwood, which can shade out the alder and then be removed after the hemlock is well established.

394. Schneider, W.G., and S.A. Knowe. 1993. Growth and survival of Douglas-fir in the Coast Range ten years after competition release treatments. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. CRAFTS Technical Report. 13 p.

The CRAFTS Coast Range Competition Release Study was initiated in 1981 to test the effectiveness of release treatments in reducing the levels of competing vegetation and increasing the survival and growth of Douglas-fir seedlings. Results after 10 yr are reported in this paper. When Douglas-fir was released from all competing vegetation, diameter and height growth increased between 5 and 10 yr after treatment, which resulted in greater total diameter, height, basal area, and volume. Operational treatments (triclopyr, glyphosate, and manual cutting) did not enhance mean growth over no treatment. Chemical treatments (triclopyr and glyphosate) did not result in greater mean growth than manual treatment, except perhaps with regard to height growth. Treatments have not influenced survival thus far.

395. Sharrow, S.H. 1993. Animal grazing in forest vegetation management: a research synthesis. P. 53-60 *in* Forest Vegetation Management Without Herbicides. T.B. Harrington and L.A. Parendes, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Agrosilvipastoralism is growing high-producing pastures and trees on the same land, while silvipastoralism is grazing native understories within an existing forest. Introduction of cattle into a mixed conifer stand in eastern Oregon increased height growth of Douglas-fir, ponderosa pine, western white pine, and western larch. In northern California, similar increases were observed; without grazing by wildlife or cattle, woody vegetation encroached very quickly. In the Willamette Valley, height and diameter growth of 4-yr-old Douglas-fir was increased by sheep grazing, and that growth response continued through age 14 yr. Grazing reduced depletion of soil moisture because grazed grass and shrubs have less root biomass to draw water than ungrazed plants. In southwestern Oregon, grazing reduced moisture stress of planted Douglas-fir seedlings almost as much as removing all competition. For competition release, the best time to control shrubs is in July and August, when the palatability of Douglas-fir is lowest and palatability of shrubs is highest. Removal of the terminal shoot of Douglas-fir seedlings results in loss of current-year height and diameter growth. However, up to 75% of the lateral branches can be removed from a young Douglas-fir without much effect on growth. Shoot removal during the spring affects the current year, whereas removal during the summer affects growth in the next season.

396. Sharrow, S.H., W.C. Leininger, and K.A. Osman. 1992. Sheep grazing effects on coastal Douglas-fir forest growth: a ten-year perspective. Forest Ecology and Management 50:75-84.

From 1981 to 1990, diameter and height growth of Douglas-fir were measured in ungrazed and grazed tree stands to evaluate the effects of controlled grazing in the Siuslaw National Forest, Oregon. The site had been clearcut in 1977, burned the following year, and replanted in 1980 with 3-yr-old trees. Also in 1980, orchardgrass was sown aerially to help slow the establishment of woody vegetation and to provide a food source for large indigenous herbivores. In 1981 and 1982, sheep removed 28 and 64%, respectively, of new tree lateral branches. The removal of terminal leaders appeared to be the main effects of browsing, however. The 1990 height of Douglas-fir was reduced by 61 cm and dbh was reduced by 1.9 cm for each terminal removed. Grazing was effective in reducing the establishment and growth of red alder. In 1990, total tree basal area was similar between grazed and ungrazed stands. More than 45% of tree basal area on ungrazed stands was composed of red alder, however, compared with 19% on grazed stands. Without associated browsing of terminal leaders, vegetation control by sheep increased height of Douglas-fir by 16% and dbh by 34% in 1990. The net effect of grazing was an increase of 6% in Douglas-fir height and of 22% in dbh on grazed compared with ungrazed timber stands.

397. Sharrow, S.H., W.C. Leininger, and B. Rhodes. 1989. Sheep grazing as a silvicultural tool to suppress brush. Journal of Range Management 42:2-4.

Sheep grazed three 4- to 6-yr-old plantations of Douglas-fir in 1981 and 1982 during the May-to-September grazing season. To evaluate the effects of grazing on vine maple, thimbleberry, and salmonberry growth, estimates of growth inside and outside a livestock exclosure in October on each plantation were used. Sheep use of brush was generally moderate to heavy, except in the spring of 1982, when it was light. On all plantations, both total growth and net current year growth of understory plants and brush were effectively reduced by grazing. Diameter growth of Douglas-fir was greater from 1981 to 1983 in association with lower biomass of brush on grazed areas. By 1985 trees were 5% taller and 7% greater in diameter in grazed areas than in ungrazed areas.

398. Steffan, D.J. 1982. Mechanical brush control on steep slopes in southwest Oregon. M.S. thesis. Oregon State University, Corvallis, Oregon. 74 p.

A modified Fallons' tool and a modified Pepiot's rake were the best methods of mechanical site preparation on slopes greater than 35%. Their use is limited for some applications, however, because both require tractor access for tailholds. Clumps of brush rigged together with connecting lines may be used; gravity rollers are another alternative to circumvent the need for anchors.

399. Stein, W.I. 1990. Site preparation on coastal sites. P. 63-64 *in* Vegetation Management: An Integrated Approach. Proceedings of the Fourth Annual Vegetation Management Workshop. E. Hamilton, ed. British Columbia Ministry of Forests, and Forestry Canada, Victoria, B.C. FRDA Report 109.

The effects of 6 site preparation methods on the survival and growth of Douglas-fir and associated vegetation were compared in areas where salmonberry was well established in the Oregon Coast Range. Tree survival and growth were clearly improved through the 7th yr where broadcast burning or aerial spraying of herbicides were used. The volume gained was greater than costs needed to produce that gain.

400. Stein, W.I. 1991. Effectiveness and cost of six site preparation methods in the establishment and growth of Douglas-fir. P. 208-214 *in* Efficiency of Stand Establishment Operations. M.I. Menzies, G.E. Parrott, and L.J. Whitehouse, eds. New Zealand Ministry of Forestry, Forest Research Institute, Rotorua, New Zealand. FRI Bulletin 156.

In areas that were broadcast burned or sprayed, tree survival, total height, and stem caliper at 15 cm above ground were greater 7 yr after site preparation than in areas that had manually cleared planting spots or no site preparation. When trees were protected from animals, primarily mountain beaver, with plastic mesh tubing, both survival and growth improved. Compared with the base costs of no site preparation, broadcast burning was the method that yielded the highest volume return relative to expenditures. The ranking among methods may vary according to changes in cost components, but the growth gains clearly show that several methods are highly effective for site preparation where salmonberry is dominant.

401. Stein, W.I. 1995. Ten-year development of Douglas-fir and associated vegetation after different site preparation on Coast Range clearcuts. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Paper PNW-RP-473. 115 p.

The effects of 6 methods of site preparation on survival and growth of Douglas-fir and associated vegetation were still increasing after 10 yr. When seedlings were protected from animals, primarily mountain beaver, with plastic tubing, survival was 13% higher and height, stem diameter, and volume were 6%, 9%, and 49% greater than for unprotected trees at 10 yr. In every site-preparation treatment, seedling performance improved with protection. Total cover was most reduced by burning. In all treatments, vegetation rapidly recovered to levels that exceeded the original levels by the 1st growing season after treatment. By the 2nd yr on spot-cleared areas, total cover almost equaled that on untreated areas, but on burned or sprayed areas cover did not reach that level until the 5th yr or later. For 5 yr after burning or spraying, herbaceous vegetation was a much higher proportion of total cover than after spot-clearing or no site preparation; woody vegetation dominated all areas eventually, however. Removal of the overstory initiated successional trends in all areas and fostered diversity among dominant plant species. Site preparation caused only minor increases in the total number of species, but large differences in the frequency of occurrence and surface area dominated by individual species. Dynamics of individual species or groups are shown by the frequency, cover, and average height of their dominance in each treatment over time.

402. Stewart, R.E. 1976. Herbicides for control of western swordfern and western bracken. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-284. 11 p.

Dicamba applied in either spring or mid-summer provided the best control of swordfern. Dicamba should be applied to individual ferns to prevent damage to conifers. Asulam provided the best control of bracken fern and did not affect the survival of Douglas-fir or lodgepole pine.

403. Stewart, R.E. 1978. Origin and development of vegetation after spraying and burning in a coastal Oregon clearcut. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-317. 11 p.

After north and south aspects on an Oregon Coast Range clearcut were sprayed and burned, numbers of brush resprouts and seedlings increased. Shrub cover was reduced when a release spray was applied 3 yr after burning, but herbaceous cover was not. In brush-threat areas of the Coast Range, good control of residual vegetation and prompt reforestation are essential after logging.

404. Stewart, R.E., A.W. Cooley, and A. Guardigli. 1979. Asulam controls western bracken (*Pteridium aquilinum*) on forest land in western Oregon. Weed Science 27:589-594.

Western bracken could be controlled in young plantations without damage to Douglas-fir seedlings by aerial application of asulam at 3.4 and 6.7 kg/ha plus non-ionic surfactant. Noble fir seedlings were damaged, however, and their growth was significantly reduced in the year of treatment. When asulam was applied without a surfactant, noble fir did not show damage. In forest soils, the half-life of asulam ranged from under 7 to 18 days. In the soil profile, vertical movement was minimal; up to 208 days after application, no herbicide residues were found in runoff water from treated areas.

405. Stewart, R.E., L.L. Gross, and B.H. Honkala. 1984. Effects of competing vegetation on forest trees: a bibliography with abstracts. USDA Forest Service, Washington, D.C. General Technical Report WO-43. 414 p.

Abstracts from 260 citations on the effects of competing vegetation on forest trees are compiled. Each abstract describes the study location, crop tree species, and associated vegetation, as well as site conditions, vegetation management practices, method, study design, and the results and conclusions.

406. Sund, J.D. 1977. Some responses of red alder to herbicide application. M.S. thesis. University of Washington, Seattle, Washington. 60 p.

Half of the variation in control of red alder with 2,4-D was associated with relative humidity and interactions of relative humidity with plant moisture stress or temperature. Best control was obtained either during the morning hours under conditions of high relative humidity, if foliage was not too wet, or during the late afternoon under conditions of rising relative humidity. Additional factors that relate to plant water relations and temperature appear to be the timing of diurnal transport of carbohydrates and herbicide to the roots and rates of respiration along the transport route. Between 1:00 and 4:00 PM, relative humidity was below 50%, plant moisture stress was 15 atmospheres, and control was poorest.

407. Tappeiner, J.C., II, R.J. Pabst, and M. Cloughesy. 1987. Stem treatments to control tanoak sprouting. Western Journal of Applied Forestry 2:41-45.

On 3 sites near Brookings, Oregon, studies were conducted in nearly pure stands of 40- to 55-yr-old tanoak. Mortality increased and sprout length and clump area decreased when herbicides were applied to cut surfaces in November or February. In August and May, treatments were less effective. Crown dieback was 80 to 99% when herbicides were injected in November, February, or May and was 47% for August injections. Spraying was least effective in February and most effective in August. Trees cut within 3 mo of treatment with either injections or sprays of herbicides had decreased sprout length and clump area.

408. Tung, C.-H., J. Batdorff, and D.R. DeYoe. 1986. Survival and growth of Douglas-fir seedlings with spot-spraying, mulching, and root-dipping. Western Journal of Applied Forestry 1:108-111.

A root-dipping treatment, Terra Sorb®, was combined with paper mulching and spot-spraying with glyphosate to test the effects on the survival and height growth of Douglas-fir seedlings on a harsh site in Oregon. When competing vegetation had been controlled with mulch or glyphosate during the first 2 growing seasons, survival was significantly higher after the 3rd season. Survival was 36 and 25% higher, respectively, for seedlings treated with mulch and glyphosate before the 2nd growing season than for untreated seedlings. No seedlings were retreated before the 3rd season, after which seedlings treated twice with glyphosate had 26, 23, and 21% higher survival than seedlings that had 1 treatment with glyphosate and 1 or 2 applications of mulch, respectively. Seedling height growth did not differ among treatments. Survival and growth were not influenced by root-dipping with Terra Sorb.

409. Wagner, R.G. 1984. Growth and survival of Douglas-fir two years following six release treatments in the Oregon and Washington Coast Range. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. CRAFTS Technical Report. 9 p.

Diameter growth of Douglas-fir increased significantly when competing vegetation was completely removed. Height growth decreased significantly during the 1st yr after early-foliar applications of Garlon® 4. Roundup® and early-foliar Garlon® 4 treatments caused the most foliage, leader, and stem injuries. Competition release treatments did not significantly affect survival.

410. Wagner, R.G. 1984. Two-year response of eight Coast Range brush species to six release treatments. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. CRAFTS Technical Report. 9 p.

Brush cover, level of encroachment, and overtopping cover decreased significantly with use of Roundup® and complete removal of vegetation. Salmonberry, thimbleberry, and red alder were effectively controlled by Roundup®. Applications of Garlon® 4 during late-season dormancy controlled vine maple and bigleaf maple; salmonberry and thimbleberry were more affected by early-season applications. Brush cover was only reduced for 1 growing season by manual cutting; within 2 yr of treatment, brush resprouted vigorously and encroachment was even greater.

411. Wagner, R.G. 1987. First-year results from treatments to control bigleaf maple sprout clumps. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. CRAFTS Technical Report. 17 p.

Arsenal foliage sprays, Garlon® 4 thinline, dormant 3% Garlon® 4 basal spray, late foliar and dormant Weedone® 170 basal sprays, and cut-surface applications of Roundup® and Garlon® 3A reduced effective crown volume over 90% during the 1st yr after treatment. Basal sprays of 3% Garlon® 4 in diesel oil were less effective when applied during the growing season than when clumps were dormant. Full-strength Garlon® 4 thinline treatments, however, showed little difference in effectiveness with time of application. Garlon® 4 and mixtures of Garlon® 4 and Roundup® were ineffective as foliage sprays.

412. **Wagner, R.G. 1988. Factors influencing the delivery and effectiveness of triclopyr in the control of bigleaf maple sprout clumps. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. CRAFTS Technical Report. 13 p.**

First-year results from a bigleaf maple sprout clump treatment screening trial were used to examine factors that were associated with the delivery and effectiveness of triclopyr (Garlon®) applications. Four treatments (thinline, 3% basal spray, foliage spray, and manual cutting with cut-surface application) were analyzed to determine whether clump crown volume, season of application, number of stems in 3 diameter classes, or study site were associated with the amount of triclopyr that was delivered to a sprout clump. Triclopyr delivery was greater for the thinline treatment than for all other treatments. Five times more triclopyr was delivered with the thinline treatment than with the 3% basal spray.

413. **Wagner, R.G., and M.W. Rognozynski. 1994. Controlling sprout clumps of bigleaf maple with herbicides and manual cutting. Western Journal of Applied Forestry 9:118-124.**

The best control of bigleaf maple over a 3-yr study was provided by imazapyr foliage sprays, triclopyr ester thinline, dormant 3% triclopyr ester basal spray, late-foliar 2,4-DP + 2,4-D basal spray, and manual cutting with triclopyr amine cut-surface application. The best long-term control came from imazapyr foliage sprays, which killed most treated clumps. Among the basal applications, the most consistent and effective results were from triclopyr ester thinline treatments. Manual cutting alone and manual cutting with glyphosate cut-surface application was less effective than stump applications of triclopyr amine.

414. **Wall, R.E. 1994. Biological control of red alder using stem treatments with the fungus *Chondrostereum purpureum*. Canadian Journal of Forest Research 24:1527-1530.**

Red alder trees that had been frilled and inoculated with *Chondrostereum purpureum* were slower to heal and had higher mortality during the 4 yr after inoculation than uninoculated controls in the June and October treatments. Trees inoculated in June and October exceeded 80% projected mortality. There was a strong correlation among inoculation treatments between tree mortality and trees on which *C. purpureum* basidiocarps were recorded. Inoculation of red alder in summer or autumn can be more effective for control than frilling alone, and widens the treatment window for manual control.

415. **Walstad, J.D., J.D. Brodie, B.C. McGinley, and C.A. Roberts. 1986. Silvicultural value of chemical brush control in the management of Douglas-fir. Western Journal of Applied Forestry 1:69-73.**

There were significant differences in stocking and growth of Douglas-fir between areas treated with phenoxy herbicides 10 to 25 yr earlier and untreated areas. Without brush control, red alder virtually excluded conifers on 2 sites. On the 3rd site in the untreated area, Douglas-fir stocking and diameter growth were reduced by dense growth of varnishleaf ceanothus. Projections of mature yield and economic returns on all 3 sites were based on current stand conditions, which indicated substantial benefits for areas where brush control treatments had been applied.

416. **Warren, L.E. 1976. Control of woody plants with cut surface applications of triclopyr. Proceedings, Western Society of Weed Science 29:126-140.**

In both spring and autumn, spaced trunk injections of triclopyr amine at 1 ml/injection (full or half strength) were effective on all 12 species of hardwoods and conifers tested except western redcedar. Except on tanoak, Tordon® 101 (picloram + 2,4-D) was effective at both periods against hardwoods. Triclopyr did not harm untreated trees but Tordon® 101 caused some injuries.

417. **Warren, L.E. 1978. Control of dormant brush with topical applications of triclopyr. Abstracts, Weed Science Society of America 1978:43-44.**

When applied to brush during the late dormancy, triclopyr low-volatile ester and picloram + 2,4,5-T were about equally effective. Triclopyr completely controlled buckbrush, blackberry, cherry, willow, red alder, oceanspray, cascara, maple, and Douglas-fir and partially controlled salmonberry, interior live oak, and greenleaf manzanita at 4.4 kg/ha.

418. **Warren, L.E. 1982. Control of brush on conifer plantations with triclopyr ester. Proceedings, Western Society of Weed Science 35:38-45.**

Helicopter applications of triclopyr at rates from 1.1 to 2.2 kg/ha during late dormancy provided good to excellent control of red alder, cascara, snowbrush, Pacific madrone, chinquapin, and scotchbroom; satisfactory control of bigleaf maple, vine maple, hazelnut, red huckleberry, and cherry; and poor control of salmonberry, salal, oceanspray, elderberry, willow, and myrtle. Prescriptions for treatments should recognize that the susceptibility of certain brush species varies with phenological stage.

419. **Warren, L.E., M. Vomocil, M. Newton, and D. Belz. 1984. Control of bigleaf maple and associated hardwoods in conifer forests with Garlon 3A. Down to Earth 40(2):8-12.**

Bigleaf maple, chokecherry, willows, and red alder were well controlled by trunk injections of Garlon® 3A in April to December; Douglas-fir and western hemlock were controlled by applications in April to November. Red alder, chokecherry, willows, and bigleaf maple under 9 in. dbh were well controlled by April to August applications of Tordon® 101; Douglas-fir, western hemlock, western redcedar, and incense-cedar were controlled by December applications. MSMA controlled Douglas-fir and Roundup® controlled red alder when applied in August.

420. **Weber, C. 1993. Manual cutting of competing vegetation in conifer plantations of the Illinois Valley Range District, Siskiyou National Forest. P. 118-122 *in* Forest Vegetation Management Without Herbicides. T.B. Harrington and L.A. Parendes, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.**

Unlike some applications of herbicides, manual methods of release can selectively target individual stems, facilitating species diversity objectives while releasing the conifers in each stand. Another advantage of manual release is that it has less risk of water contamination and can be used in riparian areas without the expense of water monitoring. Also, unless the site is simply inaccessible or snow creates unsafe footing, manual cutting is not restricted by climate. On some sites, release can be combined with precommercial thinning, which can reduce treatment and contract administration costs. Contractors perform most vegetation management work. Hardwoods that compete for moisture and limit survival and growth of conifers are the main focus of treatment. Release treatments are applied 2 to 3 yr after planting and at 8 to 15 yr during precommercial thinning on lower-elevation tanoak sites. On higher-elevation sites, release treatments occur once, at age 5 to 8 yr. In mid-May to early June, just after the period of rapid early growth and when carbohydrate reserves in the roots are lowest, release treatments should be applied. During the treatment, all woody vegetation that is taller than 1 ft and within a 4-ft radius of the planted conifer is cut, with the exception of bigleaf maple, dogwood, willow, elderberry, and Pacific yew. For up to 5 yr after treatment, there are negative impacts such as increases in fire hazard and decreases in aesthetic value.

421. **White, D.E. 1989. Weed control without herbicides — a BLM perspective six years later. Proceedings, Western Society of Weed Science 42:142-143.**

Various tested manual methods of weed control are reviewed. Unsuccessful treatments are cutting, burning, blasting, and grazing. Paper mulch has been the most successful method of controlling herbaceous weeds.

422. **White, D.E., and M. Newton. 1983. Effects of glyphosate and two formulations of hexazinone in young conifer plantations. Proceedings, Western Society of Weed Science 36:54-56.**

The effects of various formulations of hexazinone on the herbaceous community dominated by tall oatgrass, velvet-grass, blue wild rye, and trailing blackberry did not differ significantly. The mean weed-free condition increased from 67 to 85%, however, with the addition of glyphosate. The mean height of 4th-yr trees in glyphosate-treated plots was 150 cm compared with 163 cm in plots treated only with hexazinone. The effects also extended to the survival of 2nd-yr trees.

423. **White, D.E., and M. Newton. 1984. Glyphosate and hexazinone mixtures: effects on weeds**

and Douglas-fir transplants. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Note 76. 6 p.

Research plots were established in a mature herbaceous community dominated by oatgrass, velvet-grass, blue wild rye, and trailing blackberry to investigate the responses of weeds and Douglas-fir transplants to liquid and solid formulations of hexazinone. The effects of herbaceous weed control on survival of Douglas-fir, even in a wetter-than-average summer, were also investigated. At least through the 4th yr, hexazinone applications at rates of 1.1 to 2.2 kg/ha enhanced conifer growth; and all rates of hexazinone controlled weeds well. The advantage in height growth from the hexazinone was reduced when glyphosate was added at the rate of 0.62 kg/ha, but glyphosate alone resulted in better height growth than did no weed control. Weed control persisted longer with liquid hexazinone than with the dry product, although their initial effects were equal.

424. White, D.E., and M. Newton. 1990. Herbaceous weed control in young conifer plantations with formulations of nitrogen and simazine. Canadian Journal of Forest Research 20:1685-1689.

At 3 sites in Oregon, weed control and 2nd-yr survival and growth of newly planted 2+0 Douglas-fir and 2+0 noble fir seedlings were measured. The replicated complete factorial experiment had 4 levels of simazine, 3 rates of N, 2 types of N, and 2 kinds of formulations. Total control of weeds and grasses increased with increasing rates of simazine for the 1st growing season. The addition of urea + triamino-s-triazine (TST) improved total weed control over urea alone, applied in conjunction with simazine. Nitrogen rate and formulation were not significant. Douglas-fir survival decreased as the rate of urea alone increased at the beginning of the 2nd growing season after plot treatment with 1.1 kg/ha of liquid hexazinone. With little or no weed control, survival decreased and remained constant; with good weed control, survival increased as the rate of urea + TST increased. Height and diameter of noble fir and diameter of Douglas-fir decreased with poor weed control; with good weed control, those measures increased at least to the levels of untreated seedlings. The addition of N caused positive responses in noble fir. This study suggests that more complete weed control in conjunction with fertilization may benefit young conifer plantations, although simazine may be toxic to 1st-yr conifers.

425. White, D.E., M. Newton, and E.C. Cole. 1986. Enhanced herbaceous weed control in conifers with combinations of nitrogen fertilizer formulations and hexazinone. Proceedings, Western Society of Weed Science 39:102-106.

The effects of 1 to 2 lb/ac of hexazinone in combination with 0 to 200 lb/ac of nitrogen on weed control were studied in noble fir and Douglas-fir plantations at 3 sites in Oregon in 1984. When N was increased from 100 to 200 lb, forb cover decreased but grasses and conifers were not affected. Grass cover decreased with application of hexazinone, but forb cover did not, because of a community shift toward resistant species. Hexazinone did not affect Douglas-fir, but, as herbicide increased, the percentage of healthy noble fir increased. Both total cover and the percentage of healthy noble fir increased with N fertilizer. Weed control was significantly enhanced with the incorporation of nitrazine/urea and hexazinone into 1 formulation, rather than separate applications.

426. White, D.E., L. Witherspoon-Joos, and M. Newton. 1990. Herbaceous weed control in conifer plantations with hexazinone and nitrogen formulations. New Forests 4:97-105.

Various nitrogen fertilizers were applied in combination with different formulations of hexazinone and were evaluated on herbaceous weed communities to determine whether the efficacy of herbicide is affected by N fertilizer. Field studies were conducted in conifer plantations to compare 3 methods of application. A co-granular formulation of hexazinone and triamino-s-triazine most reduced total weed cover. Separate applications of liquid hexazinone and triamino-s-triazine granules provided slightly less control; granular urea followed by liquid hexazinone gave the poorest control. As the hexazinone rate increased, weed control increased. The highest rate of hexazinone significantly increased survival of noble fir and stem diameter of both Douglas-fir and noble fir. Survival of both species significantly decreased, but stem diameter was not affected by the highest N rate. A co-granular formation of hexazinone and triamino-s-triazine granules significantly increased survival of noble fir and diameter of both noble fir and Douglas-fir.

427. Wolff, N. 1987. Effects of seeded grasses upon successional vegetation: a study of Douglas-fir plantations in northwest Washington. Washington State Department of Natural Resources, Olympia, Washington. DNR Report 47. 14 p.

In northwest Washington, successional vegetation in Douglas-fir plantations was effectively and economically controlled by seeded grasses. Excellent control of woody vegetation was provided by operational-scale seeding treatments of 6 to 10 lb/ac of grass seed. In grass-seeded treatments, survival of Douglas-fir decreased by an average of 5 to 10% compared with nearby unseeded areas. On droughty soils, the impact of grasses on tree survival and height growth was most apparent

Response of Vegetation to Silvicultural Activities

428. Ahrens, G.R. 1989. Tanoak (*Lithocarpus densiflorus* (Hook. and Arn.) Rehd.) root dieback: below- and aboveground site occupancy by stump-sprouts in southwest Oregon. M.S. thesis. Oregon State University, Corvallis, Oregon. 77 p.

Stump-sprouts of tanoak have been thought to benefit from residual roots of the previous stand. Carbohydrate depletion, root mortality, and shifts in allocation priority may reduce residual root systems of stumps, as evidenced by patterns of belowground carbon allocation and root/shoot maintenance. During the first 10 yr after mature tanoak stands were cut, changes in tanoak fine-root biomass were related to aboveground development through a chronosequence approach. Preexisting fine roots were not maintained by tanoak stump sprouts. Root surface areas for 3-yr sprouts in root diameter classes of <0.25, 0.25 to 1.0, and 1.0 to 2.0 mm, were 15, 52, and 82%, respectively, of values in the mature forests. Elevated soil temperature was strongly correlated to dead root proportions, which suggests that the main cause of root death is increased respiratory depletion of carbohydrate supplies. Within 4 yr, the new sprout stands regained the root/shoot equilibrium found in mature forests because of increased root mortality and reduced root growth relative to shoot growth. By age 4, initially rapid rates of leaf area growth slowed to a lower, stable level of relative growth rate, which coincided with the period of minimum tanoak root density and root/shoot recovery. The most effective time to apply control treatments to tanoak is when sprout stands reach minimum root occupancy, which was at age 4 in this study.

429. Alaback, P.B. 1981. Biomass and production of understory vegetation in seral Sitka spruce-western hemlock forests of southeast Alaska. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 87 p.

In the coastal spruce-hemlock forests of southeast Alaska, during the first 200 yr after logging or fire disturbance, understory communities display several successional stages. Growth of residual shrubs and tree seedlings increases exponentially after removal of the overstory. Understory biomass peaks 15 to 25 yr after logging at about 5000 kg/ha. At stand ages of 25 to 35 yr, vascular plant understories are virtually eliminated when forest canopies close. During the century that follows closure, bryophytes and ferns dominate understory biomass. After 140 to 160 yr, a vascular understory of deciduous shrubs and herbs is reestablished. Vascular understory biomass then continues to increase as bryophyte biomass and tree productivity decline. Unusual conditions of stand establishment, soil, microclimate, or disturbance can cause departures from this developmental sequence.

430. Alaback, P.B. 1982. Dynamics of understory biomass in Sitka spruce-western hemlock forests of southeast Alaska. Ecology 63:1932-1948.

In the coastal Sitka spruce-western hemlock forests of southeast Alaska, understory vegetation undergoes successional stages during the first 300 yr after disturbance, such as logging or fire. Within 5 yr of overstory removal, the growth of residual shrubs and tree seedlings increases; 15 to 25 yr after logging, understory biomass peaks. At stand ages of 25 to 35 yr, shrubs and herbs are virtually eliminated from the understory after closure of forest canopies. During the century that follows, bryophytes and ferns dominate understory biomass. Thereafter, bryophyte biomass and tree productivity decline as biomass of the shrubs, herbs, and ferns continues to increase.

431. Alaback, P.B. 1984. Plant succession following logging in the Sitka spruce-western hemlock forests of southeast Alaska: implications for management. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-173. 26 p.

Among forest succession age classes, recent (0- to 30-yr-old) clearcuts produce the most shrubby vegetation. The least understory vegetation is produced by even-aged forests (30- to 150-yr old). The most structurally diverse understory vegetation is found in uneven-aged, old-growth forests. Open, patchy forest canopies produce the most vegetation in the understory. Managers need more data before techniques can be successfully used to improve wildlife habitat to match or exceed that found in unmanaged old-growth forests.

432. Alaback, P.B., and F.R. Herman. 1988. Long-term response of understory vegetation to stand density in *Picea-Tsuga* forests. Canadian Journal of Forest Research 18:1522-1530.

To determine the roles of overstory species composition and stand density on succession, the 17-yr response of understory vegetation to forest thinning was examined. Composition and abundance of shrubs, herbs, and moss species did not differ significantly between the 2 study sites at 6 mo. The Sitka spruce site had much less vegetation cover and diversity than the western hemlock site 17 yr after treatment, however. Because of their high variability in the medium and heavy treatments, the overall response of most vascular species to thinning was insignificant. The loss of understory species relative to the controls was little affected by thinning. Diversity increased with thinning, mainly because shade-tolerant species invaded. At most, only 1/3 of the original plant cover remained on study plots, regardless of thinning treatment, at stand age 30 yr.

433. Alaback, P.B., and J.C. Tappeiner II. 1991. Response of western hemlock (*Tsuga heterophylla*) and early huckleberry (*Vaccinium ovalifolium*) seedlings to forest windthrow. Canadian Journal of Forest Research 21:534-539.

For 5 yr after windthrow in a dense 45-yr-old forest, western hemlock and early huckleberry seedlings were studied to investigate the responses of woody shrubs and trees to natural disturbances in temperate rain forests. Both species increased growth and recruitment after the disturbance, and establishment of hemlock and density of huckleberry seedlings also increased. In all 3 yr, height growth, number of branches, and biomass of hemlock were linearly related to transmission of solar radiation. After an initial delay of 3 to 4 yr, the shoot growth pattern of huckleberry was exponential. Within months of the disturbance, however, the productivity of hemlock increased and its growth increased exponentially throughout the study. Dense 2nd-growth conifer canopies with infrequent openings caused either by thinning or by small-scale disturbances are likely to have dense secondary canopies of shade-tolerant trees with little understory vegetation or forage for wildlife.

434. Bailey, A.W. 1966. Forest associations and secondary plant succession in the southern Oregon coast range. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 166 p.

Over a 3-yr period, forest associations, secondary succession, and plant community-Roosevelt elk relationships were investigated in 7 forest communities. The effects on succession of soil-surface disturbance caused by logging were studied in 2 habitat types at 1- to 15-yr stages. Groundsel dominated the 1st yr after logging in the western hemlock/swordfern/Oregon oxalis type. In yr 2 to 4, slender hairgrass dominated; in the 3rd yr, bull thistle cover peaked. Silver hairgrass, trailing blackberry, cat's ears, and smooth hawksbeard had high cover in the 5- to 9-yr period. In the 10- to 15-yr period, dominance was shared by cat's ears and bracken fern, and Douglas-fir had 16% cover.

In the rhododendron/Oregon-grape habitat type, more than 65% of the disturbed areas was bare ground in the first 2 yr after logging. In the 3rd and 4th yr, slender hairgrass was dominant. In the 4th yr, stream lupine reached its maximum cover; and in the 5- to 7-yr period, cat's ears and trailing blackberry dominated. Douglas-fir became dominant with 33 to 44% cover in years 8 to 15. In this period, bracken fern, trailing blackberry, and mountain thermopsis also were high cover species.

In clearcuts without soil surface disturbance, secondary succession also was studied. Bracken fern and Oregon oxalis dominated the herb layer in the western hemlock/swordfern/Oregon oxalis type. In the 4th yr, trailing blackberry cover increased to about 50%, where it remained until decreasing when Douglas-fir increased during the 15- to 40-yr period. Oregon-grape was the dominant shrub in the rhododendron/Oregon-grape type throughout secondary succession and in climax. In the dense forest, rhododendron cover was low, but high in light spots. The first 2 yr after logging, groundsel and Australian fireweed were dominant. In the 4- to 15-yr period, trailing blackberry had high cover, which declined to less than 1% in climax. In the 7- to 25-yr period, cover of salal was at its maximum; salal is intolerant to dense shade and therefore declined to about 1% cover in climax.

435. **Brown, E.A. 1963. Early stages in plant succession on Douglas-fir clearcuts on the Mary's Peak watershed near Corvallis, Oregon. M.S. thesis. Oregon State University, Corvallis, Oregon. 61 p.**

The patterns of vegetative changes on Douglas-fir clearcuts during the first 5 yr after logging and burning were studied. In the study area, the vegetation was a Douglas-fir/vine maple association, with Oregon-grape and salal dominant on the forest floor and with traces of chinquapin, hazelnut, and dogwood. There was a general increase in total number of plant species during the 5-yr study; and in the 3rd, 4th, and 5th yr, the average total vegetation cover rose abruptly. The greatest vegetative cover was found on plots with southern exposure, followed by eastern and northern exposures. On clearcut areas, average cover values of understory vegetation exceeded those on the adjacent uncut forest by the 4th yr. During the first 3 yr, there were sharp decreases in total cover from spring to fall. During the 4th and 5th yr, increasing amounts of perennial vegetation markedly reduced the seasonal variation. In the 2nd yr, the annual herb wood groundsel was dominant in terms of mean cover trends. In the 3rd yr, deervetch and bull thistle were dominant; deervetch and velvetgrass were dominant in the 4th and 5th yr. On the plots sampled, all plant species indicated a wide range of cover values. In the sequence of cover dominance, some consistent trends were noted.

436. **Bunnell, F.L. 1990. Reproduction of salal (*Gaultheria shallon*) under forest canopy. Canadian Journal of Forest Research 20:91-100.**

During the summer of 1982 and 1983, the vegetative and sexual reproduction of salal were measured under western hemlock and Douglas-fir forest canopies with different levels of closure. Vegetative reproduction occurred under both sparse and dense canopy closure; but sexual reproduction occurred only at closures of less than or equal to 33%. Sexual reproduction was primarily influenced by the interception of radiation and associated reductions in salal vigor caused by crown closure. The spatial pattern of salal shoots under the canopy was better adapted to maintenance of plant persistence than to colonization of new areas. The rates and modes of salal reproduction are discussed with reference to implications of salal for forest management, as a competitive understory species, and for wildlife management, as an important forage species for black-tailed deer.

437. **Coates, D., and S. Haeussler. 1986. A preliminary guide to the response of major species of competing vegetation to silvicultural treatments. British Columbia Ministry of Forests, Victoria, B.C. Land Management Handbook 9. 85 p.**

Autecological information on 31 species that compete with conifers (see Haeussler, S. and Coates, D., 1986, for more detailed information) is summarized in this field notebook. It provides information about responses of these species to overstory removal, manual treatments, chemical treatments, mechanical site preparation, and prescribed burning.

438. **Dyrness, C.T. 1965. The effect of logging and slash burning on understory vegetation in the H.J. Andrews Experimental Forest. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-31. 13 p.**

After the 1st postlogging sampling, early trends in vegetation development show that very few invading plants were present and, consequently, almost all forms of vegetation encountered were remnants of the preexisting stand. Logging greatly decreased the cover of all species. During the 1st growing season after slash burning, low shrubs and herbs began a marked recovery. Some species present in small amounts in the undisturbed stand had substantially increased their coverage. Some species, such as trailing blackberry, starflower, bedstraw, and Oregon oxalis, had more cover after slash burning than they had in the undisturbed stand. A number of invading species, including wood groundsel, fireweed, willow-herb, tall annual willow-herb, western bleeding heart, and pearly everlasting, increased herbaceous cover. In determining plant distribution on clearcut units, disturbance history is at least as important as species composition of the undisturbed stand. The influence of disturbance such as logging and slash burning decreases as plant succession advances, and other site factors, such as soil characteristics and aspect, will become increasingly important in controlling cover and composition of plants.

439.Dyrness, C.T. 1973. Early stages of plant succession following logging and burning in the western Cascades of Oregon. Ecology 54:57-69.

In an old-growth Douglas-fir forest, plant cover and composition were observed the year before logging, the period after logging but before broadcast slash burning, and during each of 5 growing seasons after burning. In the 1st, 2nd, and 5th yr after burning, total plant cover was 15, 49, and 79%, respectively. From the 2nd through the 4th growing season after burning, invading herbaceous species were dominant, but by the 5th yr, residual herbaceous species regained dominance. Successional trends were strongly influenced by differences in disturbance from logging and burning. Residual species, such as vine maple, Oregon oxalis, and salal, dominated areas of undisturbed soil. A wide variety of both residual and invader species were supported on areas that had been disturbed by logging but not burned. Invaders such as snowbrush, fireweed, and tall annual willow-herb occupied light to severely burned sites.

440.Fried, J.S., J.C. Tappeiner II, and D.E. Hibbs. 1988. Bigleaf maple seedling establishment and early growth in Douglas-fir forests. Canadian Journal of Forest Research 18:1226-1233.

In western Oregon Douglas-fir stands of 1 to 250 yr, survival, age, height distributions, and stocking of bigleaf maple seedlings were studied to identify the stand developmental stage in which bigleaf maple is most likely to successfully establish from seed. Where seeds were planted and protected from rodents, emergence of maple seedlings averaged 30 to 40%; it was less than 2% for unprotected seeds. After 2 yr, survival of seedlings depended on canopy density. Of seedlings that originated from planted, protected seeds, 1st yr survival was highest in clearcuts and stands of pole-size trees with sparse understories and canopies. In young stands with dense canopies and in old stands with dense understories, survival was lowest. Aggregations of naturally regenerated bigleaf maple seedlings were most abundant in stands of pole-sized Douglas-fir. Within stands, seedling size distributions had a strongly inverse J-shaped form; within aggregations, size distributions appeared more normal. The age of seedlings rarely exceeded 15 yr. In the understory, seedlings grew slowly and were often only 25 cm tall after 8 to 10 yr. Seedlings were intensively browsed by deer. There were virtually no naturally regenerated seedlings in clearcuts, probably because poor dispersal resulted in a lack of seed, in addition to seed predation and dense competition. The interval between canopy thinning and the invasion of forbs and shrubs appears to be the best time for the establishment of bigleaf maple seedlings.

441.Froyd, C.A. 1993. Effect of riparian buffer strips on salmonberry (*Rubus spectabilis*) community structure in alder stands of the Oregon Coast Range. M.S. thesis. Oregon State University, Corvallis, Oregon. 122 p.

Buffer strips and environmental factors provoked different responses in salmonberry growing on slopes and on terraces. Total height, number of ramets or sprouting centers, cover, and estimated biomass of salmonberry increased with increasing light on the slopes. Salmonberry on slopes within buffer strips had greater cover, height, and number of ramets than salmonberry on slopes in undisturbed riparian stands adjacent to uncut stands where no buffer had been created. Harvest of the adjacent stand appeared to increase sidelight into the riparian area, which contributed to the greater dominance of salmon-berry within buffer strips. Light on the terraces was not related to any of the salmonberry characteristics. As the buffer strip aged, however, height, cover, number of ramets, and biomass of salmonberry on terraces increased.

There was a negative correlation between salmonberry and cover of herbs, vine maple, and swordfern, and also with abundance of herbaceous species. Regeneration of trees was extremely sparse. On both slopes and terraces, the 4 salmonberry community variables increased in response to the creation of buffer strips. The canopy of salmonberry was self-replacing and dominated other shrubs and herbs in the riparian community. Salmonberry could eventually dominate the riparian community without silvicultural intervention.

442.Gratkowski, H. 1961. Brush seedlings after controlled burning of brushlands in southwestern Oregon. Journal of Forestry 59:885-888.

In areas that had been burned and both sprayed and burned, there were more than 10,000 new brush seedlings per acre of mountain whitethorn (87%) and greenleaf manzanita (12%). There were only 100 new brush seedlings per acre in areas that had only been sprayed with 2,4-D or 2,4,5-T and in untreated areas. Burning will likely endanger the survival of subsequent conifer plantations because it stimulates germination and, therefore, competition from brush seedlings.

443.Gratkowski, H. 1974. Origin of mountain whitethorn brushfields on burns and cuttings in Pacific Northwest forests. Proceedings, Western Society of Weed Science 27:5-8.

Dormant mountain whitethorn seeds had maximum germination after heat treatment at 90 or 105°C for 4 to 40 min, followed by stratification in moist vermiculite for at least 12 wk. Mountain whitethorn seeds in mountain forest areas of Oregon are normally exposed to high temperatures during late summer or early autumn wildfires and then germinate and occupy the burned areas the following spring. Conditions were most favorable for germination of mountain whitethorn when small accumulations of logging debris were burned; when large amounts of slash and decayed logs were burned, soil temperatures increased to lethal levels.

444.Haeussler, S., and D. Coates. 1986. Autecological characteristics of selected species that compete with conifers in British Columbia: a literature review. British Columbia Ministry of Forests, Victoria, B.C. Land Management Report 33. 180 p.

Autecological information for 31 species of trees, shrubs, and herbs that are competitors to conifers is presented. Information about distribution and abundance in British Columbia, climatic relations, site and soil conditions, nutrient, water, light and temperature relations, growth and development, reproduction, predation and pests, effects on crop trees, and response to disturbance or management is provided for each species.

445.Haeussler, S., D. Coates, and J. Mather. 1990. Autecology of common plants in British Columbia: a literature review. British Columbia Ministry of Forests, and Forestry Canada, Victoria, B.C. FRDA Report 158. 272 p.

This is an update of "Autecological characteristics of selected species that compete with conifers in British Columbia" by S. Haeussler and D. Coates, 1986. It presents autecological information for 35 species of trees, shrubs, and herbs that compete with growth of coniferous trees. Information is given on distribution and abundance in British Columbia, climatic relations, site and soil conditions, nutrient, water, light and temperature relations, growth and development, reproduction, predation and pests, effects on crop trees, and response to disturbance or management for each species.

446.Halpern, C.B. 1989. Early successional patterns of forest species: interactions of life history traits and disturbance. Ecology 70:704-720.

Patterns of abundance of vascular plant species were examined for 21 yr in 2 clearcut and burned forests in the western Cascade Range. Species of trees included western hemlock, Douglas-fir, red alder, Pacific yew, western redcedar, bigleaf maple, chinquapin, and dogwood. There were 6 community classifications for the understory vegetation, which ranged from dogwood/salal (most xeric) to swordfern (most mesic). Within 2 yr of burning, most colonizing species had established; a series of broadly overlapping unimodal curves of constancy and canopy cover can be used to describe their responses. A gradual shift in the abundance of generally persistent species marked early successional changes. Six of the 11 identified species groups were classified as invaders and 5 as residual. This study discusses the factors governing their establishment and peak abundance.

447. **Harrington, T.B. 1994. Growth responses of tanoak sprout clumps to thinning. Western Journal of Applied Forestry 9:101-105.**

Mean relative growth rate (RGR) of tanoak increased proportionally to reductions in relative cover from thinning, but there was no consistent effect from understory suppression. Thinning produced increases in RGR of individual clumps that were considerably greater for crown width than for height. Six years after thinning and understory suppression, predicted crown width of tanoak was as much as 46% greater than that of clumps in untreated stands.

448. **Harrington, T.B., J.C. Tappeiner II, and J.D. Walstad. 1984. Predicting leaf area and biomass of 1- to 6-year-old tanoak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*) sprout clumps in southwestern Oregon. Canadian Journal of Forest Research 14:209-213.**

Equations for predicting leaf area and aboveground biomass were developed to predict site occupancy by sprouting understory hardwoods after harvest of conifers. Clump leaf area and biomass were correlated with crown cross-section area so that estimates of site occupancy could be made from aerial or ground observations. Before cutting or burning, leaf area and biomass of tanoak and madrone could be predicted from equations that related those variables to parent-tree diameter at breast height times sprout-clump age. There were significant differences between species in leaf area index per sprout clump; tanoak had 7.03 m^2 leaf area/m^2 crown area and madrone had 4.13 m^2 leaf area/m^2 crown area. There was generally no variation in those values with diameter of the parent tree stem or clump age; therefore, they represent a potential maximum leaf area index for developing sprout-clump stands up to 6 yr old for each species.

449. **Harrington, T.B., J.C. Tappeiner II, and R. Warbington. 1992. Predicting crown sizes and diameter distributions of tanoak, Pacific madrone, and giant chinkapin sprout clumps. Western Journal of Applied Forestry 7:103-108.**

Total basal area in stems of the parent tree (PBA) and number of growing seasons since burning (AGE) were used with regression equations to predict individual-clump crown size and stem diameter distributions of dominant sprouts. More than 75% of the total variation in hardwood crown width and height and 62% of the variation in sprout number could be accounted for by variables of PBA, AGE, and species in combination. Only 2% of additional variation in hardwood crown size or sprout diameter distribution could be explained by variables describing site characteristics and competing vegetation abundance.

450. **Henderson, J.A. 1978. Plant succession on the *Alnus rubra/Rubus spectabilis* habitat type in western Oregon. Northwest Science 52:156-167.**

The frequency of understory species and the percent crown cover were tabulated for fifteen 2- to 64-yr-old streamside stands. In young stands, understories were dominated by forbs and graminoids; in older stands, shrubs and ferns were dominant. For understory characteristics of total crown cover, number of species, and species diversity, regressions on overstory age were determined. There was a significant decrease in the percent crown closure of the red alder canopy over time.

451. **Huffman, D.W. 1992. Regeneration of salal: seedling establishment and the effects of overstory stand density on clonal morphology and expansion. M.S. thesis, Oregon State University, Corvallis, Oregon.**

The effects of location, substrate, and overstory density on the emergence and survival of salal seedlings were investigated. The effects of overstory stand density on the productivity of stem and rhizome populations and on clonal morphology and expansion also were tested. Study site location, overstory stand density, and substrate significantly affected emergence, survival, and seedling:seed ratios. At Cascade Head, in thinned stands, and on rotten logs and stumps, establishment was highest.

Clonal architecture was described and invader, senescent, and remnant clone types were identified in an excavation experiment. There was a negative correlation between vegetative expansion and clone size and overstory density. In low density stands, there were clones up to 218 m in total rhizome length. Rhizome systems of invader clones expanded by an average of 16.2% per year. In dense stands, clones were small and did not expand. There was a negative correlation between productivity of stem and rhizome populations and overstory density. Regressions of stem density, aboveground biomass, rhizome density, and rhizome biomass on overstory density indices had correlation coefficients that ranged from 0.58 to 0.94.

452.Huffman, D.W., J.C. Tappeiner II, and J.C. Zasada. 1994. Regeneration of salal (*Gaultheria shallon*) in the central Coast Range forests of Oregon. Canadian Journal of Botany 72:39-51.

In the central Coast Range of Oregon, regeneration by seedling establishment and vegetative expansion of salal were examined under various forest conditions. There was a negative correlation between size and expansion rate of individual clonal fragments and density of the overstory stand. Mean annual growth percentage of clone rhizome systems decreased from 23.7 to 0.0% and mean total rhizome length decreased from 102.00 to 0.89 m as overstory basal area increased from 25 to 75 m^2/ha. In dense clumps of salal, interclonal competition apparently causes clones to fragment and rhizomes to die. Rhizome biomass and density, aerial stem biomass and density, and total biomass in those patches were negatively correlated with overstory density. In clearcuts, clumps of salal had up to 178 m rhizome/m^2 and 346 stems/m^2; under dense overstories, patches had as few as 11 m rhizome/m^2 and 19 stems/m^2. In all overstory conditions, stem populations had uneven-age distributions of aerial stems. Annual production of new ramets apparently maintains this structure. Study site location, overstory density, and substrate significantly affected rates of seedling establishment in salal. The highest 2-yr survival was in thinned stands on rotten logs and stumps.

453.Hughes, T.F., C.R. Latt, J.C. Tappeiner II, and M. Newton. 1987. Biomass and leaf-area estimates for varnishleaf ceanothus, deerbrush and whiteleaf manzanita. Western Journal of Applied Forestry 2:124-128.

Aboveground biomass and leaf area of varnishleaf ceanothus, deerbrush, and whiteleaf manzanita were estimated with equations. Regression equations showed that leaf and total biomass of manzanita plants and stems of ceanothus species were highly correlated with trunk or stem diameter; other reliable estimators were stand age and average stem length. The maximum LAI for stands of varnishleaf was 5.5 m^2/m^2 by 7 yr; deerbrush and manzanita had maximum values of 2.8 and 3.5, respectively, at about 15 yr. For all 3 species, stands apparently continued to produce net biomass for well beyond the age of 16 yr.

454.Isaac, L.A. 1940. Vegetative succession following logging in the Douglas-fir region with special reference to fire. Journal of Forestry 38:716-721.

When destroyed by fire, the plant association in the Douglas-fir region goes through 4 distinct successional stages, unless again interrupted by fire or logging, before it reaches the climax type. These stages are moss-liverwort, weed-brush, intolerant even-aged Douglas-fir, and tolerant all-aged hemlock-balsam fir. Tolerant all-aged hemlock-balsam will persist. Successive fires do prolong and can perpetuate the weed-brush stage, which is most subject to fire. In some localities, colonies of exotic species are upsetting natural succession, because they are more vigorous than native species and are unpalatable. Palatable species tend to be eliminated through grazing, which favors species such as exotics, bracken, and brush. Many introduced grasses have become naturalized, however, which has improved grazing.

Some species of virgin forest ground cover have underground parts that survive fires; those species are a small part of the weed-brush stage. Invading species, such as bracken, fireweed, blackberry, and snowbrush, form the remainder. Some species run their course and disappear, while some species persist until more vigorous brush cover and the oncoming forest crowd them out. Heavy cover is detrimental to coniferous seedlings, but light cover is beneficial. Forest regeneration may be practically prohibited by a particularly dense weed-brush stage.

455.Jimerson, T.M. 1990. A seral stage and successional pathway model for the tanoak-canyon live oak/evergreen huckleberry ecological type on the Gasquet Ranger District, Six Rivers National Forest. Ph.D. thesis. University of California, Berkeley, California. 205 p.

The structural features of vegetation seral stages and the successional pathways resulting from harvesting, site preparation, and release treatment are described. Prescribed burning yielded 2 types of effects, depending on the intensity of the burn. Plots that had no or low burns maintained higher site productivity in the pole seral stage than plots that had moderate and high intensity burns. Site productivity in the pole seral stage decreased and competing vegetation increased with moderate and high intensity burns, making release treatments necessary. On sites with moderate and high intensity burns, both manual release and precommercial thinning were effective for reducing competing vegetation in the shrub/forb and pole seral stages to acceptable levels. Herbicides were not effective and appeared to shift dominance among shrub species, rather than to release conifers from competition.

456. Kraemer, J.F. 1977. The long term effect of burning on plant succession. M.S. thesis. Oregon State University, Corvallis, Oregon. 134 p.

Both burned and unburned sites had similar total brush and herbaceous cover trends. Approximately 14 yr after logging, total herbaceous cover peaked, then declined rapidly in subsequent years. During the 25-yr period, total brush cover steadily increased. In the 14 yr after logging, total brush cover increased most rapidly. On burned plots, the cover and occurrence of snowbrush was greater; on unburned plots, cover and occurrence of rhododendron, vine maple, and salal were greater. An important factor accounting for differences in successional trends was the greater cover of residual species on unburned sites. Analyses were limited by the variability between different plots pairs. In the western Cascade Range, secondary succession varied greatly between geographic localities and with elevation.

457. Latt, C.R. 1984. The development of leaf area and biomass in the whiteleaf manzanita (*Arctostaphylos visicida* Parry.) brushfields of southwest Oregon. M.S. thesis. Oregon State University, Corvallis, Oregon. 93 p.

As early as 6 yr after disturbance, full site occupancy, as indicated by canopy closure, could occur at basal areas as low as 2200 mm^2/m^2, after which leaf area, biomass, and basal area accumulation would level off. On plots of 6-yr-old shrubs, the maximum observed LAI was 3.0; 10 yr later, it had increased to 3.7. Maximum LAIs of individual open-grown shrubs were similar to those of fully occupied plots. By age 4, LAI of open-grown shrubs could be more than 3.5. Between 4 and 10 yr, there was little change in maximum LAI. At the time of canopy closure, the rate of biomass accumulation slowed. Mean leaf biomass was 1010 g/m^2 at age 16, and mean total aboveground biomass was 3176 g/m^2.

458. Long, J.N. 1977. Trends in plant species diversity associated with development in a series of *Pseudotsuga menziesii*/*Gaultheria shallon* stands. Northwest Science 51:119-130.

In 5-yr-old stands, species diversity was maximum; from 5 to 22 yr, it decreased as salal began to dominate the understory. The diversity of herbs and mosses began to increase after age 22 as salal decreased. With age, overstory cover increased. Dynamic equilibrium in terms of species richness, diversity, and cover may be approached in the understory of the 73-yr-old stand.

459. Loucks, D.M., S.R. Radosevich, T.B. Harrington, and R.G. Wagner. 1987. Prescribed fire in Pacific Northwest forests: an annotated bibliography. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. 185 p.

The citations and abstracts of more than 500 articles on prescribed fire are provided. Specific topics addressed are methods and uses for prescribed fire, effects of prescribed fire on vegetation and animals, environmental impacts, and human concerns. Although most citations pertain directly to the Pacific Northwest, some references from the Intermountain and Rocky Mountain regions are included because they consider similar types of vegetation; articles on the air, health, and public-opinion also are included, as they are widely applicable. Articles concerning wildfires were excluded from this publication unless they also considered prescribed burning.

460. Malavasi, U.C. 1978. Early plant biomass trends following forest site preparation

on the Oregon Coast Range. M.S. thesis. Oregon State University, Corvallis, Oregon. 88 p.

After a clearcut site was prepared for replanting, the rate of reoccupancy by herbs and shrubs was used to conceptualize the early stages of succession and the relative roles and strategies of both components of the system as succession progressed. On a clearcut unit, the vegetation varied in structure and composition. Abundance of both herbs and shrubs increased in early succession relative to conditions imposed by the method of site preparation. Herbaceous species appeared to control the establishment of conifers in the initial stages of succession, but, by the 4th yr, sprouting shrubs began to influence succession. Shortly after disturbance, the composition of perennials, especially sprouting woody species, greatly affected long-term community development. During the early stages of succession, components of low abundance, such as conifers, can be eradicated through selective consumption by deer and rodents. Both the composition and the density of woody cover, as well as the apparent degree of animal use, can be affected by the method of site preparation used.

461. **Maxwell, B.D. 1990. The population dynamics and growth of salmonberry (*Rubus spectabilis*) and thimbleberry (*Rubus parvifloris*). Ph.D. thesis. Oregon State University, Corvallis, Oregon. 303 p.**

A population modeling approach was used to assess practices for the management of salmonberry and thimbleberry and to facilitate study of their biology. The literature was used to develop a generic transition matrix model that could generate hypotheses and focus research on demographic processes governing population dynamics. Important processes influencing the growth of populations appear to be transition from basal buds to sprouts, shoot survival, sprout transition to mature vegetative shoots, and basal bud production on mature vegetative shoots. To refine the model, species-specific influences of phenology, environments at different sites, and intraspecific density on demographic processes were incorporated. Comparisons were made between population simulations and observations of planted and adjacent wild populations for the first 3 growing seasons. Simulations accounted for an average of 71% of the variation in planted and 81% in wild population shoot dynamics. Height growth and canopy cover were simulated as a function of density. Simulations of manual cutting and of a herbicide treatment demonstrated that the model was useful for evaluating management tactics for salmonberry and thimbleberry.

462. **Maxwell, B.D., J.C. Zasada, and S.R. Radosevich. 1993. Simulation of salmonberry and thimbleberry population establishment and growth. Canadian Journal of Forest Research 23:2194-2203.**

A simulation model developed for populations of salmonberry and thimbleberry was verified through comparisons with field observations. The influences of different species-specific phenological stages, environments, and intraspecific densities on demographic processes were incorporated into the model. At 3 phenological stages during a growing season, the number of individuals in different life-history stages could be predicted. Comparisons with low genet-density planted populations provided the most accurate simulations; salmonberry populations on a moist site were most accurately simulated. Poor prediction of sprout densities reduced the accuracy of thimbleberry simulation. The response of salmonberry and thimbleberry populations to an application of glyphosate was simulated and compared with observed canopy cover for 3 yr. The 1st yr after application, the simulated response was accurate but did not account for continued canopy cover in the observed populations. The response of salmonberry canopy cover and mean ramet height to manual cutting at 3 phenological stages was also simulated. According to the simulations, cutting at the reproductive stage of growth produced the most prolonged reduction in salmonberry cover.

463. **McGee, A.B. 1989. Vegetation response to right-of-way clearing procedures in coastal British Columbia. Ph.D. thesis. University of British Columbia, Vancouver, B.C.**

In 7 immature forest and early seral vegetation units, the environmental variable most highly correlated with vegetation was slope position. The determination of relationships between immature forest and early seral vegetation units was complicated by the degree of disturbance and by seeding with agronomic grass. Most seeds (72% in the forest samples) were found in the forest floor layer. Regardless of the level of disturbance, there were fewer germinable seeds in samples from drier than from moister vegetation units. After plot scarification, important invading species were salal, bracken fern, and trailing blackberry. Only red alder, pearly everlasting, and blackberry seedlings successfully established in significant numbers, but few survived to the next year. To successfully manage vegetation to meet tree production or transmission line right-of-way goals, more attention must be paid to the biology and reproductive ecology of both pest and acceptable crop species.

464. Messier, C., and J.P. Kimmins. 1991. Above- and below-ground vegetation recovery in recently clearcut and burned sites dominated by *Gaultheria shallon* in coastal British Columbia. Forest Ecology and Management 46:275-294.

Between 2 and 8 yr, total aboveground vegetation biomass quadrupled. The dominant species was salal, which represented 77, 87, and 73% of the total aboveground biomass on the 2-, 4-, and 8-yr-old sites, respectively. After logging and burning on these sites, the post-disturbance dominance of salal was apparently due to its ability to rapidly and completely reoccupy the site both aboveground and belowground from rhizomes present before disturbance, and to resist invasion by pre-empting resources (nutrients in this case) from other species. A conceptual model of salal leaf and fine-root biomass over 60 yr is presented.

465. Minore, D., J.E. Evans, P.G. Cunningham, and H.G. Weatherly. 1991. Growth patterns of deerbrush and snowbrush as functions of age and shrub vigor. Forest Science 37:1140-1149.

In order to predict the effects of shrubs on conifer regeneration, browse availability, soil conditions, and microclimate, estimates of ceanothus cover are needed. Stem analysis techniques were used to describe the growth of 61 open-grown deerbrush and snowbrush. As an index of growth rate, stem length at age 10 (L10) was used. The length of the longest stem was related to shrub height and crown area, and curves were constructed to illustrate crown development by age and L10. The growing space that will be occupied by open-grown shrubs of either species can be estimated from the results for any time from ages 4 to 20 yr.

466. Minore, D., H.G. Weatherly, and J.E. Means. 1988. Growth of whiteleaf manzanita (*Arctostaphylos viscida* Parry). Forest Science 34:1094-1100.

On varied sites in southwest Oregon, stem analysis techniques were applied to 47 open-grown shrubs. To estimate growth in terms of stem length, crown area, and crown volume, regression equations were developed. The growing space that open-grown shrubs will occupy can be predicted at any age up to 20 yr. These predictions should facilitate the scheduling of release treatments in conifer plantations.

467. Morris, W.G. 1958. Influence of slashburning on regeneration, other plant cover, and fire hazard in the Douglas-fir region (a progress report). USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper 29. 49 p.

Not enough is known about the effects of slash burning on regeneration. Herbaceous plants appeared unable to grow on the larger patches of severely burned soil during the first few years after a slash fire. They quickly covered moderately or lightly burned adjacent areas, however. Fireweed and trailing blackberry were dominant in the herbaceous cover on many plot pairs in the Cascade Range, without preference for burned or unburned ground. In the coastal area, western swordfern was dominant on several plots and was more frequently found on unburned than on burned ground. Herbaceous vegetation covered proportionately the same amount of burned and unburned ground. In the Cascade Range, about 30% of the area was covered by herbs in the 4th season after the fire, and there was little change in cover over the next few seasons. In the coastal area, herbs covered more ground.

468. Morris, W.G. 1970. Effects of slash burning in overmature stands of the Douglas-fir region. Forest Science 16:258-270.

In western Washington and Oregon, pairs of burned and unburned plots were established after old-growth coniferous forests were clearcut, to determine the effects of normal fall slash burning. Nearly all fine fuel was consumed by the fire, but nearly all logs were left and less than 6% of the soil surface was severely burned. The estimated rating of fire spread on the burned plots 5 yr after burning was 27% of that on the unburned plots, and estimated resistance to control was 67%. At 12 yr, difference in resistance to control ended; at 16 yr, difference in rate of spread ended. Composition of brush and herbage changed with burning, and brush cover was reduced for a few years (except where Ceanothus spp. invaded), but total herbaceous cover was not affected. The ultimate quantity of natural stocking with commercial conifers that became established after logging was not affected by burning.

469. O'Dea, M. 1993. The clonal development of vine maple during Douglas-fir stand development in the Coast Range of Oregon. M.S. thesis. Oregon State University, Corvallis, Oregon.

Vine maple clonal development and stand age were found to be strongly related. Most changes in development occurred during the first 50 yr of the stand. Throughout stand development, basal sprouting and layering were present; basal sprouting was primarily present early in the development of the stand, and layering was present in the later stages. In all stages of stand development, seed production and seedling establishment occurred, except immediately after crown closure. Cultural practices such as commercial thinning and prescribed fire strongly influenced clone regeneration. Those practices affect clone regeneration by controlling forest debris and the size of clones, as well as the abundance of seedlings in stands.

470. Roberts, C.A. 1975. Initial plant succession after brown and burn site preparation on an alder dominated brushfield in the Oregon coast range. M.S. thesis. Oregon State University, Corvallis, Oregon. 90 p.

Within 2 or 3 wk after the fire and before the first soaking rain, sprouts and germinants began to appear. The first to resprout were bracken fern and swordfern, then vine maple, bitter cherry, and bigleaf maple. The earliest germinants were phacelia, soft nettle, thistle, and geranium. On 86% of the 76 burned plots, various germinants were present in early September. On 51% of the plots, vine maple had sprouted; on 78%, swordfern had reappeared. One month after burning, canopy coverage of the vegetation present was less than 5%, but in ensuing weeks sprouts grew rapidly and germinants continued to appear. Canopy coverage had increased to about 10% by mid November, 60% of the total coverage was composed of phacelia and Oregon-grape. Although, canopy coverage was reduced drastically, many species then returned to comparable frequency ratings. The sites were completely reoccupied with vegetation 2 and 5 growing seasons after treatment. At both sites, ground cover vegetation averaged 50%. The most frequently found species was foxglove, followed closely by tansy ragwort, various grasses, and swordfern.

471. Robinson, M.C. 1968. Growth and replacement patterns occurring among selected dominant species associated with plant succession on Douglas-fir clear-cuts. Ph.D. thesis. Oregon State University, Corvallis, Oregon. 84 p.

Near Corvallis, Oregon, patterns of growth and replacement were investigated for velvetgrass, tansy ragwort, big deervetch, and Oregon-grape over 3 yr in order to detect changes in the structure and composition of vegetation. Those species grew more vigorously in mixed than in pure stands. On Douglas-fir clearcuts in the watershed area during the early stages of plant succession, competition did not appear to be an important factor in species replacement. On a young clearcut, behavior of a species depended more on its own ecology and changing soil factors than on competition from other species. On clearcuts, vegetation generally was not homogeneous and was more often composed of many small units that differed from each other both in composition and structure, forming a mosaic-like pattern.

472. Russel, D.W. 1973. The life history of vine maple on the H.J. Andrews Experimental Forest. M.S. thesis. Oregon State University, Corvallis, Oregon. 167 p.

In this study, the contributions of vine maple to the general community biomass and to the general nutrient cycling system were investigated, and its abundance was evaluated on the basis of environment and successional time frame. Within the study area, vine maple was generally ubiquitous but its abundance varied. Through successional time, the distribution and abundance of vine maple was closely related to the history of disturbance on the site. During the successional time frame, abundance followed a bi-modal distribution; after clearcutting, early abundance was followed by near extinction under conifers at the age of 40 yr. Reproduction of vine maple was primarily vegetative. Its growth and structure varied according to the general stage of successional development of the associated forest stand. Vine maple apparently can selectively remove large stems within a clump, thus altering its relative growth and biomass structure; therefore, it can improve its survival prospects when environmental conditions are less favorable.

473. Sabhasri, S. 1961. An ecological study of salal (*Gaultheria shallon* Pursh). Ph.D. thesis. University of Washington, Seattle, Washington. 134 p.

Environmental extremes limited sexual reproduction of salal, and local distribution was largely accomplished by vegetative means. Salal could establish and develop normally over a wide range of nutrient and water availability. Light conditions greatly affected photosynthetic efficiency of salal; as light increased, efficiency increased up to the limits found in this research. Like other sun plants, salal grows better as light intensity increases. Under forest stand conditions, those characteristics were evident. Salal developed better in an opening and under partial shade of a canopy than beneath a dense canopy and may be considered an intolerant species. In natural stands, salal yield varied depending on age and density. Salal roots are probably important in the nutrient cycle and comprise a large portion of the whole plant. This study explains why salal is so abundant and tenacious on lower quality forest sites, yet is not an important species on better areas in the Pacific Northwest.

474. Sabhasri, S., and W.K. Ferrell. 1960. Invasion of brush species into small stand openings in the Douglas-fir forests of the Willamette foothills. Northwest Science 34:77-88.

On south slopes in the western foothills of the Willamette Valley, the effects of environmental variables on the species, numbers, degree of cover, age, and growth of shrub species were investigated. There were 16 species of shrubs found in the area; among these were bigleaf maple, hazelnut, snowberry, poison oak, and rose, all of which were considered dominant because of their common occurrence and degree of cover. Those 5 species had considerable variation in their relation to the environment. Bigleaf maple increased percent cover, age, and growth in height in response to each opening. Poison oak decreased in response to openings and was also more sensitive to soil series. Cover, number of individuals, age, and growth of hazelnut increased in openings, and it occurred more commonly and grew better on the Dixonville soil series. When openings were created, snowberry also increased in importance, and it grew better on the Aiken soil series. The variables tested produced little response in rose.

475. Schoonmaker, P., and A. McKee. 1988. Species composition and diversity during secondary succession of coniferous forests in the western Cascade Mountains of Oregon. Forest Science 34:960-979.

Community composition and species diversity were studied on 23 similar western hemlock/Douglas-fir forest sites. The sites included undisturbed old-growth stands and stands at 2, 5, 10, 15, 20, 30, and 40 yr that had been clearcut, broadcast burned, and replanted with Douglas-fir earlier. Through the first 30 yr, herbs invaded and were dominant, followed by invading and residual shrubs, then conifers. In old-growth stands, 99% of cover was composed of late seral species, which were nearly eliminated immediately after disturbance. After 5 yr, however, they again accounted for almost 40% of vegetative cover, then 66% after 10 yr, 83% after 20 yr, and 97% at 40 yr. Species diversity increased slowly after an initial drop after disturbance; heterogeneity peaked at 15 yr and richness at 20 yr. The high initial diversity, which was higher than that of old-growth stands, was short-lived. After canopy closure, diversity declined, reaching its lowest values at 40 yr. After disturbance, only 2 mycotroph species were eradicated. Old-growth forests of the Pacific Northwest are relatively poor in species, but moderately high in heterogeneity values.

476.Stanek, W., D. Beddows, and D. State. 1979. Fertilization and thinning effects on a Douglas-fir ecosystem at Shawnigan Lake on Vancouver Island: some observations on salal and bracken fern undergrowth. Canadian Forestry Service, Pacific Forest Research Centre, Victoria, B.C. Report BC-R-1. 11 p.

Herbaceous and shrubby undergrowth were affected by thinning and fertilization applied to stands to increase their productivity. Thinning enabled more light to penetrate tree canopies, thus increasing biomass of the undergrowth. Fertilization increased the density of the tree canopies, however, thus decreasing the ground cover and biomass of the undergrowth. Fertilization and thinning in combination benefited the undergrowth; the most beneficial combination was heavy thinning and moderate fertilization. Except under very nitrogen-deficient soil conditions and in very young stands, the quantity of N tied up in undergrowth was relatively small and not likely to be critical for tree growth.

477.Steen, H.K. 1965. Variation in vegetation following slash fires near Oakridge, Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-25. 6 p.

After slash burning, typical variation in vegetation was shown by comparing paired photographs of 2 areas in the same locality. Groundsel formed a much heavier cover on burn B than on burn A in the 2nd growing season after burning. Several herbaceous species grew on burn A during the 4th growing season, while burn B was invaded by brush. The 2 pairs showed marked differences 13 yr after the slash fire; conifers were well established on A and heavy brush covered B. These variations in vegetation after burning demonstrate the predicament forest land managers face when deciding whether to use slash burning as a management tool.

478.Steen, H.K. 1966. Vegetation following slash fires in one western Oregon locality. Northwest Science 40:113-120.

Brush cover was significantly greater on unburned plots than burned plots for only the first 5 yr after burning; the differences were no longer significant by 7 yr. On burned plots, snowbrush and varnishleaf ceanothus created dense shade; on unburned plots, they created very little. Much more rhododendron grew on unburned than on burned areas. Total herbaceous plant cover was similar on burned and unburned plots (about 50% after 11 to 16 yr), but species composition differed. American twinflower shaded 14 times more area on unburned than on burned plots. Trailing blackberry shaded more of the burned area than the unburned. Throughout the study area, willow-herbs were common and covered burned and unburned plots equally.

479.Tappeiner, J., J. Zasada, P. Ryan, and M. Newton. 1991. Salmonberry clonal and population structure: the basis for a persistent cover. Ecology 72:609-618.

Individual clones and populations of salmonberry on undisturbed sites replace aerial stems by rhizome extensions, production of new genets, and sprouts from buds on old aerial stems. On these sites, the size distribution of aerial stems resembled that of an uneven-aged stand of trees, as numbers of stems decreased from small to large size classes. Salmonberry populations maintained themselves by rapidly initiating new rhizomes and aerial stems within the first 2 growing seasons after disturbance to overstory trees and to the understory. Those populations apparently continued to thrive because the greatest biomass of rhizomes and aerial stems occurred in 13- to 18-yr-old clearcuts with no overstory trees. There were significant and negative relationships between rhizome density of salmonberry populations, rhizome biomass, and aerial stem biomass and basal area of overstory trees. Measures of preharvest overstory trees, and salmonberry stem number and basal area can be used to predict population structure, rhizome length, and aerial stem, rhizome, and total biomass of salmonberry.

480.Tappeiner, J.C., II. 1981. Estimating potential hardwood and shrub cover and plantation development. P. 97-101 *in* Reforestation of Skeletal Soils. Proceedings of a Workshop. S.D. Hobbs and O.T. Helgerson, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

The diameter of the parent tanoak tree affects the size and density of sprouts that arise after cutting. In each diameter class, the number of tanoak stems can be multiplied by predicting clump size to estimate potential cover. Prescriptions can be developed to treat the hardwoods before or during harvest if the size class distribution of tanoak stems and their potential sprout development are known. Seeds stored in the forest floor may germinate after harvesting, although shrubs were not present in a stand before harvest. Stands should be examined for evidence of dead or living shrubs, or similar sites can be used to judge whether shrubs will be present in a particular stand. On unbrowsed, open-grown shrubs in plantations of known age, diameter and height measurements and site characteristics can be multiplied by number of plants per acre to estimate potential shrub cover. Predicting young stand growth involves estimating the average diameter of a stand with normal basal area, or a specified basal area goal, when that basal area is obtained. Normal basal area can be obtained from yield tables or by measuring well-stocked stands on similar sites. Expressing the average diameter in terms of annual radial growth can be used as a check to determine whether the expectations are realistic.

481. Tappeiner, J.C., II, and P.B. Alaback. 1989. Early establishment and vegetative growth of understory species in the western hemlock-Sitka spruce forests of southeast Alaska. Canadian Journal of Botany 67:318-326.

We conducted experiments on seed germinations and seedling survival and examined clonal development of Alaskan blueberry, bunchberry, spleenwort-leaved goldthread, trefoil foamflower, and five-leaved bramble to determine how they invade and maintain themselves in old-growth, young-growth, and 4- to 6-yr-old stands. In laboratory and field tests, seed of all species germinated well; but bunchberry and trefoil foamflower had low germination rates under actual field conditions, which may have slowed their invasion of young stands. All species at 3 and 4 yr had lower survival in the young stand (40 yr) than in the old stand (250+ yr), which may be related to incident solar radiation. In the young stand, average annual rhizome or stolon growth was slower than in the old stand. Clones in the clearcut had dense foliage because their internodes were shorter, there were more leaves per node, and annual rhizome and stolon growth averaged 77 to 160 cm. Among clones, both seedling establishment and continual expansion maintain species in old stands, while in young stands, invasion is primarily by seedling establishment.

482. Tappeiner, J.C., II, T.B. Harrington, and J.D. Walstad. 1984. Predicting recovery of tanoak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*) after cutting or burning. Weed Science 32:413-417.

The size of the parent stem of tanoak and Pacific madrone and the time since cutting was related to the width and area of sprout-clumps that originated from trees with stem diameter greater than 2 cm at 1.4 m height. Tanoak has a slower sprouting capacity; 5 to 6 yr after cutting, small 40- to 50-yr-old tanoaks produced sprout clumps that averaged only 37 cm in diameter. Stem-diameter distributions of these species in forest stands, along with prediction equations can be used to estimate foliar cover of hardwoods up to 6 yr after cutting.

483. Tappeiner, J.C., II, and P.M. McDonald. 1984. Development of tanoak understories in conifer stands. Canadian Journal of Forest Research 14:271-277.

On a range of sites in Oregon and California, the stocking, age, and growth rates of understory tanoak in 13 stands of 53- to 240-yr-old Douglas-fir and mixed conifer stands were studied. In all stands, the understory was uneven in age and size. For 5 to 12 yr, seedlings have a single stem; they then form a burl with dormant buds below ground, lose the original stem, and produce new stems. Tanoak age cannot be determined from stems above ground because of frequent stem mortality and sprouting, but it can be estimated from xylem rings below the burl in the stem. In the conifer understory, tanoak grows slowly, averaging 5 sprouts only 30 to 68 cm tall at 50 yr. It may take well over 100 yr to establish a dense, new understory with the capacity for vigorous sprouting after disturbance. Tanoak control may be needed less often and cost less if accomplished in 30- to 75-yr-old conifer stands.

484. Tappeiner, J.C., II, P.M. McDonald, and T.F. Hughes. 1986. Survival of tanoak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus*

***menziesii*) seedlings in forests of southwestern Oregon. New Forests 1:43-55.**

Tanoak and Pacific madrone seeds were sown in 40- to 200-yr-old clearcuts and conifer stands. Some were protected from rodents and birds and some were left unprotected. In exposed clearcuts and conifer stands in the 2nd yr, survival rates of tanoak seedlings were high (50 to 70%). Seed predators have great influence on the establishment of tanoak. Pacific madrone seedlings on the same sites as the tanoak had low (0 to 8%) survival rates, but mortality was caused by many factors. Both species grew slowly and after 3 yr had average heights of only 6 to 14 cm for tanoak and 2 to 6 cm for madrone. If populations of these seedlings are minimized, the future stocking of trees capable of vigorous sprouting after clearcutting or other disturbance will be reduced.

485. Tappeiner, J.C., II, M. Newton, P. McDonald, and T.B. Harrington. 1992. Ecology of hardwoods, shrubs and herbaceous vegetation and their effects on conifer regeneration. P. 136-164 *in* Reforestation Practices in Southwestern Oregon and Northern California. S.D. Hobbs, S.D. Tesch, P.W. Owston, R.E. Stewart, J.C. Tappeiner II, and G.E. Wells, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

The ecology of herbaceous, shrub, and hardwood species of southwestern Oregon and northern California and their effects on conifer regeneration are reviewed in 5 sections. The 1st section summarizes the different stages of forest succession and describes plant types associated with those stages; the 2nd discusses the reproduction and growth patterns of shrubs, hardwoods, and herbaceous vegetation; the 3rd examines the effects of this vegetation on conifer growth and development; the 4th addresses the effects of competing vegetation on conifer establishment; and the 5th presents techniques for measuring forest vegetation and explains how these measurements can help in the management of young conifer stands.

486. Tappeiner, J.C., and J.C. Zasada. 1993. Establishment of salmonberry, salal, vine maple, and bigleaf maple seedlings in the coastal forests of Oregon. Canadian Journal of Forest Research 23:1775-1780.

On 2 sites, seed predation, emergence, survival, and growth of 4 species of coastal Oregon shrubs and hardwoods were studied in thinned, unthinned, and clearcut conifer stands on disturbed and undisturbed soil. Seedling emergence and survival of all species were greater in thinned than in clearcut or unthinned stands. For salmonberry and salal, emergence was greater on mineral soil than on soil with intact organic layers. Salmonberry was tallest in the clearcuts, where it averaged 23 cm after 4 yr. Bigleaf maple and vine maple were tallest, averaging 16 and 15 cm, respectively, in the thinned stands, but were heavily browsed in the clearcuts. Seedlings of salal survived only in thinned stands and grew slowly; in 4 yr, their height averaged only 4 to 5 cm. Seed size was related to both seedling emergence and predation. The species with the largest seeds, vine and bigleaf maple, had the highest rates of emergence on both disturbed and undisturbed soil, but also the highest rates of seed predation.

487. Walstad, J.D., M. Newton, and R.J. Boyd, Jr. 1987. Forest vegetation problems in the northwest. P. 15-53 *in* Forest Vegetation Management for Conifer Production. J.D. Walstad and P.J. Kuch, eds. John Wiley & Sons, New York.

The types of competing vegetation in each of the subregions of the Pacific Northwest are reviewed, along with the origin of vegetation problems, the beneficial aspects of competing vegetation, and future trends in vegetation management.

488. West, N.E., and W.W. Chilcote. 1968. *Senecio sylvaticus* in relation to Douglas-fir clearcut succession in the Oregon Coast Range. Ecology 49:1101-1107.

Wood groundsel is a northern European adventive in the Douglas-fir region that has adapted well to a short-term dominance on slash-burned clearcuts at the beginning of secondary succession. Its copious production of small pappus-borne cypselas, low competitive ability, and apparent need for the highly fertile soil found with the release of minerals directly after slash burning are related to the species time-space niche. Compared with succeeding species, this low seral species has high nutrient requirements, making it an exception to the generalization that low seral species have lower nutrient demands than high seral or climax components.

489. Witler, J.W. 1975. The effect of thinning intensity upon understory growth and species composition in an Oregon Coast Range Douglas-fir stand. M.S. thesis. Oregon State University, Corvallis, Oregon. 95 p.

On 14 thinned plots, cover, frequency, and biomass of understory vegetation were estimated. Although cover varied considerably among plots, several trends appeared that corresponded with thinning treatment. The dominant species on unthinned plots were Oregon-grape and *Eurhynchium oreganum*. On all thinned plots, bracken fern and E. oreganum were dominant. Thinning produced the greatest response in herbaceous species; in the moderate and heavy thinnings, cover was highest. Bracken fern, Scouler's harebell, varied-leaf collomia, western fescue, white-flowered hawkweed, and starflower increased most with thinning. A few species occurred only on thinned or unthinned plots; but, of those, only big deervetch and broadleaf lupine occurred at relatively high frequencies on thinned plots. Species that attain high cover or frequency do not decrease significantly with thinning intensity. Trends for cover and frequency are similar to those for understory biomass, although the biomass estimates had greater sampling error.

Woody plants had no clear response to thinning. Large shrubs, especially, showed a trend towards increased woody vegetation as thinning intensity increased, although stem density data indicated that some large woody plants responded to thinning. On thinned plots, the shrubs vine maple, hazelnut, and oceanspray often grew in clumps of many young, erect stems, but large woody stems were scattered widely throughout the plots. Such clumps were not found on unthinned plots. This suggests that woody plants occurred infrequently in the original forest and that the clumps grew from the original stems or root systems in response to thinning.

490. Yerkes, V.P. 1958. Successional trends of lesser vegetation following clearcutting in old-growth Douglas-fir stands. M.S. thesis, Oregon State University, Corvallis, Oregon. 98 p.

On clearcut and burned areas of old-growth Douglas-fir, successional trends of lesser vegetation showed much variation in the amount and type of cover between clearcut areas during the first 6 yr. Over time, the vegetation became more homogeneous in both the amount of cover and the species present. The number of species on the clearcuts increased for about 4 or 5 yr, then remained about the same. After the first 2 growing seasons, annuals and unidentified species dropped out and unimportant perennials, annuals, and unidentified species disappeared thereafter. Total cover decreased as herbaceous vegetation decreased, but woody vegetation began to increase its amount of cover. There were no obvious differences in the amount and type of cover at various elevations or between burned and unburned areas. The only species with consistent differences between burned and unburned areas were wood groundsel and willow-herb, which had more cover on burned plots for the first 2 yr. There were fewer species on south slopes and less total cover as each species contributed less to the total. Dominant species had no great differences on north and south slopes.

491. Yerkes, V.P. 1960. Occurrence of shrubs and herbaceous vegetation after clear cutting old-growth Douglas-fir in the Oregon Cascades. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper 34. 12 p.

After old-growth Douglas-fir was removed, there were 101 (of 104) species found in varying amounts on north slopes and only 65 on south slopes. According to their presence or absence under the adjacent forest canopy, species were noted as either survivors or invaders. Frequency of woody survivors increased slowly; frequency of woody invaders increased even more slowly. Herbaceous survivors were relatively unimportant within the vegetative cover. Herbaceous invaders (annuals) were very frequent in the first 2 yr, then decreased; herbaceous invaders (perennials) rose rapidly in frequency for 4 or 5 yr, then increased more slowly. On unburned areas, species that were present under the forest canopy tended to be more prominent, whereas on burned areas, invading species tended to establish more rapidly. Species frequency on burned and unburned areas differed only slightly after 5 growing seasons, however.

492. **Zasada, J., J. Tappeiner, B. Maxwell, and D. Temple. 1990. Salmonberry clone and stand structure, and response to disturbance in the Oregon Coast Range. P. 51-52 *in* Vegetation Management: An Integrated Approach. Proceedings of the Fourth Annual Vegetation Management Workshop. E. Hamilton, ed. British Columbia Ministry of Forests, and Forestry Canada, Victoria, B.C. FRDA Report 109.**

It is increasingly important to understand the morphology and growth of salmonberry and its response to disturbances such as harvesting and manual control, because of limitations placed on the use of slashburning and herbicides. In various forest types, rhizome length can be predicted from the basal area of the overstory and of salmonberry, which, in combination with information on bud bank populations and salmonberry recovery rates, can provide estimates of the potential development of both cover and stand.

493. **Zasada, J., J. Tappeiner, and M. O'Dea. 1992. Clone structure of salmonberry and vine maple in the Oregon Coast Range. P. 56-60 *in* Proceedings-Symposium on Ecology and Management of Riparian Shrub Communities. W.P. Clary, E.D. McArthur, D. Bedunah, and C.L. Wambolt, eds. USDA Forest Service, Intermountain Research Station, Ogden, Utah. General Technical Report INT-289.**

Salmonberry and vine maple clones can be similar in size and dimensions but have different methods of clone formation. Salmonberry has an active clone development process that requires a rhizome to grow into an area, followed by ramet production from the rhizome bud bank. The development of vine maple clones is a relatively passive process wherein stems layer when pinned to a suitable substrate by a fallen tree or branch. The number of suitable contacts with the ground determine the number of points on which rooting will occur.

494. **Zasada, J.C., J.C. Tappeiner II, B.D. Maxwell, and M.A. Radwan. 1994. Seasonal changes in shoot and root production and in carbohydrate content of salmonberry (*Rubus spectabilis*) rhizome segments from the central Oregon Coast Ranges. Canadian Journal of Forest Research 24:272-277.**

An important aspect of the morphology and architecture of salmonberry is its extensive rhizome system, which is also important for its potential regrowth after disturbance. The periodicity of shoot and root production was assessed by determining total nonstructural carbohydrate content and incubating segments in a growth chamber. In February and March, shoot dry weight and quantity peaked; they declined from April through June, when aboveground shoot growth was greatest, then were generally low through the dry months of summer. From August through October, root production was highest and was generally lower the rest of the year. During the dormant season, total nonstructural carbohydrate content was highest, then dropped to the lowest level in midsummer. Total nonstructural carbohydrate content and shoot production were more closely related than was root production with carbohydrate content. The significant reduction in shoot production potential suggests that there may be a time in the annual growth cycle when salmonberry has a relatively low capacity for regrowth after disturbance.

Appendix
Common, Product, and Chemical Names of Herbicides

Common name	Product name[2]	Chemical Name
2,4-D	Esteron®	(2,4-dichlorophenoxy)acetic acid
2,4-DP	Weedone 170®	2,4-dichlorophenoxypropionic acid
asulam	Asulox®	methyl[(4-aminophenyl)sulfonyl]carbamate
atrazine	Aatrex®	6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine
clopyralid	Stinger®	3,6-dichloro-2-pyridinecarboxylic acid
dalapon (2,2-DPA)	Dalapon®	2,2-dichloropropanoic acid
dicamba	Banvel®	3,6-dichloro-2-methoxybenzoic acid
fluroxypyr	——	[(4-amino-3,5-dichloro-6-fluoro-2-pyridinyl)oxy]acetic acid
fosamine	Krenite®	ethyl hydrogen(aminocarbonyl)phosphonate
glyphosate	Roundup®	*N*-(phosphonomethyl)glycine
hexazinone	Velpar®	3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1*H*,3*H*)-dione
imazapyr	Arsenal®	(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid
metsulfuron methyl	Escort®	2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2yl)amino]carbonyl]amino]-sulfonyl]benzoic acid
picloram	Tordon®	4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid
pronamide	Kerb®	3,5-dichloro-*N*-(1-dimethyl-2-propynyl)benzamide
simazine	Princep®	6-chloro-*N*,*N'*-diethyl-1,3,5-triazine-2,4-diamine
sulfometuron	Oust®	2[[[[(4,6-dimethyl-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]-benzoic acid
triclopyr	Garlon®	[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid

[1]Weed Science Society of America. 1989. Herbicide Handbook, 6th ed. Champaign, Illinois.

[2]Product names given are examples only and will vary, depending on manufacturer.

British-to-metric Conversions

1 inch (in.) = 2.54 centimeters (cm)

1 foot (ft) = 0.305 meter (m)

1 square foot (ft^2) = 0.09 square meter (m^2)

1 acre (ac) = 0.405 hectare (ha)

1 gallon (gal) = 3.79 liters (l)

1 ounce (oz) = 28.34 grams (g)

1 pound (lb) = 0.454 kilogram (kg)

1 bar = 10^5 pascals (Pa)

degrees Fahrenheit (°F) = 1.8 (°C) + 32

Abbreviations:

a.e. = acid equivalent

a.i. = active ingredient

dbh = diameter at breast height

dw = dry weight

lai= leaf area index

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Loucks, D.M., S.A. Knowe, L.J. Shainsky, and A.A. Pancheco. 1996. REGENERATING COASTAL FORESTS IN OREGON: AN ANNOTATED BIBLIOGRAPHY OF SELECTED ECOLOGICAL LITERATURE. Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 14, 122 p.

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